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FINAL

FEASIBILITY STUDY REPORT
OPERABLE UNIT NO. 6 (SITE 36)

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0303

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LIST OF ACRONYMS AND ABBREVIATIONS

ARARs	applicable or relevant and appropriate requirements
Baker	Baker Environmental, Incorporated
bgs	below ground surface
BRA	Baseline Human Health Risk Assessment
CAA	Clean Air Act
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
COCs	contaminants of concern
COPCs	contaminants of potential concern
CSFs	cancer slope factors
CWA	Clean Water Act
DCE	dichloroethene
DENR	Department of Environmental and Natural Resources
DoN	Department of the Navy
DOT	Department of Transportation
EPIC	Environmental Photographic Interpretation Center
ER-L	effects range-low
ESE	Environmental Science and Engineering
FFA	Federal Facilities Agreement
FS	Feasibility Study
gpm	gallons per minute
HI	Hazard Index
IAS	Initial Assessment Study
ICR	Incremental Lifetime Cancer Risk
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCLs	maximum contaminant levels
mg/L	milligrams per liter
mg/kg	milligrams per kilogram
NCAC	North Carolina Administrative Code
NC DENR	North Carolina Department of Environment and Natural Resources
N.C.G.S.	North Carolina General Statute
NCP	National Oil and Hazardous Substances Pollution Contingency Plan

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

NCWQSs	North Carolina Water Quality Standards
NOAA	National Oceanic and Atmospheric Administration
"NOTICE"	Notice of Inactive Hazardous Substance and Site Waste Disposal
NPL	National Priorities List
NPW	net present worth
ORP	oxidation-reduction potential
OSWER	Office of Solid Waste and Emergency Response
OU	Operable Unit
O&M	operating and maintenance
PAHs	polynuclear aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethene
POTWs	publicly owned treatment works
PRAP	Proposed Remedial Action Plan
RAAs	remedial action alternatives
RBC	Region III Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RfDs	reference doses
RI/FS	Remedial Investigation/Feasibility Study
RI	Remedial Investigation
RLs	remediation levels
RME	reasonable maximum exposure
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SSSVs	surface soil screening values
STP	Sewage Treatment Plant
SVOCs	semivolatile organic compounds
TAL	target analyte list
TBC	to be considered
TCE	trichloroethene
TCRA	time critical removal action
TCL	target compound list
TCLP	toxicity characteristic leachate procedure
TOC	total organic carbon
TRC	Technical Review Committee
TRVs	terrestrial reference values
µg/L	micrograms per liter
µg/kg	micrograms per kilogram

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

UBK	uptake/biokinetic
USEPA	United States Environmental Protection Agency
VOCs	volatile organic compounds
WAR	Water and Air Research, Incorporated
WQS	Water Quality Standard

EXECUTIVE SUMMARY

INTRODUCTION

This report presents the Feasibility Study (FS) conducted for Site 36 (the Camp Geiger Area Dump), one of five sites that comprise Operable Unit (OU) No. 6 at Marine Corps Base (MCB), Camp Lejeune, North Carolina. Baker Environmental, Inc. (Baker) has prepared this FS for Contract Task Order 0303 under the Department of the Navy (DoN) Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) program. The FS is primarily based on data collected during a Remedial Investigation (RI) and post-RI field investigation conducted for Site 36.

SITE HISTORY

Site 36 is reported to have been used for the disposal of municipal wastes and mixed industrial wastes including trash, waste oils, solvents, and hydraulic fluids that were generated at the Marine Corps Air Station (MCAS), New River. The dump was active from the late 1940s to the late 1950s. Most of the material was first burned and then buried; however, some unburned material was also buried. Reportedly, less than five percent of all waste hydrocarbon material generated at the MCAS was disposed of at Site 36. The remaining waste oil was reportedly used for dust control on roads or discharged directly into storm drains.

REMEDIAL ACTION OBJECTIVES

Volatile organic compounds (VOCs), trichloroethene (TCE) and tetrachloroethene (PCE), were detected in the surficial aquifer at concentrations exceeding their respective Federal and State criteria. The maximum detected concentration of TCE was 97 micrograms per liter (µg/L); its Federal Maximum Contaminant Level (MCL) is 5 µg/L and its North Carolina State Water Quality Standard (NCWQS) is 2.8 µg/L. The maximum detected concentration of PCE was 2 µg/L; its Federal MCL is 5 µg/L and its NCWQS is 0.7 µg/L. Potential human health risks from exposure to these VOCs were evaluated within the RI, but they did not generate unacceptable risks. However, an area of concern containing TCE and PCE was defined in the northern portion of the site; and therefore, remedial action objectives were developed to address this VOC area of concern.

The remedial action objectives developed for Site 36 include:

- Prevent future potential exposure to contaminated groundwater.
- Protect uncontaminated groundwater for future potential beneficial use.

In addition to the VOCs detected in groundwater, lead in the surface and subsurface soils, and iron in the subsurface soil and groundwater were detected at concentrations exceeding their remediation levels. Lead was detected at a maximum concentration of 836 milligrams per kilogram (mg/kg) in the surface soil and at a maximum concentration of 2,680 mg/kg in the subsurface soil; its surface soil remediation level is the Office of Solid Waste and Emergency Response (OSWER) level of 400 mg/kg. Iron was detected in the subsurface soil at a maximum concentration of 132,000 mg/kg; its remediation level is 2,300 mg/kg. Iron was detected in groundwater at a maximum concentration of 16,900 µg/L; its remediation level is based on the NCWQS of 300 µg/L.

Lead and iron were not addressed by the remedial action objectives for the following reasons. The elevated lead levels were detected in only two surface soil samples collected from the open area at Site 36 and there is no discernible pattern to their detections. Although lead was detected in 14 percent of the subsurface soil samples, at levels greater than 400 mg/kg, remediation of the lead-bearing subsurface soil is not warranted as toxicity, characteristic, leachate procedure (TCLP) results support the RI conclusion that the lead at Site 36 does not appear to be mobile. Similarly, iron naturally occurs at high levels in groundwater and soil throughout the Base. In addition, there is no historical record of lead or iron use at Site 36.

Arsenic, lead, and mercury levels in the fish and/or crab tissues contributed to unacceptable human health risks upon direct ingestion. The Division of Water quality of the NC DENR has directed and undertaken fish collection and tissue sampling from the Brinson Creek area. In November of 1997, the State abandoned the collection efforts, but anticipated additional collection and sampling in 1998.

REMEDIAL ACTION ALTERNATIVES

Based on the remedial action objectives developed for Site 36, five remedial action alternatives (RAAs) were developed and evaluated:

- RAA 1: No Action
- RAA 2: Institutional Controls
- RAA 3: Monitored Natural Attenuation
- RAA 4: Extraction and On-Site Treatment
- RAA 5: In Situ Volatilization (In-Well Aeration)

The following paragraphs briefly describe each alternative.

RAA 1: No Action

Capital Cost:	$0
Annual Operation and Maintenance (O&M) Cost:	$0
Net Present Worth (NPW):	$0
Time to Implement:	None

Under the no action RAA, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants identified in groundwater at Site 36. The no action alternative is required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) to provide a baseline for comparison with other RAAs that provide a greater level of response. Although this RAA does not involve active remediation, passive remediation of the groundwater may occur via processes associated with the natural attenuation of contaminants. However, since there will be no monitoring under the no action alternative, it will be unknown how or if the natural attenuation processes would reduce contaminants at Site 36. Overall protection of human health and the environment will remain unknown.

RAA 2: Institutional Controls

Capital Cost:	$0
Annual O&M Cost:	$22,000
NPW (30 years):	$338,000
Time to Implement:	Institutional controls could be implemented within half of one year.

Under RAA 2, a groundwater/surface water monitoring program and aquifer use restrictions will be implemented as institutional controls. Under the program, groundwater samples will be collected semiannually at three existing shallow wells, three existing intermediate, and one existing deep well. Samples collected from these wells will be analyzed for Target Compound List (TCL) VOCs. Surface water samples will be collected from three locations along Brinson Creek and analyzed for TCL VOCs. Additional sampling locations may be added to the program, if necessary. In addition to groundwater/surface water monitoring, the Base Master Plan will be modified to include institutional controls for aquifer use restrictions to prohibit future use of the surficial aquifer as a potable water source. Further, annual certification that the Base Master Plan restrictions will remain unchanged must be completed and returned to the State. Recordatoin of a Notice of Inactive Hazardous Substance or Waste Sites (required by N.C.G.S. 130A-310.8(a)), and modification of the RCRA Permit Modifiction under 40 CFR 270.41 imposing the site restriction, will be requried. If property is transferred from the United States Marines, MCB, Camp Lejeune shall record the site restrictions in the form of restrictive covenants at the Onslow County register of deeds' office prior to any property transfer.

RAA 3: Monitored Natural Attenuation

Capital Cost:	$72,000
Annual O&M Cost:	$141,000
NPW (30 years):	$902,000
Time to Implement:	Natural Attenuation monitoring could be implemented within half of one year.

Remedial actions associated with RAA 3 include the in-situ, naturally occurring biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization/destruction of the VOCs in groundwater. These remedial actions will take place via "natural attenuation", which refers to the naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in these media. At Site 36, site-specific evidence suggests that natural attenuation processes are successfully degrading the chlorinated solvent contamination in the surficial aquifer.

Similar to the plan identified under RAA 2, the monitoring program for RAA 3 will include both groundwater and surface water sampling. The surface water samples will be analyzed solely for TCL VOCs, while the groundwater samples will include laboratory analyses of the following parameters: TCL VOCs, total organic carbon (TOC), nitrate, sulfate, methane, ethane, ethene, and chloride. Additionally, field analyses will be conducted on groundwater samples to determine the levels of oxygen, iron II, alkalinity, oxidation-reduction potential (ORP), pH, temperature, conductivity, major cations, and hydrogen. Collection and review of the analytical results will indicate the type of bioremediation that is occurring, and will be used to predict the kind and amount of contaminant reduction that has occurred or is expected. Monitoring will continue until groundwater standards for chlorinated solvents are met. In an effort to provide additional evidence

that natural attenuation is occurring, RAA 3 incorporates the option of annually performing a contaminant fate and transport model. Similar to RAA 2, this alternative also includes the same modifications to the Base Master Plan and institutional controls for aquifer use restrictions to prohibit future use of the surficial aquifer within a 1,500 foot radius of the estimated plume at Site 36.

RAA 4: Extraction and On-Site Treatment

Capital Cost:	$403,000
Annual O&M Cost:	$56,000
NPW (30 years):	$1,264,000
Time to Implement:	Approximately 1.5 to 2 years would be required to design and construct the extraction and on-site treatment system.

RAA 4 is a conventional extraction and treatment alternative in which two extraction wells, each with an estimated capture radius of 100 feet and pumping rate of 5 gallons per minute (gpm), will be installed to collect groundwater from the surficial aquifer. The extraction wells will be positioned so that their combined cones of influence intercept the contaminated plume. Each extraction well will be screened near the confining unit at approximately 40 feet bgs. After being extracted, the groundwater will be transported by pipeline to an on-site treatment plant. At the treatment plant, the groundwater will undergo suspended solids and metals removal via neutralization, precipitation, flocculation, sedimentation, and filtration units, and VOC treatment via a low profile air stripper. In addition, carbon adsorption will provide secondary treatment of the VOC emissions from the air stripper and of the treated groundwater. After receiving treatment, groundwater will be discharged to Brinson Creek. RAA 4 also incorporates the same groundwater/surface water monitoring program and aquifer use restrictions that were included under RAA 2 (i.e., annual certifications, recordation of a Notice of Inactive Hazardous Substances and Waste Disposal Sites, etc.).

RAA 5: In Situ Volatilization (In-Well Aeration)

Capital Cost:	$824,000
Annual O&M Cost for Groundwater Monitoring:	$22,000
Annual O&M Cost for the Treatment System:	$17,000
NPW (30 years):	$1,293,000
Time to Implement:	Approximately 1 to 1.5 years would be required to design and construct the in-well aeration treatment system.

Under RAA 5, nine aeration wells, each with an estimated radius of influence of 65 feet, will be installed at Site 36. The wells will have overlapping capture radii that will intercept the contaminated groundwater. A separate knockout tank, vacuum pump, and carbon adsorption unit will be located near the opening of each aeration well. The knockout tank will remove any liquids that may have traveled up the well and the carbon adsorption unit will treat off-gases that were stripped within the well. A field pilot test is recommended prior to the design of the in-well aeration system. RAA 5 also incorporates the same groundwater/surface water monitoring program and aquifer use restrictions that were included under RAAs 2 and 4.

1.0 INTRODUCTION

This Feasibility Study (FS) has been prepared by Baker Environmental, Incorporated (Baker) for the Department of the Navy (DoN), Atlantic Division Naval Facilities Engineering Command, Comprehensive Long-Term Environmental Action Navy (CLEAN) Program. Activities associated with this FS have been conducted in accordance with requirements delineated in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) [40 Code of Federal Regulations (CFR) 300.430] for Operable Unit (OU) No. 6 at Marine Corps Base (MCB), Camp Lejeune, North Carolina. The NCP guidelines which dictate the FS process were promulgated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), commonly referred to as Superfund, and amended by the Superfund Amendments and Reauthorization Act (SARA). The United States Environmental Protection Agency (USEPA) document Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988) was used as a guidance document during the preparation of this report.

MCB, Camp Lejeune was placed on Superfund's National Priorities List (NPL) on October 4, 1989 (54 Federal Register 41015, 1989). Subsequent to this listing, USEPA Region IV; the North Carolina Department of Environment and Natural Resources (NC DENR); and the DoN entered into a Federal Facilities Agreement (FFA). The continuing purpose of the FFA is to ensure that environmental impacts associated with past and present activities at MCB, Camp Lejeune are thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives are developed and implemented, as necessary, to protect public health, welfare, and the environment (FFA, 1989).

The Fiscal Year 1997 Site Management Plan for MCB, Camp Lejeune (Baker, September 1996a), the primary document referenced in the FFA, identifies 42 sites that require Remedial Investigation/Feasibility Study (RI/FS) activities. These 42 sites have been grouped into 18 operable units to simplify RI/FS activities. A Remedial Investigation (RI) was conducted at OU No. 6, Sites 36, 43, 44, 54, and 86 during 1995. A post-RI field investigation was conducted at OU No. 6, Sites 36, 54, and 86 during 1997. This report provides the FS conducted for Site 36 the Camp Geiger Area Dump. Additional reports have been prepared that address each of the other OU No. 6 sites. Figure 1-1 depicts the location of the five sites that comprise OU No. 6. [Note that all tables and figures are presented at the back of each section.]

1.1 Purpose and Organization of the Report

The subsections which follow describe the purpose of and organization of the FS report.

1.1.1 Purpose of the Feasibility Study

The purpose of this FS for Site 36 is to identify remedial alternatives that are protective of human health and the environment, and that cost-effectively attain appropriate Federal and State requirements. In general, the FS process under CERCLA serves to ensure that appropriate remedial alternatives are developed and evaluated, such that pertinent information concerning the remedial action options can be presented and an appropriate remedy selected. The FS involves two major phases:

1. Development and screening of remedial action alternatives, and
2. Detailed analysis of remedial action alternatives.

The first phase includes the following activities:

- Developing remedial action objectives and remediation levels
- Developing general response actions
- Identifying volumes or areas of affected media
- Identifying and screening potential technologies and process options
- Evaluating process options
- Assembling alternatives
- Defining alternatives
- Screening and evaluating alternatives

Section 121(b)(1) of CERCLA requires that an assessment be conducted to investigate possible solutions and alternative treatment technologies or resource recovery technologies that, in whole or in part, will result in a permanent and significant decrease in the toxicity, mobility, or volume of the hazardous substance, pollutant, or contaminant. In addition, according to CERCLA, treatment alternatives should be developed ranging from an alternative that, to the degree possible, would eliminate the need for long-term management of alternatives which involve treatment that would reduce toxicity, mobility, or volume as their principal element. A containment option involving little or no treatment and a no-action alternative should also be developed.

The second phase of the FS consists of: (1) evaluating the potential alternatives in detail with respect to nine evaluation criteria that address statutory requirements and preferences of CERCLA; and (2) performing a comparison analysis of the evaluated alternatives.

1.1.2 Report Organization

This FS is organized in five sections. The Introduction (Section 1.0) presents the purpose of the report, a brief discussion of the FS process, and pertinent site background information including a summary of the nature and extent of contamination at Site 36. Information from both the RI human health and ecological risk assessments are also presented in Section 1.0. Section 2.0 contains the remedial action objectives and remediation levels that have been established for the site. Section 3.0 contains the identification of general response actions, and the identification and preliminary screening of the remedial action technologies and process options. Sections 4.0 and 5.0 contain the development, detailed analysis, and comparison of remedial action alternatives for Site 36. The detailed analysis is based on a set of nine criteria including short- and long-term effectiveness, implementability, cost, acceptance, compliance with applicable regulations, and overall protection of human health and the environment. References are provided within each of the five sections.

1.2 Background and Setting of Site 36

The following section provides both the location and setting of Site 36. Brief summaries of past waste management activities and findings of previous investigations are also provided within this section.

1.2.1 Site Location and Setting

The Camp Geiger Area Dump (Site 36) is located approximately 1,000 feet east of the developed portion of Camp Geiger and 500 feet west of the New River, adjacent to the Camp Geiger Sewage Treatment Plant (STP). Camp Geiger is situated directly north of Marine Corps Air Station (MCAS), New River and approximately 3 miles southwest of Jacksonville, North Carolina (refer to Figure 1-1). Camp Geiger contains a mixture of troop housing, personnel support, and supply, storage, and training facilities. Currently, the Camp Geiger area is utilized by a number of groups which have no direct relationship to one another.

A mixture of old and new facilities are located within Camp Geiger, the result of which is a patchwork of land use areas arranged in a north to south configuration. Evolution of the approximately 216 acres within Camp Geiger has resulted in land uses that are not interrelated physically or functionally. Supply and storage facilities, which are concentrated along the eastern edge and central portions of the developed area, comprise approximately 50 of the 216 total acres. Maintenance buildings are located adjacent to the supply and storage areas. Supply, storage, and maintenance areas account for nearly 32 percent of the land within Camp Geiger. The remaining land area is primarily comprised of buffer zones, marshland unsuitable for building, and training areas.

Figure 1-2 depicts Site 36 within the Camp Geiger Development Area. During an initial assessment of potential sites at MCB, Camp Lejeune, Site 36 was estimated to be approximately 1.5 acres in size (ESE, 1990). Based upon a review of aerial photographs and observations recorded during the RI site scoping visit, the size of the site was adjusted to include nearly 20 acres. The site is comprised primarily of open fields and wooded areas with dense understory. A gravel road bisects the site and provides access to Jack's Point Recreation Area, located approximately one-quarter mile east of the study area. The site is bordered to the north and east by Brinson Creek and woods, to the east by woods, to the south by an unnamed tributary to Brinson Creek, and to the west by an improved (i.e., coarse gravel) road. Further to the west of the improved road lies an abandoned railroad right-of-way, once part of the Seaboard Coastline Railroad.

1.2.1.1 Geology

Much of the surface soil and sediment at Site 36 has been disturbed by human activity, as evidenced by mounds, ridges, roads, and cleared areas observed throughout the study area. Generally, regraded soil and debris were encountered in borings in the eastern and central portions of Site 36. The soil was observed to be predominantly sand, silt, and clay, with a lesser amount of debris. The debris encountered included gravel, concrete, glass, metal, bricks, and wood.

The uppermost formation at Site 36, the undifferentiated formation, is comprised of several units of Holocene and Pleistocene ages. This formation typically extends to a depth between 30 and 40 feet below ground surface. A fine sand, with lesser amounts of silt and clay occupies the uppermost portion of the formation. This sand unit is typically 5 feet thick. Below the sand is a clay layer with lesser amounts of fine sand and silt, approximately 2 to 5 feet thick. A second fine sand layer is below the clay. Zones of medium and coarse sand are present within this second sand unit. This sand unit also contains a lesser amount of silt and clay, and is approximately 5 to 15 feet thick. Additionally, laminae features are distinct in some portions of the unit. A unit composed of predominantly shell fragments lies below the second sand. This unit also contains of a lesser amount

of fine sand, silt, and clay. This unit occupies the lower portion of the formation, and is 15 to 20 feet thick. Sands within the undifferentiated formation tend to be loose to medium dense, the clays are soft to medium stiff, and the shell fragment layer is dense to very dense.

The Belgrade Formation is comprised of fine sand with lesser amounts of shell fragments, silt, and clay of the Miocene age. The Belgrade Formation constitutes part of the surficial aquifer and Castle Hayne confining unit (Cardinell et al., 1993). The top of this formation lies 30 to 40 feet below ground surface, is 15 to 20 feet thick, and has a distinct green or greenish-gray color. The sediments of this formation are medium dense to dense. The River Bend formation lies below the Belgrade Formation and is primarily characterized by beds of partially cemented shell fragments, with lesser amounts of shell fragments, silt, and clay of the Oligocene age. This formation lies approximately 60 feet below ground surface at Site 36. The sediments of this formation are very dense. The upper portion of the Castle Hayne aquifer lies within sediments of the River Bend Formation.

1.2.1.2 Hydrogeology

The surficial aquifer is approximately 25 to 30 feet thick in the vicinity of Site 36 and occurs in sediments of the undifferentiated formation, within 10 feet of ground surface. The Castle Hayne aquifer occurs approximately 60 feet below ground surface and is approximately 200 feet thick in the vicinity of Camp Geiger (Cardinell et al., 1993). The Castle Hayne confining unit is approximately 17 to 23 feet thick at Site 36. Groundwater flow in the surficial aquifer at Site 36 is east toward Brinson Creek, with an average velocity of 0.1 feet/day. Groundwater flow in the upper portion of the Castle Hayne aquifer is to the northeast, with an average velocity of 0.3 feet/day. Because the hydraulic conductivity varies, groundwater may exhibit preferential flow paths following the relatively highly conductive medium and coarse sands. There appears to be some degree of connection between the surficial and Castle Hayne aquifers.

Brinson Creek and the unnamed tributary that borders Site 36 to the south, represent groundwater flow boundaries for the surficial aquifer at Site 36. Groundwater flow in the upper 10 to 15 feet of the surficial aquifer is complicated by the presence of a clay layer under much of the site. The position of the clay layer roughly corresponds to the water table. During the investigation, water was observed in sands and silts above the clay in the western portion of the site. It appears that water infiltrating the sands and silts is slow to infiltrate through the clay layer, creating a thin, perched groundwater zone. This perched zone was typically less than 1 foot thick, and limited in extent. No perched zone was evident in the eastern portion of the site, where the depth to groundwater tended to be within or below the discontinuous clay unit.

1.2.2 Site History

Site 36 is reported to have been used for the disposal of municipal wastes and mixed industrial wastes including trash, waste oils, solvents, and hydraulic fluids that were generated at MCAS, New River. The dump was reportedly active from the late 1940s to the late 1950s. Most of the material was first burned and then buried; however, some unburned material was buried. According to interviews conducted by Water and Air Research, Incorporated (WAR) during the Initial Assessment Study (IAS), less than five percent of all waste hydrocarbon material generated at the air station was disposed of at Site 36. The remaining waste oil was reportedly used for dust control on roads or went directly into storm drains (WAR, 1983). Sampling was done to ascertain the contamination in the Base drainageways at Site 36. These sample locations are shown on Figures 1-3 and 1-6.

1.2.3 Previous Investigations

The subsections which follow detail previous investigation activities and information regarding Site 36.

1.2.3.1 Initial Assessment Study

An IAS was conducted at Site 36 by WAR in 1983. The IAS evaluated the potential hazards at various sites throughout the Base, including Site 36. The IAS was based upon review of historical records, aerial photographs, inspections, and personnel interviews. As a result of this process, the IAS recommended that a Confirmation Study be performed at Site 36.

1.2.3.2 Confirmation Study

A two-part Confirmation Study was conducted at Site 36 by Environmental Science and Engineering (ESE) from 1984 through 1987. The Verification Step was performed in 1984 and the Confirmation Step was performed in 1986 and 1987. The Confirmation Study at Site 36 focused on the presence of potential contaminants in groundwater, surface water, and sediment.

The Confirmation Study identified a number of target contaminants in environmental media throughout Site 36. Metals were the most prevalent contaminant group encountered during both rounds of the groundwater investigation. Concentrations of metals in groundwater generally decreased from one sampling round to the next (1984 to 1986). Analytical results from groundwater, surface water, and sediment samples indicated that the actual disposal area may extend further to the west than was first estimated.

The Confirmation Study recommended that further characterization of groundwater, from both the shallow and deep aquifer, be implemented to complete the RI/FS process. Supplemental surface water and sediment investigations were suggested to determine possible upstream sources of contamination. In addition to groundwater and surface water, a thorough characterization of unsaturated soils within the identified disposal area was recommended to fulfill data requirements. Following the characterization of potentially impacted environmental media, a risk assessment was also recommended to identify if there were any unacceptable risks to human health and the environment.

1.2.3.3 RI Scoping Investigation

A RI scoping investigation was conducted at Site 36 during June 1994. Following the identification of 11 abandoned containers (i.e., 5-gallon containers and 55-gallon drums) during a March 1994 site survey, a limited drum and soil sampling program was proposed to address potentially impacted media. The objective of the drum sampling program was to collect representative samples from each of the containers and determine appropriate disposal options. During the intervening months between the site survey and the drum investigation, however, a majority of the containers were removed from the study area by unidentified personnel. Accordingly, only four five-gallon containers were sampled during the investigation. A number of confirmatory soil samples were also obtained to determine if the contents of the various containers had leaked onto the ground surface.

Waste samples were collected from four five-gallon containers that were located near the south central portion of the study area. A sample from each container was analyzed for waste compatibility using a field test kit. Based upon test kit results and field observations, the containerized substance was determined to be a non-reactive flammable liquid. Accordingly, one composite sample representing the contents of the four containers was submitted for analysis of toxicity characteristic leachate procedure (TCLP) contaminants and RCRA waste characteristics (i.e., reactivity, corrosivity, and ignitability). Results of these analyses and visual inspections indicated that the material was a weathered paint product. Lead (2.2 milligrams per liter [mg/L]) and 2-butanone (15 mg/L) were each detected at low levels within the composite sample.

Soil samples were collected at each of the four drum or container areas to determine if possible contaminants had leaked onto the ground surface. A total of 17 soil samples were collected at the four areas using a hand auger. Both surface (0 to 12 inches) and subsurface (one to three feet) samples were obtained from eight of the nine soil borings. Low levels of either styrene, toluene, or 2-butanone were detected in 9 of the 17 soil samples collected at the drum or container areas. Concentrations of these volatile compounds ranged from 1.0 J micrograms per kilogram (µg/kg) of styrene to 170 µg/kg of 2-butanone. The polynuclear aromatic hydrocarbons (PAHs) fluoranthene, chrysene, pyrene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, or benzo(a)pyrene were detected in six of the soil samples. Concentrations of the PAH compounds ranged from 26 J to 540 µg/kg. In addition, at least one of the pesticides 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, aldrin, or dieldrin were detected in 13 of the 17 soil samples. Pesticide concentrations ranged from 4.6 to 420 µg/kg.

The most prevalent contaminants found in soil at Site 36 were PAH compounds, pesticides, and metals. Positive detections of pesticides in soil were typically low and evenly dispersed throughout the four areas. Pesticide concentrations of this magnitude have historically been encountered throughout MCB, Camp Lejeune. Unlike the detected pesticide compounds, the majority of PAHs were found at two of the four drum areas.

1.3 Remedial Investigations

A RI was conducted at Site 36 from February through May 1995. The RI consisted of the following field activities: a soil investigation, a groundwater investigation, a surface water and sediment investigation, an aquatic investigation, and a habitat investigation. In June of 1997, a Post-RI Field Investigation was conducted for volatile organic compounds (VOCs) in groundwater.

1.3.1 Remedial Investigation

Field investigations at Site 36 were initiated to assess the nature and extent of contamination that may have resulted from previous management practices or site activities; assess the human health, ecological, and environmental risks associated with exposure to site media; and characterize the geologic and hydrogeologic setting of the study area. This section discusses the site-specific RI field investigation activities that were conducted to fulfill that objective. The field investigation was conducted during 1995 and consisted of a site survey; a soil investigation, which involved direct-push sample collection; a groundwater investigation, which included temporary, shallow, intermediate, and deep monitoring well installations, sampling, and aquifer testing; a surface water and sediment investigation; an aquatic investigation; and a habitat evaluation. The following provides an overview of the various investigation activities carried out during the RI:

•	Soil Test Borings Completed	67
•	Exploratory Test Pits Completed	7
•	Temporary Wells Installed and Sampled	2
•	Existing Shallow Wells Sampled	5
•	Shallow Wells Installed and Sampled	8
•	Intermediate Wells Installed and Sampled	3
•	Deep Wells Installed and Sampled	4
•	Surface Water Samples Collected	7
•	Sediment Samples Collected	13

More than one round of groundwater samples were collected from monitoring wells which exhibited organic contaminants during the initial sampling round. Supplemental soil, groundwater, and sediment samples were also collected based upon the occurrence of potential contaminants in site environmental media. Details of the soil, groundwater, surface water/sediment, and aquatic investigations conducted during the RI are discussed below.

1.3.1.1 Soil Investigation

Representative samples from the study area were collected and submitted for laboratory analysis of target compound list (TCL) organics (i.e., volatiles, semivolatiles, pesticides, and polychlorinated biphenyls [PCBs]) and target analyte list (TAL) metals. A total of 67 test borings were sampled during the soil investigation. Soil samples were collected throughout Site 36 as shown on Figure 1-3. The sampling distribution employed was intended to identify if contamination was present and, if so, to evaluate the vertical and horizontal extent within the study area. The soil sampling program at Site 36 focused on known or suspected disposal areas. Historic aerial photographs from the USEPA's Environmental Photographic Interpretation Center (EPIC), previous investigatory data, and background reports were used to locate potential sampling locations.

A total of 67 borings were advanced to assess suspected waste disposal at Site 36; 8 of those borings were utilized for the installation of monitoring wells (refer to Figure 1-3). Nine of the boring locations were advanced within the Former Disposal Area identified in the IAS report, including one monitoring well test boring. A total of 14 soil borings and one monitoring well test boring were advanced within a cleared area located in the southwestern portion of the study area. Within the northern portion of Site 36, soil samples from six borings and three monitoring well test borings were collected. Six soil borings and one monitoring well test boring were completed in the open field located in the central portion of Site 36. The remaining soil borings were completed at the various locations throughout the site. Three additional borings, to the west of the study area, were advanced to assess background contaminant concentrations (36-BB-SB01, 36-BB-SB02, and 36-BB-SB03).

Three potentially impacted areas were identified using expedited soil and groundwater sample analyses performed while investigation activities continued elsewhere. Twenty-two of the 67 soil borings mentioned above were added to the investigation as a result of these sample analyses. Additional soil borings were completed at two suspect soil boring locations, 36-OA-SB01 and 36-OF-SB06. A total of nine borings were completed in an area immediately adjacent to 36-OA-SB01, and an additional four borings were placed within 15 feet of 36-OF-SB06. The northern portion of the study area was also determined to be of potential concern and was identified

through groundwater analysis from a newly-installed monitoring well. An additional six soil borings and three monitoring well test borings were advanced beyond the northern site boundary to provide adequate coverage of the area.

1.3.1.1.1 Exploratory Test Pits

A total of seven exploratory test pits were completed in conjunction with the soil investigation at Site 36 (refer to Figure 1-3). The exploratory test pit investigation was conducted to assess the nature of any buried material within suspected disposal areas. Soil samples from selected exploratory test pits were submitted for laboratory analysis of compounds associated with TCLP and RCRA waste characteristics. Laboratory confirmation analysis of excavated soil was necessary when staining was evident or when organic contamination was indicated through field screening.

Potential test pit locations were identified through visual site inspection and use of a hand-held magnetometer. The visual site inspection sought to identify signs of contamination or waste disposal activity such as soil staining, debris, fill areas, or depressions. In conjunction with the visual site inspection, a magnetometer was employed during the test pit investigation to identify buried metallic objects. Because of the presence and wide distribution of metallic debris throughout the study area, only locations with magnetic detections indicating metallic objects greater than three feet in length were selected for excavation activities.

1.3.1.2 Groundwater Investigation

Nine shallow and three intermediate Type II monitoring wells (i.e., wells installed without casing) were installed at Site 36 from February through April of 1995. Locations of the newly installed and existing monitoring wells at Site 36 are depicted on Figure 1-3. The nine shallow and three intermediate monitoring wells were situated spatially to intercept potentially impacted groundwater from the suspected disposal areas, and to characterize the nature and horizontal extent of possible contamination. The existing and newly-installed monitoring wells were also used to evaluate groundwater flow patterns within the upper and lower portions of the surficial aquifer. In addition to the shallow and intermediate wells, four deep Type III monitoring wells (i.e., wells installed with casing to seal off a confining or semi-confining layer) were installed during February, March, and July of 1995, at Site 36 (refer to Figure 1-3). The four deep wells were installed to assess the nature and vertical extent of contamination and to evaluate the flow pattern of the deeper aquifer (i.e., the Castle Hayne aquifer). Placement of the newly installed monitoring wells was based on review of historical aerial photographs, previous investigations, and analytical data generated during the initial phase of the RI (i.e., seven-day soil and groundwater data).

Round one groundwater samples were collected in March of 1995 from five existing shallow wells (36-GW01 through 36-GW05), the six newly installed shallow wells (36-GW06 through 36-GW11), two temporary wells (36-TW01 and 36-TW02), and the three newly installed deep wells (36-GW06DW, 36-GW07DW, and 36-GW11DW) at Site 36. The locations of the newly installed, temporary, and existing monitoring wells are depicted on Figure 1-3. Based upon the analytical results generated during the March sampling round, an additional three shallow (36-GW12, 36-GW13, and 36-GW14) and three intermediate monitoring wells (36-GW10IW, 36-GW12IW, and 36-GW13IW) were installed in April and sampled in May of 1995.

A second round of groundwater sampling was performed in July of 1995 that included the sampling of one newly installed deep monitoring well (36-GW10DW) and the resampling of the supplemental monitoring wells installed in April. The second round was conducted to confirm the presence of VOCs detected in samples retained from the northern portion of the study area.

1.3.1.3 Surface Water and Sediment Investigation

The surface water and sediment investigation at Site 36 was conducted during RI activities at OU No. 10 (Site 35, the Camp Geiger Area Fuel Farm) in April 1994. As part of this investigation, surface water and sediment samples were retained from a total of ten sampling stations on Brinson Creek and four stations on the unnamed tributary that borders the southern portion of Site 36. Three of the Brinson Creek sampling stations were situated adjacent to Site 36. The remaining seven Brinson Creek samples were retained from locations adjacent to and upstream of Site 35. Site 35 is also situated along the southern bank of Brinson Creek, approximately 2,500 feet upstream of Site 36. Although the surface water and sediment investigation at Site 36 was not performed concurrently with the Site 36 RI, analytical results from the investigation are presented within the Nature and Extent of Potential Site Contaminants section of this report (Section 1.4).

A total of 7 surface water and 13 sediment samples were collected at Site 36 with each sampling station yielding one surface water and two sediment samples. Three of the sampling stations were located in Brinson Creek and four were located in an unnamed tributary to Brinson Creek. Based upon results of the initial investigation, two additional sediment samples were collected to confirm the presence of lead at one of the originally sampled sediment locations. A supplemental round of surface water samples was collected in April of 1995 and submitted for laboratory analysis of dissolved metals. The two additional sediment samples were collected in October of 1995 and submitted for analysis of TAL metals only.

1.3.1.4 Aquatic Investigation

An aquatic investigation of Brinson Creek, like the surface water and sediment investigation, was performed in conjunction with RI activities at OU No. 10 (Site 35). During the aquatic investigation of Brinson Creek, fish and benthic macroinvertebrate samples were retained from five and nine sampling stations, respectively. Biological samples collected at Site 36 were comprised of fish, crabs, and benthic macroinvertebrates. The biological samples were collected to obtain population statistics of fish and benthic macroinvertebrates and to obtain fish and crab tissue samples for chemical analysis.

Fish and crabs were collected from three stations in Brinson Creek adjacent to Site 36 (36-FS01, 36-FS02, and 36-FS03). Benthic macroinvertebrates were also collected from three stations adjacent to Site 36 in Brinson Creek (36-BN01, 36-BN02, and 36-BN03). Figure 1-3 depicts the approximate locations of the three fish and three benthic sampling stations.

1.3.2 Post-RI Field Investigation

Based on the RI information for Site 36, it was determined that additional analytical data would be needed in order to select the most appropriate remedial alternative for Site 36. As a result, two additional groundwater wells were installed at Site 36 to collect site-specific data.

Two monitoring wells, IR36-GW16IW and IR36-GW17, were installed in June 1997. These wells were sampled on July 2, 1997 and analyzed for TCL volatiles. The locations of the newly installed wells are provided in Figure 1-3. The wells are located upgradient of the RI-estimated VOC plume which was identified in the northern portion of Site 36.

1.4 Nature and Extent of Potential Site Contaminants

A brief summary of site contamination is presented within the following subsections. The summary focuses on the primary site concerns and is not intended to address all media or analytical results in detail. Detailed findings and an evaluation of analytical data are presented in the RI Report (Baker, 1996b) or the Post-RI Field Investigation Letter Report (Baker, 1997a). However, a summary of site contamination (as presented in the RI) is provided in Table 1-1.

1.4.1 Soil

Soil samples were collected and analyzed only for the RI.

Volatile compounds in both surface and subsurface soils at Site 36 appear to be the result of limited site activities within certain portions of the study area. VOCs were detected in 19 of the 123 surface and subsurface soil samples collected throughout Site 36. The positive detections were identified in samples from the central, northern, western, eastern, and southeastern portions of Site 36. The VOCs 1,2-dichloroethene (DCE), trichloroethene (TCE), benzene (PCE), tetrachloroethene, and total xylenes were each detected at very low maximum concentrations (i.e., less than 10 μg/kg) and were detected infrequently. Given the limited extent and concentration of volatile compounds at Site 36, their presence is most likely the result of previous site operations and not necessarily long-term disposal.

The presence and dispersion of semivolatile organic compounds (SVOCs) in soil, particularly PAH compounds, are also most likely the result of limited operational activities within the study area. Concentrations of PAH compounds in soil samples are consistent with the historical use of the site as a dump and indicative of waste or refuse incineration. SVOCs were identified in both surface and subsurface soil samples throughout the site; however, considerably higher concentrations of SVOCs were limited to the eastern, southeastern, and central portion of the study area. Concentrations of SVOCs were typically higher in surface samples than in those samples obtained from the subsurface. In general, the SVOC detections correspond directly to the visual identification of fill and burnt material recorded during the field investigation of the study area.

Positive detections of pesticides were observed in both surface and subsurface soil samples throughout Site 36. The detected pesticide levels were generally low and most likely the result of routine pesticide application. A number of the higher pesticide detections were observed in surface samples obtained from the central and a small area near the western site boundary. Soil samples obtained from the eastern portion had a majority of the higher subsurface pesticide concentrations. As described in Section 1.2, the eastern and central portions of the study area are composed of fill and burned material that may have also included residual concentrations of pesticides. The frequency and overall concentration of pesticides in soil does not suggest routine or widespread pesticide disposal activities.

Fourteen of 16 positive detections of PCBs were observed in samples obtained from soil borings located along the western boundary of the site, immediately adjacent to the main site access road. Each of the positive detections of a PCB was observed in conjunction with positive pesticide detections. At one time it was not uncommon to use oil, possibly containing PCBs, as a dust suppressor on roads. The occurrence of both pesticides and PCBs in soil samples suggests that these organic compounds were introduced to the site concurrently.

Fewer than 15 of the 103 samples submitted for analysis had TAL metal concentrations greater than one order of magnitude above Base-specific background levels. Inorganic analytes were detected in both surface and subsurface soil samples from the eastern, southeastern, and central portions of the study area at concentrations greater than one order of magnitude above twice the average Base-specific background levels. The metals copper, lead, and zinc were observed at maximum concentrations greater than two orders of magnitude above Base-specific background levels in a limited number of soil samples from the eastern portion of the study area. Findings from the analytical program are consistent with visual observations of buried metallic objects and fill material recorded during the field investigation. Concentrations of metals in samples obtained from these portions of the study area coincide directly with areas of fill and buried material.

1.4.2 Groundwater

Groundwater samples were collected and analyzed for both the RI and the post-RI field investigation. Samples collected during the post-RI field investigation were only analyzed for volatiles.

RI and post-RI positive detections of organic compounds in the groundwater samples collected at Site 36 are depicted on Figure 1-4. Figure 1-5 presents TAL metal sampling results in excess of either Federal maximum contaminant levels (MCLs) or North Carolina Water Quality Standards (NCWQSs). A positive detection summary of organic compounds from the first sampling round is presented in Table 1-2. Total metal results from the first sampling round are presented in Table 1-3. Organic compounds detected in samples acquired during the second sampling round are presented in Table 1-4. The post-RI groundwater volatile positive detections are presented in Table 1-5. Semivolatile and PCB compounds were not detected in any of the shallow or deep aquifer samples submitted for analysis from Site 36. As a result of those analyses, the extent of semivolatile and PCB contamination in groundwater will not be addressed. Inorganic analyses were not requested during the second sampling round.

1.4.2.1 Remedial Investigation Results

Positive detections of volatile compounds were limited to samples obtained from the shallow aquifer. The lack of positive VOC detections in samples obtained from the deep aquifer suggests that these contaminants have not migrated vertically from the surficial aquifer. The majority of volatile detections were observed in samples from intermediate and shallow wells in the northern portion of the study area; however, three monitoring wells located on the western portion of the site had low concentrations of 1,2-dichloroethene. The highest concentration of a single VOC, trichloroethene at 97 micrograms per liter (µg/L), was detected in well 36-GW10IW. Monitoring well 36-GW10IW lies within the northern potion of the study area. Four other volatile compounds were detected in the shallow and intermediate wells in that vicinity.

The concentrations of the VOCs detected in other wells which are hydraulically upgradient of the northern portion of the site suggest that the extent of VOC contamination in groundwater is limited to the northern location. Moreover, the limited extent of VOC contamination (i.e., in both soil and groundwater) suggests that the source may have resulted from unintentional spillage or limited disposal rather than from long-term disposal or leaking, buried containers.

The pesticide 4,4'-DDD was detected in only one of the 17 groundwater samples submitted for analysis from Site 36. A sample obtained from monitoring well 36-GW10, located in the northern portion of the study area, exhibited a 0.056 μg/L concentration of 4,4'-DDD. No pesticides were detected in a confirmatory sample retained from the same monitoring well. Subsurface soil analytical results throughout the site indicate the presence of pesticides. Pesticides tend to adhere to soil material; suspended soil particles (colloids) in groundwater samples are likely to have introduced pesticide contaminants into the sample. Due to a lack of additional detections, the extent of groundwater pesticide contamination will not be considered further.

Inorganic analytes were detected in each of the 22 groundwater samples submitted for analysis from Site 36. Iron and manganese were the only TAL inorganics detected, among samples obtained from the 21 permanent monitoring wells, at levels in excess of either Federal MCLs or NCWQS (see Figure 1-5). Positive detections of both iron and manganese were distributed throughout the site, indicative of natural site conditions rather than disposal activities. Mercury was detected within one sample obtained from a temporary well at a concentration which exceeded the NCWQS of 1 μg/L by only 0.4 μg/L. Generally, concentrations of TAL metals in shallow groundwater at Site 36 appear to be higher in samples obtained from the western portion of the study area.

Iron and manganese concentrations from a number of wells at Site 36 exceeded the NCWQS but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. Additionally, positive detections of both iron and manganese among groundwater samples retained from the upper-most portion of the surficial aquifer had no discernible pattern of distribution. The presence and concentrations of both iron and manganese in groundwater samples obtained at Site 36 appear to be indicative of natural site conditions rather than disposal activities.

1.4.2.2 Post-RI Field Investigation Results

Results of the post-RI groundwater sampling indicated the presence of low levels of TCE (6 J μg/L) and 1,2-DCE (5 J μg/L) within newly installed monitoring well IR36-GW16IW. Based on this well's location and the detected concentrations with respect to the northern area, the results of the post-RI field investigation are consistent with the RI findings related to the extent of VOC groundwater contamination. Analytical results collected from the second newly installed monitoring well, IR36-GW17, were below all of the TCL volatile organic detection llimits. These results support the conclusion that the VOCs identified in the norhtern portion of Site 36 are not the result of an off-site (upgradient) source.

1.4.3 Surface Water

Semivolatile, pesticide, and PCB contaminants were not detected in any of the 7 surface water samples submitted for analysis from Site 36. As a result of those analyses, the extent of semivolatile, pesticide, and PCB contamination in surface water will not be addressed. VOCs were not detected in the three surface water samples retained from Brinson Creek, correspondingly, the

extent of volatile contamination in Brinson Creek will not be addressed. However, VOCs with respect to the unnamed tributary, and inorganics with respect to both Brinson Creek and the unnamed tributary will be discussed below.

1.4.3.1 Volatiles

Unnamed Tributary

One volatile contaminant, 1,2-DCE, was detected at a concentration of 7 µg/L (the surface water standard for 1,2-DCE is also 7 µg/L). Sediment results from the same sample station, located along the southern boundary of the study area, exhibited positive detections of semivolatile compounds. The occurrence of one positive detection suggests that volatile compounds are not migrating from surface and subsurface soils or sediments at Site 36 via surface water, particularly from areas identified with positive volatile detections in soil.

1.4.3.2 Metals

Brinson Creek

None of the TAL metals identified in the three Brinson Creek surface water samples were detected at concentrations in excess of saltwater chronic screening values. Positive detections of metals were compared to contaminant standards for water bodies classified as tidally influenced (i.e., containing at least five percent saltwater).

Unnamed Tributary

Copper, iron, and nickel were the only TAL metals identified among the four unnamed tributary samples that exceeded State or Federal chronic screening values. Three of the unnamed tributary samples had positive detections of iron above the 1,000 µg/L freshwater screening value and the maximum Base-specific background concentration of 1,416 µg/L. Iron concentrations among the three samples ranged from 2,320 to 4,840 µg/L. Nickel was detected in one downgradient sample at a concentration of 23.2 µg/L which exceeded the 8.3 µg/L saltwater chronic screening value. Copper was detected in an upgradient sample at a concentration of 56.5 mg/L which exceeded the 6.5 µg/L freshwater chronic screening value. The frequency and concentrations of TAL metals that were detected in excess of screening criteria are not indicative of disposal-related operations. The unnamed tributary that borders the southern portion of the study area serves as one of the many drainages for nearby roadways, parking lots, and operational areas. The location of the unnamed tributary, relative to these operational areas, may account for the metals observed in surface water samples.

1.4.4 Sediment

PCBs were not detected in any of the 13 sediment samples submitted for analysis from Site 36. In addition, volatile compounds were not detected in any of the Brinson Creek sediment samples. As a result of those analyses, PCB contamination and Brinson Creek volatile contamination of sediments will not be addressed.

1.4.4.1 Volatiles

Unnamed Tributary

PCE was the only VOC detected in one of the seven unnamed tributary sediment samples collected at Site 36. The only detection of PCE, 4 µg/kg, was observed in a sample collected approximately 100 feet upstream of Brinson Creek. The sample location is also within two-hundred feet of the New River and Edwards Creek. The isolated detection and low concentration of PCE suggests that its presence may be the result of migration from the northern portion of Site 36. PCE was detected in both surface soils and groundwater samples obtained from the northern portion of the study area.

1.4.4.2 Semivolatiles

Brinson Creek

Two SVOCs were identified within the six Brinson Creek sediment samples. Diethylphthalate and di-n-butylphthalate were identified in two samples retained from locations adjacent to the northern portion of the study area. The localized occurrence of SVOCs in sediment at Site 36 may indicate that semivolatile contaminants have migrated to the sediments of Brinson Creek. Soil erosion may provide one possible explanation for the presence of SVOCs in the sediment. At these locations soil from the northern portion of the study area, or from other upstream sources, may have been washed into the creek channel.

Unnamed Tributary

Three semivolatile compounds were detected within the seven sediment samples obtained from the unnamed tributary that borders the southern portion of Site 36. The highest concentrations of SVOCs were detected in sediment samples located adjacent to the study area. The maximum semivolatile concentration was that of diethylphthalate, 896 µg/kg, at a sampling station located adjacent to a known fill area and former drum area. Soil erosion from areas known to have semivolatile contaminants provides one possible explanation for the presence of these compounds in sediments.

1.4.4.3 Pesticides

Brinson Creek

The pesticides dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, endrin aldehyde, and alpha-chlordane were detected within sediment samples from analysis from Brinson Creek. The maximum concentrations of 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT were obtained from a sample located just downstream of the unnamed tributary's outlet into Brinson Creek. The maximum detections observed at this downstream location may be the result of particles settling out of suspension as they reach this area of lesser hydraulic gradient. In general, higher detections of pesticides were observed in samples retained from Brinson Creek. The detection of organic pesticide contaminants within the sediments at Site 36 was anticipated, based upon their frequent detection and wide dispersion in environmental media throughout MCB, Camp Lejeune.

Unnamed Tributary

The pesticides aldrin, dieldrin, 4,4'-DDE, endrin, endosulfan sulfate, 4,4'-DDD, 4,4'-DDT, endrin ketone, and endrin aldehyde were detected within sediment samples from the unnamed tributary. The maximum concentrations of pesticides in these samples were generally less than these samples collected from Brinson Creek. The maximum pesticide concentration was that of 4,4'-DDD at 1,030 µg/kg. Concentrations of organic pesticides observed in sediment samples collected at Site 36 are comparable to those seen throughout MCB, Camp Lejeune.

1.4.4.4 Metals

Brinson Creek

A single lead concentration in one of the six Brinson Creek sediment samples exceeded National Oceanic and Atmospheric Administration (NOAA) chronic screening values by more than two orders of magnitude. Only two other sediment samples from Brinson Creek had a concentration of lead that exceeded the screening value. The single detection of lead at 15,100 µg/kg from station 36-SD06 also exceeded Base background concentrations. Two confirmatory sediment samples, collected immediately adjacent to 36-SD06, did not exhibit lead concentrations above the 35 µg/kg screening value. The area from which these particular sediment samples were collected served as a boat wharf from approximately the 1940s to the 1970s. The construction or maintenance of the wharf area may account for the localized presence of lead at this location.

Unnamed Tributary

Cadmium, lead, mercury, and zinc were each identified at concentrations in excess of NOAA effects range-low (ER-L) screening values. Each of the four metals were detected in excess of sediment screening values within at least one of the samples from the unnamed tributary. Lead was detected at three locations adjacent to and downstream of the central and southeastern portions of the study area. Cadmium, mercury, and zinc were each detected at concentrations that exceeded NOAA screening values only once among samples retained from the unnamed tributary. No other total metal concentrations, among the seven sediment samples, exceeded screening values. The limited dispersion of TAL metals in sediment samples from the unnamed tributary do not appear to be the result of industrial operations, however, may reflect the presence of surficial and buried metallic debris.

1.5 Human Health Risk Assessment

Conclusions from the human health risk assessment are presented in the subsections which follow. Section 6.7 of the Final RI identifies sources of uncertainty related to the Site 36 human health risk assessment. This section of the RI was not entirely reproduced for this FS; however for clarification, several points are reprinted.

- Overall, the data quality was acceptable.
- USEPA's Rapid Assessment of Exposure to Particulate Emissions from Surface Contaminated Sites (Cowherd, et. al., 1985) was used to estimate the potential inhalation of fugitive dusts.

- Groundwater samples were analyzed for total (unfiltered) and dissolved (filtered) inorganic contaminants. To be conservative, total (unfiltered) inorganic results were used to estimate the potential intake associated with groundwater use.

- The assessment of surface soil exposure at the site is certain, based on collection of samples from the shallowest depth, zero to one foot.

- The use of conservative assumptions results in quantitative indices of toxicity that are not expected to underestimate potential toxic effects, but may overestimate these effects by an order of magnitude or more.

A site conceptual model of potential sources was developed as part of the RI risk assessment. The model was used to define the potential exposure pathways and receptors at Site 36. Current and future potential receptors were evaluated for possible exposure to site media, including current military personnel, current trespassers (i.e., children and adults), future residents (i.e., children and adults), a current and future fisherman, and current and future construction workers. The total risk from the site to 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 trespassers. Military receptors were assessed only for surface soil risks. Fish and crab tissue ingestion was only evaluated for the fisherman. Surface soil, subsurface soil, groundwater, surface water, and sediment exposures were evaluated for all of the future receptors.

1.5.1 Current Scenario

The following potential current receptors were assessed: military personnel, recreational fishermen, recreational users of the site surface water, trespassers, and construction workers. Receptor exposure to surface soil, surface water, sediment, fish tissue, and crab tissue was evaluated. The potential risks associated with potential receptors, excluding the fisherman, however, were within acceptable risk levels. For the current fisherman, the total noncarcinogenic risk (9.1) and total carcinogenic risk (1.1×10^{-3}), mainly from fish and crab tissue ingestion, were greater than the acceptable risk levels of one and 1×10^{-4} for noncarcinogenic and carcinogenic effects, respectively. (A description of the noncarcinogenic and carcinogenic risk values is presented in detail in Section 2.3.3 of this FS). The levels of arsenic and mercury found in the fish tissue and the maximum levels of arsenic and lead detected in the crab tissue contributed to these risks. Exposure to the maximum concentration of lead in the surface soil and crab tissue for a child receptor also indicates the potential for adverse health effects.

The maximum level of arsenic was detected once in a white catfish fillet sample. The maximum level of mercury was found in a largemouth bass fillet sample. These two samples represent fish typically caught and ingested by residents of the area. Crabbing may be less prevalent than recreational fishing in the area, because access to the site surface water where crabs are more abundant is limited. These metals were also detected in the underlying sediment. However, they were not found in the surrounding surface water. Tables 1-6 and 1-7 present summaries of both current and future health risks associated with possible human exposure to various site media.

1.5.2 Future Scenario

Future potential child and adult residents were assessed for possible exposure to groundwater, surface soil, subsurface soil, surface water, and sediment. A construction worker was evaluated for surface and subsurface soil exposure. There were no unacceptable risks associated with the construction worker. However, there were potential noncarcinogenic risks calculated for the child resident from groundwater (5.2, ingestion and dermal contact), subsurface soil (2.3, ingestion, inhalation, and dermal contact), and exposure. Similarly, there was a noncarcinogenic risk (2.2, ingestion and dermal contact) calculated for the adult resident from groundwater exposure. These risk values exceeded the acceptable risk value of one for noncarcinogenic effects. The maximum level of iron in groundwater contributed to these risks. In terms of lead effects, exposure to the maximum concentration of lead in the subsurface soil for a child receptor indicates the potential for adverse health effects.

As stated previously, groundwater at Site 36 is not used as a potable source and future residential development of the site is unlikely. Based on this information, future exposure to groundwater is unlikely to occur.

Iron is an essential nutrient. The toxicity values associated with exposure to this metal are based on provisional studies, which have not been verified by USEPA. In fact, if iron were removed from the evaluation of risk from groundwater ingestion, the noncarcinogenic risk for the child would decrease from 5.1 (ingestion only) to 1.5 and, for the adult, from 2.2 (ingestion only) to 0.7, which is an acceptable noncarcinogenic risk value. The noncarcinogenic risk from ingestion of subsurface soil for the child receptor would decrease to acceptable risk value (i.e., 2.2 to 0.9) if iron were removed from the evaluation. As a result, the potential human health risk from exposure to iron in groundwater and subsurface soil is a conservative and unrealistic estimate.

1.6 Ecological Risk Assessment

The subsections which follow detail the ecological risks to aquatic and terrestrial receptors posed by potential exposure to various site media.

1.6.1 Aquatic Ecosystem

The ecological risk assessment performed for Site 36 was based upon two contributing factors: (1) changes in the structure of benthic macroinvertebrate communities resulting from site-related contaminants and; (2) the potential reduction of an aquatic receptor population or subpopulation attributable to site-related contaminants. The assessment was performed using a series of measurement endpoints to determine potential impacts to aquatic receptors.

Based upon the assessment of ecological risks, there is a slight potential for metals in the surface water and sediment, and a moderate potential for pesticides (4,4'-DDD and 4,4'-DDT) and diethylphthalate in the sediment, to decrease in the population of aquatic life at the freshwater stations. Pesticides reportedly have not been stored or disposed at Site 36. Therefore, the probable source of the pesticides in the sediment is the wide-spread application of pesticides that was conducted at MCB, Camp Lejeune.

The high lead concentration in the sediment was detected at the sample collected adjacent to the site. The source of the high lead concentration is not known. However, based upon additional sediment sampling, it appears that the high lead concentration may have been an anomaly and does not appear to be indicative of actual site concentrations.

Overall, the contaminants in the surface water and sediment have a slight potential to reduce the aquatic receptor population in the freshwater stations. There is a very slight potential for metals in the surface water (copper, nickel), and a moderate potential for metals (lead), pesticides (4,4'-DDD and 4,4-DDE) and diethylphthalate in the sediment, to decrease the population of aquatic life at the saltwater stations. The benthic macroinvertebrates do not appear to be impacted based upon the results of the sampling events. Some of the contaminants in the fish tissue are elevated. However, due to the lack of toxicological data, the potential risk to the fish from those contaminants cannot be evaluated.

1.6.2 Terrestrial Ecosystem

Assessment criteria were used to evaluate the risks posed by possible exposure to site media of terrestrial receptor populations and subpopulations. Several organic compounds and inorganic analytes were detected at concentrations that exceeded applicable surface soil screening values (SSSVs). A comparison of chronic daily intake (CDI) versus terrestrial reference values (TRVs) was also performed for Site 36. The CDI exceeded the TRV for all five terrestrial species evaluated. However, the potential exposure risks were higher for the cottontail rabbit and the raccoon. The risks to these species are due to a few potential contaminants rather than one specific contaminant driving risk.

Aldrin, dieldrin, 4,4'-DDD, and 4,4'-DDE were the only pesticides detected in the whole body fish tissue samples at concentrations above the proposed piscivorous wildlife criteria. The pesticides may have accumulated as a result of exposure to sediment at Site 36. None of the pesticides generated a risk for the raccoon from ingesting the fish. Lead in the fish and crabs were slightly elevated versus the background samples. However, it did not cause a risk to the raccoon ingesting the fish. Cadmium was the only metal detected in the whole-body tissue samples above the wildlife dietary levels that posed a risk to the raccoon. However, the cadmium in the tissue samples does not appear to be site-related.

Some potential impacts to soil invertebrates and plants may occur as a result of potential exposure to site contaminants. There is also a slight potential for a decrease in the terrestrial vertebrate population from exposure to site contaminants based on the terrestrial intake model. It should be noted, however, that SSSVs incorporate much uncertainty into the evaluation of ecological risks.

1.7 Remedial Investigation Conclusions

Based upon the information and findings supplied within the RI report. The following conclusions for Site 36 are presented.

1.7.1 Carcinogenic Human Health Risks

There are no unacceptable site-related carcinogenic risks associated with exposure to environmental media (groundwater, surface soil, subsurface soil, surface water, and sediments) at Site 36. Multiple

exposure pathways were evaluated for current and future potential human receptors; resultant estimates indicate that carcinogenic site risks are within the acceptable risk range as defined by USEPA. There was, however, a potential carcinogenic risk posed by the dietary ingestion of fish and crabs obtained from Brinson Creek. Possible fishermen could, under assumed conditions, be adversely affected by ingestion of arsenic, lead, and mercury at the maximum concentrations detected among all fish and crab tissue samples.

1.7.2 Noncarcinogenic Human Health Risks

An assessment of potential noncarcinogenic risks posed by exposure to environmental media at Site 36 was also completed for possible current and future human receptors. This conservative evaluation of site risk suggests that future residents, given a number of exposure assumptions, could experience some adverse health effects. The evaluation was based upon the potential exposure of future child and future adult residents. A majority of the noncarcinogenic risks generated by the future residential scenario was the result of presumed shallow groundwater and subsurface soil ingestion. Ingestion of iron at the maximum concentrations detected among groundwater samples obtained from Site 36 were used in the estimation of risk. Additionally, ingestion of iron and lead at the maximum concentrations detected among subsurface soil samples constituted much of the remaining noncarcinogenic risk to future child residents. It is important to note that this risk assessment is highly protective of human health and that future residential development of the site is unlikely.

1.7.3 Surficial Aquifer as Drinking Water Source

The majority of site-related noncarcinogenic risk to future residents was generated by possible ingestion of inorganic analytes in groundwater. Hydraulic conductivity results from Site 36 suggest that potable wells supplying groundwater for human consumption from the surficial aquifer would not be practical. Groundwater flow rates would not be sufficient to support a potable source of drinking water. In addition, suspended material resulting from loose surficial soils would further inhibit groundwater flow capacities through siltation. Given these circumstances, it is unlikely that the surficial aquifer could be used as a drinking water source. If a potable well were required in the future at Site 36 it would most likely supply groundwater from the deeper, Castle Hayne aquifer.

1.7.4 Ecological Risks

An ecological risk assessment of potential site-related impacts to both aquatic and terrestrial ecosystems was performed. Based upon this assessment, the significance of potential risks to ecological receptors at Site 36 is considered slight to moderate. Environmental media were assessed to determine the theoretical risks posed to various on-site ecological communities. Results of the ecological risk assessment indicate that the aquatic environment may potentially be impacted by metals and pesticides detected in site media and that risks posed to the terrestrial environment are a result of naturally occurring inorganic analytes detected in the surface water and surface soil. Similar aquatic and terrestrial risks have been demonstrated by reference samples collected throughout MCB, Camp Lejeune from areas not known or suspected of having been impacted by facility operations.

1.7.5 Positive Detections in Excess of Screening Criteria

A number of organic compounds and inorganic analytes were detected among environmental samples obtained from Site 36 at concentrations which exceeded screening criteria established by either State or Federal agencies. Positive detections of organic compounds in groundwater were limited to the northern and western portions of the study area. The presence of volatile compounds in the surficial aquifer in the northern portion of the study area, as indicated by the initial round of sampling results, were confirmed by results of the second sampling round. Six positive detections of TCE from four separate monitoring wells exceeded the NCWQS of 2.8 µg/L. The maximum TCE detection was 97 µg/L from well 36-GW10IW collected during the second sampling round. Both positive detections of PCE slightly exceeded the State standard of 0.7 µg/L. Iron, manganese, and mercury were the only TAL metals detected in groundwater at concentrations in excess of State or Federal screening standards. Iron and manganese detections exceeded applicable State standards among a number of the shallow groundwater samples, but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. Only one positive detection of mercury exceeded the State standard. Copper, iron, and nickel were the only TAL total metals identified among the surface water samples obtained from Site 36 that exceeded State or Federal chronic screening values. Iron was identified among three of the seven surface water samples at concentrations in excess of chronic screening values. The pesticides 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, and alpha-chlordane were detected among the sediment samples retained for analysis from Site 36. Each of the pesticide detections exceeded applicable NOAA ER-L chronic sediment screening values. Cadmium, lead, mercury, nickel, and zinc were each detected at concentrations which exceeded applicable Federal chronic screening values at least once among the 15 sediment samples obtained from Site 36.

1.7.6 Prevalence of Inorganic Analytes in Site Media

Inorganic analytes were detected in soil, groundwater, surface water, and sediment samples obtained during the field investigation at Site 36. Analytes such as arsenic, iron, lead, mercury, and zinc were principal contributors to both human health and ecological site risks. These and other inorganic analytes naturally occur, often abundantly, in Base-wide media. Figures 1-6 and 1-7, respectively, depict the iron and lead concentrations detected in the surface and subsurface soils (and sediment detections for lead) at Site 36. As shown, only four surface soil detections of iron were in excess of the residential Region III Risk Based Concentration (RBC) of 23,000 milligrams per kilograms (mg/kg). These four iron detections were scattered over approximately 6 acres of the primarily wooded portions of Site 36. Similarly, the Office of Solid Waste and Emergency Response (OSWER) lead value of 400 mg/kg for surface soil was exceeded at only two locations, borings OA-SB04 and OA-SB08. These two lead detections are located approximately 920 feet apart. Therefore, a discernible pattern of analyte distribution was not evident among the various constituents or media sampled. The natural abundance and broad distribution of inorganic analytes throughout the environmental media at Site 36 make remediation of those analytes contributing to site risk unrealistic and impractical.

1.8 Post-RI Activities and Conclusions

Following submittal of the Final RI for Site 36 on August 22, 1996, three separate investigative activities have transpired. These three activities include: the re-calculation of human health risks

associated with exposure to the site sediments; additional subsurface soil analysis (TCLP for lead); and the time critical removal action (TCRA) for PCB-contaminated soil.

The updated (re-calculated) sediment human health risk calculations were completed to include assessment of two additional constituents, arsenic and chromium. The updated sediment risk calculations reviewed both sediment ingestion and dermal contact for the following receptors: a fisherman, a current and future residential child, a child trespasser, a current and future residential adult, and an adult trespasser. Similar to the previous risk assessment results, inclusion of the additional two constituents did not modify the initial outcome. As such, no risks were associated with exposure to site sediments. Copies of the updated sediment human health risk calculations are presented in Appendix A.

On December 18, 1996 a subsurface soil sample was collected for analysis of TCLP-lead from location 36-OA-SB07R-01 which is located in the southeastern portion of Site 36. This soil sample was collected from a depth of 3 to 3.5 feet below the ground surface and was located adjacent to location OA-SB07 (see Figure 1-3). The TCLP-lead soil sample was collected next to OA-SB07, as OA-SB07 had exhibited the highest subsurface lead concentration during the RI. Results of the TCLP-lead analysis indicated lead at a concentration of 0.115 mg/L, far below the Federal TCLP-lead action level of 5 mg/L. This additional analytical result reinforces the RI conclusion that the soil conditions at Site 36 are not conducive to leaching.

The RI surface soil results collected from the west central portion of Site 36 indicated the presence of PCBs. Based on the original RI soil results and subsequent soil analyses, a TCRA of PCB-contaminated soil was determined to be the most appropriate action for Site 36. A Final TCRA Design Package (Baker, 1997b) was completed on April 1, 1997. Post-RI PCB-sampling and results are documented within the Final TCRA Design Package and the Draft Closeout Report (OHM, 1998). Following completion of the PCB removal action, the soil remaining in this area of Site 36 will contain PCB concentrations of zero or less than 10 mg/kg which represents the lower limit of EPA's preliminary cleanup goal for industrial (non-residential) use.

1.9 References

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SECTION 1.0 TABLES

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Surface Soil	Volatiles	Trichloroethene	NA	NA	4	4	FDA-SB03	1/61	eastern, former disposal area
		Tetrachloroethene	NA	NA	2	3	36-GW12	3/61	northern, ground scar area
		Toluene	NA	NA	8	98	OF-SB01	4/61	south central, open field
		Styrene	NA	NA	39	39	GS-SB03	1/61	northern, ground scar area
		Xylene (total)	NA	NA	7	7	OF-SB06B	1/61	south central, open field
	Semivolatiles	n-Nitro-di-n-propylamine	NA	NA	320	320	DAB-SB03	1/57	southeastern, drum area
		Naphthalene (PAH)	NA	NA	48	120	OF-SB04	2/57	1 south central, 1 western
		2-Methylnapthalene	NA	NA	54	82	OA-SB01A	2/57	1 south central, 1 western
		Acenaphthene (PAH)	NA	NA	330	330	OF-SB04	1/57	south central, open field
		Dibenzofuran	NA	NA	150	150	OF-SB04	1/57	south central, open field
		Fluorene (PAH)	NA	NA	200	200	OF-SB04	1/57	south central, open field
		Phenanthrene (PAH)	NA	NA	59	2,500	OF-SB04	4/57	scattered
		Anthracene (PAH)	NA	NA	780	780	OF-SB04	1/57	south central, open field
		Carbazole	NA	NA	240	240	OF-SB04	1/57	south central, open field
		Fluoranthene (PAH)	NA	NA	54	5,500	OF-SB04	5/57	4 southeastern, drum area
		Pyrene (PAH)	NA	NA	41	11,000	OF-SB04	8/57	5 southeastern, drum area
		Butylbenzylphthalate	NA	NA	51	290	OA-SB03	3/57	western
		B(a)anthracene (PAH)	NA	NA	46	3,900	OF-SB04	2/57	1 south central, 1 southeastern
		Chrysene (PAH)	NA	NA	51	4,600	OF-SB04	5/57	3 southeastern, drum area
		B(b)fluoranthene (PAH)	NA	NA	51	3,600	OF-SB04	3/57	scattered
		B(k)fluoranthene (PAH)	NA	NA	39	1,500	OF-SB04	2/57	1 south central, 1 southeastern
		Benzo(a)pyrene (PAH)	NA	NA	40	3,300	OF-SB04	2/57	1 south central, 1 western
		I(1,2,3-cd)pyrene (PAH)	NA	NA	46	2,700	OF-SB04	3/57	scattered
		D(a,h)anthracene (PAH)	NA	NA	720	720	OF-SB04	1/57	south central, open field
		B(g,h,i)perylene (PAH)	NA	NA	2,400	2,400	OF-SB04	1/57	south central, open field

TABLE 1-1

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FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Surface Soil (Continued)	Pesticides	gamma-BHC (Lindane)	NA	NA	4.0	4.0	OF-SB06D	1/57	south central, open field
		Heptachlor	NA	NA	1.9	1.9	FCA-SB12	1/57	southwestern, former cleared area
		Aldrin	NA	NA	5.5	1,400	OF-SB03	3/57	1 open field, 2 adjacent to SB01
		Heptachlor epoxide	NA	NA	2	67	OA-SB01I	10/57	scattered, 3 adjacent to SB01
		Endosulfan I	NA	NA	8.3	36	OA-SB01E	3/57	all adjacent to SB01
		Dieldrin	NA	NA	2	16,000	OF-SB03	21/57	scattered
		4-4'-DDE	NA	NA	2.2	2,600	OA-SB01A	49/57	widely scattered, prevalent
		Endrin	NA	NA	9.9	9.9	OA-SB08	1/57	eastern, former disposal area
		4-4'-DDD	NA	NA	2.8	550	OA-SB01A	37/57	widely scattered, prevalent
		Endosulfan Sulfate	NA	NA	2.5	4.2	OF-SB06	2/57	1 south central, 1 western
		4-4'-DDT	NA	NA	1.8	12,000	OA-SB01A	48/57	widely scattered, prevalent
		Endrin Ketone	NA	NA	15	15	OF-SB03	1/57	south central, open field
		Endrin aldehyde	NA	NA	12	12	OF-SB02	1/57	south central, open field
		alpha-Chlordane	NA	NA	1.2	980	OA-SB05	15/57	scattered
		gamma-Chlordane	NA	NA	1.2	840	OA-SB05	10/57	scattered
	PCBs	Aroclor 1248	NA	NA	68	24,000	OA-SB01I	9/57	western, surrounding SB01
		Aroclor 1254	NA	NA	92	530	OA-SB01	3/57	western, surrounding SB01
	Metals (1)	Antimony	NA	5.3	3.3	31.7	OA-SB08	7/46	5 exceed BB, scattered
		Arsenic	NA	1.3	0.4	10.4	OA-SB08	43/52	22 exceed BB, scattered
		Cadmium	NA	0.7	0.7	6.3	OA-SB08	8/52	7 exceed BB, scattered
		Chromium	NA	6.7	1.6	51.6	OA-SB08	52/52	27 exceed BB, scattered
		Copper	NA	7.2	0.6	445	OA-SB08	39/52	25 exceed BB, scattered
		Lead	NA	23.7	4.3	836	OA-SB08	48/52	24 exceed BB, scattered
		Mercury	NA	0.1	0.1	2.4	OA-SB05	18/52	18 exceed BB, scattered
		Nickel	NA	3.4	1	48.3	OA-SB08	26/52	13 exceed BB, scattered
		Silver	NA	0.9	0.6	12	OF-SB04	8/48	5 exceed BB, 3 south central
		Zinc	NA	13.9	2.1	1,320	OA-SB08	50/52	34 exceed BB, scattered

TABLE 1-1

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SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Subsurface Soil	Volatiles	Acetone	NA	NA	12	480	GS-SB03	8/62	1 exceeds blank, ground scar area
		1,2-Dichloroethene (total)	NA	NA	4	4	OA-SB01	1/62	western
		Trichloroethene	NA	NA	3	5	FDA-SB01	3/62	2 eastern, 1 western
		Benzene	NA	NA	3	3	FDA-SB01	1/62	eastern, former disposal area
		Toluene	NA	NA	5	17	OF-SB06	5/62	south central, open field
		Xylene (total)	NA	NA	2	6	FDA-SB06	8/62	scattered
	Semivolatiles	1,4-Dichlorobenzene	NA	NA	97	97	DAB-SB02	1/57	southeastern, drum area
		2-Methylphenol	NA	NA	510	510	DAB-SB01	1/58	southeastern, drum area
		4-Methylphenol	NA	NA	43	43	DAB-SB01	1/58	southeastern, drum area
		Isophorone	NA	NA	2,100	2,100	DAB-SB01	1/58	southeastern, drum area
		Naphthalene (PAH)	NA	NA	41	41	OA-SB01A	1/57	western
		2-Methylnaphthalene	NA	NA	65	85	FDA-SB02	2/57	1 eastern, 1 western
		Phenanthrene (PAH)	NA	NA	48	190	OA-SB07	3/57	scattered
		Di-n-butylphtalate	NA	NA	56	56	OA-SB01	1/58	western
		Fluoranthene (PAH)	NA	NA	130	320	OA-SB07	3/57	2 eastern, 1 south central
		Pyrene (PAH)	NA	NA	59	320	OA-SB07	5/57	scattered
		Butylbenzylphtalate	NA	NA	42	170	OA-SB03	3/57	scattered
		B(a)anthracene (PAH)	NA	NA	69	140	OA-SB07	3/57	scattered
		Chrysene (PAH)	NA	NA	41	200	OA-SB07	5/57	3 eastern, former disposal area
		B(b)fluoranthene (PAH)	NA	NA	44	170	OA-SB07	5/57	4 eastern, 1 south central
		B(k)fluoranthene (PAH)	NA	NA	42	68	OA-SB07	3/57	eastern, former disposal area
		Benzo(a)pyrene (PAH)	NA	NA	72	450	GS-SB03	4/57	3 eastern, 1 northern
		I(1,2,3-cd)pyrene (PAH)	NA	NA	48	110	OA-SB07	3/57	eastern, former disposal area
		B(g,h,i)perylene (PAH)	NA	NA	42	89	OA-SB07	2/57	eastern, former disposal area

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SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Subsurface Soil (Continued)	Pesticides	gamma-BHC (Lindane)	NA	NA	4	4	OF-SB06D	1/56	open field
		Aldrin	NA	NA	1.5	16	36-GW11	5/56	3 southeastern, 2 eastern
		Heptachlor Epoxide	NA	NA	3.4	14	36-GW11	3/56	3 eastern, former disposal area
		Dieldrin	NA	NA	2.2	1,200	FDA-SB05	17/56	scattered
		4,4'-DDE	NA	NA	2.3	1,700	OA-SB01A	29/56	widely scattered, prevalent
		Endrin	NA	NA	2.4	5	OF-SB06B	5/56	scattered
		Endosulfan II	NA	NA	2.0	2.0	OF-SB06B	1/56	south central, open field
		4,4'-DDD	NA	NA	2.3	1,300	FDA-SB05	30/56	widely scattered, prevalent
		4,4'-DDT	NA	NA	2.8	3,100	OA-SB01A	28/56	widely scattered, prevalent
		Endrin Aldehyde	NA	NA	3.5	32	FDA-SB05	3/56	2 south central, 1 eastern
		alpha-Chlordane	NA	NA	1.6	750	36-GW11	12/56	primarily eastern
		gamma-Chlordane	NA	NA	2.3	770	36-GW11	9/56	primarily eastern
	PCBs	Aroclor 1248	NA	NA	19	850	OA-SB01	5/56	western, adjacent to SB01
	Metals (1)	Antimony	NA	6.4	4.9	21.6	36-GW11	7/44	3 exceed BB, eastern
		Arsenic	NA	1.9	0.2	25.9	FDA-SB01	41/51	18 exceed BB, eastern and central
		Cadmium	NA	0.7	0.7	42.8	36-GW11	11/51	9 exceed BB, eastern and central
		Chromium	NA	12.6	1.4	71.9	36-GW11	50/51	14 exceed BB, eastern and central
		Copper	NA	2.4	0.5	1,320	OF-SB06B	31/51	25 exceed BB, scattered
		Lead	NA	8.3	1.2	2,680	OA-SB07	50/51	32 exceed BB, scattered
		Mercury	NA	0.1	0.1	3.9	OA-SB07	13/51	12 exceed BB, east/southeastern
		Nickel	NA	3.7	1.1	72.1	DAD-SB02	24/51	19 exceed BB, scattered
		Selenium	NA	0.8	0.4	1.2	OF-SB06	4/51	1 exceeds BB, southcentral
		Zinc	NA	6.7	0.9	2,580	FDA-SB05	41/51	28 exceed BB, scattered
Groundwater	Volatiles (2)	Methylene Chloride	NCWQS - 5	NA	1	1	36-GW10	1/29	does not exceed standard
		1,2-Dichloroethene (total)	MCL - 70	NA	4	37	36-GW10IW	8/29	none exceed standard
		Trichloroethene	NCWQS - 2.8	NA	3	97	36-GW10IW	10/29	10 exceed standard, northern
		Tetrachloroethene	NCWQS - 0.7	NA	1	2	36-GW10IW	2/29	both exceed standard, northern

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Groundwater (Continued)		1,1,2,2-Tetrachloroethane	NA	NA	3	10	36-GW10IW	6/29	northern, former ground scar area
	Semivolatiles	ND	NCWQS/MCL	NA				0/17	
	Pesticides	4,4'-DDD	NA	NA	0.06	0.06	36-GW10	1/18	northern, during Round One only
	PCBs	ND	NCWQS/MCL	NA				0/18	
	Total Metals	Iron	NCWQS - 300	NA	3.3	16,900	36-GW02	20/22	12 exceed standard, scattered
		Manganese	NCWQS - 50	NA	19.2	3,180	36-GW09	20/22	12 exceed standard, scattered
		Mercury	NCWQS - 1.1	NA	1.4	1.4	36-TW02	1/22	1 exceeds standard, southern
Surface Water (3)	Volatiles	1,2-Dichloroethene (total)	NA	NA	7	7	36-SW02	1/7	UT, upgradient of open field
	Semivolatiles	ND	NCWQS/NOAA	NA				0/7	
	Pesticides	ND	NCWQS/NOAA	NA				0/7	
	PCBs	ND	NCWQS/NOAA	NA				0/7	
	Metals (4)	Copper	NOAA - 6.5	4 - 129	56.5	56.5	36-SW01	1/7	1 exceeds fresh standard, not BB
		Iron	NOAA - 1,000	413 - 1416	967	4840	36-SW03	7/7	3 exceed fresh standard and BB
		Nickel	NOAA - 8.3	ND	16.4	31.4	36-SW02	4/7	1 exceeds salt standard
Sediment	Volatiles	Tetrachloroethane	NA	NA	4	4	36-SD04	1/13	near mouth of UT at BC
	Semivolatiles	Diethylphthalate	NA	NA	330	2,135	36-SD05	3/13	UT and near mouth of UT
		Anthracene	NOAA - 85	NA	46	46	36-SD04	1/13	does not exceed standard, UT
		Di-n-butylphthalate	NA	NA	218	218	36-SD06	1/13	BC, adjacent to ground scar area
		Pyrene (PAH)	NOAA - 350	NA	316	316	36-SD02	1/13	UT, does not exceed standard
	Pesticides	Aldrin	NA	NA	0.9	0.9	36-SD01	1/13	UT, upgradient
		Dieldrin	NA	NA	0.8	52	36-SD06	3/13	2 from BC, minimum from UT
		4,4'-DDE	NOAA - 2	NA	32	1,200	36-SD05	9/13	9 exceed standard, higher in BC
		Endrin	NOAA - 0.02	NA	6.6	6.6	36-SD02	1/13	UT, upgradient of open field
		4,4'-DDD	NOAA - 2	NA	14	1,140	36-SD05	12/13	12 exceed standard
		Endosulfan Sulfate	NA	NA	3	3	36-SD02	1/13	UT, upgradient of open field
		4,4'-DDT	NOAA - 1	NA	3	46	36-SD05	11/13	11 exceed standard
		Endrin Ketone	NA	NA	11	11	36-SD03	1/13	UT, adjacent to open field

TABLE 1-1

SUMMARY OF SITE CONTAMINATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Fraction	Detected Contaminants	Comparison Criteria		Site Contamination				
			Standard	Base Background	Min.	Max.	Max. Location	Detection Frequency	Distribution
Sediment (Continued)	Pesticides (Continued)	Endrin Aldehyde	NA	NA	3.5	7.6	36-SD05	2/13	1 from BC, 1 from UT
		alpha-Chlordane	NOAA - 0.5	NA	6.5	13	36-SD07	2/13	2 exceed standard, upgradient BC
	PCBs	ND	NOAA	NA				0/13	
	Metals (4)	Cadmium	NOAA - 5	0.5 - 1.3	1.4	8.7	36-SD02	2/15	1 exceeds standard and BB, UT
		Lead	NOAA - 35	1 - 314	7.1	15,100	36-SD06	12/15	7 exceed standard, 1 exceeds BB
		Mercury	NOAA - 0.15	ND	0.2	0.7	36-SD04	3/4	3 exceed standard, 11 rejected
		Nickel	NOAA - 30	2.8 - 6.0	2.1	77.1	36-SD03	11/15	1 exceeds standard, from UT
		Zinc	NOAA - 120	12 - 926	25.3	140	36-SD02	5/5	1 exceeds standard, not BB, UT

Notes:

- Concentrations are presented in µg/L for liquid and µg/Kg for solids (ppb), metal concentrations for soils and sediments are presented in mg/Kg (ppm).

(1) Metals in both surface and subsurface soils were compared to twice the average base background positive concentrations for priority pollutant metals only (i.e., antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, thallium, zinc).

(2) An additional round of groundwater samples were collected from wells which exhibited concentrations of volatiles during the first round.

(3) Surface water detections were compared to appropriate NCWQS and NOAA screening values, based upon the observed percentage of saltwater at each sampling location.

(4) Total metals in surface water and sediment were compared to the range of positve detections in upgradient samples at MCB, Camp Lejeune.

BB - Base background, value equals two times average

BC - Brinson Creek

BEHP - bis(2-ethylhexyl)phthalate

NA - Not applicable

NCWQS - North Carolina Water Quality Standard

ND - Not detected

NOAA - National Oceanic and Atmospheric Administration

MCL - Federal Maximum Contaminant Level

PAH - Polynuclear aromatic hydrocarbon

UT - Unnamed Tributary

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TCL ORGANICS

LOCATION	36-GW01-01	36-GW02-01	36-GW03-01	36-GW04-01	36-GW05-01	36-GW06-01
DATE SAMPLED	03/28/95	03/27/95	03/26/95	03/26/95	03/26/95	03/27/95
VOLATILES (ug/l)						
1,2-DICHLOROETHENE (TOTAL)	10 U	10 U	10 U	4 J	10 U	10 U
TRICHLOROETHENE	10 U	10 U	10 U	10 U	10 U	10 U
1,1,2,2-TETRACHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)						
BIS(2-ETHYLHEXYL)PHTHALATE	10 U	10 U	10 U	10 U	9 U	10 U
PESTICIDES/PCBs (ug/l)						
4,4'-DDD	0.093 U	0.1 UJ	0.092 U	0.097 UJ	0.095 UJ	0.096 UJ

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TCL ORGANICS

LOCATION	36-GW06DW-01	36-GW07-01	36-GW07DW-01	36-GW08-01	36-GW09-01	36-GW10-01
DATE SAMPLED	03/26/95	03/26/95	03/26/95	03/27/95	03/27/95	03/25/95
VOLATILES (ug/l)						
1,2-DICHLOROETHENE (TOTAL)	10 U	10 U	10 U	5 J	10 U	10 U
TRICHLOROETHENE	10 U	10 U	10 U	10 U	10 U	8 J
1,1,2,2-TETRACHLOROETHANE	10 U	10 U	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)						
BIS(2-ETHYLHEXYL)PHTHALATE	10 U	9 U	10 U	10 U	5 J	10 U
PESTICIDES/PCBs (ug/l)						
4,4'-DDD	0.096 UJ	0.095 UJ	0.094 UJ	0.093 U	0.1 UJ	0.056 J

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TCL ORGANICS

LOCATION	36-GW10IW-01	36-GW10DW-01	36-GW11-01	36-GW11DW-01	36-GW12-01	36-GW12IW-01
DATE SAMPLED	05/09/95	07/12/95	03/27/95	03/27/95	05/08/95	05/08/95
VOLATILES (ug/l)						
1,2-DICHLOROETHENE (TOTAL)	31 J	10 U	10 U	10 U	10 UJ	10 UJ
TRICHLOROETHENE	70	10 U	10 U	10 U	9 J	10 U
1,1,2,2-TETRACHLOROETHANE	10	10 U	10 U	10 U	6 J	10 U
SEMIVOLATILES (ug/l)						
BIS(2-ETHYLHEXYL)PHTHALATE	NA	10 U	10 U	10 U	NA	NA
PESTICIDES/PCBs (ug/l)						
4,4'-DDD	NA	0.096 UJ	0.095 U	0.095 UJ	NA	NA

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-2
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TCL ORGANICS

LOCATION	36-GW13-01	36-GW13IW-01	36-GW14-01	36-TW01-01	36-TW02-01
DATE SAMPLED	05/09/95	05/08/95	05/08/95	03/15/95	03/14/95
VOLATILES (ug/l)					
1,2-DICHLOROETHENE (TOTAL)	8 J	14 J	10 UJ	10 U	10 U
TRICHLOROETHENE	6 J	3 J	10 U	10 U	10 U
1,1,2,2-TETRACHLOROETHANE	10 U	10 U	10 U	10 U	10 U
SEMIVOLATILES (ug/l)					
BIS(2-ETHYLHEXYL)PHTHALATE	NA	NA	NA	1 J	11 U
PESTICIDES/PCBs (ug/l)					
4,4'-DDD	NA	NA	NA	0.11 UJ	0.1 UJ

UG/L - microgram per liter
J - value is estimated
NA - not analyzed
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TAL METALS

LOCATION	36-GW01-01	36-GW02-01	36-GW03-01	36-GW04-01	36-GW05-01	36-GW06-01
DATE SAMPLED	03/28/95	03/27/95	03/26/95	03/26/95	03/26/95	03/27/95
ANALYTE (ug/l)						
ALUMINUM, TOTAL	58.3 U	64.9 U	21.9	128	143	590
ARSENIC, TOTAL	3.6	3.4	1.9 U	1.9 U	1.9 U	1.9 U
BARIUM, TOTAL	290	69	4.4 U	81.5	43.9	61.5
CADMIUM, TOTAL	2.8 U	2.8 U	2.9 U	2.9 U	2.9 U	2.9 U
CALCIUM, TOTAL	139000	92300	1740	27300	18100	6110
IRON, TOTAL	13300 J	16900 J	160	32.8	692	4870
LEAD, TOTAL	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
MAGNESIUM, TOTAL	13000	28900	274	4420	3830	2630
MANGANESE, TOTAL	1150	452	54.5	19.2	4.9 U	22.3
MERCURY, TOTAL	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL, TOTAL	10.8 U	10.8 U	4.2 U	4.2 U	4.2 U	4.2 U
POTASSIUM, TOTAL	11600	37500	2470	1340	620	854
SELENIUM, TOTAL	1.4 U	1.4 U	1.5 U	1.6	1.5 U	1.5 U
SODIUM, TOTAL	14800	46400	42200	11200	10600	11600
VANADIUM, TOTAL	2.3 U	2.3 U	2.1 U	2.1 U	2.1 U	2.1 U
ZINC, TOTAL	3.8 U	3.8 U	1.9 U	1.9 U	1.9 U	1.9 U

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TAL METALS

LOCATION	36-GW06DW-01	36-GW07-01	36-GW07DW-01	36-GW08-01	36-GW09-01	36-GW10-01
DATE SAMPLED	03/26/95	03/26/95	03/26/95	03/27/95	03/27/95	03/25/95
ANALYTE (ug/l)						
ALUMINUM, TOTAL	16.8 U	16.8 U	16.8 U	136 U	72.9	16.8 U
ARSENIC, TOTAL	1.9 U	1.9 U	1.9 U	1.6 U	1.9 U	1.9 U
BARIUM, TOTAL	2.9 U	12.3	2.8 U	54.5	45.8	49.2
CADMIUM, TOTAL	2.9 U	2.9 U	2.9 U	2.8 U	2.9 U	2.9 U
CALCIUM, TOTAL	45700	70600	42500	28600	165000	121000
IRON, TOTAL	49.5	341	27.4	172 J	2880	3.3
LEAD, TOTAL	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U	1.6 U
MAGNESIUM, TOTAL	2580	1930	2020	4430	41500	5960
MANGANESE, TOTAL	34.7	37.7	40.8	21.1	3180	207
MERCURY, TOTAL	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL, TOTAL	4.2 U	4.2 U	4.2 U	10.8 U	7.4	4.2 U
POTASSIUM, TOTAL	5930	1230	4260	6450	26000	1150
SELENIUM, TOTAL	1.5 U	1.5 U	1.5 U	1.4 U	1.5 UJ	1.5 U
SODIUM, TOTAL	33400	13500	33100	17700	49100	12800
VANADIUM, TOTAL	2.1 U	2.3 U	2.1 U	2.3 U	2.1 U	2.1 U
ZINC, TOTAL	166	1.9 U	1.9 U	16.8 U	224	1.9 U

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TAL METALS

LOCATION	36-GW10IW-01	36-GW10DW-01	36-GW11-01	36-GW11DW-01	36-GW12-01	36-GW12IW-01
DATE SAMPLED	05/09/95	07/12/95	03/27/95	03/27/95	05/08/95	05/08/95
ANALYTE (ug/l)						
ALUMINUM, TOTAL	88.4 U	56.3	31.2 U	16.8 U	705	36.8 U
ARSENIC, TOTAL	1.5 U	1.8 U	1.6 U	1.9 U	1.5 U	1.5 U
BARIUM, TOTAL	28.4	15.1	57.8	11.5	41.2	52.2
CADMIUM, TOTAL	3.9 U	3.7 U	2.8 U	3	3.9 U	3.9 U
CALCIUM, TOTAL	159000	39000	191000	50400	106000	102000
IRON, TOTAL	101	18.9	375 J	106	686	17.1 U
LEAD, TOTAL	1.6 U	2.2	1.6 U	1.6 U	3.4 U	14.7
MAGNESIUM, TOTAL	11300	16000	42800	21700	4690	4030
MANGANESE, TOTAL	92.4	2.2	126	84	44.6	51.3
MERCURY, TOTAL	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U	0.2 U
NICKEL, TOTAL	5.4 U	4.8 U	10.8 U	4.2 U	5.4 U	5.4 U
POTASSIUM, TOTAL	3850	24700	37900	20100	2650	3210
SELENIUM, TOTAL	1.8 U	1.6 U	3.3	1.5 U	1.8 U	1.8 U
SODIUM, TOTAL	41300	61700	46100	70700	13900	19200
VANADIUM, TOTAL	1.5 U	6.7	2.3 U	2.1 U	2.9 U	1.5 U
ZINC, TOTAL	2.5 U	3.7	6.5 U	1.9 U	3.9 U	2.8 U

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-3
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 1
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TAL METALS

LOCATION	36-GW13-01	36-GW13IW-01	36-GW14-01	36-TW02-01
DATE SAMPLED	05/09/95	05/08/95	05/08/95	03/14/95
ANALYTE (ug/l)				
ALUMINUM, TOTAL	41.1 U	58 U	386	155 U
ARSENIC, TOTAL	1.5 U	1.5 U	1.5 U	1.9 U
BARIUM, TOTAL	23.2	12.3	36.7	204
CADMIUM, TOTAL	3.9 U	3.9 U	3.9 U	2.8 U
CALCIUM, TOTAL	120000	76300	47800	68400
IRON, TOTAL	337	425	6650	7640
LEAD, TOTAL	1.9 U	12.7	0.9 U	1 U
MAGNESIUM, TOTAL	4640	9590	2480	36200
MANGANESE, TOTAL	183	66.6	31.6	210
MERCURY, TOTAL	0.2 U	0.2 U	0.2 U	1.4
NICKEL, TOTAL	5.4 U	5.4 U	5.4 U	65.2
POTASSIUM, TOTAL	2310	5060	758	15300
SELENIUM, TOTAL	1.8 U	1.8 U	1.8 U	1.5 U
SODIUM, TOTAL	13000	40200	6710	308000
VANADIUM, TOTAL	1.5 U	1.5 U	1.5 U	2.6
ZINC, TOTAL	2.4 U	2.2 U	4.7 U	8.5

UG/L - microgram per liter
J - value is estimated
U - not detected
UJ - not detected, value is estimated

TABLE 1-4
GROUNDWATER - POSITIVE DETECTION SUMMARY
ROUND 2
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA
TCL ORGANICS

LOCATION	36-GW10-02	36-GW10IW-02	36-GW12-02	36-GW12IW-02	36-GW13-02	36-GW13IW-02
DATE SAMPLED	07/11/95	07/11/95	07/11/95	07/11/95	07/11/95	07/11/95
VOLATILES (ug/l)						
METHYLENE CHLORIDE	1 J	10 U	10 U	10 U	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	10 U	37	10 U	10 U	13	9 J
TRICHLOROETHENE	10	97	4 J	10 U	5 J	3 J
TETRACHLOROETHENE	1 J	2 J	10 U	10 U	10 U	10 U
1,1,2,2-TETRACHLOROETHANE	3 J	8 J	3 J	10 U	4 J	10 U
SEMIVOLATILES (ug/l)						
BIS(2-ETHYLHEXYL)PHTHALATE	NA	NA	NA	NA	NA	NA
PESTICIDES/PCB's (ug/l)						
4,4'-DDD	ND	NA	NA	NA	NA	NA

UG/L - microgram per liter
J - value is estimated
U - not detected
NA - not analyzed
ND - not detected

TABLE 1-5

POST-RI GROUNDWATER-VOLATILE ORGANICS
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

SAMPLE ID	IR36-GW16IW-01	IR36-GW17-01
DATE SAMPLED	07/02/97	07/02/97
VOLATILES (ug/L)		
CHLOROMETHANE	10 U	10 U
BROMOMETHANE	10 U	10 U
VINYL CHLORIDE	10 U	10 U
CHLOROETHANE	10 U	10 U
METHYLENE CHLORIDE	10 U	10 U
ACETONE	10 U	10 U
CARBON DISULFIDE	10 U	10 U
1,1-DICHLOROETHENE	10 U	10 U
1,1-DICHLOROETHANE	10 U	10 U
1,2-DICHLOROETHENE (TOTAL)	5 J	10 U
CHLOROFORM	10 U	10 U
1,2-DICHLOROETHANE	10 U	10 U
2-BUTANONE	10 U	10 U
1,1,1-TRICHLOROETHANE	10 U	10 U
CARBON TETRACHLORIDE	10 U	10 U
BROMODICHLOROMETHANE	10 U	10 U
1,2-DICHLOROPROPANE	10 U	10 U
CIS-1,3-DICHLOROPROPENE	10 U	10 U
TRICHLOROETHENE	6 J	10 U
DIBROMOCHLOROMETHANE	10 U	10 U
1,1,2-TRICHLOROETHANE	10 U	10 U
BENZENE	10 U	10 U

NOTES

U = Not detected

J = Estimated Value

ug/L = micrograms per liter

TABLE 1-5

POST-RI GROUNDWATER-VOLATILE ORGANICS
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

SAMPLE ID	IR36-GW16IW-01	IR36-GW17-01
DATE SAMPLED	07/02/97	07/02/97
VOLATILES (ug/L) (cont)		
TRANS-1,3-DICHLOROPROPENE	10 U	10 U
BROMOFORM	10 U	10 U
4-METHYL-2-PENTANONE	10 U	10 U
2-HEXANONE	10 U	10 U
TETRACHLOROETHENE	10 U	10 U
1,1,2,2-TETRACHLOROETHANE	10 U	10 U
TOLUENE	10 U	10 U
CHLOROBENZENE	10 U	10 U
ETHYLBENZENE	10 U	10 U
STYRENE	10 U	10 U
XYLENE (TOTAL)	10 U	10 U

NOTES

U = Not detected

J = Estimated Value

ug/L = micrograms per liter

TABLE 1-6

SUMMARY OF CURRENT POTENTIAL HUMAN HEALTH RISKS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Human Receptor	Potential Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Military	**Surface Soil**		
	Ingestion	7.0E-02	7.3E-07
	Dermal Contact	1.8E-02	5.0E-07
	Inhalation	9.6E-07	6.5E-09
	Total Risk	8.7E-02	1.2E-06
Child Trespasser	**Surface Soil**		
	Ingestion	1.7E-01	2.7E-06
	Dermal Contact	2.0E-02	8.4E-07
	Inhalation	7.8E-07	7.9E-09
	Total Risk	1.9E-01	3.5E-06
	Surface Water		
	Ingestion	1.0E-02	--
	Dermal Contact	3.1E-02	--
	Total	4.1E-02	--
	Sediment		
	Ingestion	1.5E-01	7.1E-07
	Dermal Contact	7.7E-03	6.8E-08
	Total	1.5E-01	7.8E-07
	Total Risk	3.9E-01	4.3E-06
Adult Trespasser	**Surface Soil**		
	Ingestion	6.0E-03	4.7E-07
	Dermal Contact	3.6E-03	7.5E-07
	Inhalation	1.1E-07	5.6E-09
	Total	9.5E-03	1.2E-06
	Surface Water		
	Ingestion	2.1E-03	--
	Dermal Contact	1.7E-02	--
	Total	1.9E-02	--
	Sediment		
	Ingestion	1.6E-02	3.8E-07
	Dermal Contact	4.1E-03	1.8E-07
	Total	2.0E-02	5.6E-07
	Total Risk	4.8E-02	1.8E-06
Fisherman	**Surface Water**		
	Ingestion	2.3E-03	--
	Dermal Contact	1.3E-02	--
	Total	1.6E-02	--
	Sediment		
	Ingestion	1.7E-02	4.1E-07
	Dermal Contact	5.1E-03	2.3E-07
	Total	2.2E-02	6.3E-07
	Fish Ingestion	**5.3**	**5.3E-04**
	Crab Ingestion	**3.8**	**5.4E-04**
	Total Risk	**9.1**	**1.1E-03**

Notes:

-- = Not Applicable
Bolded values indicate risk values that exceed the acceptable risk value of 1.0 for noncarcinogenic effects or $1x10^{-4}$ for carcinogenic effects.

TABLE 1-7

SUMMARY OF FUTURE POTENTIAL HUMAN HEALTH RISKS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Human Receptor	Potential Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
Future Child Resident	**Surface Soil**		
	Ingestion	9.1E-01	1.4E-05
	Dermal Contact	6.2E-02	2.6E-06
	Inhalation	3.1E-06	3.2E-08
	Total	9.7E-01	1.7E-05
	Subsurface Soil		
	Ingestion	**2.2**	1.4E-05
	Dermal Contact	1.3E-01	1.2E-06
	Inhalation	2.8E-06	4.8E-08
	Total	**2.3**	1.5E-05
	Groundwater		
	Ingestion	**5.1**	1.8E-05
	Dermal Contact	7.4E-02	4.8E-07
	Inhalation	--	5.0E-07
	Total	**5.2**	1.9E-05
	Surface Water		
	Ingestion	1.0E-02	--
	Dermal Contact	2.3E-02	--
	Total	3.3E-02	--
	Sediment		
	Ingestion	1.5E-01	7.1E-07
	Dermal Contact	8.9E-03	7.8E-08
	Total	1.6E-01	7.9E-07
	Total Future Risk	**8.7**	5.2E-05
Future Adult Resident	**Surface Soil**		
	Ingestion	9.7E-02	7.7E-06
	Dermal Contact	3.4E-02	7.0E-06
	Inhalation	9.0E-07	4.6E-08
	Total	1.3E-01	1.5E-05
	Subsurface Soil		
	Ingestion	2.3E-01	7.5E-06
	Dermal Contact	6.9E-02	3.2E-06
	Inhalation	7.9E-07	6.9E-08
	Total	3.0E-01	1.1E-05
	Groundwater		
	Ingestion	**2.2**	3.9E-05
	Dermal Contact	3.6E-02	1.2E-06
	Inhalation	--	4.1E-07
	Total	**2.2**	4.1E-05

TABLE 1-7 (Continued)

SUMMARY OF FUTURE POTENTIAL HUMAN HEALTH RISKS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Human Receptor	Potential Exposure Pathway	Noncarcinogenic Risk	Carcinogenic Risk
	Surface Water		
	Ingestion	2.1E-03	--
	Dermal Contact	1.3E-02	--
	Total	1.5E-02	--
	Sediment		
	Ingestion	1.6E-02	3.8E-07
	Dermal Contact	4.8E-03	2.1E-07
	Total	2.1E-02	5.9E-07
	Total Future Risk	**2.7**	6.7x10-5
Construction Worker	**Surface Soil**		
	Ingestion	1.2E-01	3.1E-07
	Dermal Contact	6.4E-03	4.5E-08
	Inhalation	2.3E-07	3.9E-08
	Total	1.3E-01	3.6E-07
	Subsurface Soil		
	Ingestion	2.9E-01	3.1E-07
	Dermal Contact	1.3E-02	2.1E-08
	Inhalation	2.0E-07	5.9E-10
	Total	3.0E-01	3.3E-07
	Total Future Risk	4.3E-01	6.9E-07

Notes:

-- = Not Applicable
Bolded values indicate risk values that exceed the acceptable risk value of 1.0 for noncarcinogenic effects or $1x10^{-4}$ for carcinogenic effects.

SECTION 1.0 FIGURES

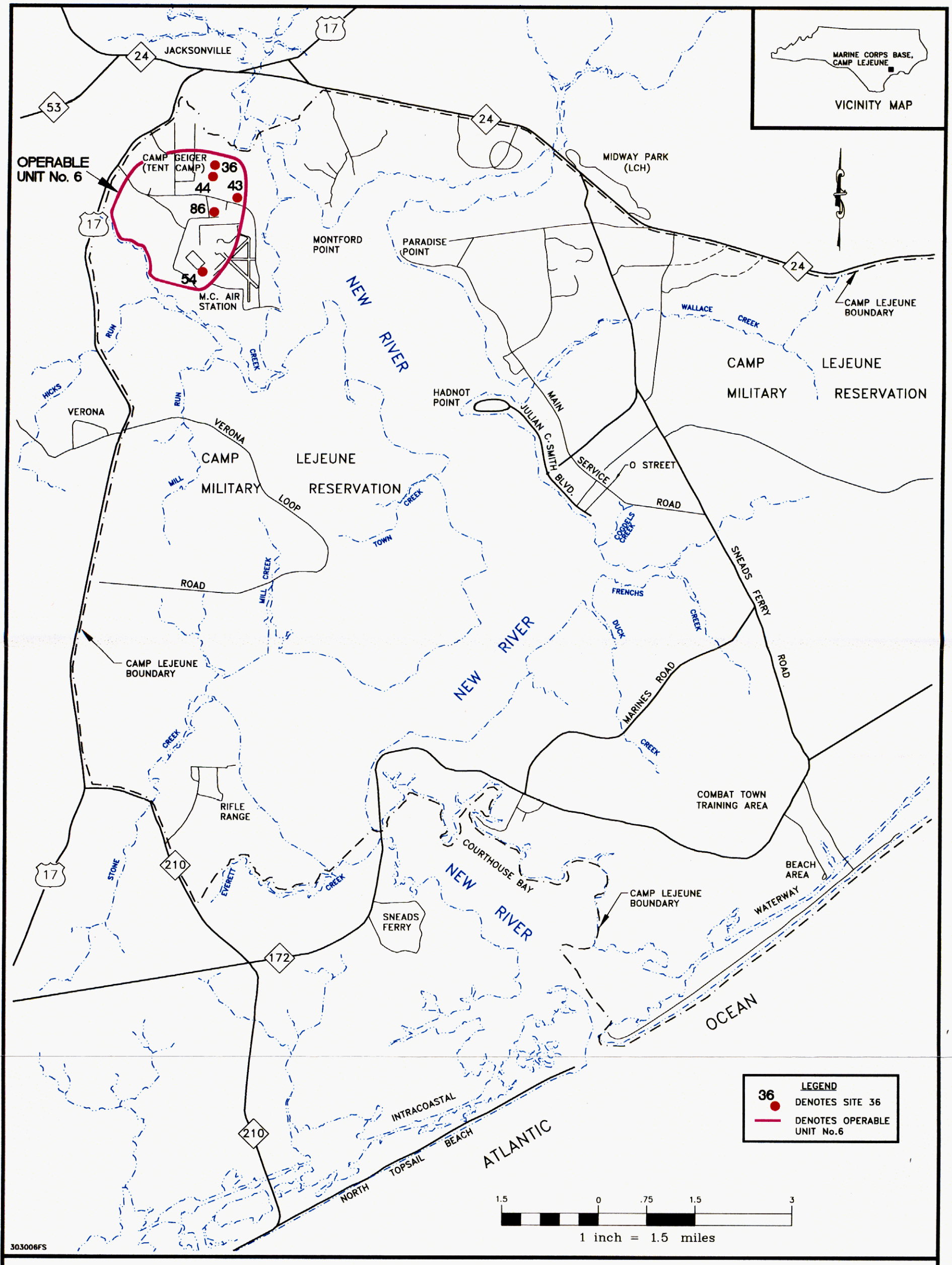
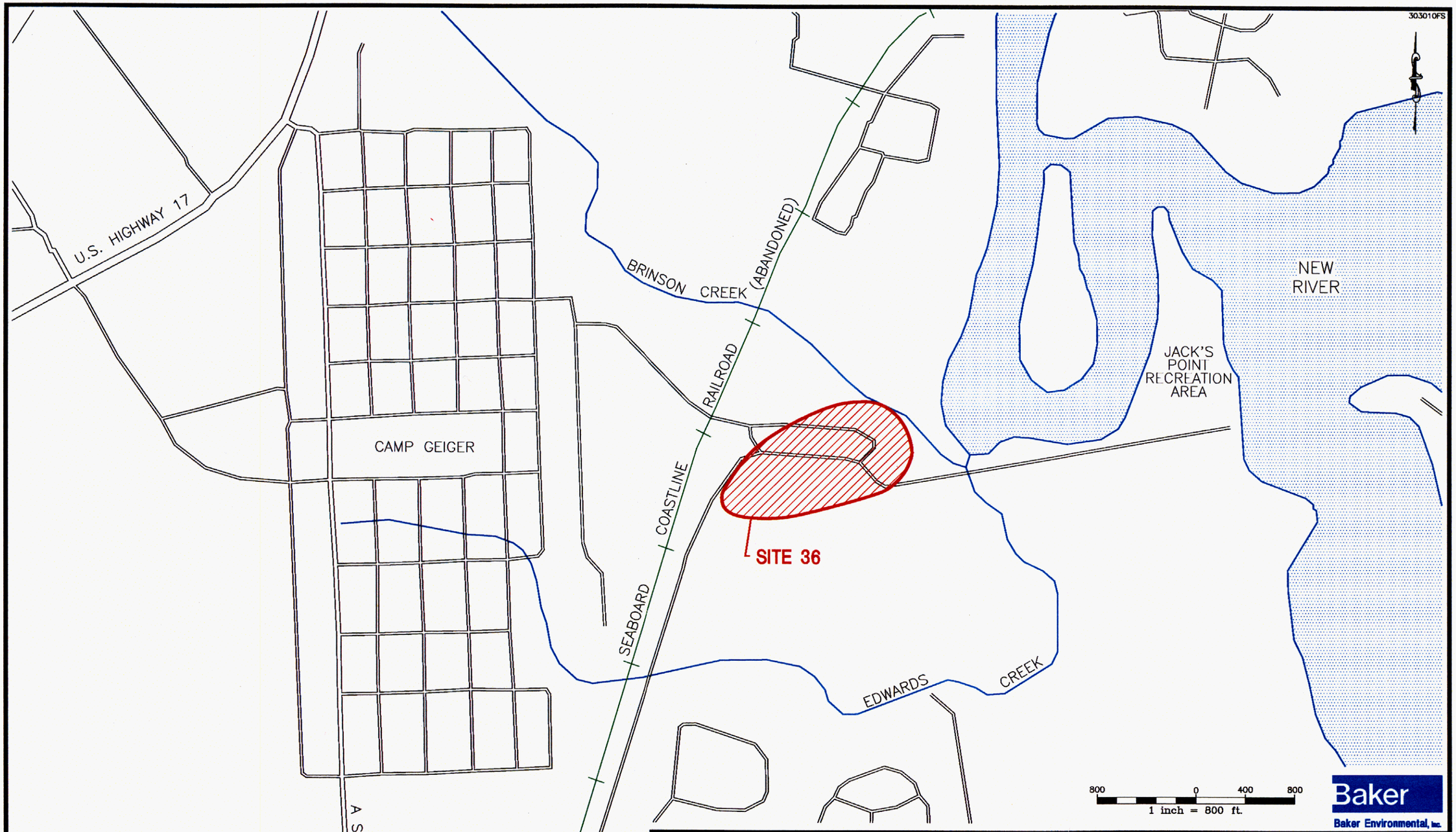


FIGURE 1-1
OPERABLE UNIT No. 6 – SITES 36, 43, 44, 54, AND 86
FEASIBILTY STUDY, CTO-0303

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02645CBIY

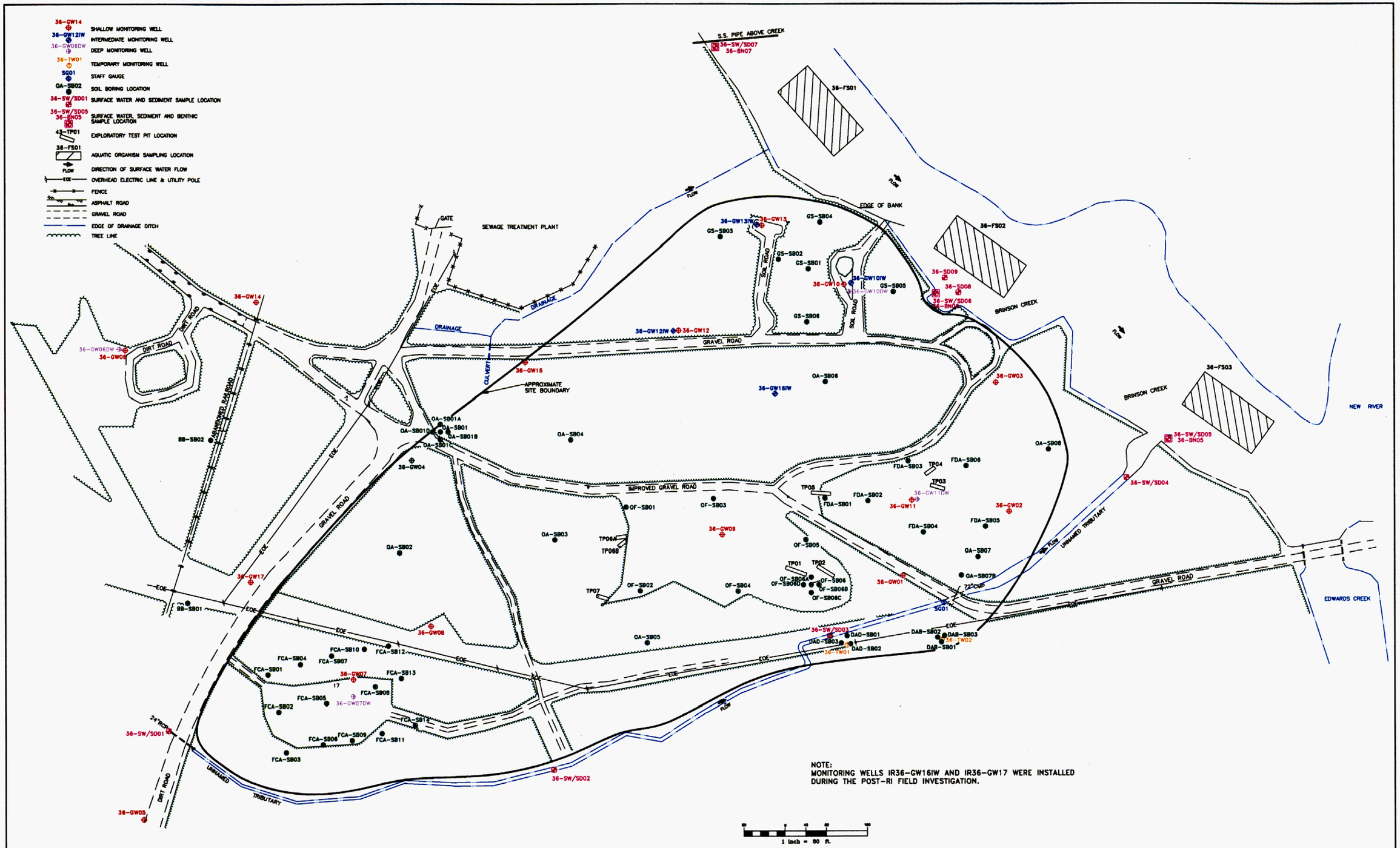


LEGEND

- EDGE OF CREEK OR RIVER
- IMPROVED ROADS
- SEABOARD COAST LINE RAILROAD

SOURCE: U.S.G.S. QUAD MAP, 1986

FIGURE 1-2
SITE LOCATION MAP
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



NOTE:
MONITORING WELLS IR36-GW16IW AND IR36-GW17 WERE INSTALLED DURING THE POST-RI FIELD INVESTIGATION.

REVISIONS			
JUNE 1998 - POST-RI GROUNDWATER SAMPLING LOCATIONS.	DRAWN	WJH	NORTH
	REVIEWED	TFT/JEZ	
	S.O.#	62470-303	
SOURCE: LANTDIV, 1992	CADD#	303514FS	

FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

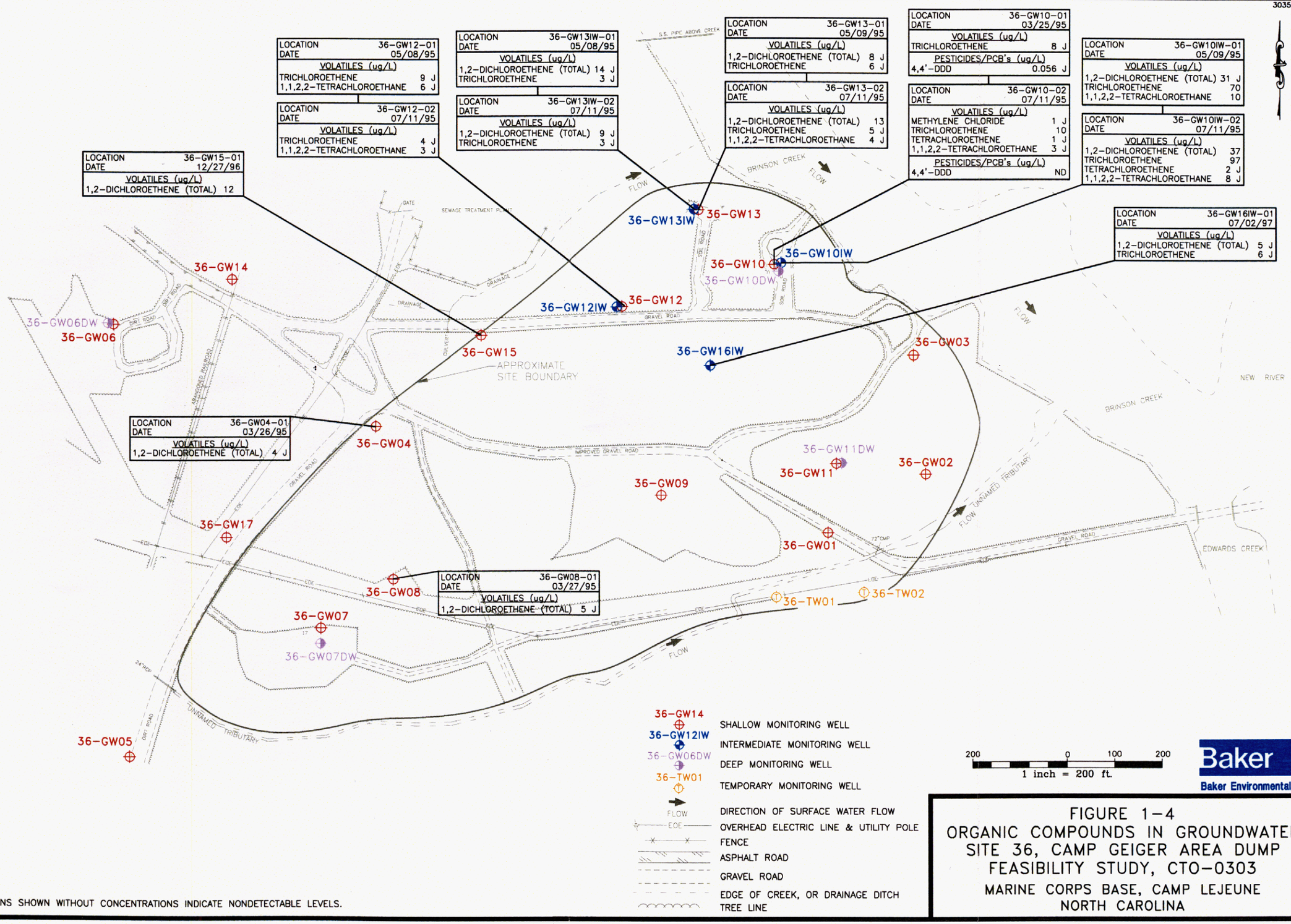
Baker
Baker Environmental, Inc.

REMEDIAL INVESTIGATION
SAMPLING LOCATIONS
SITE 36, CAMP GIEGER AREA DUMP

SCALE 1"= 80'
DATE JUNE 1998

FIGURE No.
1-3

303515FS



NOTE: LOCATIONS SHOWN WITHOUT CONCENTRATIONS INDICATE NONDETECTABLE LEVELS.

Baker
Baker Environmental, Inc.

FIGURE 1-4
ORGANIC COMPOUNDS IN GROUNDWATER
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

303008FS

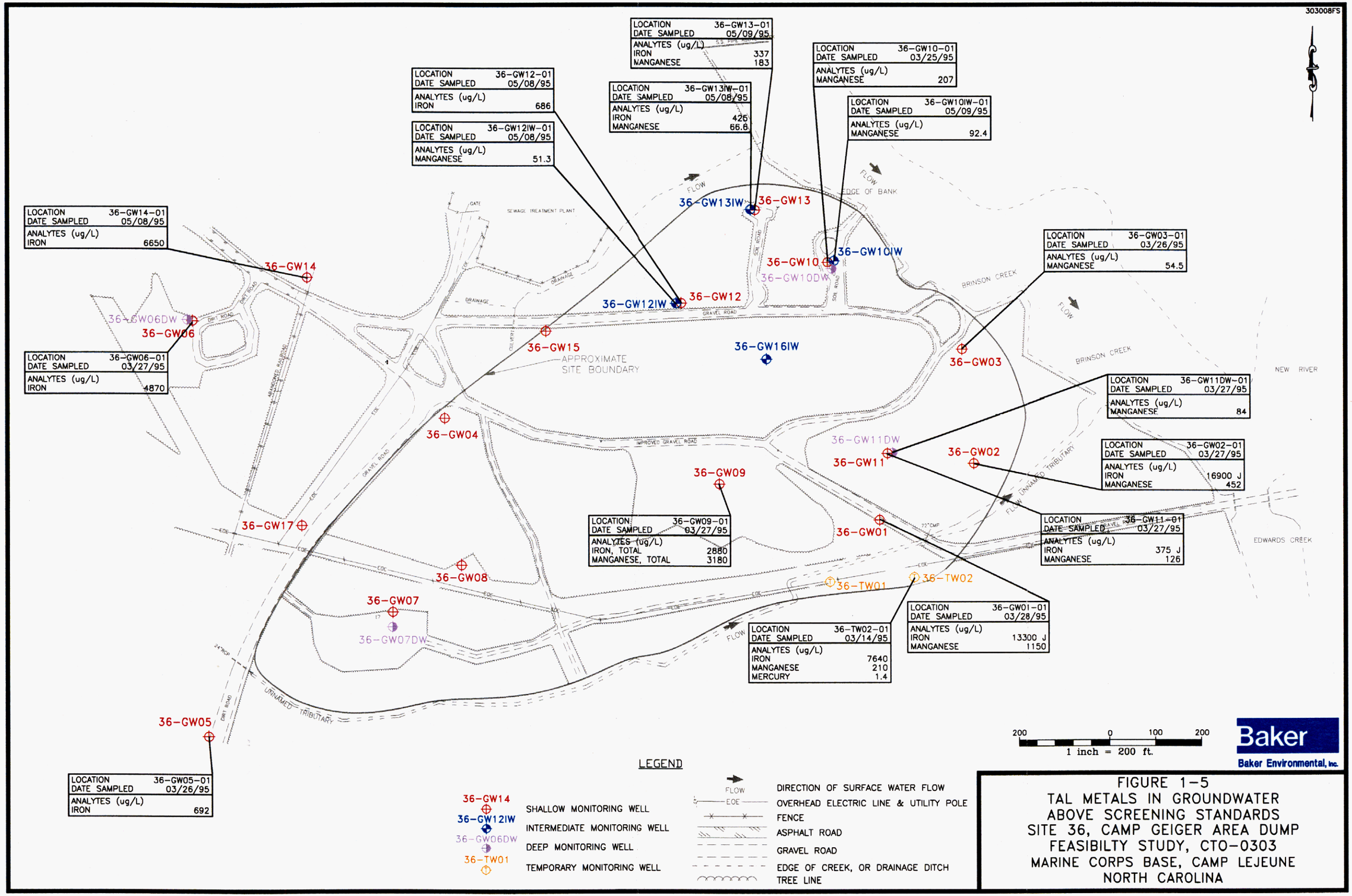
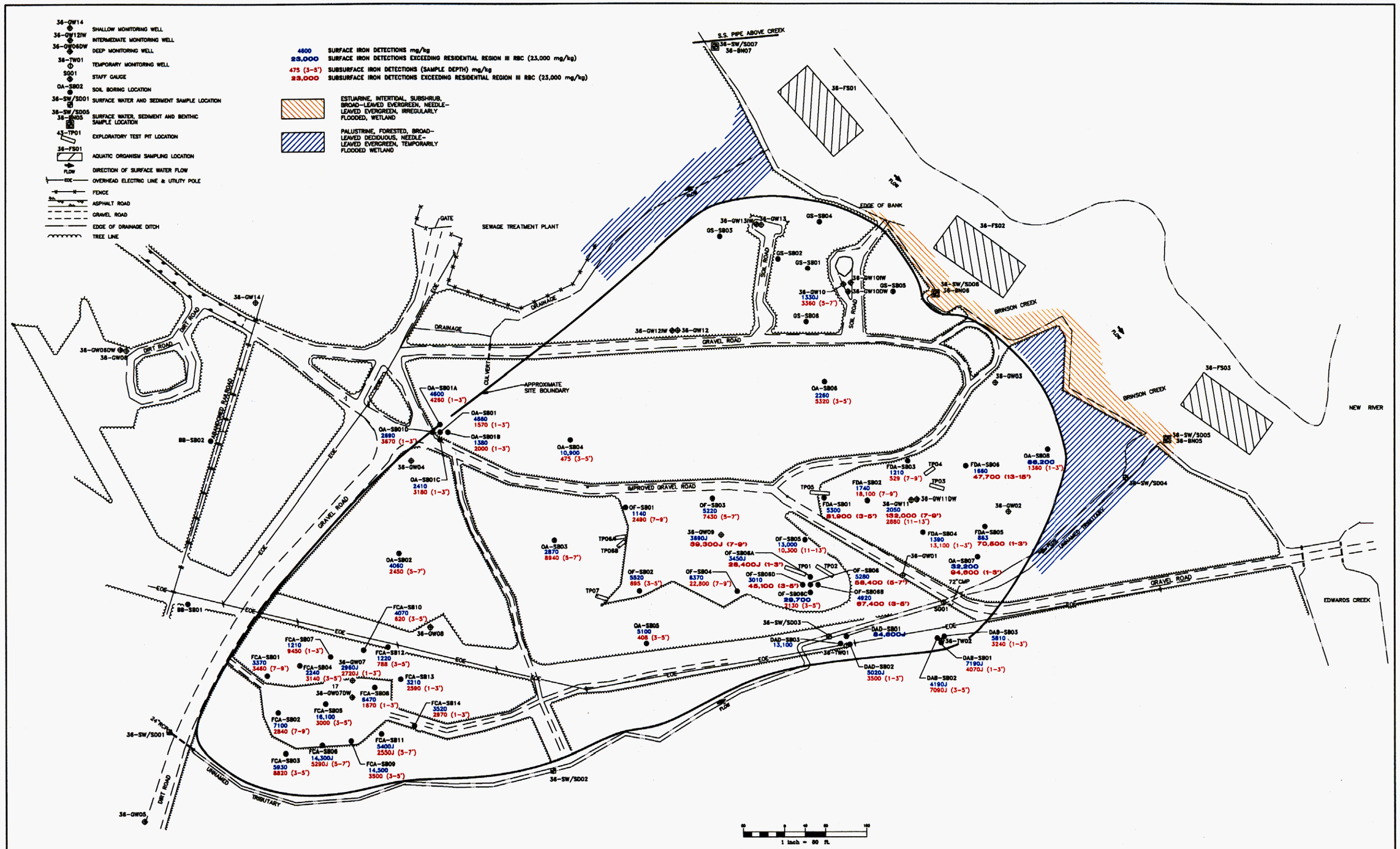


FIGURE 1-5
TAL METALS IN GROUNDWATER
ABOVE SCREENING STANDARDS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILTY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



REVISIONS			
SOURCE: LANTDIV, 1992	DRAWN REL REVIEWED TFT/JEZ S.O.# 62470-303 CADD# 303703PM	NORTH	

FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

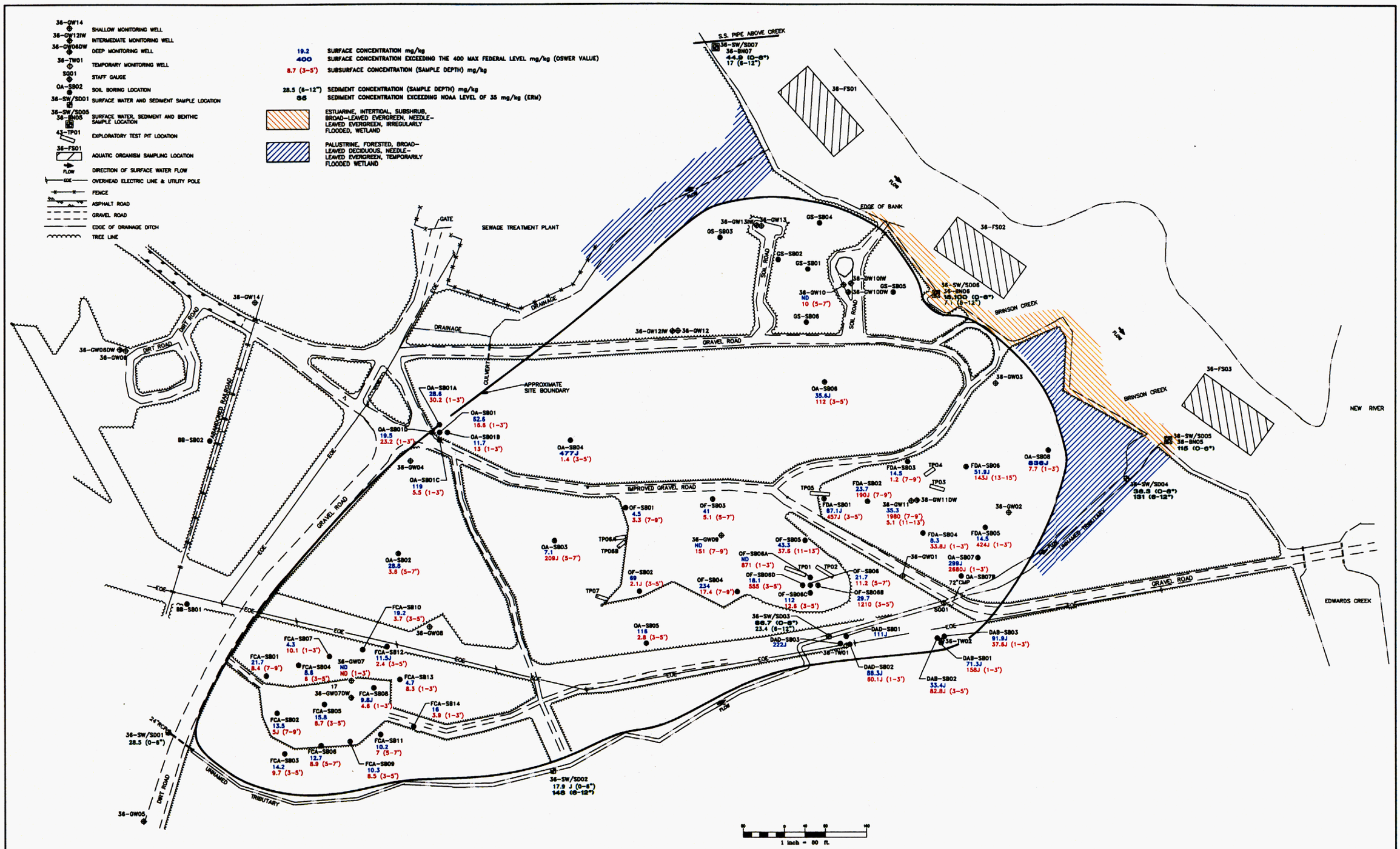
BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

DETECTED IRON CONCENTRATIONS IN SURFACE AND SUBSURFACE SOILS
SITE 36, CAMP GIEGER AREA DUMP

SCALE 1"= 80'
DATE OCTOBER 1996

FIGURE No.
1-6



REVISIONS					
SOURCE: LANTDIV, 1992	DRAWN REL REVIEWED TFT/JEZ S.O.# 62470-303 CADD# 303524FS	NORTH		FEASIBILITY STUDY, CTO-0303 MARINE CORPS BASE, CAMP LEJEUNE NORTH CAROLINA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.

DETECTED LEAD IN SURFACE SOILS, SUBSURFACE SOILS, AND SEDIMENTS
SITE 36, CAMP GIEGER AREA DUMP

SCALE 1"= 80' | DATE OCTOBER 1996

FIGURE No. 1-7

2.0 REMEDIATION GOAL OPTIONS, REMEDIATION LEVELS, AND REMEDIAL ACTION OBJECTIVES - SITE 36

This section presents remediation goal options, remediation levels, and remedial action objectives for OU No. 6, Site 36. Section 2.1 is an identification of the media and contaminants of concern, and Section 2.2 presents the exposure routes and receptors at Site 36. In Section 2.3, remediation goal options and final remediation levels are developed. Section 2.3 also includes a final set of contaminants of concern (COCs) for the FS. Based on the remediation levels, remedial action objectives and areas of concern are identified in Section 2.4.

2.1 Media of Concern/Contaminants of Concern

The media of concern at Site 36 are groundwater, surface soil, subsurface soil, fish tissue, and crab tissue. Exposure to groundwater and subsurface soil generated unacceptable noncarcinogenic human health risks. Calculated risks from fish and crab tissue exposure exceeded acceptable carcinogenic and noncarcinogenic risk levels. Lead in surface soil generated an unacceptable risk for the child receptor. Calculated risks from exposure to surface water and sediment were within acceptable risk levels. Consequently, surface water and sediment were not considered to be of concern from a human health standpoint.

From an ecological risk standpoint, constituents detected in the site surface water and sediment have a slight to very slight potential to reduce the aquatic receptor population in freshwater and saltwater environments, respectively. Some of the constituents detected in fish tissue were found to be elevated upon comparison to literature values. Lead concentrations in crab tissue were slightly greater than Base-specific background levels. Some potential adverse impacts to terrestrial receptors may occur from exposure to site surface soil. However, the mathematical models used to determine these impacts are highly protective of ecological quality and can be uncertain. Consequently, exposure to surface soil, surface water, and sediment by ecological receptors was not evaluated as part of this FS.

The set of groundwater, surface soil, subsurface soil, fish tissue, and crab tissue contaminants of potential concern (COPCs) evaluated during the Baseline Human Health Risk Assessment (BRA) is listed on Table 2-1. The COPCs that contributed to unacceptable risks were considered preliminary COCs for this FS. In addition, two VOCs in groundwater, PCE and TCE, were included in the evaluation. Although these two COPCs did not generate unacceptable risks, they were included in the FS because their maximum concentrations exceeded federal and state criteria. Two sampling rounds of data indicate that TCE and PCE detections were limited to the northern portion of the site. TCE was found during both sampling rounds at concentrations greater than criteria (e.g., Federal MCL and State NCWQS). Although PCE was not detected in the first sampling round, it was detected in this northern region during the second round at a concentration which exceeded the State water quality standard (WQS). As a result, these VOCs were also considered preliminary COCs for this FS.

Lead was identified as a COC in crab tissue, surface soil, and subsurface soil. There are no criteria available for lead in crab tissue. However, the action level of lead in surface soil is 400 mg/kg (USEPA, 1994). This level was exceeded only twice in surface soil; once at OA-SB04 at a level of 477J mg/kg and at OA-SB08 at a level of 836J mg/kg. These samples were located in two distinct open areas at Site 36; and therefore, do not appear to indicate a discernable pattern of lead contamination in the surface soil.

In the subsurface soil, the OWSER surface soil screening level was exceeded in 7 of the 50 samples (i.e, 14 percent) where lead was detected. The exceedances were as follows: 457J mg/kg at FDA-SB01; 424J at FDA-SB05; 1,980 mg/kg at 36-GW11; 2,680J mg/kg at OA-SB07, 871 mg/kg at OF-SB06A; 1,210 mg/kg at OF-SB06B; and 555 mg/kg at OF-SB06D.

The concentrations of the preliminary COCs will be compared to the remediation levels developed in Section 2.3.4 to generate a final list of COCs for the FS. Any preliminary COC that does not exceed its applicable regulatory or health based remediation level will be eliminated from the final list of COCs, thus eliminating it from further consideration in the FS. The final set of COCs will become the basis for a set of remedial action objectives applicable to Site 36.

2.2 Exposure Routes and Receptors

To determine risk-based action levels in the remaining media of concern at the site, all possible exposure pathways were considered for each medium. For Site 36, the following exposure scenarios were evaluated further within Section 2.3.3:

- Groundwater ingestion and dermal contact for an adult and child resident
- Subsurface soil ingestion and dermal contact for a child resident
- Fish and crab tissue ingestion for a recreational fisherman

Although exposure to groundwater and subsurface soil can occur via inhalation of volatile compounds and particulates, respectively, these exposure pathways were not included. The preliminary COC in subsurface soil and groundwater at this site was iron, which is not volatile and does not have an inhalation toxicity value available for quantitation. As a result, inhalation of iron in groundwater and subsurface soil was not included in the calculation of a groundwater or subsurface soil action level. Because lead was the only preliminary COC in surface soil, and there are no toxicity values available for lead, no risk-based levels were calculated for exposure to lead. Similarly, there are no toxicity values available for the lead detected in the crab tissue; therefore, no risk-based levels were calculated for ingestion of lead in crab tissue.

2.3 Remediation Goal Options and Remediation Levels

Remediation goal options are established based on Federal and State criteria and risk-based action levels. Section 2.3.1 presents the definition of applicable or relevant and appropriate Federal and State requirements (ARARs) and "to be considered" (TBC) requirements. Section 2.3.2 provides an evaluation of Federal and State criteria applicable to the COCs at Site 36. Development of site-specific risk-based action levels for the COCs at Site 36 are provided in Section 2.3.3. The Federal and State criteria and risk-based action levels developed for each COC are considered remediation goal options. One remediation goal option is chosen for each COC to develop a final set of remediation levels for the FS.

2.3.1 Definition of Applicable or Relevant and Appropriate Federal and State Requirements and "To Be Considered" Requirements

Under Section 121(d)(1) of CERCLA, remedial actions must attain a degree of cleanup which assures protection of human health and the environment. Additionally, CERCLA remedial actions

that leave any hazardous substances, pollutants, or contaminants on site must meet, upon completion of the remedial action, a level or standard of control that at least attains standards, requirements, limitations, or criteria that are "applicable or relevant and appropriate" under the circumstances of the release. These requirements are known as "ARARs" or applicable or relevant and appropriate requirements. ARARs are derived from both Federal and State laws. USEPA Interim Guidance (52 Fed. Reg. 32496, 1987) provides the following definition of "Applicable Requirements":

> ...cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.

Drinking water criteria may be an applicable requirement for a site with contaminated groundwater that is used as a drinking water source. The definition of "Relevant and Appropriate Requirements" is:

> ...cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site.

There are three types of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs include requirements which set health or risk-based concentration limits or ranges for specific hazardous substances, pollutants, or contaminants. MCLs established under the Safe Drinking Water Act (SDWA) are examples of chemical-specific ARARs.

Location-specific ARARs set restrictions on activities based upon the characteristics of the site and/or the nearby suburbs. Examples include federal and state siting laws for hazardous waste facilities and sites on the National Register of Historic Places.

The third classification of ARARs, action-specific, refers to requirements that set controls or restrictions on particular activities related to the management of hazardous substances, pollutants, or contaminants. RCRA regulations for closure of hazardous waste storage units, RCRA incineration standards, and pretreatment standards under the Clean Water Act (CWA) for discharges to publicly owned treatment works (POTWs) are examples of action-specific ARARs.

Subsection 121(d) of CERCLA requires that the remedial action meet a level or standard which at least attains Federal and State substantive requirements that qualify as ARARs. Federal, State, or local permits are not necessary for removal or remedial actions to be implemented on-site, but their substantive requirements or ARARs must be met. "On-site" is interpreted by the USEPA to include the areal extent of contamination and all suitable areas in reasonable proximity to the contamination necessary for implementation of the response action.

ARARs can be identified only on a site-specific basis. They depend on the detected contaminants at a site, site-specific characteristics, and particular remedial actions proposed for the site. Potential ARARs identified for Site 36 are presented in Section 2.3.2.

The preamble to the proposed rule in 40 CFR Part 300.400(g)(3) states that "advisories, criteria, or guidance TBC that do not meet the definition of ARAR may be necessary to determine what is protective or may be useful in developing Superfund remedies. The ARARs preamble described three types of TBCs: health effects information with a high degree of credibility, technical information on how to perform or evaluate site investigations or remedial actions, and policy" (USEPA, 1990).

2.3.2 Potential ARARs and TBCs Identified for Site 36

A set of chemical-specific, location-specific, and action-specific ARARs were identified and evaluated for Site 36 and are discussed below.

2.3.2.1 Chemical-Specific ARARs and TBCs

Potential chemical-specific ARARs and TBCs identified for the preliminary COCs at Site 36 are listed on Table 2-2. These ARARs/TBCs are Federal MCLs, NCWQS applicable to groundwater, and the OSWER lead directive. A brief description of these standards is presented below.

Federal Maximum Contaminant Levels - MCLs are enforceable standards for public water supplies promulgated under the SDWA 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. These standards 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. As shown on Table 2-2, MCLs have been established for most of the groundwater COPCs. However, there is no Federal primary MCL for iron (secondary standard only). The Federal MCL will not be an applicable ARAR for iron in groundwater; however, the secondary standards could be a TBC (USEPA, 1996).

North Carolina Water Quality Standards (Groundwater) - Under the North Carolina Administrative Code (NCAC), Title 15A, Subchapter 2L, Section .0200, (15A NCAC 2L.0200) the NC DENR has established groundwater standards (NCWQSs) for three classifications of groundwater within the State: GA, GSA, and GC. Class GA waters are those groundwaters in the State naturally containing 250 mg/L or less of chloride. These waters are an existing or potential source of drinking water supply for humans. Class GSA waters are those groundwaters in the State naturally containing greater than 250 mg/L of chloride. These waters are an existing or potential source of water supply for potable mineral water and conversion to fresh water. Class GC water is defined as a source of water supply for purposes other than drinking. The NCAC T15A:02L.0300 has established sixteen river basins within the State as Class GC ground waters (15A NCAC 2L.0201 and 2L.0300). The North Carolina Drinking Water Act (130A NCGS 311-327) also regulates water systems within the State that supply drinking water that may affect the public health.

The water quality standards for groundwater are the maximum allowable concentrations resulting from any discharge of contaminants to the land or water of the State, which may be tolerated without creating a threat to human health or which would otherwise render the groundwater unsuitable for its intended best usage. If the water quality standard of a substance is less than the limit of detectability, the substance shall not be permitted in detectable concentrations. If naturally occurring substances exceed the established standard, the standard will be the naturally occurring concentration as determined by the State. Substances which are not naturally occurring and for

which no standard is specified are not permitted in detectable concentrations for Class GA or Class GSA groundwaters (15A NCAC 2L.0202).

The NCWQS for substances in Class GA and Class GSA groundwaters are established as the lesser of:

- Systemic threshold concentration (based on reference dose and average consumption)
- Concentration which corresponds to an incremental lifetime cancer risk of $1x10^{-6}$
- Taste threshold limit value
- Odor threshold limit value
- MCL
- National Secondary Drinking Water Standard

Note that the water quality standards for Class GA and Class GSA groundwaters are the same except for chloride and total dissolved solids concentrations (15A NCAC 2L.0202).

The Class GA groundwater NCWQSs for the groundwater COCs for Site 36 are listed on Table 2-2. The NCWQS will be considered an ARAR for Site 36.

North Carolina Water Quality Standards (Surface Water) - Under NCAC, Title 15A, Subchapter 2B, Sections .0100 - .0400 (15A NCAC 2B .0100 - .0400), the NC DENR has established a series of classifications and water quality standards for surface waters.

OSWER Directive for Lead - As part of the Superfund Administrative Improvements Initiative, an interim directive established a streamlined approach for determining protective lead levels in soil at CERCLA and RCRA facilities that are subject to corrective action under RCRA Section 3004 (u) or 3008(h). This directive recommended a screening level for lead in surface soil for residential land use at 400 mg/kg. This interim directive, dated July 14, 1994, replaced all previous directives on soil lead cleanup for CERCLA and RCRA programs (USEPA, 1994).

A screening level represents a level of contamination above which there may be enough concern to warrant a study of potential risks. This level is not a cleanup goal. Rather, this screening level may be used as a tool to determine which areas require further study and to encourage voluntary cleanup. Levels of contamination above the screening level would not automatically require a removal action or designate the area as lead contaminated. Consequently, this value will be the ARAR used in this study for lead detected in the surface soil.

North Carolina Air Pollution Control Regulations - Under NCAC, Title 15A, Subchapter 2D, 2H .0600, 2Q (15A NCAC 2D, 2H .0600, 2Q), the NC DENR regulates ambient air quality and establishes air quality standards for hazardous air pollutants.

North Carolina Hazardous Waste Management Rules - Under NCAC, Title 15A, Subchapter 13A .0009 and .0012 (15A NCAC 13A .0009 and .0012), the NC DENR has established standards for hazardous waste that is excavated and stored or treated as part of a remedial action.

2.3.2.2 Location-Specific ARARs

Potential location-specific ARARs identified for Site 36 are listed on Table 2-3. An evaluation determining the applicability of these location-specific ARARs with respect to Site 36 is also presented and summarized on Table 2-3. Based on this evaluation, specific sections of the following location-specific ARARs may be applicable to Site 36:

- Fish and Wildlife Coordination Act
- Federal Endangered Species Act
- Executive Order 11990 Protection of Wetlands
- RCRA Location Requirements
- Executive Order 11988 Floodplain Management
- NC Hazardous Waste Management Rules
- NC Recordation of Inactive Hazardous Substance or Waste Disposal Site Statute
- NC Coastal Management

Please note that the citations listed on Table 2-3 should not be interpreted to indicate that the entire citation is an ARAR. The citation listing is provided on the table as a general reference.

2.3.2.3 Action-Specific ARARs

Action-specific ARARs are typically evaluated following the development of alternatives, since they are dependent on the type of action being considered. Therefore, at this step in the FS process, potential action-specific ARARs have only been identified, not evaluated, for Site 36. A set of potential action-specific ARARs are listed on Table 2-4. These ARARs are based on RCRA, CWA, SDWA, Department of Transportation (DOT), OSWER Directive, Clean Air Act (CAA), NC DENR and 1973 Sedimentation Control Act requirements. Note that the citations listed on Table 2-4 should not be interpreted to indicate that the entire citation is an ARAR. The citation listing is provided on the table as a general reference.

These ARARs will be evaluated following development of the remedial action alternatives for Site 36. Additional action-specific ARARs may also be identified and evaluated at that time.

2.3.3 Site-Specific Risk-Based Action Levels

In this section of the FS, site-specific risk-based action levels are developed for the preliminary COCs. The determination of derived action levels for Site 36 involves establishing acceptable

human health risk criteria, determining allowable risk associated with the COCs, and back calculating media-specific concentrations for the established risk levels.

The methodology used for the derived action levels is in accordance with USEPA risk assessment guidance (USEPA, 1989; USEPA, 1991). For noncarcinogenic effects, concentrations were calculated to correspond to an Hazard Index (HI) of 1.0, 0.1 and 0.01. At these levels of contaminant exposure, via all significant exposure pathways for a given medium, even the most sensitive populations are unlikely to experience health effects. A 1.0 risk level was used as an end point for determining noncarcinogenic action levels for remediation. For carcinogenic effects, concentrations were calculated to correspond to $1x10^{-4}$ (one in ten thousand), $1x10^{-5}$ (one in one hundred thousand), and $1x10^{-6}$ (one in one million) estimated Incremental Lifetime Cancer Risk (ICR) over a lifetime of exposure to the carcinogen. Exposure was evaluated for all significant exposure pathways for a given medium. A $1x10^{-4}$ risk level was used as an end point for determining carcinogenic action levels for remediation. Based on the NCP (40 CFR 300.430; USEPA, 1990) for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an ICR between $1x10^{-4}$ and $1x10^{-6}$. Action levels are representative of acceptable incremental risks at the evaluated site based on current and probable future use of the area.

Three steps were involved in estimating the risk-based action levels for the preliminary COCs. These steps involved identifying the most significant (1) exposure pathways and routes, (2) exposure parameters, and (3) equations. The equations included calculations of total intake from a given medium and were based on identified exposure pathways and associated parameters.

2.3.3.1 Risk Evaluation Assessment

Medium-specific risk-based action levels were determined in accordance with USEPA guidance (USEPA, 1989). Reference doses (RfDs) were used to evaluate noncarcinogenic action levels, while cancer slope factors (CSFs) were used to evaluate carcinogenic action levels. These toxicity values were dermally-adjusted when evaluating the dermal contact exposure scenario.

Consistent with USEPA guidance, noncarcinogenic health effects were estimated using an average annual exposure. The action level incorporates the exposure time and/or frequency that represents the number of hours per day and the number of days per year exposure occurs. This is used with a term known as the averaging time, which converts the daily exposure to an annual exposure. Carcinogenic health effects were calculated as an incremental lifetime cancer risk, and, therefore, represent exposure duration over the course of a potentially exposed individual's lifetime (i.e., 70 years).

Estimation methods and models used in this section are consistent with current USEPA risk assessment guidance (USEPA, 1989; USEPA, 1991). Exposure estimates associated with the exposure route are presented below. Carcinogenic action levels for the future residential land use (i.e., ingestion of groundwater) were based on 6 years for a child (weighing 15 kg on average) and 24 years for an adult (weighing 70 kg on average). The following presents the equations and inputs used to estimate action levels.

Ingestion of Groundwater

Currently, there are no receptors exposed to groundwater. Groundwater is obtained from noncontaminated MCB, Camp Lejeune supply wells and pumped to water treatment plants. The

treated water is distributed via the Base water system. However, for the purposes of calculating action levels, it is assumed that the site wells are potable and supply groundwater for public consumption. Groundwater ingestion action levels can be characterized using the following equation:

$$Cw = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * EF * ED * IR}$$

Where:

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (yr)
IR	=	ingestion rate (L/day)

Under the residential use scenario, the following input parameters were used to estimate action levels: adult residents were assumed to ingest 2 liters of water per day, 350 days per year over a 30 year exposure duration; and child residents are assumed to ingest 1 liter of water per day, 350 days per year for an exposure period of 6 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the groundwater ingestion action levels.

Dermal Contact with Groundwater

Groundwater dermal contact action levels can be characterized using the following equation:

$$Cw = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * SA * PC * ET * EF * ED * CF}$$

Where:

Cw	=	contaminant concentration in groundwater (mg/L)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
SA	=	skin surface area (cm^2)
PC	=	chemical-specific dermal permeability constant (cm/hr)

ET	=	exposure time (0.25 hours)
EF	=	exposure frequency (day/yr)
ED	=	exposure duration (yr)
CF	=	conversion factor (0.001L/ml)

Under the residential use scenario, the following input parameters were used to estimate action levels: adult residents were assumed have surface areas of 23,000 cm^2 available for dermal contact for 350 days per year over a 30 year exposure duration; and child residents are assumed to have 10,000 cm^2 available for dermal contact 350 days per year for an exposure period of 6 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the groundwater exposure action levels.

Ingestion of Subsurface Soil

Currently, there are no receptors exposed to subsurface soil. However, for the purposes of calculating action levels, it is assumed that exposure to subsurface soil may occur in the future scenario. Subsurface soil exposure from ingestion action levels can be determined using the following equation:

$$C = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * EF * ED * IR * CF}$$

Where:

C	=	contaminant concentration in subsurface soil (mg/kg)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (yr)
IR	=	ingestion rate (mg/day)
CF	=	conversion factor (10^{-6} kg/mg)

Under the residential use scenario, child residents are assumed to ingest 200 mg of soil per day, 350 days per year for an exposure period of 6 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the groundwater ingestion action levels.

Dermal Contact with Subsurface Soil

Subsurface soil exposure from dermal contact action levels can be calculated using the following equation:

$$C = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * EF * ED * SA * AF * ABS * CF}$$

Where:

C	=	contaminant concentration in subsurface soil (mg/kg)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)
EF	=	exposure frequency (day/year)
ED	=	exposure duration (yr)
SA	=	surface area (cm^2)
AF	=	adherence factor (1 mg/cm^2)
ABS	=	fraction absorbed (0.001 for metals)
CF	=	conversion factor (10^{-6} kg/mg)

Under the residential use scenario, child residents are assumed to have 2,300 cm^2 of skin surface available for dermal contact for 350 days per year for an exposure period of 6 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the subsurface soil dermal contact action levels.

Ingestion of Fish and Crab Tissue

Currently, recreational fishing and crabbing occur at Site 36. Fish and crab tissue ingestion action levels can be determined using the following equation:

$$C = \frac{TR \text{ or } THI * BW * ATc \text{ or } ATnc * DY}{CSF \text{ or } 1/RfD * EF * ED * IR * FI}$$

Where:

C	=	contaminant concentration in tissue (mg/kg)
TR	=	total lifetime risk
THI	=	total hazard index
BW	=	adult body weight (kg)
ATc	=	averaging time carcinogens (yr)
ATnc	=	averaging time noncarcinogens (yr)
DY	=	days per year (day/year)
CSF	=	cancer slope factor $(mg/kg\text{-}day)^{-1}$
RfD	=	reference dose (mg/kg-day)

EF	=	exposure frequency (meals/year)
ED	=	exposure duration (yr)
IR	=	ingestion rate (kg/meal)
FI	=	fraction ingested (100 percent)

Recreational fishermen were assumed to consume 0.284 kg of fish per meal for 48 days a year for 30 years (USEPA, 1989). Table 2-5 summarizes the input parameters used to estimate the fish and crab tissue ingestion action levels.

2.3.3.2 Summary of Site-Specific Risk-Based Action Levels

Site-specific risk-based action levels were calculated from the risk evaluation assessment. These action levels represent the risk-based cleanup levels for specific media and are used in determining remediation levels.

Risk-based action levels were only generated for contaminants with available toxicity data. A summary of the action levels calculated for the potential exposure scenarios is presented below. Separate action levels for current/future recreational fishermen, future adult residents, and future child residents were calculated. When applicable, both carcinogenic and noncarcinogenic action levels were determined. Calculations are provided in Appendix A of this report.

All possible routes of exposure were included when calculating the action levels. As a result, ingestion and dermal contact were assessed for groundwater and subsurface soil action levels. Inhalation was not included for two reasons: 1) the COC in groundwater and subsurface soil is iron, which is not a volatile compound; 2) there is no inhalation toxicity value available for iron. Tables 2-6 through 2-11 present the risk-based action levels calculated for the carcinogenic and noncarcinogenic COCs in the groundwater, subsurface soil, and fish and crab tissue.

2.3.3.3 Comparison of Action Levels to Maximum Contaminant Concentrations in Groundwater

Generally, risk-based action levels are not required for any contaminants in a medium with a cumulative cancer risk of less than 1.0×10^{-6}, where an HI is less than or equal to 1.0, or where the action levels are clearly defined by ARARs. However, there may be cases where a medium or contaminant appears to meet the protectiveness criterion but contributes to the risk of another medium. In some cases, contamination may be unevenly distributed across the site resulting in hot spots (areas of high contamination relative to other areas of the site). Therefore, if the hot spot is located in an area which is visited or used more frequently, exposure to the spot should be assessed separately.

In order to decrease uncertainties in estimating the reasonable maximum exposure (RME) (i.e., the maximum exposure that is reasonably expected to occur at the site), the maximum concentration of a contaminant in a medium can be compared to the estimated action level, instead of using the concentration term (i.e., the 95th percent upper confidence limit), which is used to estimate the RME. To assess hot spot contaminants, a more conservative approach is followed. This maximum value is usually compared to the estimated risk-based action level, because, in most situations, assuming long-term contact with the maximum contaminant concentration is not reasonable.

Conclusions of the BRA indicate that the cumulative current and future baseline noncancer and cancer risks associated with groundwater, subsurface soil, fish tissue, and crab tissue were not within

the USEPA's acceptable risk level of one for noncancer risks and/or the range of $1x10^{-4}$ to $1x10^{-6}$ for cancer risks, primarily because of the presence of iron, lead, arsenic, and mercury. A comparison between the maximum detected concentrations of these COCs and the risk-based action levels and chemical-specific ARARs is shown on Tables 2-6 through 2-8. The maximum detected concentrations of these COCs exceeded risk-based action levels and ARARs.

Identifying remedial alternatives should not rely solely on estimating risk-based action levels, especially in the event of hot spot contamination. Comparing maximum contaminant concentrations to risk-based action levels provides an upper-bound (i.e., worse case) conservative estimate, and aids in screening and identifying remedial alternatives. Risk-based action levels are not to be used solely in making final remedial decisions.

2.3.3.4 Uncertainty Analysis

Uncertainties associated with calculating risk-based action levels are summarized below. The action level estimates presented in the previous section are quantitative in nature and are highly dependent upon input accuracy. The accuracy with which input values can be quantified is critical to the degree of confidence that the decision maker has in the action levels.

Most scientific computations involve a limited number of input variables, tied together by a scenario to provide a desired output. Some action level inputs are based on literature values rather than measured values. In such cases, the degree of certainty may be expressed in terms of whether the estimate was based on literature values or measured values, and not how well defined the distribution of the input was. Some action levels are based on estimated parameters; the qualitative statement that the action level was based on estimated inputs defines certainty in a qualitative manner.

Toxicity factors (i.e., CSFs and RfDs), have uncertainties built into the assumptions used to calculate these values. Because the toxicity factors are determined from high doses administered to experimental animals and extrapolated to low doses to which humans may be exposed, uncertainties exist. Thus, toxicity factors could either overestimate or underestimate potential effects on humans. However, because human data exists for very few chemicals, risks are based on these conservative values obtained primarily from animal studies.

In order to estimate an intake, certain assumptions must be made about exposure events, exposure durations, and the corresponding assimilation of contaminants by the receptor. Exposure factors have been generated by the scientific community and have undergone review by the USEPA. Regardless of the validity of these exposure factors, they have been derived from a range of values generated by studies of a limited number of individuals. In all instances, values used in the risk assessment, scientific judgements, and conservative assumptions agree with those of the USEPA. Conservative assumptions designed not to underestimate daily intakes were employed throughout this section and should error conservatively, thus adequately protecting human health and allowing establishment of reasonable cleanup goals.

2.3.4 Summary of Remediation Levels and Final COCs

Remediation levels (RLs) associated with the preliminary COCs at Site 36 are presented on Table 2-9. This list was based on a comparison of chemical-specific ARARs and the site-specific risk-based action levels identified throughout Sections 2.3.2 and 2.3.3. If a COC had an ARAR, the most limiting (or conservative) ARAR was selected as the RL for that contaminant. If a COC did

not have an ARAR, the most conservative risk-based action level was selected as the RL. The basis for each of the RLs is also presented on Table 2-9.

In order to determine the final set of COCs, the maximum contaminant concentrations detected in the media of concern were compared to the remediation levels presented on Table 2-9. The contaminants that exceeded at least one of the remediation levels were retained as COCs. The contaminants that did not exceed any of the remediation levels were no longer considered COCs with respect to this FS. Based on this comparison, the following COCs exceeded a remediation level and were retained as COCs for Site 36: arsenic, mercury, and lead in the fish or crab tissue; iron, PCE, and TCE in groundwater; and iron and lead in the soil. The final set of COCs and the associated RLs are presented on Table 2-9.

2.4 Remedial Action Objectives and Areas of Concern

Currently, the levels of arsenic and mercury in the fish tissue and arsenic and lead in the crab tissue contribute to unacceptable health risks upon direct ingestion. As a result, the Division of Water Quality of the NC DENR has directed and also undertaken fish collectin and tissue sampling from the Brinson Creek area. In November of 1997, the Division of Water Quality submitted a letter to MCB, Camp Lejeune to inform the Base that the State had abandoned the collection efforts, as both low flow and high salinity conditions hindered several collection attempts. The State did note that future attempts were anticipated.

PCE and TCE were detected in site groundwater at levels in excess of their respective Federal and State criteria. The limited extent of VOCs, both horizontally and vertically, suggests that the source may have resulted from unintentional spillage or limited disposal rather than long-term disposal or buried containers. Although the results of the risk assessment conducted within the RI indicated that these VOCs did not generate unacceptable human health risks, a defined area of concern was identified in the northern portion of the site. The identified area of concern is shown on Figure 2-1. Due to their presence and defined location at Site 36, the remainder of this FS focuses on remedial alternatives which specifically address the presence of VOCs in the groundwater.

Remedial objectives developed for the groundwater at Site 36 include:

- Prevent future potential exposure to VOC-contaminated groundwater.
- Protect uncontaminated groundwater for future potential beneficial use.

As noted on Table 2-9, lead and iron were retained as final COCs for Site 36. Lead was retained based upon the surface and subsurface soil concentrations detected in excess of the OSWER surface soil value of 400 mg/kg. Iron was retained as a final COC based upon the detections within the groundwater and subsurface soil at Site 36. Neither of these inorganics are addressed further within the remainder of this FS; and therefore, remedial action objectives were not developed for these constituents.

2.4.1 Rationale for Exclusion of Inorganic Remedial Actions

The rationale for eliminating remedial actions, based upon the lead and iron concentrations detected in various media at Site 36, is presented in the following sections.

2.4.1.1 Lead

- The OSWER value of 400 mg/kg for surface soil was exceeded only twice, at locations OA-SB04 and OA-SB08, which are located in two distinct open areas at Site 36. These locations are approximately 920 feet apart; therefore, a pattern of surface contamination above the OSWER surface soil value is not evident.

- Prior to finalization of the FS, a TCLP analysis for lead was completed on sample 36-OA-SB07R-01 which was collected from a depth of 3 to 3.5 feet below the ground surface. The sample was collected near OA-SB07, which exhibited the highest subsurface lead concentration detected during the RI. The TCLP results indicated lead at a concentration of 0.115 µg/L, far below the Federal TCLP lead level of 5 mg/L. Therefore, the site-specific TCLP result supports the conclusion that the soil conditions at Site 36 are not conducive to leaching.

- Lead was only detected three times in groundwater, at wells 36-GW10DW, 36-GW12IW, and 36-GW13IW which are all located northwest of the maximum detections of lead in soil. The maximum lead detected in the groundwater was 14.7 µg/L. Thus, all three of the groundwater lead detections are all below the NCWQS and the Federal MCL of 15 µg/L.

- The maximum lead concentrations detected in surface soil (836J mg/kg), subsurface soil (2,680J mg/kg), and crab tissue (0.61 mg/kg) resulted in potential unacceptable health risks to child receptors based on the lead uptake/biokinetic (UBK) model. Literature documents that the natural levels of lead in soil can range from 2 to 20 mg/kg (USEPA, 1994). One example notes that the mean concentration range of lead detected in street dust from residential and commercial areas was 1,000 to 2,400 mg/kg. Yet another example showed the maximum level of lead in soil to be 20,000 mg/kg. Similar studies show that the range of lead detected can range from 0.17 to 0.21 mg/kg in shellfish, 0.34 to 0.80 mg/kg in fish, and 0.01 to 2.5 mg/kg in food.

- The existing use of Site 36 is limited to occasional military maneuvers, primarily due to its location and marshy conditions. In addition, the U.S. Route 17 By-Pass will impact a majority of the eastern portion of the site. Therefore, the likelihood of future residential development of Site 36 is remote.

2.4.1.2 Iron

- Only four surface soil iron detections were in excess of the Residential Region III RBC of 23,000 mg/kg. These four detections were scattered over approximately 6 acres of the primarily wooded site. Due to the location of Site 36 next to the New River and Brinson Creek, as well as the fluctuating groundwater table, the depths of the deep soil samples ranged from 1 to 3, 5 to 7 and 7 to 9 feet below the ground surface. Therefore, the detections in excess of the Region III RBC value are somewhat scattered horizontally, as well as vertically.

- Table 2-10 summarizes a comparison of the site iron levels to literature values of similar media. The iron concentrations detected in the groundwater ranged from

0.003 mg/L to 16.9 mg/L. As noted on Table 2-10, comparison of these detections to the iron literature values indicates that the iron groundwater detections are elevated. However, the iron concentrations detected in the site soils are within typical concentrations noted in literature values for similar media.

- Potential noncarcinogenic risks were calculated due to ingestion of subsurface soil (iron, HI = 2.3) and exposure to site groundwater (iron, HI = 5.2) for the future child resident. If iron were removed from the calculation of risk, these noncarcinogenic risks would equate to HIs of 0.86 for ingestion of the subsurface soil and 1.5 for exposure to groundwater. Similarly, the noncarcinogenic risk from groundwater exposure (iron, HI = 2.2) for the future adult resident would decrease to an HI of 0.64 if iron were removed from the calculation of risk.

- As noted above, due to the existing marshy conditions and proposed highway impacts, future residential development of Site 36 is highly unlikely.

2.5 References

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SECTION 2.0 TABLES

TABLE 2-1

PRELIMINARY CONTAMINANTS OF CONCERN FOR THE FS
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminant of Potential Concern Evaluated in the RA [1]	Preliminary Contaminant of Concern for the FS [2]
Groundwater	1,2-Dichloroethene (total)	
	Trichloroethene	X
	Tetrachloroethene	X
	1,1,2,2-Tetrachloroethane	
	Bis(2-ethylhexyl)phthalate	
	Aluminum	
	Arsenic	
	Barium	
	Cadmium (water)	
	Iron	X
	Manganese (water)	
Surface Soil	n-Nitroso-di-n-propylamine	
	Benzo(a)anthracene	
	Benzo(b)fluoranthene	
	Benzo(a)pyrene	
	Dibenzo(a,h)anthracene	
	Indeno(1,2,3-cd)pyrene	
	Aldrin	
	Dieldrin	
	4,4'-DDE	
	4,4'-DDT	
	alpha-Chlordane	
	gamma-Chlordane	
	Aroclor-1248	
	Aroclor-1254	
	Aluminum	
	Antimony	
	Arsenic	
	Cadmium	
	Chromium	
	Copper	
	Iron	
	Lead	X
	Mercury	
Subsurface Soil	Benzo(a)pyrene	
	Dieldrin	
	4,4'-DDT	
	alpha-Chlordane	
	gamma-Chlordane	
	Aroclor-1248	
	Aluminum	
	Antimony	
	Arsenic	
	Beryllium	
	Cadmium (soil)	
	Chromium	
	Copper	
	Iron	X
	Lead	X
	Manganese (soil)	
	Mercury	
	Zinc	

TABLE 2-1 (Continued)

PRELIMINARY CONTAMINANTS OF CONCERN FOR THE FS
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminant of Potential Concern Evaluated in the RA [1]	Preliminary Contaminant of Concern for the FS [2]
Fish Tissue	beta-BHC	
	gamma-BHC (Lindane)	
	Heptachlor	
	Aldrin	
	Heptachlor epoxide	
	Dieldrin	
	4,4'-DDE	
	Endrin	
	4,4'-DDD	
	4,4'-DDT	
	alpha-Chlordane	
	Arsenic	X
	Cadmium (soil)	
	Chromium	
	Copper	
	Iron	
	Mercury	X
	Selenium	
	Silver	
	Vanadium	
	Zinc	
Crab Tissue	beta-BHC	
	gamma-BHC (Lindane)	
	Heptachlor	
	Aldrin	
	Dieldrin	
	4,4'-DDE	
	4,4'-DDD	
	alpha-Chlordane	
	Arsenic	X
	Cadmium (soil)	
	Copper	
	Lead	X
	Selenium	
	Zinc	

Notes:

(1) This list includes all of the contaminants of potential concern evaluated in the Risk Assessment (Baker, 1996).

(2) The determination of the set of preliminary contaminants of concern for the FS was based on whether the contaminant was found to be a contaminant of concern from the results of the RA. In addition, if the maximum detected levels exceeded state criteria, these contaminants were included in the evaluation. For this site, these contaminants were TCE and PCE in groundwater.

TABLE 2-2

POTENTIAL CHEMICAL-SPECIFIC ARARs AND TBCs
FOR SITE COCs
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	Federal MCL (µg/L)	NCWQS (µg/L)	OSWER level in residential soil (mg/kg)
Tetrachloroethane	5	0.7	NA
Trichloroethene	5	2.8	NA
Iron	NE	300	NA
Lead	15	15	400

Notes:

MCL = Safe Drinking Water Act Maximum Contaminant Level
NCWQS = North Carolina Water Quality Standards for Groundwater
OSWER = Office of Solid Waste and Emergency Response
NE = No Criteria Established
NA = Not Applicable
The federal MCL identified for lead is the action level.

TABLE 2-3

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
National Historic Preservation Act of 1966 - requires action to take into account effects on properties included in or eligible for the National Register of Historic Places and to minimize harm to National Historic Landmarks.	16 USC 470, 40-CFR-6.301(b), and 36 CFR 800	No known historic properties are within or near Site 36; therefore, this act will not be considered an ARAR.
Archeological and Historic Preservation Act - establishes procedures to provide for preservation of historical and archeological data which might be destroyed through alteration of terrain.	16 USC 469, and 40 CFR 6.301©	No known historical or archeological data is known to be present at Site 36; therefore, this act will not be considered an ARAR.
Historic Sites, Buildings and Antiquities Act - requires action to avoid undesirable impacts on landmarks on the National Registry of Natural Landmarks.	16-USC 461467, and 40 CFR 6.301(a)	No known historic sites, buildings or antiquities are within or near Site 36; therefore, this act will not be considered an ARAR.
Fish and Wildlife Coordination Act - requires action to protect fish and wildlife from actions modifying streams or areas affecting streams.	16 USC 661-666	Brinson Creek and an unnamed tributary to the New River are located near and/or within Site 36 boundaries. If remedial actions are implemented to modify these waterways, this act will be considered an ARAR.
Federal Endangered Species Act - requires action to avoid jeopardizing the continued existence of listed endangered species or modification of their habitat.	16-USC 1531, 50 CFR 200, and 50 CFR 402	No protected species have been sighted near and on-site. However, the American alligator and endangered woodpecker have been sighted on Base and may inhabit Site 36. Therefore, this act will be considered an ARAR.
North Carolina Endangered Species Act - per the North Carolina Wildlife Resources Commission. Similar to the Federal Endangered Species Act, but also includes State special concern species, State significantly rare species, and the State watch list.	GS 113-331 to 113-337	No protected species have been sighted near or on-site. Therefore, this will not be considered an ARAR.
Rivers and Harbors Act of 1899 (Section 10 Permit) - requires permit for structures or work in or affecting navigable waters.	33 USC 403	No remedial actions will affect the navigable waters of the New River. Therefore, this act will not be considered an ARAR.

TABLE 2-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
Executive Order 11990 on Protection of Wetlands - establishes special requirements for Federal agencies to avoid the adverse impacts associated with the destruction or loss of wetlands and to avoid support of new construction in wetlands if a practicable alternative exists.	Executive Order Number 11990, and 40-CFR-6	Wetlands are present at Site 36. Therefore, this will be an applicable ARAR.
Executive Order 11988 on Floodplain Management - establishes special requirements for Federal agencies to evaluate the adverse impacts associated with direct and indirect development of a floodplain.	Executive Order Number 11988, and 40 CFR 6	Based on the Federal Emergency Management Agency's Flood Insurance Rate Map for Onslow County, OU No. 6 is primarily within a minimal flooding zone (outside the 500-year floodplain). Site boundary areas around Site 36, namely along Brinson Creek and the unnamed tributary to the New River are within the 100-year floodplain (FEMA, 1987). Therefore, this order will be an ARAR for Site 36.
Wilderness Act - requires that federally owned wilderness areas are not impacted. Establishes nondegradation, maximum restoration, and protection of wilderness areas as primary management principles.	16-USC-1131, and 50-CFR-35.1	No known federally owned wilderness areas near Site 36; therefore, this act will not be considered an ARAR.
National Wildlife Refuge System - restricts activities within a National Wildlife Refuge.	16 USC 668, and 50 CFR 27	No known National Wildlife Refuge areas near Site 36; therefore, this will not be considered an ARAR.
Scenic Rivers Act - requires action to avoid adverse effects on designated wild or scenic rivers.	16 USC 1271, and 40 CFR 6.302(e)	No known wild or scenic rivers near Site 36; therefore, this act will not be considered an ARAR.
Coastal Zone Management Act - requires activities affecting land or water uses in a coastal zone to certify noninterference with coastal zone management.	16-USC 1451	Although activities will not affect land or water uses located in a coastal zone, this act may be considered an ARAR.
Clean Water Act (Section 404) - prohibits discharge of dredged or fill material into wetland without a permit.	33 USC 404	No actions to discharge dredged or fill material into wetlands will be considered for Site 36; therefore, this act will not be considered an ARAR.

TABLE 2-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Potential Location-Specific ARAR	General Citation	ARAR Evaluation
RCRA Location Requirements - limitations on where on-site storage, treatment, or disposal of RCRA hazardous waste may occur.	40 CFR 264.18	These requirements may be applicable if the remedial actions for the site includes the on-site storage, treatment, or disposal of RCRA hazardous waste. Therefore, these requirements may be applicable ARARs for Site 36.
North Carolina Hazardous Waste Management Rules	15A NCAC 13A.0009 and .0012	These requirements may be applicable if hazardous waste will be excavated, stored and treated on site. Therefore, these locations and land disposal restriction requirements may be applicable ARARs for Site 36.
North Carolina Solid Waste Management Rules	15A NCAC 13B.1600	Solid waste landfill facility will not be sited at Site 36. Therefore, these rules will not be considered an ARAR for Site 36.
North Carolina Recordation of Inactive Hazardous Substance or Waste Disposal Site Statute	N.C.G.S. 130A-310.8	Site 36 is no longer an active dump. Therefore, the State requirements for recordation of inactive hazardous sites may apply. This requirement may be an applicable ARAR for Site 36.
North Carolina Coastal Management	15A NCAC 7H	Site 36 may be in a coastal management zone. Therefore, these requirements may be applicable for Site 36.

TABLE 2-4

POTENTIAL ACTION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Standard[1]	Action	General Citation
RCRA	Capping	40 CFR 264
	Closure	40 CFR 264, 244
	Container Storage	40 CFR 264
	New Surface Impoundment	40 CFR 264
	Dike Stabilization	40 CFR 264
	Discharge to Groundwater	40 CFR 264
	Excavation, Groundwater Diversion	40 CFR 264, 268
	Identification and Listing of Hazardous Waste	40 CFR 261
	Incineration	40 CFR 264, 761
	Land Treatment	40 CFR 264
	Land Disposal	40 CFR 264, 268
	Slurry Wall	40 CFR 264, 268
	Tank Storage	40 CFR 264, 268
	Treatment	40 CFR 264, 265, 268; 42 USC 6924; 51 FR 40641; 52 FR 25760
	Waste Pile	40 CFR 264, 268
CWA	Discharge to Water of United States	40 CFR 122, 125, 136
	Direct Discharge to Ocean	40 CFR 125
	Discharge to POTW	40 CFR 403, 270
	Dredge/Fill	40 CFR 264; 33 CFR 320-330; 33 USC 403
SDWA	Underground Injection Control	40 CFR 144, 146, 147, 268
DOT	DOT Rules for Transportation	49 CFR 171, 172
OSWER Directive	Air Emission Controls	OSWER 9355.0-28
	Monitored Natural Attenuation	OSWER 9200.4-17
CAA	Discharge to Air	40 CFR, 50, 52, 60, 61; 40 USC 7410
NCDENR	Treated Groundwater Discharge	Title 15A, Chapter 2, Section .0100
	Water Quality Guidance	Title 15A, Chapter 2L
	Groundwater Corrective Action	Title 15A, Chapter 2L, Sections .0106-.0113
	Well and Injection Well Construction	Title 15A, Chapter 2C, Section .0100-.0200
	Waste Water Discharge	Title 15A, Chapter 2H, Sections .0100 and .0200
	Hazardous Waste Management	Title 15A, Chapter 13A
	Solid Waste Management	Title 15A, Chapter 13B
	Air Emission Controls	Title 15A, Chapters 2D, 2H.0600, 2Q
	Sedimentation Control	Title 15A, Chapter 2H, Section .1000
NC Sedimentation Control Act of 1973	Land Disturbing Activities	Chapter 113A

TABLE 2-4 (Continued)

POTENTIAL ACTION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Notes:

(1)

RCRA	=	Resource Conservation Act
CWA	=	Clean Water Act
SDWA	=	Safe Drinking Water Act
DOT	=	Department of Transportation
OSWER	=	Office of Solid Waste and Emergency Response
CAA	=	Clean Air Act
NCDENR	=	North Carolina Department of Environment and Natural Resources

TABLE 2-5

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY CTO-303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Receptor		
		Future Residential Child	Future Residential Adult	Current/Future Recreational Fisherman
Groundwater (mg/L)				
Ingestion Rate, IR	L/d	1	2	NA
Surface Area, SA	cm^2	10,000	23,000	NA
Exposure Frequency, EF	d/y	350	350	NA
Exposure Duration, ED	y	6	30	NA
Exposure Time, ET	h/d	0.25	0.25	NA
Averaging Time, Noncarc., ATnc	d	2,190	10,950	NA
Averaging Time, Carc., ATcarc	d	25,550	25,550	NA
Conversion Factor, CF	L/cm^3	0.001	0.001	NA
Body Weight, BW	kg	15	70	NA
Soil (mg/kg)				
Ingestion Rate, IR	mg/d	200	100	NA
Fraction Ingested, FI	unitless	1	1	NA
Exposure Frequency, EF	d/y	350	350	NA
Exposure Duration, ED	y	6	30	NA
Surface Area, SA	cm^2	2,300	5,800	NA
Adherence Factor, AF	mg/cm^2	1	1	NA
Averaging Time, Noncarc., ATnc	d	2,190	10,950	NA
Averaging Time, Carc., ATcarc	d	25,550	25,550	NA
Body Weight, BW	kg	15	70	NA
Conversion Factor, CF	kg/mg	$1x10^{-6}$	$1x10^{-6}$	NA
Absorbance Factor, ABS	unitless	Organics = 0.01; Inorganics = 0.001 NA		
Fish/Crab (mg/kg)				
Ingestion rate, IR	kg/d	NA	NA	0.284
Fraction Ingested, FI	unitless	NA	NA	1
Exposure Frequency, EF	meals/yr	NA	NA	48
Exposure Duration, ED	y	NA	NA	30
Averaging Time, Noncarc., ATnc	d	NA	NA	10,950
Averaging Time, Carc, ATcarc	d	NA	NA	25,550
Body Weight, BW	kg	NA	NA	70

TABLE 2-5 (Continued)

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY CTO-303
MCB CAMP LEJEUNE, NORTH CAROLINA

References:

USEPA Risk Assessment for Superfund Volume I. Human Health Manual (Part A) Interim Final, December, 1989

USEPA Exposure Factors Handbook, July, 1989

USEPA Risk Assessment for Superfund Volume I. Human Health Evaluation Manual Supplemental Guidance. "Standard Default Exposure Factors" Interim Final. March 25, 1991

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

USEPA Region IV Guidance for Soil Absorbance

TABLE 2-6

COMPARISON OF SITE MAXIMUM LEVEL TO CRITERIA
FUTURE ADULT RESIDENT
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY CTO-303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Maximum Level (mg/L)	Noncarcinogenic Risk - Based Action Level (1) (mg/L)	Carcinogenic Risk - Based Action Level (2) (mg/L)	Federal Level (mg/L)	NCWQS (mg/L)	Region III RBC (mg/L)
Iron	16.9	11	NA	NA	0.3	0.0011
Tetrachloroethene	0.002	0.37	0.14	0.005	0.0007	0.0011
Trichloroethene	0.097	0.22	0.66	0.005	0.0028	0.0016
Surface Soil (mg/kg)						
Lead	836	NA	NA	400	NA	NA
Subsurface Soil (mg/kg)						
Iron	132,000	170,000	NA	NA	NA	2,300
Lead	2,680	NA	NA	400	NA	NA

Notes:

The risk-based action level was based on exposure to groundwater via ingestion and dermal contact. Only iron in groundwater was identified as contributing to a noncarcinogenic risk in the BRA. Consequently, the inhalation pathway was not included in the calculation of a groundwater action level for iron.

(1) These risk-based levels are based on a total noncarcinogenic risk of 1.0. The risk-based action levels for iron are 1.1 mg/L and 0.11 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. Similarly, the risk-based action levels for PCE are 0.037 mg/L and 0.0037 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for TCE are 0.022 mg/L and 0.0022 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. However, remediation is based on a total noncarcinogenic risk of 1.0. The risk-based subsurface soil action levels are 17,000 mg/kg and 1,700 mg/kg for total noncarcinogenic risks of 0.1 and 0.01, respectively.

(2) This risk-based level is based on a total carcinogenic risk of $1x10^{-4}$. The risk-based action levels for PCE are 0.014 mg/L and 0.0014 mg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. Similarly, the risk-based action levels for TCE are 0.066 mg/L and 0.0066 mg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. However, remediation is based on a total noncarcinogenic risk of $1x10^{-4}$.

MCL = Maximum Contaminant Level
NCWQS = North Carolina Water Quality Standards for Groundwater
RBC = Region III Risk-Based Concentration (October, 1995)
NA = Not Applicable

TABLE 2-7

COMPARISON OF SITE MAXIMUM LEVELS IN GROUNDWATER AND SOIL TO CRITERIA FUTURE CHILD RESIDENT SITE 36, CAMP GEIGER AREA DUMP FEASIBILITY STUDY CTO-0303 MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Maximum Level	Noncarcinogenic Risk - Based Action Level (1)	Carcinogenic Risk - Based Action Level (2)	Federal Level	NCWQS	Region III RBC
Groundwater (mg/L)						
Iron	16.9	4.85	NA	NA	0.3	0.0011
Tetrachloroethene	0.002	0.16	0.31	0.005	0.0007	0.0011
Trichloroethene	0.097	0.098	1.2	0.005	0.0028	0.0016
Surface Soil (mg/kg)						
Lead	836	NA	NA	400	NA	NA
Subsurface Soil (mg/kg)						
Iron	132,000	23,000	NA	NA	NA	2,300
Lead	2,680	NA	NA	400	NA	NA

Notes:

- The groundwater risk-based action level was based on exposure to groundwater via ingestion and dermal contact. Only iron in groundwater was identified as contributing to a noncarcinogenic risk in the BRA. Consequently, the inhalation pathway was not included in the calculation of a groundwater action level for iron.

- The subsurface soil risk-based action level was also based on exposure via ingestion and dermal contact. There are no inhalation toxicity values available for iron. As a result, exposure to iron in soil via inhalation was not included in the calculations.

(1) The risk-based levels are based on a total noncarcinogenic risk of 1.0. The risk-based groundwater action levels are 0.485 mg/L and 0.0485 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based subsurface soil action levels are 2,300 mg/kg and 230 mg/kg for total noncarcinogenic risks of 0.1 and 0.01, respectively. Similarly, the risk-based action levels for PCE are 0.016 mg/L and 0.0016 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. The risk-based action levels for TCE are 0.0098 mg/L and 0.00098 mg/L for total noncarcinogenic risks of 0.1 and 0.01, respectively. However, remediation is based on a total noncarcinogenic risk of 1.0.

(2) This risk-based level is based on a total carcinogenic risk of $1x10^{-4}$. The risk-based action levels for PCE are 0.031 mg/L and 0.0031 mg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. Similarly, the risk-based action levels for TCE are 0.12 mg/L and 0.012 mg/L for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. However, remediation is based on a total noncarcinogenic risk of $1x10^{-4}$.

Federal levels include the MCL and/or OSWER directive for lead in soil
NCWQS = North Carolina Water Quality Standards for Groundwater
RBC = Region III Risk-Based Concentration (October, 1995)
NA = Not Applicable

TABLE 2-8

COMPARISON OF SITE MAXIMUM LEVELS IN FISH AND CRAB TISSUE TO CRITERIA CURRENT/FUTURE RECREATIONAL FISHERMAN SITE 36, CAMP GEIGER AREA DUMP FEASIBILITY STUDY CTO-0303 MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Maximum Level	Noncarcinogenic Risk - Based Action Level [3]	Carcinogenic Risk-Based Action Level [4]	Fish Tissue RBC[1]
Fish Tissue (mg/kg)				
Arsenic	1.8	0.56	0.3	0.041/ 0.0021[2]
Mercury	1.3	0.56	NA	0.041
Crab Tissue (mg/kg)				
Arsenic	1.4	0.56	0.3	0.041/0.0021[2]

Notes:

Risk-based levels are based on exposure via ingestion.
RBC = Region III Risk-Based Concentration (October, 1995)
NA = Not applicable

(1) The fish tissue RBCs were also used for comparison with the crab tissue results.

(2) The noncarcinogenic and carcinogenic fish tissue RBCs for arsenic are presented, respectively.

(3) These noncarcinogenic risk-based levels are based on a total noncarcinogenic risk of 1.0. The risk-based tissue action levels for both arsenic and mercury are 0.056 mg/kg and 0.0056 mg/kg for total noncarcinogenic risks of 0.1 and 0.01, respectively. However, remediation is based on a total noncarcinogenic risk of 1.0.

(4) These carcinogenic risk-based levels are based on a total carcinogenic risk of $1x10^{-4}$. The carcinogenic risk-based action levels are 0.03 mg/kg and 0.003 mg/kg for total carcinogenic risks of $1x10^{-5}$ and $1x10^{-6}$, respectively. However, remediation is based on a total noncarcinogenic risk of $1x10^{-4}$.

TABLE 2-9

FINAL SET OF COCs
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Remediation Level	Units	Basis of Remediation Level
Arsenic	0.041/0.0021[1]	mg/kg	Region III RBC in fish tissue
Mercury	0.041	mg/kg	Region III RBC in fish tissue
Iron	300	µg/L	NCWQS
Iron	2,300	mg/kg	Region III RBC in soil
Lead	400	mg/kg	OSWER level in surface soil
Lead	0.15	mg/kg	Risk-Based UBK Model in crab tissue
Tetrachloroethene	0.7	µg/L	NCWQS
Trichloroethene	2.8	µg/L	NCWQS

Notes:

NCWQS = North Carolina Water Quality Standards for Groundwater
OSWER = Office of Solid Waste and Emergency Response
RBC = Region III Risk-Based Concentration (October, 1995)
UBK = Uptake/biokinetic

(1) The noncarcinogenic and carcinogenic fish tissue RBCs for arsenic are presented, respectively.

TABLE 2-10

COMPARISON OF SITE IRON LEVELS TO LITERATURE VALUES
SITE 36, CAMP GEIGER AREA DUMP
REMEDIAL INVESTIGATION CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Parameter	Minimum	Maximum
Iron in Site Media		
Groundwater (mg/L)	0.0033	16.9
Surface Soil (mg/kg)	863	86,200
Subsurface Soil (mg/kg)	408	132,000
Surface Water (mg/L)	0.967	4.84
Sediment (mg/kg)	1,090	15,900
Fish Tissue(mg/kg)	28.00	53.60
Crab Tissue (mg/kg)	20.40	40.20
Levels in the Environment [2]		
Freshwater & Public Water Supplies (mg/L)	0.01	1.0
Rivers (mg/L)	-	0.67
Seawater (mg/L)	0.001	0.06
Soil (mg/kg)	7,000	550,000
Other Levels		
Total Body Stores[1] (mg/L)	0.012	0.3
Lethal Doses[1] (mg/kg)	200	300
Food[2,3] (mg/kg)	30	150
Grains and Fruits[2] (mg/kg)	1	20
Human and Cow Milk [2] (mg/L)	-	0.5
Reported Daily Intake[2] (mg/d)	9	35
NOEL Chronic Daily Intake [2] (mg/kg/day)	0.15	0.27

1 Risk Assessment Issue Paper for Derivation of a Provisional RfD for Iron. September 1993 (USEPA, 1993).

2 Handbook on the Toxicology of Metals Volume II, Friberg et al. 1990 (Friberg, et al., 1990).

3 Includes liver, kidney, beef, ham, egg yolk, and soybeans in mg Fe/kg fresh weight.

SECTION 2.0 FIGURES

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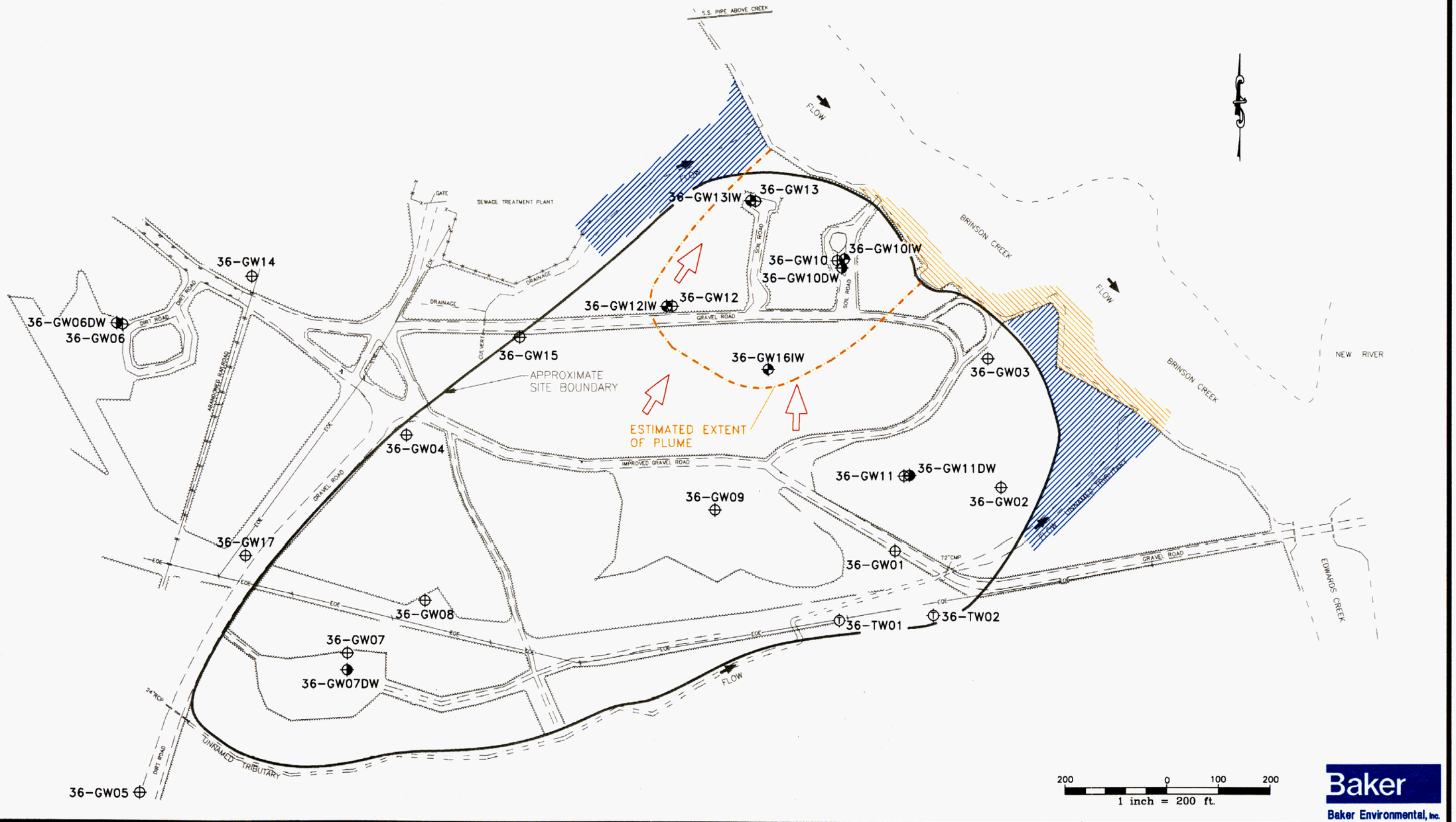


LEGEND:

- 36-GW14 — SHALLOW MONITORING WELL
- 36-GW12IW — INTERMEDIATE MONITORING WELL
- 36-GW06DW — DEEP MONITORING WELL
- 36-TW01 — TEMPORARY MONITORING WELL
- 36-SW100 — FUTURE SURFACE WATER SAMPLE LOCATION
- DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE VOC AREA OF CONCERN
- FLOW — DIRECTION OF SURFACE WATER FLOW
- EOE — OVERHEAD ELECTRIC LINE & UTILITY POLE
- FENCE
- ASPHALT ROAD
- GRAVEL ROAD
- EDGE OF CREEK, RIVER, OR DRAINAGE
- TREE LINE
- ESTUARINE, INTERTIDAL, SUBSHRUB, BROAD-LEAVED EVERGREEN, NEEDLE-LEAVED EVERGREEN, IRREGULARLY FLOODED, WETLAND
- PALUSTRINE, FORESTED, BROAD-LEAVED DECIDUOUS, NEEDLE-LEAVED EVERGREEN, TEMPORARILY FLOODED WETLAND

FIGURE 2-1
VOC AREA OF CONCERN
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02445C02Y

3.0 IDENTIFICATION AND PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES

Section 3.0 includes the identification and preliminary screening of remedial action technology types and process options that may be applicable to the remediation of groundwater at Site 36. More specifically, Section 3.1 identifies a set of general response actions, Section 3.2 identifies remedial action technology types and process options for each general response action, and Section 3.3 presents the preliminary screening of the remedial action technology types and process options. After the preliminary screening, the remaining technology types/process options undergo a process option evaluation in Section 3.4. The final set of remedial action technology types and a brief description of the options that pass the process option evaluation are presented in Section 3.5.

3.1 General Response Actions

General response actions are broad-based, medium-specific categories of actions that can be identified to satisfy the remedial action objectives of an FS. Five general response actions have been identified for the Site 36 remedial action objectives: no action, institutional controls, containment/collection actions, treatment actions, and discharge actions. A brief description of these general response actions follows.

3.1.1 No Action

The NCP requires the evaluation of the no action response as part of the FS process. A no action response provides a baseline assessment for comparisons involving other remedial alternatives that offer a greater level of response. A no action alternative may be considered appropriate when there are no adverse or unacceptable risks to human health or the environment, or when a response action may cause a greater environmental or health danger than the no action alternative.

3.1.2 Institutional Controls

Institutional controls are various "institutional" actions that can be implemented as part of a complete remedial action alternative. Institutional controls are designed to minimize exposure to potential site specific hazards. With respect to groundwater, institutional controls may include monitoring programs, access restrictions, and aquifer use restrictions. With respect to surface water, institutional controls may include monitoring.

3.1.3 Containment/Collection Actions

This general response action combines both containment and collection actions. Containment actions include technologies which contain and/or isolate contaminants by covering, sealing, chemically stabilizing, or providing an effective barrier against specific areas of concern. These actions also provide isolation and prevent direct exposure with or migration of the contaminated media. Collection actions include technologies that collect contaminants via withdrawal techniques such as extraction or subsurface drains.

3.1.4 Treatment Actions

Treatment actions for contaminated groundwater include biological, physical/chemical, and thermal treatments; engineered wetlands; and off-site and in situ treatment systems. Treatment actions are usually followed by discharge actions.

3.1.5 Discharge Actions

Discharge actions involve the on-site and/or off-site destinations where groundwater may be discharged. Discharge actions are usually employed following groundwater treatment.

3.2 Identification of Remedial Action Technologies and Process Options

In this step, an extensive set of potentially applicable technologies and process options have been identified for each general response action. The term "technology type" refers to general categories of technologies such as biological treatment, physical/chemical treatment, thermal treatment, engineered wetlands, or off-site and in situ treatment. The term "process option" refers to specific processes, or technologies, within each generalized technology type. For example, air stripping, carbon adsorption, and reverse osmosis are process options that fall under the technology type identified as physical/chemical treatment. Several technology types may be identified for each general response action, and numerous process options may exist within each generalized technology type.

With respect to their corresponding general response action, the remedial action technology types and the associated process options that are potentially applicable at Site 36 are identified on Table 3-1.

3.3 Preliminary Screening of Remedial Action Technologies and Process Options

During the preliminary screening, the set of remedial action technology types and process options identified on Table 3-1 have been screened (or reduced) by evaluating the technology types with respect to contaminant-specific and site-specific factors. This screening step was accomplished by using readily available information from the RI (with respect to contaminant types, contaminant concentrations, and on-site characteristics) to screen out technology types and process options that cannot be effectively implemented at the site (USEPA, 1988). In general, all technology types and process options which appear to be applicable to the site contaminants and site conditions has been retained for further evaluation. The preliminary screening for Site 36 is presented on Table 3-2.

As shown on Table 3-2, several technology types and/or process options were eliminated from further evaluation because they were determined to be inappropriate for the site-specific characteristics and/or contaminant-specific characteristics. The groundwater technology types/process options that were eliminated include:

- Access Restrictions/Deed Restrictions, Fencing
- Capping/Clay-Soil Cap, Asphalt-Concrete Cap, Soil Cover, Multilayered Cap
- Vertical Barriers/Grout Curtain, Slurry Wall, Sheet Piling, and Rock Grouting

- Horizontal Barriers/Grout Injection and Block Displacement
- Extraction/Extraction-Injection Wells and Hydrofracturing
- Biological Treatment/Aerobic
- Physical/Chemical Treatment/Hydrolysis, Chemical Dechlorination, Chemical Oxidation, Chemical Reduction, Reverse Osmosis, Ion Exchange, Electrolysis, Electrodialysis, Electrochemical Ion Generation, Distillation, and Oil/Water Separation
- Thermal Treatment/Liquid Injection Incineration, Molten Glass, Plasma Arc Torch, Pyrolysis, Wet Air Oxidation, and Supercritical Oxidation
- Engineered Wetland Treatment/Constructed Wetlands
- Off-site Treatment/Sewage Treatment Plant
- In Situ Treatment/Dual Phase Extraction
- On-site Discharge/Reinjection

The technology types and process options that passed the preliminary screening are summarized on Table 3-3.

3.4 Process Option Evaluation

The objective of the process option evaluation is to select the most appropriate process option for each applicable remedial technology type in order to simplify the subsequent development and evaluation of alternatives without limiting flexibility during remedial design. More than one process option may be selected for a technology type if the processes are sufficiently different in their performance that one would not adequately represent the other. The representative process provides a basis for developing performance specifications during preliminary design. However, the specific process option used to implement the remedial action may not be selected until the remedial design phase.

During the process option evaluation, the process options listed on Table 3-3 were evaluated based on three criteria: effectiveness, implementability, and relative cost. The evaluation of effectiveness focused on: the potential effectiveness of a process option in meeting the remedial action objectives; the potential impacts to human health and the environment during the construction and implementation phase; and how reliable the process is with respect to the contaminants of concern. The evaluation of implementability focused on the administrative feasibility of implementing a technology (e.g., obtaining permits), since the technical implementability was previously considered in the preliminary screening. The evaluation of relative cost played a limited role in this screening. Only relative capital and operating and maintenance (O&M) costs were used instead of detailed estimates. As per the USEPA guidance, the relative cost analysis was made on the basis of engineering judgement.

A summary of the process option evaluation is presented on Table 3-4. It is important to note that the elimination of a process option does not mean that the process option can never be reconsidered

for the site. As previously stated, the purpose of this part of the FS process is to simplify the development and evaluation of the most appropriate potential alternatives.

3.5 Final Set of Remedial Action Technologies/Process Options

Table 3-5 identifies the final set of feasible technology types and process options that were used to develop remedial action alternatives for Site 36. A brief description of each technology type/process option is presented below.

3.5.1 No Action

The no action response provides a baseline for comparison with other response actions. Under the no action response, groundwater at Site 36 will be left in place, allowing the effects of natural, passive remediation to occur. Passive remediation involves natural attenuation processes, such as biodegradation, volatilization, leaching, adsorption, and chemical reactions between subsurface materials. Under the no action response; however, no actions will be undertaken to monitor or track remedial success.

3.5.2 Groundwater/Surface Water Monitoring

A groundwater/surface water monitoring program could be implemented at Site 36 as an institutional control or as monitored natural attenuation. Programs such as these would provide continual information regarding the effectiveness and timing of any passive remedial activity, as well as, contaminant migration over time.

3.5.3 Restrictions in Base Master Plan

Aquifer-use restrictions could be instituted via the Base Master Plan to restrict the use of the surficial aquifer at Site 36 as a drinking water source. These restrictions would help reduce the risk to both human and ecological populations from ingestion and direct contact with the contaminants within the aquifer. All use of groundwater located beneath Site 36, other than for monitoring purposes, shall be prohibited. No wells would be installed within a determined distance (generally 1,500 feet) of Site 36, other than wells constructed for monitoring purposes as part of the site monitoring program.

To ensure that restrictions are upheld, annual certification that the restrictions in the Base Master Plan have remained unchanged and deed recordation of a Notice of Inactive Hazardous Substance or Waste Disposal Sites ("Notice") will be required. Upon signature of the ROD, the plat associated with the "Notice" shall be submitted for NCDENR concurrence. The RCRA Permit Modification that imposes site restrictions will be modified. Finally, in the event that the property is transferred to another party, MCB Camp Lejeune shall state that the site has been used as a hazardous waste disposal site, record the site restrictions, and outline the responsibilities of the Navy and the transferee in the form of restrictive covenants at the Onslow County register of deeds' office prior to the transfer.

3.5.4 Extraction Wells

The extent and migration of a contaminated groundwater plume may be contained or collected via pumping techniques. Existing wells or additional extraction wells, strategically located according

to the hydrogeologic characteristics of the surficial aquifer and the chemical characteristics of the contaminants of concern, can be used. The extraction wells are pumped at specific rates such that the capture radius from the well system intercepts the contaminant plume. Groundwater pumping may be combined with additional treatment technology types. Pumping techniques utilizing extraction wells are proven techniques for the containment of groundwater contamination but may not be appropriate for complete aquifer restoration.

3.5.5 Volatilization (Air/Steam Stripping)

Air/steam stripping is a physical/chemical treatment process in which water and air/steam are brought into contact with each other for the purpose of transferring volatile substances from solution in a liquid to a solution in a gas. As compared to steam stripping, air stripping has been most cost-effectively used for the treatment of low concentrations of VOCs or as a pretreatment step prior to an activated carbon treatment technology. The off-gas generated during the treatment process may require collection and subsequent treatment.

3.5.6 Carbon Adsorption

Carbon adsorption is a physical/chemical treatment process that binds organic molecules to the surface of the activated carbon particles. The adsorption process involves contacting a waste stream with carbon, usually by flow through a series of packed-bed reactors. Once the micropore surfaces of the carbon are saturated with organics, the carbon is "spent" and must be replaced or regenerated. The time to reach breakthrough is the most critical operating parameter of this type of treatment system (Rich, 1987).

3.5.7 Neutralization

Neutralization is the interaction of an acid with a base, or vice versa, to yield a final pH of approximately 7.0. This process option is one of the most common types of chemical treatments used by industrial wastewater treatment facilities. Pretreatment of the waste stream may be needed for large amounts of suspended solids, oils, and grease. The major limitation of neutralization is that it is subject to the influence of temperature (USEPA, 1990).

3.5.8 Precipitation

Precipitation is a process in which materials in solution are transferred into a solid phase for removal. Removal of heavy metals is the most common precipitation application in wastewater treatment. Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank. Flocculating agents such as alum, ferric chloride, and ferric sulfate may be added to enhance the agglomeration of precipitate particles. The insoluble precipitate is then removed for recovery or disposal using solids separation technologies such as sedimentation or filtration.

3.5.9 Filtration

Filtration is a physical process used to remove suspended solids and biological floc from wastewater. The separation is accomplished by passing water through a physically restrictive medium, resulting in the entrapment of suspended particulate matter. The media typically used for filtration includes sand, coal, garnet, and diatomaceous earth. Filtration is generally preceded by chemical precipitation and neutralization.

3.5.10 Flocculation

Flocculation is a process in which chemical coagulants cause colloidal particles to agglomerate into larger particles. Similar to precipitation, the removal of heavy metals is the most common flocculation application in wastewater treatment. Alum, ferric chloride and ferric sulfate are added to the wastewater to agglomerate the flocculated particles.

3.5.11 Sedimentation

Sedimentation is a physical process in which colloidal particles are allowed to settle out of an aqueous waste stream via gravity separation.

3.5.12 In Situ Volatilization (Air Sparging, In-Well Aeration)

Air sparging offers a commercially proven technology, while in-well aeration is a somewhat new and innovative technology. In-well aeration, also referred to as "vacuum vapor extraction", is a variation of air sparging. Where as air sparging can be thought of as in situ air stripping, in-well aeration can be thought of as in-well air stripping. Air sparging incorporates the injection of air into the water saturated zone for the purpose of removing organic contaminants via volatilization. Once volatilized, the sparged contaminants are generally collected. Soil vapor extraction may be used to collect the volatilized contaminants and convey them to an off-gas treatment system. The process of in-well aeration involves injecting air that is not intended to enter the aquifer into a well (although the air may enter the aquifer in a dissolved form). The resulting in-well airlift pump effect causes water to flow into the well from the deeper screened portion of the well and out of the well from the shallower screened portion (Hinchee, 1994). Volatiles are stripped from the groundwater within the well, rise to the top of the well with the injection air, and are collected and treated at an above ground treatment facility. Under the air sparging or in-well aeration system, groundwater is treated without being extracted out of the ground. In addition to treating contaminants via volatilization, both technologies may provide enhanced bioremediation within the aquifer and vadose zone.

3.5.13 Monitored Natural Attenuation

The remedial actions associated with monitored natural attenuation include groundwater/surface water monitoring and groundwater modeling to demonstrate the remedial success of the natural attenuation processes. Factors that influence these natural processes include: water content in soil, soil porosity/permeability, clay content, adsorption, soil density, pH, oxidation/reduction potential, temperature, wind, evaporation, precipitation, microbial community, chemical composition and concentration, soil management, and availability of nutrients. Under this response action, many of these natural attenuation parameters would be monitored in addition to monitoring the TCL VOCs within the groundwater and surface water.

3.5.14 On-Site Surface Water Discharge

Treated groundwater from Site 36 can be discharged on-site directly into Brinson Creek. The capacity of Brinson Creek, as well as any required discharge permits, must be considered if it is to be used as a discharge location.

3.6 References

Hinchee, 1994. Air Sparging for Site Remediation. Lewis Publishers, Columbus, Ohio.

Rich, Gerald and Kenneth Cherry. 1987. Hazardous Waste Treatment Technologies. Third Printing. Pudvan Publishing Company, Northbrook, Illinois.

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

USEPA, 1990. United States Environmental Protection Agency. National Oil and Hazardous Substances Pollution Contingency Plan. 55FR8665. Office of Emergency and Remedial Response. Washington, D.C. March 1990.

SECTION 3.0 TABLES

TABLE 3-1

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater/Surface Water Monitoring
		Access Restrictions	Deed Restrictions
			Fencing
		Aquifer Use Restrictions	Restrictions in Base Master Plan
	Containment/Collection Actions	Capping	Clay/Soil Cap
			Asphalt/Concrete Cap
			Soil Cover
			Multilayered Cap
		Vertical Barriers	Grout Curtain
			Slurry Wall
			Sheet Piling
			Rock Grouting
		Horizontal Barriers	Grout Injection
			Block Displacement
		Extraction	Extraction Wells
			Extraction/Injection Wells
			Hydrofracturing
		Subsurface Drains	Interceptor Trenches
	Treatment Actions	Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powdered Activated Carbon Treatment • Trickling Filter • Rotating Biological Contactor
			Anaerobic
		Physical/Chemical Treatment	Volatilization (Air Stripping/ Steam Stripping)
			Carbon Adsorption
			Hydrolysis
			Chemical Dechlorination
			Ultraviolet (UV) Oxidation

TABLE 3-1 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater (Continued)	Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Chemical Oxidation • Hydrogen Peroxide • Chlorine • Potassium Permanganate • Ozonation
			Chemical Reduction
			Reverse Osmosis
			Ion Exchange
			Electrolysis
			Electrodialysis
			Electrochemical Ion Generation
			Distillation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
			Oil/Water Separation
		Thermal Treatment	Liquid Injection Incineration
			Molten Glass
			Plasma Arc Torch
			Pyrolysis
			Wet Air Oxidation
			Supercritical Oxidation
		Engineered Wetland Treatment	Constructed Wetlands
		Off-site Treatment	RCRA Facility
			Site 82 Treatment System
			Sewage Treatment Plant
		In Situ Treatment	Biodegradation
			In situ Volatilization/Air Sparging/In-Well Aeration
			Dual Phase Extraction
			Passive Treatment Wall
			Monitored Natural Attenuation

TABLE 3-1 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater (Continued)	Discharge Actions	On-site Discharge	Surface Water
			Reinjection • Injection Wells • Infiltration Galleries
		Off-site Discharge	Sewage Treatment Plant

TABLE 3-2

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No Action - Contaminated groundwater remains as is.	Potentially applicable; required by the NCP.	Retained
Institutional Controls	Monitoring	Groundwater/Surface Water Monitoring	Ongoing monitoring of existing and/or newly installed wells and Brinson Creek.	Potentially applicable.	Retained
	Access Restrictions	Deed Restrictions	Limit the future use of land including placement of wells.	Deed restrictions are not applicable to military installation not on closure list.	Eliminated
		Fencing	Limit access by installing a fence around contamination area.	A fence alone will not prevent contaminant migration.	Eliminated
	Aquifer Use Restrictions	Restrictions in Base Master Plan	Prohibit use of the contaminated aquifer as a potable water source.	Potentially applicable.	Retained
Containment/Collection Actions	Capping	Clay/Soil Cap Asphalt/Concrete Cap Soil Cover Multilayered Cap	Capping material placed over areas of contamination.	This process option would not be feasible due to the close proximity to Brinson Creek and the site's flood-prone location.	Eliminated
	Vertical Barriers	Grout Curtain	Pressure injection of grout in a regular pattern of drilled holes to contain contamination.	Because the confining layer is deep (approximately 60' bgs), this process option would be impractical.	Eliminated
		Slurry Wall	Trench around areas of contamination. The trench is filled with a soil bentonite slurry to limit migration of contaminants.	Because the confining layer is deep (approximately 60' bgs), this process option would be impractical.	Eliminated
		Sheet Piling	Interlocking sheet pilings installed via drop hammer around areas of contamination.	Because the confining layer is deep (approximately 60' bgs), this process option would be impractical.	Eliminated
		Rock Grouting	Specialty operation for sealing fractures, fissures, solution cavities, or other voids in rock to control flow of groundwater.	The depth to bedrock limits the practicality of this process option.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Containment/Collection Actions (Continued)	Horizontal Barriers	Grout Injection	Pressure injection of grout to form a bottom seal across a site at a specific depth.	Technique is in the experimental stage. Grout injection alone will not prevent contaminant migration.	Eliminated
		Block Displacement	Continued pumping of grout into specially notched holes causing displacement of a block of contaminated earth.	Technique is in the experimental stage.	Eliminated
	Extraction	Extraction Wells	Series of wells used to extract contaminated groundwater. Well screen must be placed within the identified plume for maximum contaminant collection.	Potentially applicable.	Retained
		Extraction/Injection Wells	Injection wells inject uncontaminated groundwater to enhance collection of contaminated groundwater via the extraction wells. Injection wells can also inject material into an aquifer to remediate groundwater.	Based on the relatively low permeability of soil at the site, injected liquid may mound in the subsurface formations rather than flowing though.	Eliminated
		Hydrofracturing	Pressurized water is injected to create fractures in the formation, thus improving permeability. Can be used to enhance pump and treat systems.	The fractures may open new passageways through which contaminants can spread.	Eliminated
	Subsurface Drains	Interceptor Trenches	Perforated pipe installed in trenches backfilled with porous media to collect contaminated groundwater. Generally limited to shallow depths.	Potentially applicable.	Retained
Treatment Actions	Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powdered Activated Carbon Treatment • Trickling Filter • Rotating Biological Contactor	Degradation of organics using microorganisms in an aerobic environment.	Not highly effective for halogenated VOCs such as TCE.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Biological Treatment (Continued)	Anaerobic	Degradation of organics using microorganisms in an anaerobic environment.	Potentially applicable to halogenated VOCs such as TCE.	Retained
	Physical/Chemical Treatment	Volatilization (Air Stripping/Steam Stripping)	Mixing large volumes of air/steam with water in a packed column to promote transfer of VOCs to air. Effective for VOCs and some SVOCs.	Potentially applicable to VOCs.	Retained
		Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing water through carbon column. Effective for wide range of organics.	Potentially applicable to VOCs.	Retained
		Hydrolysis	By adding chemicals or irradiation, molecular bonds are broken making contaminants water-soluble. Used primarily to treat aqueous wastes containing refractory organics.	Primary COC (TCE) is not water-reactive.	Eliminated
		Chemical Dechlorination	Process which uses specially synthesized chemical reagents to destroy hazardous chlorinated molecules or to detoxify them to form other less harmful compounds. Effective for PCBs, chlorinated hydrocarbons and dioxins.	Groundwater may require extensive dewatering prior to the application of this technology. Not highly effective for TCE.	Eliminated
		Ultraviolet (UV) Oxidation	UV radiation is used to destroy organic contaminants as water flows into a treatment tank; an ozone destruction unit treats off-gases from treatment tank.	Potentially applicable to VOCs.	Retained

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Chemical Oxidation • Hydrogen Peroxide • Chlorine • Potassium Permanganate • Ozonation	Addition of an oxidizing agent to raise the oxidation state of a substance. Effective for organics (primarily phenols, pesticides, and sulfur containing wastes), and some metals (primarily iron and manganese).	Not applicable to TCE.	Eliminated
		Chemical Reduction	Addition of a reducing agent to lower the oxidation state of a substance to reduce toxicity/solubility. Effective for chromium, mercury and lead.	Not applicable to TCE.	Eliminated
		Reverse Osmosis	Using high pressure to force water through a RO membrane leaving contaminants behind. Effective for dissolved solids (organic and inorganic).	Not applicable as dissolved solids are not anticipated to be primary treatment concern.	Eliminated
		Ion Exchange	Contaminated water is passed through a resin bed where ions are exchanged between resin and water. Effective for inorganics, but not iron and manganese.	Not applicable to TCE, and inorganics are not primary treatment concerns.	Eliminated
		Electrolysis	Metal ions are removed when an electric current drives contaminated water through ion exchangers in membrane form. Effective for recoverable metals or cyanide.	Not applicable to TCE.	Eliminated
		Electrodialysis	Metal ions are removed when an electric current drives contaminated water through ion exchangers in membrane form.	Not applicable to TCE.	Eliminated
		Electrochemical Ion Generation	Electrical currents are used to put ferrous and hydroxyl ions into solution for subsequent removal via precipitation. Effective for metals removal.	Not applicable to TCE.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Distillation	Contaminated water is heated so it evaporates leaving contaminants behind. The water vapor is then cooled resulting in condensate of purified water. Highly energy intensive.	Because it is highly energy intensive, this method is not effective for treating groundwater with relatively low contaminant concentrations.	Eliminated
		Neutralization	Addition of an acid or base to a waste in order to adjust its pH. Applicable to acidic or basic waste streams.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Precipitation	Materials in solution are transferred into a solid phase for removal. Effective for suspended solids and metals.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Filtration	Removal of suspended solids from solution by forcing the liquid through a porous medium. Effective for suspended solids and inorganics.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Flocculation	Small, unsettleable particles suspended in a liquid medium are made to agglomerate into large particles by the addition of flocculating agents. Effective for suspended solids and inorganics.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Sedimentation	Removal of suspended solids in an aqueous waste stream via gravity separation. Effective for suspended solids.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Oil/Water Separation	Materials in solution are transferred into separate phases for removal. Applicable to petroleum hydrocarbons.	Not applicable to TCE.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Thermal Treatment	Liquid Injection Incineration	Combustion of waste at high temperatures. Effective for pumpable organic wastes.	Incineration is relatively expensive when there are low contaminant concentrations in groundwater; such as the TCE at Site 36.	Eliminated
		Molten Glass	Advanced incineration; waste contacts hot molten salt to undergo catalytic destruction. Effective for hazardous liquids, low ash, high chlorine wastes.	Incineration is relatively expensive when there are low contaminant concentrations in groundwater; such as the TCE at Site 36.	Eliminated
		Plasma Arc Torch	Advanced incineration; pyrolyzing wastes into combustible gases in contact with a gas which has been energized to its plasma state by an electrical discharge. Effective for liquid organic waste.	Incineration is relatively expensive when there are low contaminant concentrations in groundwater; such as the TCE at Site 36.	Eliminated
		Pyrolysis	Advanced incineration; thermal conversion of organic material into solid, liquid, and gaseous components; takes place in an oxygen-deficient atmosphere. Effective for organics and inorganics.	Incineration is relatively expensive when there are low contaminant concentrations in groundwater; such as the TCE at Site 36.	Eliminated
		Wet Air Oxidation	Advanced incineration; aqueous phase oxidation of dissolved or suspended organic substances at elevated temperatures and pressures. Effective for organics with high COD, high strength wastes, and for oxidizable inorganics.	Incineration is relatively expensive when there are low contaminant concentrations in groundwater; such as the TCE at Site 36.	Eliminated
		Supercritical Oxidation	An enhanced wet-air oxidation process with reaction conditions in supercritical range of water.	Incineration is relatively expensive when there are low contaminant concentrations in groundwater; such as the TCE at Site 36.	Eliminated

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	Engineered Wetland Treatment	Constructed Wetlands	An engineered complex of plants, substrates, water, and microbial populations. Contaminants are removed via plant uptake, biodegradation (organics only), precipitation, and sorption processes.	Wetlands are better suited for removal of metals within soils and sediments. Implementation of this technology may present challenging construction obstacles.	Eliminated
	Off-site Treatment	RCRA Facility	Extracted groundwater transported to licensed RCRA facility for treatment and/or disposal.	Potentially applicable.	Retained
		Site 82 Treatment System	Extracted groundwater discharged to treatment system constructed at Site 82.	Potentially applicable.	Retained
		Sewage Treatment Plant	Extracted groundwater discharged to STP for treatment.	Not implementable as STP will not accept untreated groundwater.	Eliminated
	In Situ Treatment	Biodegradation	System of introducing nutrients and oxygen to waste for the stimulation or augmentation of microbial activity to degrade contamination. Effective for a wide range of organic compounds.	Potentially applicable to VOCs.	Retained
		In Situ Volatilization (Air Sparging, In-Well Aeration)	"In Situ Air Stripping" uses the injection of air under pressure to remove VOCs via volatilization. May be used in conjunction with soil vapor extraction to collect volatilized contaminants in the vadose zone. "In-Well Aeration" is a process of inducing air into a well by applying a vacuum that serves to strip volatiles from groundwater inside the well.	Potentially applicable to VOCs.	Retained

TABLE 3-2 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment Actions (Continued)	In Situ Treatment (Continued)	Dual Phase Extraction	A high vacuum placed in a well removes liquid and gas. Effective for VOCs in low permeability or heterogeneous formations.	The maximum suction lift is approximately 30 ft. bgs, but the plume at Site 36 is located at approximately 30 to 40 ft. bgs.	Eliminated
		Passive Treatment Wall	A permeable wall is installed across the flow path of a contaminant plume, treating the plume as it passively moves through the wall.	Potentially applicable to VOCs.	Retained
		Monitored Natural Attenuation	Natural subsuface processes, including dilution, volatilization, biodegradation, adsorption, and chemical reactions. Process option considers groundwater monitoring combined with modeling to demonstrate on-going contaminant degradation via natural attenuation.	Potentially applicable.	Retained
Discharge Actions	On-site Discharge	Surface Water	Treated water discharged to Brinson Creek.	Potentially applicable.	Retained
		Reinjection • Injection Wells • Infiltration Galleries	Treated water reinjection into the site aquifer via use of shallow infiltration galleries (trenches) or via injection wells.	Based on the relatively low permeability of soil at the site, injected liquid may mound in the subsurface formations rather than flowing through.	Eliminated
	Off-site Discharge	Sewage Treatment Plant	Treated water discharged to STP.	Potentially applicable.	Retained

TABLE 3-3

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING SITE 36, CAMP GEIGER AREA DUMP FEASIBILITY STUDY, CTO-0303 MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater/Surface Water Monitoring
		Aquifer Use Restrictions	Restrictions in Base Master Plan
	Containment/Collection Actions	Extraction	Extraction Wells
		Subsurface Drains	Interceptor Trenches
	Treatment Actions	Biological Treatment	Anaerobic
		Physical/Chemical Treatment	Volatilization (Air/Steam Stripping)
			Carbon Adsorption
			Ultraviolet (UV) Oxidation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		Off-Site Treatment	RCRA Facility
			Site 82 Treatment System
		In Situ Treatment	Biodegradation
			In Situ Volatilization (Air Sparging, In-Well Aeration)
			Passive Treatment Wall
			Monitored Natural Attenuation
	Discharge Actions	On-Site Discharge	Surface Water
		Off-Site Discharge	Sewage Treatment Plant

TABLE 3-4

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
No Action	No Action	Not Applicable	• Effectiveness depends on contaminant concentrations, risks associated with the contaminants, and the effects of natural attenuation	• Easily implemented • No means to monitor site conditions	• No cost	Retained as per the requirements of the NCP
Institutional Controls	Monitoring	Groundwater/ Surface Water Monitoring	• Effectively detects contaminant trends so that exposure can be avoided	• Easily implemented	• Low capital • Low O&M	Retained because of its effectiveness, implementability, and low cost
	Aquifer Use Restrictions	Restrictions in Base Master Plan	• Effective at preventing future exposure to contaminated groundwater • Effectiveness dependent on continual implementation	• Easily implemented • A Notice of Inactive Hazardous Substances or Waste Disposal Sites would require NC DENR concurrence	• Negligible cost	Retained because of its effectiveness, ease of implementation and negligible cost
Containment/ Collection Actions	Extraction	Extraction Wells	• Conventional, widely demonstrated technology • Effective for collecting and/or containing a contaminated groundwater plume • Inorganics may precipitate and clog well screens, necessitating frequent maintenance and equipment replacement	• Easily implemented • Potential exposures during implementation • Equipment readily available	• Moderate capital • Low O&M	Retained because it is a conventional technology and it will be more easy to implement than an interceptor trench
	Subsurface Drains	Interceptor Trenches	• Effective for collecting and/or containing a contaminated groundwater plume • More effective for shallow aquifers • Slower recovery than extraction wells • Potential exposures during installation	• Requires an experienced specialty contractor • Requires extensive excavation/trenching • Requires more surface area than extraction wells • Equipment readily available	• Moderate to high capital • Low to moderate O&M	Eliminated because the contaminated aquifer is located 30-40 ft. bgs and trenches require more surface area than extraction wells

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions	Biological Treatment	Anaerobic	• Technology is still under development so it is not widely demonstrated • Elevated VOCs may be toxic to organisms • Very slow process • Effectiveness is susceptible to variation in waste stream characteristics and environmental parameters	• Mobile units available • Methane gas is produced and must be utilized or disposed • Low contaminant concentrations may make operation difficult	• Moderate capital • Moderate O&M	Eliminated because it has not been widely demonstrated
	Physical/Chemical Treatment	Volatilization (Air/Steam Stripping)	• Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling • Commercially proven technology • Contaminant transfer rather than destruction technology • Lower efficiency in cold weather (steam stripping)	• Off-gas and/or tower scale treatment may be required • May require air emissions permit • Mobile units available • Equipment and vendors readily available • Steam stripping is not as common as air stripping	• Moderate capital • Low to moderate O&M	Retained because of its effectiveness for contaminants that are highly volatile with low water solubility (i.e. TCE), its commercial availability, performance record, and its relatively low cost
		Carbon Adsorption	• Inorganics can foul the system • Commercially proven and widely used technology • Contaminant transfer rather than destruction technology • Can be used as a polishing step following air stripping	• Spent carbon must be regenerated or properly disposed • Pretreatment may be required to reduce or remove suspended solids, oil and grease and unstable chemical compounds • Equipment readily available and conventional	• Moderate capital • Moderate to high O&M (dependent on loading rates and carbon life)	Retained because of its commercial availability and performance record, and its relatively moderate cost
		UV Oxidation	• Commercially proven technology • Inorganics such as chromium, iron, and manganese may limit effectiveness • High turbidity limits the transmission of UV light • Contaminant destruction rather than transfer technology • Off-gas treatment will be required	• Energy-intensive • Handling and storage of oxidizers requires special safety precautions • System is easily automated • System is easy to transport and set up	• Moderate to high capital • High O&M	Eliminated because it is energy-intensive and has a relatively high cost

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	Physical/Chemical Treatment (Continued)	Neutralization	• Can be used in a treatment train for pH adjustment	• Widely used and well-demonstrated • Simple and readily available equipment/materials	• Low capital • Low to moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
		Precipitation	• Effective, reliable, permanent, and conventional technology • Typically used for removal of heavy metals • Followed by solids-separation method • Generates sludge which can be voluminous, difficult to dewater, and may require treatment	• Equipment is basic and easily designed • Compact, single units can be delivered to the site	• Low capital • Moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
		Filtration	• Conventional, proven method of removing suspended solids from wastewater • Does not remove contaminants other than suspended solids • Generates a sludge which requires proper handling	• Equipment is relatively simple to install and no chemicals are required • Package units available	• Low capital • Low O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
		Flocculation	• Conventional, proven technology • Applicable to aqueous waste stream where particles must be agglomerated into larger more settleable particles prior to other types of treatment • Performance depends on the variability of the composition of the waste being treated	• Equipment is readily available and easy to operate • Can be easily integrated into more complex treatment systems	• Low capital • Moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption
		Sedimentation	• Conventional, proven technology • Effective for removing suspended solids and precipitated materials from wastewater • Performance depends on density and particle size of the solids, effective charge on the suspended particles, types of chemicals used in pretreatment, surface loading, upflow rate, and rejection time • Feasible for large volumes of water to be treated	• Effluent streams include the effluent water, scum, and settled solids	• Moderate capital • Moderate O&M	Retained because it may be necessary as a pretreatment for air stripping and/or carbon adsorption

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	Off-Site Treatment	RCRA Facility	• Preliminary testing is required to determine effectiveness and reliability • Potential hazards associated with transporting contaminated groundwater	• Readily implementable if facility will accept waste • May be difficult to gain facility acceptance of waste • Modifications to permits may be required • Distance to nearest facility may make implementation more difficult	• Moderate capital • Moderate O&M	Eliminated because the nearest facility is not located nearby and implementation may be difficult
		Site 82 Treatment System	• Effective and reliable for VOC removal • Potential hazards associated with transporting contaminated groundwater	• System has capacity to accept the groundwater • Transportation via pipeline may not be feasible due to distance to the system • Transportation via trucking is feasible; however, the distance to Site 82 may make implementation via trucking more difficult	• Moderate to high capital • Moderate O&M	Eliminated because implementation may be difficult
	In Situ Treatment	Biodegradation	• Technology is still under development so it is not widely demonstrated • Very slow process • Injection of substrate and nutrients into groundwater may mobilize contaminants • Most effective for a site that has both soil and groundwater contamination, rather than just groundwater contamination	• Injection of substrate and nutrients into groundwater may require a permit • Equipment readily available	• Moderate to high capital • Low to moderate O&M	Eliminated because there is no soil contamination associated with groundwater contamination at Site 36
		In Situ Volatilization (Air Sparging, In-Well Aeration)	• Groundwater does not need to be lifted above ground surface in order to be treated • Contaminant transfer rather than destruction technology • More effective for larger vadose zones • Fouling of the system may occur by oxidized constituents in the groundwater • Commercially proven technology (Air Sparging)	• Secondary treatment of off-gas may be required • May require air emissions permit	• Moderate to high capital • Low to moderate O&M	Retained due to effectiveness

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment Actions (Continued)	In Situ Treatment (Continued)	In Situ Volatilization (Air Sparging, In-Well Aeration) (Continued)	• Contamination of the vadose zone may occur as contaminated groundwater passes through it (Air Sparging) • Soil vapor extraction may be necessary to collect volatilized contaminants (Air Sparging) • Limited commercial track record (In-Well Aeration) • Provides a closed loop system for air circulation; volatiles are less likely to escape because they will be collected within the aeration wells (In-Well Aeration)			
		Passive Treatment Wall	• Not widely demonstrated • Groundwater may mound around the wall rather than flowing through it • More effective if used in conjunction with vertical barriers acting as funnel gates • More effective if used in conjunction with extraction wells to increase groundwater velocity through the wall • Inorganics precipitation may occur resulting in a reduction of permeability through the wall • Groundwater constituents exiting the wall may require further treatment	• Treatment does not create contaminated residue, sludge, or other materials requiring disposal • No external energy source is required for the treatment process • Deep confining layers make implementation more difficult	• Moderate to high capital • Low O&M	Eliminated due to depth of confining layer and the potential for groundwater to mound around the wall
		Monitored Natural Attenuation	• Effectively detects contaminant increases and decreases so that exposure can be avoided • The existence of TCE and DCE at Site 36 suggests that natural attenuation is occurring • There are no human health risks associated with contaminated groundwater at Site 36 • Natural attenuation processes have demonstrated effective reduction of TCE over time	• Easily implemented • Minimal mechanical equipment required • Requires long-term monitoring of groundwater and Brinson Creek surface water	• Low to moderate capital • Moderate O&M	Retained because of its effectiveness and implementability

TABLE 3-4 (Continued)

SUMMARY OF THE PROCESS OPTION EVALUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology Type	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Discharge Actions	On-Site Discharge	Surface Water	• Effective and reliable discharge method • Post-treatment action; therefore, minimal risks during construction and operation	• Based on the low pumping rates expected, Brinson Creek should have the capacity to handle discharge from a extraction and treatment system	• Low capital • Low O&M	Retained due to implementability and low cost
	Off-Site Discharge	Sewage Treatment Plant	• Effective and reliable discharge method • Extensive pretreatment of waste required	• Discharge permit may require modification • Pipeline modifications and flow diversions may be required • The Camp Geiger STP is scheduled to be decommissioned	• Moderate capital • Moderate O&M	Eliminated because of scheduled decommissioning

TABLE 3-5

FINAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	General Response Action	Remedial Action Technology Type	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater/Surface Water Monitoring
		Aquifer Use Restrictions	Restrictions in Base Master Plan
	Containment/Collection Actions	Extraction	Extraction Wells
	Treatment Actions	Physical/Chemical Treatment	Volatilization (Air/Steam Stripping)
			Carbon Adsorption
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		In Situ Treatment	In Situ Volatilization (Air Sparging, In-Well Aeration)
			Monitored Natural Attenuation
	Discharge Actions	On-Site Discharge	Surface Water

4.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

In this section, remedial action technologies and process options chosen for Site 36 were combined to form remedial action alternatives (RAAs). The development process associated with each of these RAAs is presented in Section 4.1. Section 4.2 presents the evaluation of each RAA against the short-term and long-term aspects of three criteria: effectiveness, implementability, and cost. The RAAs with the most favorable evaluation will be retained for further consideration during the detailed analysis presented in Section 5.0. The screening evaluation of the most favorable RAAs is optional, and will only be conducted if too many RAAs are initially developed.

4.1 Development of Remedial Action Alternatives

RAAs were developed by combining the general response actions, remedial action technologies, and process options identified on Table 3-5. Five RAAs were developed to address the volatile groundwater contamination at Site 36; they include: no action, institutional controls, monitored natural attenuation, extraction and on-site treatment, and in-situ volatilization (in-well aeration). The following subsections describe these RAAs.

4.1.1 RAA 1: No Action

Under the no action RAA, no physical remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminants identified in groundwater at Site 36. The no action alternative is required by the NCP to provide a baseline for comparison with other RAAs that provide a greater level of response.

Although this RAA does not involve physical remediation, remediation of the groundwater is expected to occur via processes associated wtih the natural attenuation of contaminants. Under the no action RAA; however, no means are considered or incorporated to monitor or confirm the natural remediation process. Therefore, overall protection of human health and the environment will remain unknown.

Since contaminants will remain at Site 36 under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years.

4.1.2 RAA 2: Institutional Controls

Under RAA 2, no physical remedial actions (e.g., groundwater extraction) will be performed at Site 36. Instead, a groundwater/surface water monitoring program and aquifer use restrictions will be implemented as institutional controls.

The purpose of the groundwater/surface water monitoring program is to track the VOC plume's migration over time and to evaluate any fluctuations in COC levels. Under the program, groundwater samples will be collected semiannually at the monitoring wells identified on Figure 4-1. As shown, seven wells will be monitored under this program: three existing shallow wells (36-GW10, 36-GW12, 36-GW13), three existing intermediate wells (36-GW10IW, 36-GW12IW, and 36-GW13IW), and one existing deep well (36-GW10DW). The shallow and intermediate wells will monitor COC levels in the upper and lower portions of the surficial aquifer and the deep well will monitor the upper portion of the Castle Hayne aquifer to ensure that COCs have not migrated vertically. Samples collected from these wells will be analyzed for TCL VOCs. Additional wells

may be added to the program, if necessary. Likewise, if the analytical results indicate that the groundwater quality has improved, the monitoring program may be refined to include fewer sampling locations or less frequent sampling events. Surface water samples will also be collected from three locations (36-SW100, 36-SW200, and 36-SW300) along Brinson Creek (Figure 4-1) to assist in determining if the VOCs are impacting the creek. Similar to groundwater samples, the surface water samples will be analyzed for TCL VOCs.

In addition, the Base Master Plan will be modified to include aquifer use restrictions. These restrictions will prohibit future use of the aquifer as a potable water source. To ensure that the restrictions are upheld, annual certification that the restrictions in the Base Master Plan have remained unchanged and deed recordation of a Notice of Inactive Hazardous Substance or Waste Disposal Sites ("Notice") will be required. Upon signature of the ROD, the plat associated with "Notice" shall be submitted for NCDENR concurrence. The RCRA Permit Modification that imposes site restrictions will be modified. Finally, in the event that the property is transferred to another party, MCB Camp Lejeune shall state that the site has been used as a hazardous waste disposal site, record the site restrictions, and outline the responsibilities of the Navy and the transferee in the form of restrictive covenants at the Onslow County register of deeds' office prior to the transfer. Similar to RAA 1, remediation of the groundwater is expected to occur via the process associated with natural attenuation. Although the monitoring under RAA2 will track the constituent concentrations, this RAA does not incorporate the sampling requirements necessary to confirm the progress of the natural attenuation processes at Site 36.

Since contaminants will remain at the site under this RAA, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years.

4.1.3 RAA 3: Monitored Natural Attenuation

Under RAA 3, no physical remedial actions will be conducted to reduce the toxicity, mobility, or volume of the groundwater contaminants at Site 36. Remedial actions associated with the in-situ, naturally occurring biodegradation, dispersion, dilution, adsorption, volatilization, and chemical or biological stabilization/destruction of the VOCs in groundwater are expected in the form of natural attenuation. The term "natural attenuation" refers to the "naturally occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in these media" (Weidemeier, 1996).

Biodegradation may occur as an aerobic, anaerobic, or cometabolic process. Aerobic processes involve oxidation-reduction reactions in which oxygen is the electron receptor. Anaerobic processes involve iron-reducing, denitrifying, and sulfate-reducing reactions. Cometabolic processes involve carbon dioxide-reducing reactions and result in the accumulation of methane as a final product. The natural biodegradation of fuel-related compounds (e.g., benzene) is more fully documented than the natural biodegradation of chlorinated solvent contaminants (e.g., TCE, 1,2-DCE, vinyl chloride). Technical literature, however, indicates that both fuel and chlorinated solvent contamination can undergo natural attenuation through one or a combination of the biodegradation processes mentioned. The following evidence suggests that natural attenuation processes are successfully degrading the chlorinated solvent contamination in the surficial aquifer at Site 36:

- PCE and TCE have been detected within the isolated northern area of Site 36. In addition, the TCE daughter product (1,2-DCE) has also been detected.

- PCE and TCE were not detected in soil samples collected from this area, thus suggesting that the source has degraded or migrated to the surficial groundwater.

- The locations and concentrations of the TCE and 1,2-DCE detections within the northern area of the site are positioned as to suggest that the daughter product is a direct result of the PCE and TCE degredation. Based upon this information, the monitored natural attenuation alternative appears to be a justifiable remedial option for the chlorinated solvent contamination detected in the surficial aquifer.

The primary component of RAA 3 is an extensive monitoring program. Similar to the plan identified under RAA 2, the monitoring program for RAA 3 will include both groundwater and surface water sampling. However, the surface water samples will be analyzed solely for TCL VOCs. Groundwater samples will include laboratory analyses of the following parameters: TCL VOCs, nitrate, sulfate, methane, ethane, ethene, and chloride. Additionally, field analyses will be conducted on groundwater samples to determine the levels of oxygen, iron II, alkalinity, oxidation-reduction potential (ORP), pH, temperature, conductivity, major cations, and hydrogen. Select soil samples will be collected for laboratory analysis of total organic carbon (TOC). Both the laboratory and field parameters are identified and described in more detail on Table 4-1. Collection and review of the analytical results will indicate the type of bioremediation that is occurring, (i.e., aerobic, iron-reducing, denitrifing, sulfate-reducing, or methanogenic). Over time, the results will be used to predict the kind and amount of contaminant reduction that has occurred, as well as, the amount of contaminant reduction that is expected.

Figure 4-2 identifies the following eleven wells that will monitor both TCL VOCs and the aforementioned natural attenuation parameters: 36-GW08, 36-GW09, 36-GW10, 36-GW12, 36-GW13, 36-GW15, 36-GW10IW, 36-GW12IW, 36-GW13IW, 36-GW16IW, and 36GW10DW. The shallow and intermediate wells will monitor concentrations in the surficial aquifer, while the deep well will monitor the Castle Hayne aquifer to ensure that contaminants have not migrated vertically. Should additional sampling locations be necessary, they will be added to the monitoring program. If the analytical results indicate that the groundwater quality has improved, the monitoring program may be refined to include fewer sampling locations or less frequent sampling events. Monitoring, in some capacity, will continue until groundwater standards for chlorinated solvents have been met. However, for cost estimating purposes, 5 years of quarterly sampling, followed by 25 years of semiannual sampling will be assumed. In turn, the cost estimate for RAA 3 also incorporates the reduction of analytical costs by 50 percent starting in the sixth year of the program.

In an effort to provide additional evidence that natural attenuation is occurring, RAA 3 incorporates the option of performing a contaminant fate and transport model similar to the model included within this FS (Appendix B). The cost estimate accounts for annual modeling, as new results become available.

RAA 3 also includes aquifer use restrictions to prohibit future use of the surficial aquifer within a 1,500 foot radius of estimated plume at Site 36. These restrictions eliminate the surficial aquifer from being used as a potable water source. As defined under RAA 2 and Section 3.5.3, these restrictions will be implemented through modifications to the Base Master Plan, annual certification, deed recordation, and restrictive covenants (in the event of property transfers).

Until remediation levels are met, the NCP [40 CFR 300.430(f)(4)] requires that the lead agency review the effects of this alternative at least once every five years.

4.1.4 RAA 4: Extraction and On-Site Treatment

Extraction and on-site treatment, selected as RAA 4, is a conventional extraction alternative in which groundwater will be collected by extraction wells, and transported to an on-site treatment plant for VOC removal. Once treated, the groundwater will then be discharged to Brinson Creek which flows into the New River.

Since pump tests have never been conducted at Site 36, there is no conclusive way to determine the pumping rate and capture radius for an extraction well at the site. In lieu of a pump test, the pumping rate and capture radius were estimated based on slug test data, the site geology, and the site hydrogeology. This information was then used for the Surfer™ two-dimensional groundwater model to best represent site conditions and extraction influence (Appendix B). Based on the model results, the pumping rate per extraction well was estimated to be 5 gallons per minute (gpm) and the radius of influence was estimated to be 100 feet. This information was used to develop the conceptual system layout and cost estimate for the FS. These estimations are not intended to be used as design parameters. If RAA 4 is selected as the preferred RAA, a pump test should be conducted to more accurately determine the pumping rate and capture radius that can be expected at the site. Data from the pump test will then be utilized to perform more sophisticated groundwater flow and transport models (three-dimensional) to further evaluate the number and placement of extraction wells. The cost associated with a pump test and modeling efforts has been included in the RAA 4 cost estimate.

Figure 4-3 identifies the conceptual system layout that will be used for RAA 4. This conceptual layout is subject to change during the design phase based on new and/or more accurate information that may become available. The conceptual layout was based on information available to date and was adequate for developing the FS cost estimate. Therefore, the conceptual layout is not intended to be the final design layout should this RAA be selected.

As shown on Figure 4-3, two extraction wells will be installed to collect groundwater from the surficial aquifer. The extraction wells will be positioned so that their combined zones of influence intercept the contaminated plume. Each extraction well will be screened near the confining unit, approximately 40 feet below ground surface bgs.

After being extracted, the groundwater will be transported by pipeline to the on-site treatment plant. At the treatment plant, the groundwater will undergo suspended solids and metals removal via neutralization, precipitation, flocculation, sedimentation, and filtration units, and VOC treatment via a low profile air stripper. In addition, vapor phase and liquid phase carbon adsorption will provide secondary treatment of the VOC emissions from the air stripper and of the treated groundwater. A conceptual process flow diagram for the presented treatment process is shown on Figure 4-4. After receiving treatment, groundwater will be discharged to Brinson Creek which flows into the New River. Brinson Creek is expected to have the capacity to accept the 10 gpm discharge.

In addition to groundwater extraction, treatment, and discharge, RAA 4 incorporates a groundwater/surface water monitoring program to measure the effects of this remedial action alternative over time. The monitoring wells and surface water sampling locations included under this program are those identified under RAA 2. The wells include 36-GW10, 36-GW12, 36-GW13, 36-GW10IW, 36-GW12IW, 36-GW13IW, and 36-GW10DW; while the surface water sampling locations include 36-SW100, 36-SW200, and 36-SW300. These locations are also identified on Figure 4-3. Monitoring will be conducted semiannually and samples will be analyzed for TCL

VOCs. Additional wells may be added to this monitoring program if necessary. Likewise, if the analytical results indicate that the groundwater quality has improved, the monitoring program may be refined to include fewer sampling locations or less frequent sampling events.

Aquifer use restrictions prohibiting the use of the surficial aquifer as a potable water source will be implemented via the Base Master Plan, and other requirements, as described under RAA 2 and Section 3.5.3.

Until remediation levels are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years.

4.1.5 RAA 5: In-Situ Volatilization (In-Well Aeration)

For the purpose of alternative cost estimating and development, in-well aeration was selected over air sparging to best remediate the groundwater at Site 36. This selection was based on present site specific information (e.g., depth of groundwater); however, is not intended to eliminate air sparging from future in-situ volatilization consideration.

Currently, an in-well aeration pilot test is being conducted at Site 69, Rifle Range Chemical Dump. Similarly, an air sparging pilot test is being conducted at Site 35, Camp Geiger Fuel Farm. Both of these pilot tests are nearing completion of their original approach. The preliminary results of the Site 69 in-well aeration pilot test will be combined with data collected through July of 1997. A summary report, including recommendations, is anticipated in September, 1997. Similarly, the air sparging pilot test at Site 35 will be modified to include horizontal sparging. Construction and operation of the Site 35 pilot test is anticipated through the Spring of 1998. Results and recommendations of the Site 35 pilot test will be documented in the Fall of 1998. Once definitive data becomes available regarding system operations and remedial success, RAA 5 may be modified to better describe the most appropriate in-situ volatilization process for Site 36.

As initially described, in-well aeration is a type of air sparging in which air is injected into a well creating an in-well air-lift pump effect. This pump effect causes the groundwater to flow in a circulation pattern: into the bottom of the well and out of the top of the well. As the groundwater circulates through the well, the injected air stream strips volatiles. (As a result, in-well aeration is often referred to as in-well air stripping.) The volatiles are captured at the top of the well and treated via a vapor phase carbon adsorption unit. Appendix C contains some technical information that further describes the in-well aeration technology.

Figure 4-5 presents a conceptual layout for the in-well aeration system. This conceptual layout is subject to change during the design phase based on new and/or more accurate information that may become available. The conceptual layout was based on information available to date and will be adequate for developing the FS cost estimate. However, the conceptual layout is not intended to be the final design layout should RAA 5 be selected.

At Site 36, the approximate radius of influence for an aeration well has been estimated to be 65 feet. This estimate, made by a technology vendor, was based on site-specific geologic and hydrogeologic parameters. As shown on Figure 4-5, nine aeration wells will be arranged to intercept the contaminated groundwater. The majority of these wells provide plume coverage via overlapping radii of influence.

A typical in-well aeration well and the associated treatment processes are depicted on Figure 4-6. As shown, a separate knockout tank, vacuum pump, and carbon adsorption unit will be located near the opening of each aeration well. The knockout tank will remove any liquids that may have traveled up the well (the amount of knockout liquid is anticipated to be minimal) and the vapor phase carbon adsorption unit will treat off-gases that were stripped within the well. A field pilot test is recommended to determine the loss of efficiency over time as a result of the expected inorganic precipitation and oxidation, the radius of influence of the wells under various heads of pressure, and the rate of off-gas organic contaminant removal via carbon adsorption.

In addition to the in-well aeration system, RAA 5 incorporates a groundwater/surface water monitoring program to measure the effects of this remedial action alternative. Similar to RAAs 2 and 4, seven monitoring wells and three surface water samples are included under this program. The locations of the wells and surface water samples are identified on Figure 4-5. Monitoring will be conducted semiannually and samples will be analyzed for TCL VOCs. Additional wells may be added to this monitoring program if necessary; and should results indicate improvement in groundwater quality, the monitoring program may be refined to include fewer sampling locations and/or events. Also, aquifer use restrictions prohibiting the use of the surficial aquifer as a potable water source will be implemented via the Base Master Plan and other requirements as described under RAA 2 and Section 3.5.3.

Until remediation levels are met, the NCP [40 CFR 300.430(f)(4)] requires the lead agency to review the effects of this alternative no less often than once every five years.

4.2 Screening of Alternatives

Typically, this section of the FS presents the initial screening of the potential RAAs. The objective of this screening is to make comparisons between similar alternatives so that only the most promising ones are carried forward for further evaluation (USEPA, 1988). This screening is an optional step in the FS process, and is usually conducted if there are too many RAAs to perform the detailed evaluation on. For Site 36, the decision was made to eliminate this preliminary RAA screening step. Therefore, all of the developed RAAs will undergo the detailed evaluation presented in Section 5.0.

4.3 References

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

Wiedemeier, T.H.; Swanson, M.A.; Montoux, D.E.; Gordon, E.K.; Wilson, J.T.; Wilson, B.H.; Kampbell, D.H.; Hansen, J.E.; Haas, P.; Chapelle, F.H. 1996. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Parsons Engineering, Inc., USEPA, AFCEE Technology Transfer Division, and USGS, 1996.

SECTION 4.0 TABLE

TABLE 4-1

NATURAL ATTENUATION PARAMETERS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Soil	Total organic carbon (TOC)	SW9060 modified for soil samples	The rate of migration of petroleum contaminants in groundwater is dependent upon the amount of TOC in the aquifer matrix.	Fixed-Base Laboratory
Water	VOCs	Contract Laboratory Protocol	Method of analysis includes BTEX and chlorinated solvents/byproducts, which are the primary target analytes for monitoring natural attenuation.	Fixed-Base Laboratory
Water	Oxygen	Dissolved oxygen meter	Concentrations less than 1 mg/L generally indicate an anaerobic pathway.	Field
Water	Nitrate	IC Method E300	Substrate for microbial respiration if oxygen is depleted.	Fixed-Base Laboratory
Water	Iron (II) (Fe^{2+})	Colorimetric Hach Method #8146	May indicate an anaerobic degradation process due to depletion of oxygen, nitrate, and manganese.	Field
Water	Sulfate (SO_4^{2-})	IC Method E300	Substrate for anaerobic microbial respiration.	Fixed-Base Laboratory
Water	Methane, ethane, and ethene	Kampbell et al., 1989 or SW3810 Modified	The presence of CH_4 suggests BTEX degradation via methanogenesis. Ethane and ethene data are used where chlorinated solvents are suspected of undergoing biological transformation.	Fixed-Base Laboratory

TABLE 4-1 (Continued)

NATURAL ATTENUATION PARAMETERS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Water	Alkalinity	Hach alkalinity test kit model AL AP MG-L	General water quality parameter used (1) to measure the buffering capacity of groundwater, and (2) as a marker to verify that all site samples are obtained from the same groundwater system.	Field
Water	Oxidation-reduction potential (ORP)	A2580B	The ORP of groundwater influences and is influenced by the nature of the biologically mediated degradation of contaminants; the ORP of groundwater may range from more than 800 mV to less than -400 mV.	Field
Water	pH	Field probe with direct reading meter	Aerobic and anaerobic processes are pH-sensitive.	Field
Water	Temperature	Field probe with direct reading meter	Well development.	Field
Water	Conductivity	E120.1/SW9050, direct reading meter	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system.	Field
Water	Major cations	SW6010	Can be used to evaluate other remedial actions.	Field

TABLE 4-1 (Continued)

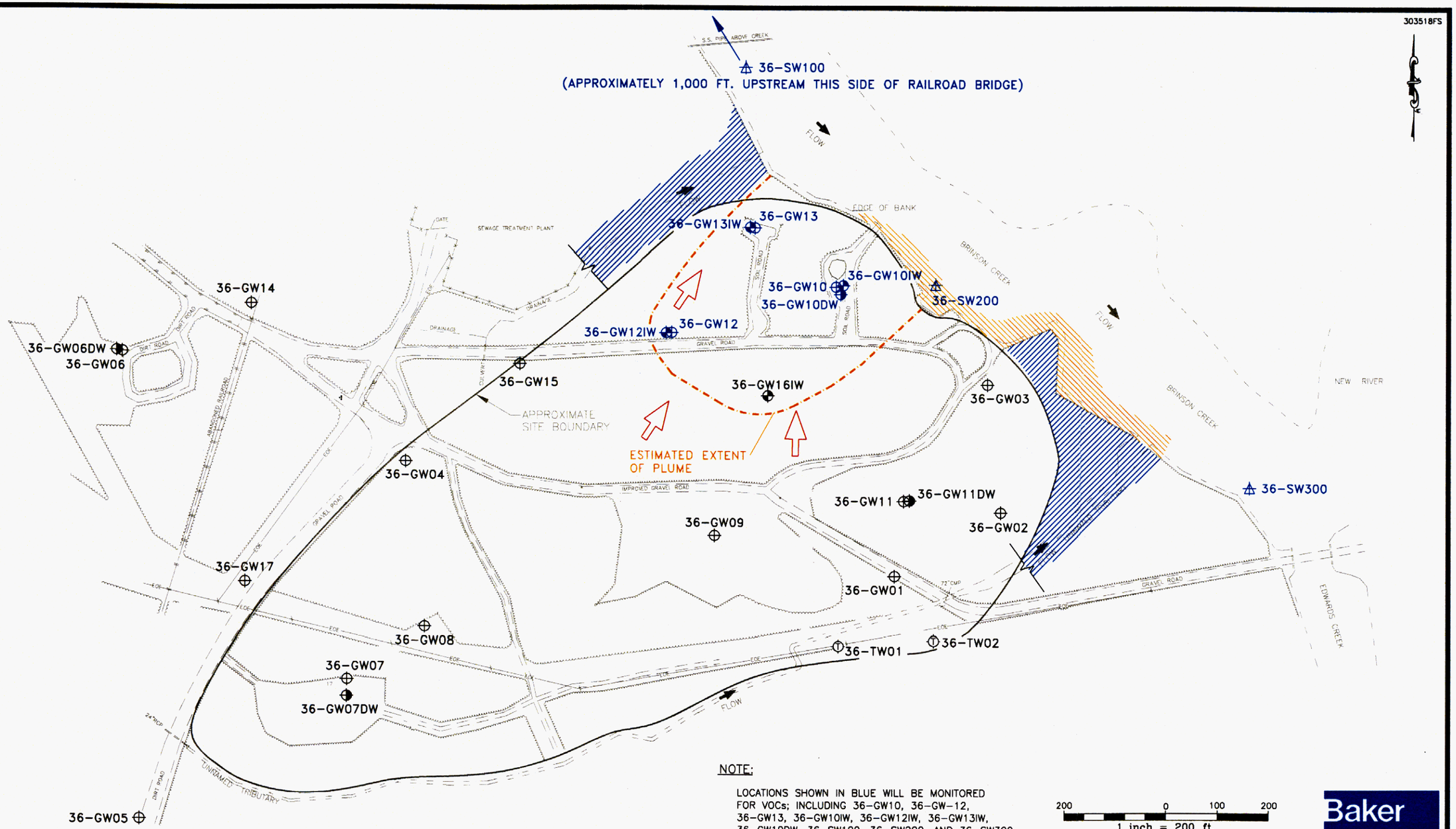
NATURAL ATTENUATION PARAMETERS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

Matrix	Analysis	Method/Reference	Data Use	Field or Fixed-Base Laboratory
Water	Chloride	IC Method E300	General water quality parameter used as a marker to verify that site samples are obtained from the same groundwater system. Final product of chlorinated solvent reduction.	Fixed-Base Laboratory
Water	Total Organic Carbon	SW9060	Used to classify plume and to determine if cometabolism is possible in the absence of anthropogenic carbon.	Fixed-Base Laboratory
Water	Hydrogen (H_2)[a/]	Equilibration with gas in the field. Determined with a reducing gas detector.	Determine terminal electron accepting process. Predicts the possibility for reductive dechlorination.	Field

Reference: Wiedemeier, Todd, et al. 1996. Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater. Air Force Center for Environmental Excellence, Technology Transfer Division. Brooks Air Force Base, San Antonio, Texas.

SECTION 4.0 FIGURES

303518FS



NOTE:

LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs; INCLUDING 36-GW10, 36-GW-12, 36-GW13, 36-GW10IW, 36-GW12IW, 36-GW13IW, 36-GW10DW, 36-SW100, 36-SW200, AND 36-SW300.

200 0 100 200
1 inch = 200 ft.

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LEGEND:

- 36-GW14 — SHALLOW MONITORING WELL
- 36-GW12IW — INTERMEDIATE MONITORING WELL
- 36-GW06DW — DEEP MONITORING WELL
- 36-TW01 — TEMPORARY MONITORING WELL
- 36-SW100 — FUTURE SURFACE WATER SAMPLE LOCATION
- DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE VOC AREA OF CONCERN
- FLOW — DIRECTION OF SURFACE WATER FLOW
- EOE — OVERHEAD ELECTRIC LINE & UTILITY POLE
- FENCE
- ASPHALT ROAD
- GRAVEL ROAD
- EDGE OF CREEK, RIVER, OR DRAINAGE
- TREE LINE
- ESTUARINE, INTERTIDAL, SUBSHRUB, BROAD-LEAVED EVERGREEN, NEEDLE-LEAVED EVERGREEN, IRREGULARLY FLOODED, WETLAND
- PALUSTRINE, FORESTED, BROAD-LEAVED DECIDUOUS, NEEDLE-LEAVED EVERGREEN, TEMPORARILY FLOODED WETLAND

FIGURE 4-1
RAA 2: INSTITUTIONAL CONTROLS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02645CB3Y

303517FS

36-SW100
(APPROXIMATELY 1,000 FT. UPSTREAM)

FLOW

EDGE OF BANK

BRINSON CREEK

36-GW13IW
36-GW13
36-GW10
36-GW10IW
36-GW10DW
36-SW200
36-GW12IW
36-GW12
36-GW15
36-GW16IW
36-GW03
36-GW14
36-GW06DW
36-GW06
36-GW04
36-GW09
36-GW11
36-GW11DW
36-GW02
36-SW300
36-GW17
36-GW01
36-GW08
36-TW01
36-TW02
36-GW07
36-GW07DW
36-GW05

SEWAGE TREATMENT PLANT

GATE

DRAINAGE

DIRT ROAD

GRAVEL ROAD

IMPROVED GRAVEL ROAD

SOIL ROAD

BANDONED RAILROAD

APPROXIMATE SITE BOUNDARY

ESTIMATED EXTENT OF PLUME

NEW RIVER

EDWARDS CREEK

UNNAMED TRIBUTARY

EOE

NOTES:

1. LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs AND NATURAL ATTENUATION PARAMETERS; INCLUDING EXISTING WELLS 36-GW08, 36-GW09, 36-GW10, 36-GW12, 36-GW13, 36-GW15, 36-GW10IW, 36-GW12IW, 36-GW13IW, 36GW16IW, AND 36-GW10DW.
2. SURFACE WATER SAMPLES COLLECTED FROM LOCATIONS 36-SW100, 36-SW200, AND 36-SW300 WILL BE MONITORED FOR VOCs.

200 0 100 200
1 inch = 200 ft.

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LEGEND:

36-GW14 — SHALLOW MONITORING WELL
36-GW12IW — INTERMEDIATE MONITORING WELL
36-GW06DW — DEEP MONITORING WELL
36-TW01 — TEMPORARY MONITORING WELL
36-SW100 — FUTURE SURFACE WATER SAMPLE LOCATION
DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE VOC AREA OF CONCERN
FLOW — DIRECTION OF SURFACE WATER FLOW
EOE — OVERHEAD ELECTRIC LINE & UTILITY POLE
FENCE
ASPHALT ROAD
GRAVEL ROAD
EDGE OF CREEK, RIVER, OR DRAINAGE
TREE LINE
ESTUARINE, INTERTIDAL, SUBSHRUB, BROAD-LEAVED EVERGREEN, NEEDLE-LEAVED EVERGREEN, IRREGULARLY FLOODED, WETLAND
PALUSTRINE, FORESTED, BROAD-LEAVED DECIDUOUS, NEEDLE-LEAVED EVERGREEN, TEMPORARILY FLOODED WETLAND

FIGURE 4-2
RAA 3: MONITORED NATURAL ATTENUATION
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

303519FS

36-SW100
(APPROXIMATELY 1,000 FT. UPSTREAM)

ESTIMATED RADII OF INFLUENCE

REQUIRED CLEARING

EDGE OF BANK

36-GW13IW 36-GW13

36-GW10IW 36-SW200

36-GW10 36-GW10DW

GROUNDWATER DISCHARGE

BRINSON CREEK

SEWAGE TREATMENT PLANT

GATE

DRAINAGE

36-GW14

36-GW06DW
36-GW06

36-GW12IW 36-GW12

TREATMENT PLANT

36-GW15

IMPROVE GRAVEL ROADWAY

36-GW16IW

36-GW03

APPROXIMATE SITE BOUNDARY

REQUIRED CLEARING

ESTIMATED EXTENT OF PLUME

36-GW04

IMPROVED GRAVEL ROAD

36-GW11 36-GW11DW

36-GW09

36-GW02

36-SW300

NEW RIVER

FLOW

36-GW17

36-GW01

GRAVEL ROAD

EDWARDS CREEK

36-GW08

36-TW01 36-TW02

36-GW07

36-GW07DW

UNNAMED TRIBUTARY

36-GW05

NOTE:

LOCATIONS SHOWN IN BLUE WILL BE MONITORED FOR VOCs; INCLUDING 36-GW10, 36-GW12, 36-GW13, 36-GW10IW, 36-GW12IW, 36-GW13IW, 36-GW10DW, 36-SW100, 36-SW200, AND 36-SW300.

200 0 100 200
1 inch = 200 ft.

Baker
Baker Environmental, Inc.

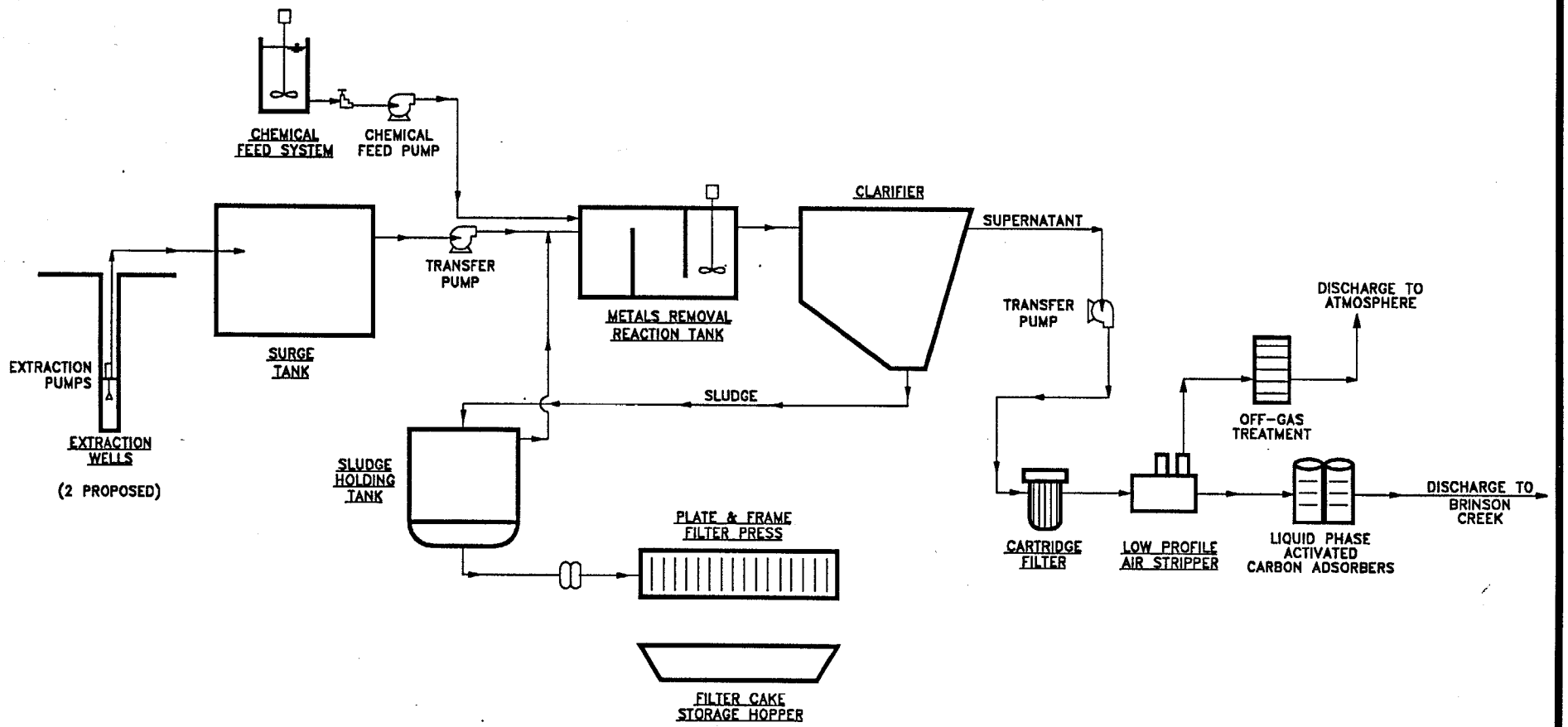
LEGEND:

36-GW14 — SHALLOW MONITORING WELL
36-GW12IW — INTERMEDIATE MONITORING WELL
36-GW06DW — DEEP MONITORING WELL
36-TW01 — TEMPORARY MONITORING WELL
36-SW100 — FUTURE SURFACE WATER SAMPLE LOCATION

FLOW — DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE VOC AREA OF CONCERN
FLOW — DIRECTION OF SURFACE WATER FLOW
EOE — OVERHEAD ELECTRIC LINE & UTILITY POLE
FENCE
ASPHALT ROAD
GRAVEL ROAD
EDGE OF CREEK, RIVER, OR DRAINAGE
TREE LINE

EXTRACTION WELL
GROUNDWATER CONVEYANCE PIPELINE
E E — OVERHEAD ELECTRIC LINE
ESTUARINE, INTERTIDAL, SUBSHRUB, BROAD-LEAVED EVERGREEN, NEEDLE-LEAVED EVERGREEN, IRREGULARLY FLOODED, WETLAND
PALUSTRINE, FORESTED, BROAD-LEAVED DECIDUOUS, NEEDLE-LEAVED EVERGREEN, TEMPORARILY FLOODED WETLAND

FIGURE 4-3
RAA 4: EXTRACTION WITH ON-SITE TREATMENT
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker

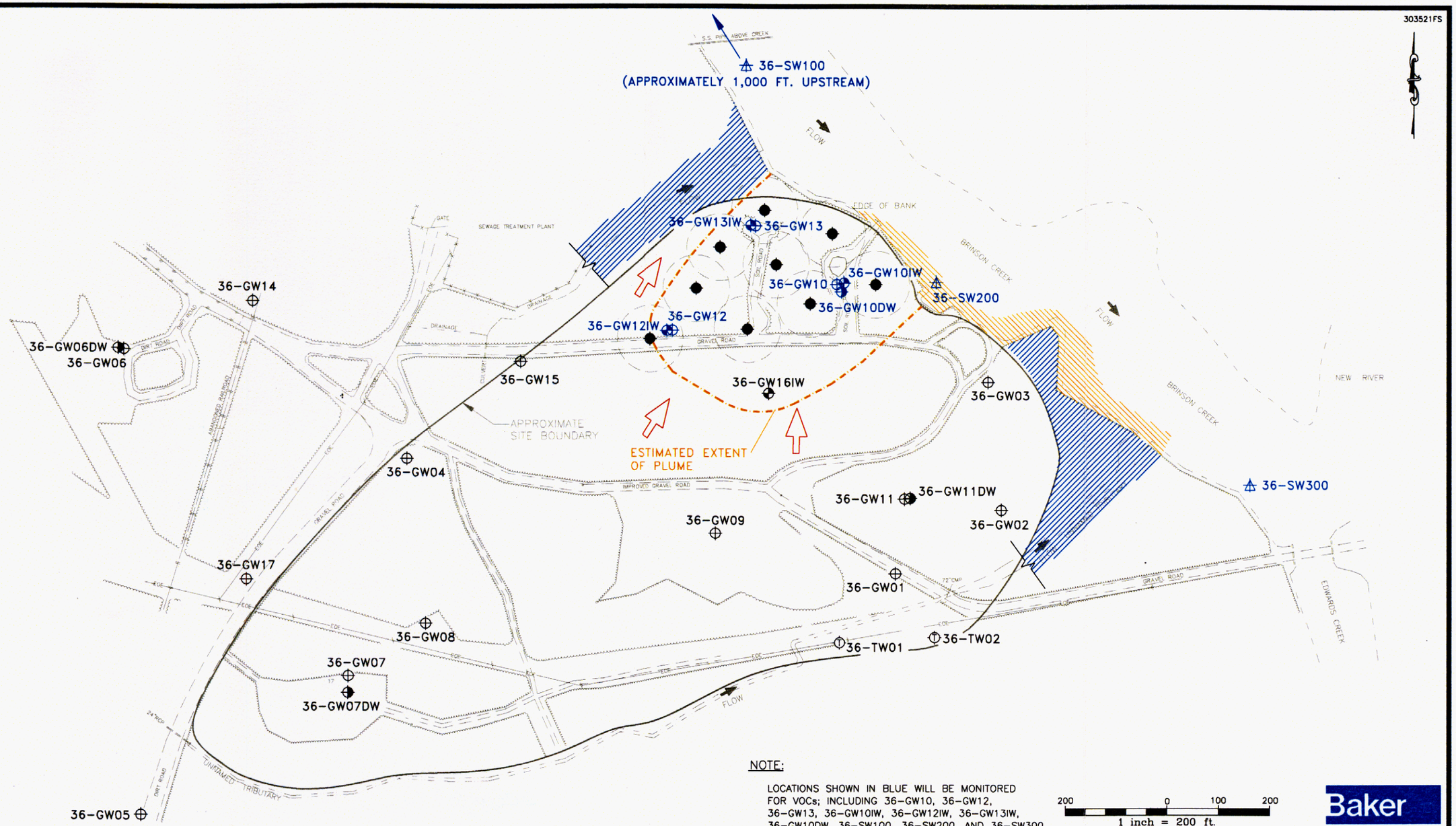
Baker Environmental, Inc.

FIGURE 4-4
RAA 4: EXTRACTION WITH ON-SITE TREATMENT PROCESS FLOW DIAGRAM
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

303520FS

303521FS



LEGEND:

- 36-GW14 — SHALLOW MONITORING WELL
- 36-GW12IW — INTERMEDIATE MONITORING WELL
- 36-GW06DW — DEEP MONITORING WELL
- 36-TW01 — TEMPORARY MONITORING WELL
- 36-SW100 — FUTURE SURFACE WATER SAMPLE LOCATION
- DIRECTION OF GROUNDWATER FLOW IN THE VICINITY OF THE VOC AREA OF CONCERN
- FLOW — DIRECTION OF SURFACE WATER FLOW
- EOE — OVERHEAD ELECTRIC LINE & UTILITY POLE
- FENCE
- ASPHALT ROAD
- GRAVEL ROAD
- EDGE OF CREEK, RIVER, OR DRAINAGE
- TREE LINE
- AERATION WELL
- ESTUARINE, INTERTIDAL, SUBSHRUB, BROAD-LEAVED EVERGREEN, NEEDLE-LEAVED EVERGREEN, IRREGULARLY FLOODED, WETLAND
- PALUSTRINE, FORESTED, BROAD-LEAVED DECIDUOUS, NEEDLE-LEAVED EVERGREEN, TEMPORARILY FLOODED WETLAND

FIGURE 4-5
RAA 5: IN-SITU VOLATILIZATION
(IN-WELL AERATION)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

02645044

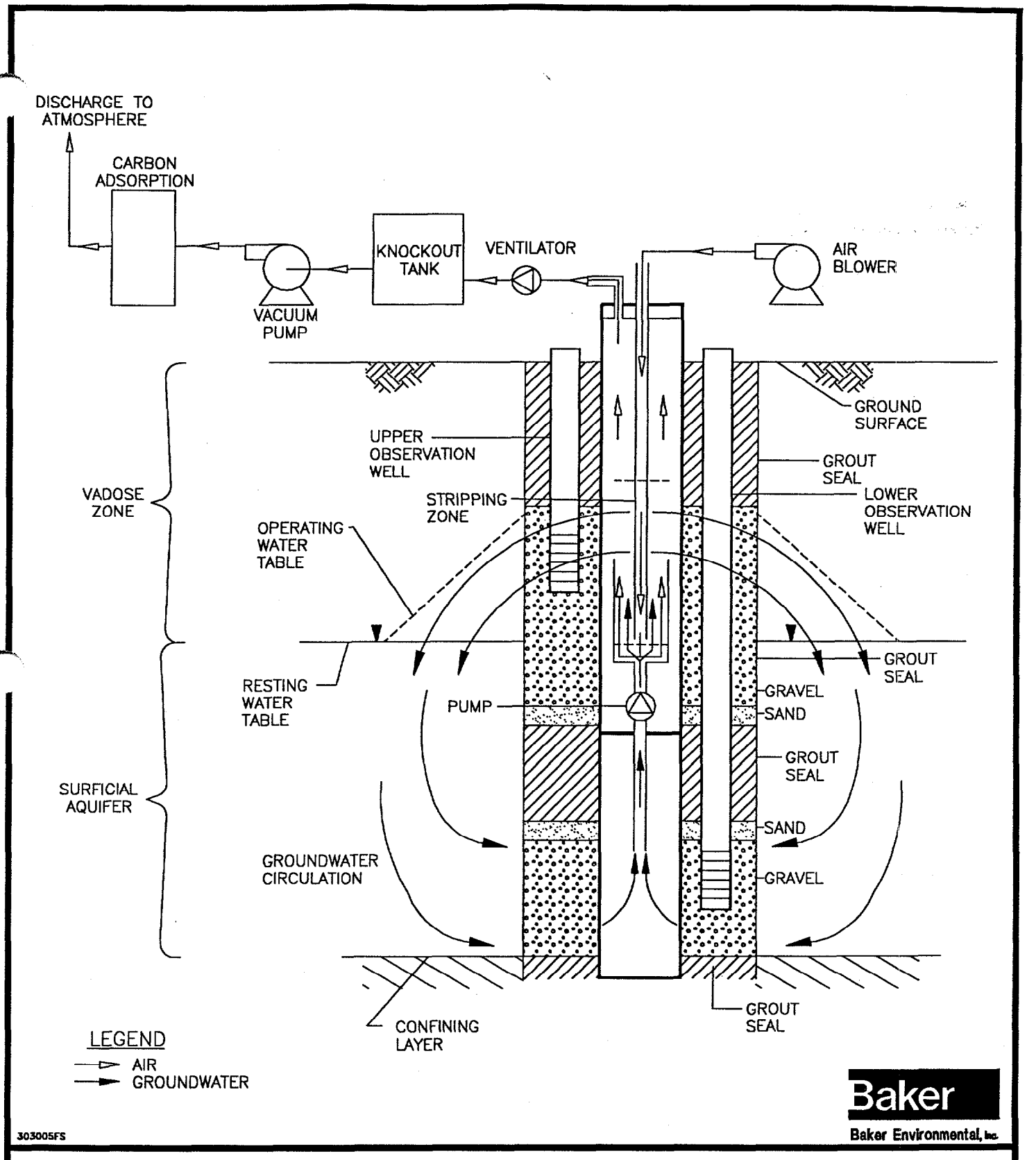


FIGURE 4-6
RAA 5: IN-SITU VOLATILIZATION (IN-WELL AERATION)
TYPICAL WELL DETAIL AND PROCESS FLOW DIAGRAM
SITE 36, CAMP GEIGER AREA DUMP

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

5.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES

This section presents the detailed analysis of the remedial action alternatives that were developed in Section 4.0. Section 5.1 presents an overview of evaluation criteria that will be used in the detailed analysis. Sections 5.2 and 5.3 present two parts of the detailed analysis: the individual analyses of remedial action alternatives, and the comparative analysis of remedial action alternatives, respectively.

This detailed analysis has been conducted to provide sufficient information to adequately compare the alternatives, select an appropriate remedy for the site, and demonstrate satisfaction of the CERCLA remedy selection requirements in the Record of Decision (ROD). The extent to which alternatives are assessed during the detailed analysis is influenced by the available data, the number and types of alternatives being analyzed, and the degree to which alternatives were previously analyzed during their development and screening (USEPA, 1988). (There was no initial screening of the alternatives for Site 36.)

The detailed analysis of alternatives was conducted in accordance with the "Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA" (USEPA, 1988) and the NCP, including the February 1990 revisions. In conformance with the NCP, seven of the following nine criteria were used for the detailed analysis:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance (not evaluated at this time)
- Community acceptance (not evaluated at this time)

State acceptance and community acceptance will be evaluated in the ROD by addressing comments received after the Technical Review Committee (TRC) has reviewed the FS and Proposed Remedial Action Plan (PRAP). The TRC includes participants from the NC DENR, USEPA Region IV, and the public.

5.1 Overview of Evaluation Criteria

The following paragraphs describe the evaluation criteria that are used in the detailed analysis.

Overall Protection of Human Health and the Environment: Overall protection of human health and the environment is the primary criteria that a remedial action must meet. A remedy is considered protective if it adequately eliminates, reduces, or controls all current and potential site risks posed through each exposure pathway at the site. A site where hazardous substances remain without engineering or institutional controls allows for unlimited exposure for human and environmental receptors. Adequate engineering controls, institutional controls, or some combination of the two, can be implemented to control exposure and thereby ensure reliable protection over time. In addition, implementation of a remedy cannot result in unacceptable short-term risks or cross-media impacts on human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements: Compliance with ARARs is one of the statutory requirements for remedy selection. Alternatives are developed and refined throughout the FS process to ensure that they will meet all ARARs or that there is a sound rationale for waiving an ARAR. During the detailed analysis, the alternatives will be analyzed based on the Federal and State chemical-specific ARARs, the action-specific ARARs, and the location-specific ARARs that were presented in Section 2.0 of this FS.

Long-Term Effectiveness and Permanence: This criterion reflects CERCLA's emphasis on implementing remedies that will ensure protection of human health and the environment in the distant future, as well as the near future. In evaluating alternatives for their long-term effectiveness and the degree of permanence they afford, the analysis will focus on the residual risks present at the site after the completion of the remedial action. The analysis will also include consideration of the following:

- Degree of threat posed by the hazardous substances remaining at the site.
- Adequacy of any controls (e.g., engineering and institutional controls) used to manage the hazardous substances remaining at the site.
- Reliability of those controls.
- Potential impacts on human health and the environment, should the remedy fail, based on assumptions included in the reasonable maximum exposure scenario.

Reduction of Toxicity, Mobility, or Volume Through Treatment: This criterion addresses the statutory preference for remedies that employ treatment as a principal element. The criterion ensures that the relative performance of the various treatment alternatives in reducing the toxicity, mobility, or volume will be assessed. Specifically, the analysis will examine the magnitude, significance, and irreversibility of reductions.

Short-Term Effectiveness: This criterion examines the short-term impacts associated with implementing the alternative. Implementation may impact the neighboring community, workers, or the surrounding environment. Short-term effectiveness also includes potential threats to human health and the environment associated with the excavation, treatment, and transportation of hazardous substances, the potential cross-media impacts of the remedy, and the time required to achieve protection of human health and the environment.

Implementability: Implementability considerations include the technical and administrative feasibility of the alternatives, as well as the availability of goods and services (including treatment, storage, or disposal capacity) associated with the alternative. Implementability considerations often affect the timing of remedial actions (e.g., limitations on the season in which the remedy can be implemented, the number and complexity of material handling steps, and the need to secure technical services). On-site activities must comply with the substantive portions of applicable permitting regulations.

Cost: Cost includes all capital costs and annual operation and maintenance costs incurred over the life of the project. The focus during the detailed analysis is on the present worth of these costs. Costs are used to select the most cost-effective alternative that will achieve the remedial action objectives.

In accordance with USEPA guidance (USEPA, 1988), the cost estimates will have an accuracy of -30 to +50 percent. The exact accuracy of each cost estimate depends upon the assumptions made and the availability of costing information. In order to calculate the net present worth (NPW) the operating costs for each year of operation in the future are converted to current dollars assuming a five percent discount factor and a zero percent inflation rate. The converted annual costs are totaled and then added to the capital costs to find the NPW of the alternative.

Unless noted otherwise, it has been assumed that groundwater/surface water monitoring will be conducted for thirty years. This assumption has been made for costing purposes only.

State Acceptance: This criterion, which is an ongoing concern throughout the remedial process, reflects the statutory requirement to provide for substantial and meaningful State involvement. State comments will be addressed during the development of the FS, the PRAP, and the ROD, as appropriate. The State will confirm its acceptance of the remedy with a concurrence letter to be included with the Final ROD.

Community Acceptance: This criterion addresses the community's comments on the remedial alternatives under consideration, where "community" is broadly defined to include all interested parties. These comments are taken into account throughout the FS process. However, formal public comment will not be received until after the public comment period for the PRAP is held, so only preliminary assessment of community acceptance can be conducted during the development of the FS.

5.2 Individual Analysis of Alternatives

The following subsections present the detailed analysis of RAAs on an individual basis. This individual analysis includes a brief description of each RAA and an assessment of how well the RAA performs against seven of the nine previously introduced evaluation criteria. Table 5-1 summarizes the individual, detailed analysis of alternatives.

5.2.1 RAA 1: No Action

Description

Under the no action alternative, groundwater at Site 36 will remain as is. No physical remedial actions will be implemented.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 1, no physical remedial actions will be implemented. Even though natural attenuation processes may occur, overall protection of human health and the environment will be unknown since monitoring will not take place.

Compliance With ARARs: Under RAA 1, no active effort will be made to reduce contaminant levels to below Federal and State chemical-specific ARARs. Over an indefinite period of time, however, passive remediation, in the form of natural attenuation processes, may reduce VOC levels to below ARARs. However, under the no action alternative, acknowledgement and/or confirmation of the passive remediatiion will not be completed.

No location-specific ARARs apply to this no action alternative.

However, RAA 1 does not comply with the action-specific ARAR for North Carolina groundwater corrective actions (15A NCAC 2L .0106-.0113).

Long-Term Effectiveness and Permanence: Residual risk will remain at the site under the no action alternative as humans could potentially come in contact with the contaminated groundwater. However, it is highly unlikely that this scenario will occur because the on-site groundwater is not used as a potable source. Similarly, it is unlikely that the area would be developed for future residents. In addition, the VOC contaminants did not generate unacceptable risks. Thus, the residual risks associated with leaving contaminants untreated at the site will be minimal.

Under the no action alternative, any long-term or permanent effect on contaminant levels will depend on the effectiveness of the natural attenuation processes. The extent to which natural attenuation may reduce contaminant levels, and the time it will take, are difficult to predict. However, based on the groundwater flow and transport models completed for Site 36, (included within Appendix B), a 41 percent reduction of the maximum detected TCE concentration may be experienced in 30 years.

Because the contaminants will remain on site at levels exceeding ARARs, RAA 1 will require 5-year reviews to ensure that adequate protection of human health and the environment is maintained. The 5-year reviews will include a site visit to see if there is evidence of contaminant migration and a review of applicable regulations. If there is a change at the site, appropriate actions will be evaluated.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The no action alternative does not provide physical treatment processes for toxicity, mobility, or volume reduction of contaminated groundwater. Groundwater models indicate that passive treatment processes (i.e., natural attenuation) may eventually provide toxicity and volume reduction of the contaminated plume. However, the extent to which natural attenuation may reduce contaminant toxicity and volume is difficult to predict. Because there is no physical treatment process, there will be no treatment residuals. Although this alternative may satisfy the statutory preference for treatment through natural attenuation, no means are provided to measure the effects. Thus, the statutory preference for treatment cannot be justified.

Short-Term Effectiveness: There are no physical remedial action activities associated with RAA 1. As a result, short-term potential risks to the community will not be increased, there will be no risks to workers, and there will be no additional environmental impacts. The exact time until the action is complete (i.e., the time required for natural attenuation to remediate the aquifer) is unknown.

Implementability: The no action alternative is implementable since no additional construction or operation activities will be conducted. In terms of administrative feasibility, RAA 1 should not require additional coordination with other agencies, although a waiver of the State ARARs may be required since VOC levels exceeding these ARARs will be left on-site indefinitely. The availability of services, materials, and/or technologies is not applicable to this alternative.

If site-specific data identifies that the groundwater quality appears to be deteriorating, remedial actions could easily be implemented under RAA 1.

Cost: There are no capital costs or O&M costs associated with this alternative. Therefore, the NPW is $0.

5.2.2 RAA 2: Institutional Controls

Description

RAA 2 differs from the no action alternative by including the following institutional controls: a groundwater/surface water monitoring program, access restrictions, and aquifer use restrictions. Under the proposed monitoring program, samples will be collected semiannually from seven wells (three existing shallow wells, three existing intermediate wells, and one existing deep well) and three surface water locations along Brinson Creek. All of the samples will be analyzed for VOCs. Aquifer use restrictions, implemented via the Base Master Plan, annual certification, "Notice" recordation, modification of the RCRA Permit, and property transfer requriements as described in Section 3.5.3 of this FS report. The restrictions will prohibit future use of the surficial aquifer within 1,500 feet of the estimated groundwater plume.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 2, institutional controls will reduce potential human health risks associated with exposure to groundwater. The monitoring program will indicate any increase in and/or migration of VOC concentrations so that appropriate action(s) can be taken. Thus, the monitoring program mitigates the potential for human exposure. Aquifer use restrictions also mitigate the potential for human exposure by prohibiting the use of the surficial aquifer and providing recordation of the Notice at the Onslow County Courthouse. While VOCs did not generate unacceptable human health risks, there will be no measurable reduction in potential ecological risks. Although, ecological risks were determined to be minimal.

Compliance With ARARs: Under RAA 2, no physical remedial effort will be made to reduce contaminant levels below Federal and State chemical-specific ARARs. Over an indefinite period of time, however, passive remediation in the form of natural attenuation processes, may reduce contaminant levels to or below their associated ARARs.

No location-specific ARARs apply to this alternative.

However, this RAA will not comply with the action-specific ARAR 15A NCAC 2L.0113 without a variance.

Long-Term Effectiveness and Permanence: The magnitude of residual risk associated with leaving contaminated groundwater untreated at the site is minimal. The VOC contaminants did not generate unacceptable risks, even for the highly unlikely scenario: future residential development. Nevertheless, RAA 2 will reduce any residual risk that remains at the site because the aquifer use restrictions will restrict groundwater from being used for any purpose (except for monitoring under the remedial action). Ingestion of potentially contaminated fish will be minimized as the monitoring program will detect improvements or deterioration in groundwater and surface water quality. Therefore, RAA 2 will provide long-term effectiveness for mitigating potential exposure.

Because RAA 2 does not include physical groundwater remediation, any long-term or permanent effect on contaminant levels will depend on the effectiveness of natural attenuation. Based on the

enclosed groundwater flow and transport models (Appendix B), a 41 percent reduction of the maximum detected TCE concentration may be experienced in 30 years. However, the extent to which natural attenuation may reduce contaminant levels, and the exact time it will take, are difficult to predict.

RAA 2 is based on adequate and reliable institutional controls that will help to manage the untreated groundwater contamination remaining in the aquifer. The proposed monitoring program will be an adequate and reliable control for assessing the effectiveness of the RAA, and aquifer use restrictions will be adequate and reliable controls for preventing future use of the surficial aquifer as a potable water source. Access and aquifer use restrictions, however, must be enforced over time to ensure their adequacy and reliability.

Because contamination will remain on site, RAA 2 will require 5-year reviews to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: RAA 2 does not provide an active treatment process for toxicity, mobility, or volume reduction of the contaminated groundwater. Over an indefinite period of time, passive treatment processes (i.e., natural attenuation) may eventually provide toxicity, mobility, and volume reduction. The extent to which this will occur, however, is difficult to predict. Because there is no physical treatment process, there will be no treatment residuals. RAA 2 may satisfy the statutory preference for treatment through natural attenuation; however, this alternative offers no means of monitoring its progress. Therefore, the statutory preference for treatment cannot be justified.

Short-Term Effectiveness: Under RAA 2, there will be no increase of short-term potential risks to the community or workers. RAA 2 will not create any additional environmental impacts. The exact time required for the action (i.e., natural attenuation) to be complete is unknown; however, groundwater/surface water monitoring was assumed for 30 years for cost estimating purposes.

Implementability: RAA 2 is technically implementable since groundwater sampling and aquifer use restrictions have been easily implemented in the past. In addition, groundwater/surface water sampling have proven to be a reliable, easy to maintain technology.

If groundwater quality appears to be deteriorating over time, additional remedial actions could easily be implemented along with RAA 2.

In terms of administrative feasibility, semiannual reports must be submitted to document sampling procedures. All required services, materials, and/or technologies should be readily available.

Cost: Table 5-2 presents a cost estimate for RAA 2. As shown, there are no estimated capital costs associated with RAA 2. O&M costs of approximately $22,000 annually are projected for sampling seven wells and three surface water locations semiannually for 30 years. Assuming a discount rate of 5 percent, the NPW of this alternative is $338,000.

5.2.3 RAA 3: Monitored Natural Attenuation

Description

Under RAA 3, no physical remedial actions will be implemented to reduce the aquifer contamination. Instead, treatment via natural attenuation processes will be relied upon to reduce contaminant levels. The main component of RAA 3 is an expanded groundwater and surface water monitoring program. Groundwater samples will be analyzed for TCL VOCs and natural attenuation parameters. These parameters will indicate the type of natural biodegradation that is occurring in the aquifer, and the amount of contaminant reduction that has occurred over time or that can be expected. Monitoring has been estimated for a period of 30 years, but will continue until groundwater standards for the detected chlorinated solvents are met. Surface water samples will be analyzed for TCL VOCs. RAA 3 includes aquifer use restrictions to prohibit future use of the surficial aquifer within 1,500 feet of the estimated groundwater plume. To further support the occurrence of natural attenuation, RAA 3 may include optional contaminant fate and transport modeling.

Assessment

Overall Protection of Human Health and the Environment: Under RAA 3, contaminants in the surficial aquifer will remain and will continue to discharge into Brinson Creek. However, these contaminants do not appear to be adversely affecting human health or the environment for the following reasons:

- Results of the human health and ecological risk assessments indicate that the chlorinated solvent contaminants are not expected to create significant, unacceptable risks now or in the future.

- Volatile contaminants were not detected in the surface water samples collected from Brinson Creek; therefore, the groundwater contamination that is migrating toward Brinson Creek appears to be discharging at levels that will not adversely affect potential receptors. The North Carolina DENR Risk Analysis Framework (located in Appendix D)was used to determine the maximum groundwater concentrations that can discharge into Brinson Creek before unsafe surface water conditions develop. The maximum contaminant concentration detected at the site (TCE at 97 μg/L) is below the computed acceptable discharge limit (computed, allowable maximum TCE groundwater concentration for Site 36 is 1,757 μg/L). In addition, the maximum groundwater detection of TCE (97 μg/L) was only slightly higher than the State surface water TCE standard (92.4 μg/L).

- Current technical literature indicates that chlorinated solvents are capable of naturally attenuating, provided the appropriate conditions are present at the site. The contamination at Site 36 appears to be naturally attenuating as TCE and the daughter product of TCE degradation (1,2-DCE) have been detected. Thus, the solvent contamination in the surficial aquifer is expected to naturally attenuate over time.

Based on this information, additional physical groundwater treatment is not necessary to provide a justifiable solution for the surficial aquifer. RAA 3 ensures the protection of human health and the

environment through natural attenuation, monitoring, aquifer use restrictions, and optional fate and transport modeling. Thus, RAA 3 will mitigate the potential for direct exposure and provide overall protection of human health and the environment.

Compliance With ARARs: Under RAA 3, no physical effort will be made to enhance or reduce contaminant levels to below chemical-specific ARARs. Natural attenuation processes; however, are expected to eventually achieve these ARARs. Thus, RAA 3 has the potential to remediate the groundwater over an extended period of time. No location-specific ARARs apply to this alternative. However, this RAA would have to comply with the groundwater corrective action ARAR 15A NCAC 2L.0106(l).

Long-Term Effectiveness and Permanence: Allowing the groundwater to naturally attenuate is a justifiable solution because: 1) the potential human health and ecological risks appear to be insignificant at present and in the future; 2) the North Carolina DENR Risk Analysis Framework indicates that the groundwater contamination is not adversely impacting Brinson Creek; and 3) the chlorinated solvent contamination appears to be naturally attenuating. Through monitoring and aquifer use restrictions, RAA 3 provides a means for monitoring contaminant concentrations over time, prohibiting future potable use of the surficial aquifer, and documentation that natural attenuation processes are indeed occurring. As a result, RAA 3 will ensure the safety of potential receptors over time and will provide long-term effectiveness and permanence.

Under RAA 3, 5-year reviews by the lead agency will be required to ensure that adequate protection of human health and the environment is maintained.

Reduction of Toxicity, Mobility, or Volume Through Treatment: RAA 3 does not provide additional physical treatment processes; however, some reduction in toxicity, mobility, and volume through natural attenuation processes is anticipated and will be measured. Thus, RAA 3 satisfies the statutory preference for treatment.

Short-Term Effectiveness: Under RAA 3, the only activities that may increase risks to the community and to workers include monitoring well installation and periodic groundwater and surface water sampling. However, proper material handling procedures and personal protective equipment should sufficiently protect the community and workers against these risks. RAA 3 will not create any additional environmental impacts. The time required for the action to be complete is unknown, but 30 years of monitoring was assumed for cost estimating purposes.

Implementability: RAA 3 is a technically implementable alternative since monitoring well installation, groundwater and surface water monitoring, and aquifer use restrictions have been easily implemented in the past. If water quality appears to be deteriorating over time, additional remedial actions could easily be implemented under RAA 3.

In terms of administrative feasibility, this alternative will not require additional coordination with other agencies. However, semiannual reports must be submitted to document sampling procedures. All required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA 3 is $72,000. The projected annual O&M costs are approximately $87,000 for quarterly sampling in years 1-5, and $54,000 for semiannual sampling in years 6-30. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $902,000. Table 5-3 presents the cost estimate for RAA 3.

5.2.4 RAA 4: Extraction and On-Site Treatment

Description

Prior to initiating the system design, a site-specific pump test and three-dimensional groundwater flow/transport models will be performed. For alternative development; however, RAA 4 involves the installation of two extraction wells that will intercept the contaminated plume as it moves in the direction of groundwater flow. Each extraction well will have an estimated capacity of 5 gpm. Once the groundwater is extracted, it will undergo VOC treatment at an on-site treatment plant. The treatment will consist of suspended solids/metals removal, air stripping, and vapor phase carbon adsorption of the VOC air stripper emissions. Likewise, the groundwater will receive secondary treatment via liquid phase carbon adsorption prior to being discharged to Brinson Creek. In addition, RAA 4 includes a groundwater/surface water monitoring program and aquifer use restrictions as institutional controls.

Assessment

Overall Protection of Human Health and the Environment: Because RAA 4 provides institutional controls and active groundwater remediation, this RAA will reduce potential risks to human health. The monitoring program will indicate any increase in and/or migration of VOC concentrations so that appropriate actions can be taken. Thus, the monitoring program mitigates the potential for human exposure. Aquifer use restrictions also mitigate the potential for human exposure by prohibiting the use of the surficial aquifer. The extraction/treatment system mitigates human health risks by decreasing the VOC concentrations. Under RAA 4, there will be a reduction in potential ecological risks via active treatment and institutional controls. Overall; however, ecological risks were determined to be minimal.

Compliance With ARARs: Under RAA 4, the groundwater quality will be improved through the use of an active remediation system, groundwater extraction and treatment. Over time, contaminant concentrations may meet Federal and State chemical-specific groundwater ARARs via active remediation. RAA 4 can be designed to meet the chemical-specific ARARs regulating air and water discharge.

In addition, RAA 4 can be designed to meet the location-specific and action-specific ARARs that apply.

Long-Term Effectiveness and Permanence: The magnitude of residual risk associated with leaving contaminated groundwater at the site is minimal, because the VOC contaminants did not generate unacceptable risks. Nevertheless, RAA 4 will reduce any residual risk that remains at the site because: (1) the aquifer use restriction will prohibit groundwater from being used as a potable water source in the future,(2) the monitoring program will detect any improvement or deterioration in groundwater/surface water quality, and (3) groundwater extraction and treatment will reduce VOC levels. As a result, RAA 4 is expected to provide long-term effectiveness and performance.

Groundwater extraction/treatment methods are both adequate and reliable controls. However, technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into subsurface pore spaces or fissures where they become difficult to extract. Also, contaminants may continue to leach from solid particles below the vadose zone. Due to this partitioning of contaminants, extraction technologies may not

be reliable for completely remediating the aquifer. The potential for inorganic precipitation to clog well screens also limits the reliability of extraction wells. As with most remediation equipment, there is a potential for replacement and/or repairs. However, all of the treatment technologies associated with RAA 4 (for example, air stripping) have demonstrated their adequacy and reliability.

RAA 4 includes adequate and reliable institutional controls that will help monitor contaminant levels remaining in the aquifer. The proposed monitoring program will be an adequate and reliable control for assessing the effectiveness of the RAA. Aquifer use restrictions will be adequate and reliable controls for preventing the future use of the aquifer at Site 36. These restrictions (as described in Section 3.5.3), however, must be enforced over time to ensure their adequacy and reliability.

RAA 4 will require 5-year reviews by the lead agency.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The treatment processes associated with RAA 4 include neutralization, precipitation, flocculation, sedimentation, and filtration for suspended solids/metals removal, air stripping for VOC removal, and secondary treatment of VOC emissions from the air stripper and the treated groundwater (carbon adsorption). These treatment processes will be effective for pretreating inorganics and primarily treating VOCs in the groundwater.

The treatment processes associated with RAA 4 will reduce the toxicity and volume of contaminated groundwater; while the pumping effect of the extraction wells will reduce the mobility of the contaminated groundwater plume. In addition, the treatment processes are expected to have irreversible effects.

Residuals remaining after treatment may include metals sludge, spent carbon, and treated groundwater. The sludge is expected to be non-hazardous, but will require proper disposal. The spent carbon will require regeneration or proper disposal. Treated groundwater is expected to be within acceptable discharge limits; therefore, discharge to Brinson Creek is anticipated.

RAA 4 satisfies the statutory preference for treatment.

Short-Term Effectiveness: Proper site controls may be necessary to minimize dust production during the underground piping and extraction well installation. In addition, workers may require protection during the installation and operation of the extraction/treatment system. In terms of environmental impacts, RAA 4 may cause localized aquifer drawdown during groundwater extraction. Similarly, due to the close proximity of the contaminated groundwater plume and Brinson Creek, models indicate that the extraction wells may draw in creek water. Overall environmental impacts due to extraction can be assessed upon alternative selection and during future 3-dimensional modeling.

With respect to the time required to complete the remedial action, the groundwater extraction/treatment system is expected to operate for many years prior to achieving complete groundwater restoration. The exact amount of time is unknown; however, 30 years of operation have been assumed for costing purposes.

Implementability: RAA 4 is technically implementable. Based on past experience and case studies, no major technical difficulties are anticipated during the construction and operation of the

extraction/treatment system. All of the associated technologies/process options are conventional and have proven to be implementable.

There is a potential for high dissolved metals to precipitate out of solution and clog the well screens. This would require frequent well maintenance and replacement. There is also a potential for equipment replacement at the treatment plant. Releases of VOCs from the air stripper may also be a concern; however, measures to control atmospheric emissions have been included.

Another disadvantage for system operation is the fact that groundwater must be lifted above ground surface. This requires more power, more extensive treatment processes, and the need to discharge the treated groundwater.

If the monitoring program associated with this alternative indicates that groundwater quality is deteriorating, additional remedial actions could easily be implemented under RAA 4.

In terms of administrative feasibility, RAA 4 requires extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of air and water discharge permits will have to be met. However, all required services, materials, and/or technologies should be readily available.

Cost: Table 5-4 presents a cost estimate for RAA 4 and Appendix E includes the applicable vendor cost quotation for the air sparging treatment system. As shown, the estimated capital cost is approximately $403,000, including the $27,000 cost associated with the pump test and three-dimensional groundwater modeling. O&M costs of approximately $56,000 are projected for treatment plant O&M and groundwater/surface water monitoring over 30 years. Assuming a discount rate of 5 percent, the NPW of this alternative is $1,264,000.

5.2.5 RAA 5: In-Situ Volatilization (In-Well Aeration)

Description

As presented, RAA 5 involves the installation of nine in-well aeration wells. The wells will be installed with overlapping radii of influence so that they intercept the contaminated groundwater. The VOCs collected by each aeration well will receive carbon adsorption treatment. A field pilot test will be conducted to provide site-specific information needed to support the design. In addition, RAA 5 includes a groundwater/surface water monitoring program and aquifer use restrictions as institutional controls.

Assessment

Overall Protection of Human Health and the Environment: Because RAA 5 provides institutional controls and active groundwater remediation, this RAA will reduce potential risks to human health. The monitoring program will indicate any increase in and/or migration of VOC or inorganics concentrations so that appropriate action can be taken. Thus, the monitoring program mitigates the potential for human exposure. Aquifer use restrictions mitigate the potential for human exposure by prohibiting the use of the surficial aquifer. In-well aeration mitigates human health risks by decreasing VOC concentrations. Under RAA 5, there will be a reduction in potential ecological risks. Even though VOCs did not generate unacceptable human health risks, overall ecological risks were determined to be minimal.

***Compliance With ARARs*:** Under RAA 5, the groundwater quality will be improved through the use of an active remediation system, in-well aeration. Over time, the contaminated groundwater may meet Federal and State ARARs as a result of active remediation. RAA 5 can be designed to meet chemical-specific ARARs regulating air and water discharge, as well as the applicable location-specific and action-specific ARARs.

***Long-Term Effectiveness and Permanence*:** RAA 5 will reduce the magnitude of residual risks for the following reasons: (1) the aquifer use restrictions will restrict groundwater from being used for any purpose (except related, remedial monitoring), (2) the monitoring program will detect any improvement or deterioration in groundwater/surface water quality, and (3) the in-well aeration system will reduce VOC levels.

Because in-well aeration is a new and innovative technology that has not been well demonstrated, its adequacy and reliability is uncertain. Based on its limited performance record, in-well aeration appears to be an adequate and reliable alternative to remediate the contaminated groundwater at Site 36. Also, the surficial aquifer's hydraulic conductivity at Site 36, estimated by conducting slug tests (1.8×10^{-3} cm/sec), will allow injected air to flow freely through the saturated zone. Since the target contaminant groups for in-well aeration include halogenated volatiles, the technology will be effective for treating TCE.

Like most groundwater remediation methods, in-well aeration will only be adequate and reliable to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into subsurface pore spaces or fissures where they become difficult to extract. Also, contaminants may continue to leach from solid particles below the vadose zone. As a result, remediation methods may not be completely reliable for extracting contaminants from the groundwater. In addition, because of the groundwater circulation effect it creates, in-well aeration may spread contaminants from the groundwater to non-contaminated soil in the vadose zone. This may limit its long-term effectiveness.

The potential for inorganics to precipitate and clog the well screens may also limit the long-term effectiveness of in-well aeration. As with most remediation equipment, there is the potential for equipment repair and/or replacement.

Under RAA 5, the proposed monitoring program and periodic O&M system checks will be adequate and reliable controls for determining the effectiveness of the alternative. If they are enforced over time, aquifer use restrictions will be adequate and reliable controls for preventing future exposure to the groundwater.

RAA 5 will require 5-year reviews by the lead agency.

***Reduction of Toxicity, Mobility, or Volume Through Treatment*:** The treatment processes associated with RAA 5 include in-well air stripping and off-gas carbon adsorption for VOC removal. These treatment processes are effective for treating halogenated VOCs. Thus, the in-well aeration system will reduce the toxicity and volume of contaminated groundwater. While the treatment effects are expected to be irreversible, the groundwater circulation effect that the wells create will reduce the mobility of the contaminated plume.

Residuals remaining after treatment will include the small amount of condensed vapor left in the knockout tanks and the spent carbon. The liquid within the knockout tanks is expected to be non-

hazardous; however, the spent carbon will contain adsorbed contaminants and will require disposal or regeneration.

RAA 5 satisfies the statutory preference for treatment.

Short-Term Effectiveness: Adequate site controls may be necessary to minimize dust production during the aeration well installation, thus minimizing the short-term risk to the community. In addition, workers may require protection during the installation and operation of the system. However, the system will create no additional environmental impacts.

The time required to complete the remedial action cannot be estimated; however, ten years of operation and 30 years of monitoring have been assumed for cost estimating purposes.

Implementability: Although in-well aeration has been commercially applied, it is still a relatively new technology. Regardless, RAA 5 appears to be technically implementable at Site 36 based on current knowledge of the site. Two important advantages of this system are the apparent reduction of time required to reach clean-up levels and the fact that groundwater does not have to be lifted above the ground surface in order to be treated. However, in any in situ system where oxygen is injected, metals precipitation and oxidation may occur. At high enough levels, these metals can clog the well screens requiring frequent maintenance and equipment replacement.

If the monitoring program indicates that groundwater quality is deteriorating, additional remedial actions could easily be implemented under RAA 5.

In terms of administrative feasibility, RAA 5 will require extensive coordination with the Base Public Works/Planning Department. Although there are a limited number of in-well aeration vendors, the required services, materials, and/or technologies should be available.

Cost: Table 5-5 presents a cost estimate for RAA 5; and Appendix E includes the applicable in-well aeration vendor cost quotation. As shown, the estimated capital cost is $824,000. O&M costs of $17,000 and $22,000 are projected for 10 years of system operation and 30 years of groundwater/surface water monitoring, respectively. Assuming a discount rate of 5 percent, the NPW of this alternative is $1,293,000.

5.3 Comparative Analysis

This section presents a comparative analysis of the five groundwater alternatives presented for Site 36. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each RAA. Thus, seven of the nine previously introduced criteria used for the detailed analysis will be the basis for the following comparative analysis.

5.3.1 Overall Protection of Human Health and the Environment

RAA 1, the no action alternative, does not reduce potential risks to human health nor the environment. On the other hand, RAAs 2, 3, 4 and 5 reduce potential human health risks because they all involve institutional controls which prevent future exposure to the groundwater. RAAs 4 and 5 involve active remediation systems (extraction and on-site treatment and in-well aeration) which provide additional protection to human health. However, the additional protection that

RAAs 4 and 5 provide may not be necessary considering the minimal human health risks associated with contaminated groundwater.

Human health risk values for groundwater at Site 36 were generated primarily from the detection and concentrations of inorganic constituents under the future residential exposure scenario. However, it is highly unlikely that future residential development will ever occur at Site 36, as the existing use of Site 36 is limited, primarily due to its location and marshy conditions. In addition, U.S. Route 17 By-Pass will impact a good portion of Site 36. As a result, the future residential exposure scenario and all risk values generated there under are overly conservative and unrealistic. Risk values generated under the current land use scenario at Site 36 were within acceptable limits. Likewise, the risk values generated for TCE contamination under the future child resident ingestion scenario calculated to 6.9×10^{-7}; well below acceptable limits. Thus, the risks associated with VOC contamination appears minimal.

Considering the minimal human health risks associated with contaminated groundwater, monitored natural attenuation (RAA 3) should be adequate for protecting human health and the environment. Active treatment via groundwater extraction and treatment (RAA 4) or in-well aeration (RAA 5) will be unnecessary to provide adequate human health or environmental protection. No action provides no protection, while RAA 2 (institutional controls) allows the natural attenuation treatment process to continue virtually unnoticed. Therefore, RAAs 1 and 2 may be inferior to the other three alternatives, while RAAs 4 and 5 may overcompensate for the minor risks that exist at the site.

RAAs 3, 4, and 5 provide for risk reduction to ecological receptors. However, ecological risks only slightly exceeded acceptable limits and were determined to be minimal. In addition, VOCs (including TCE) did not generate unacceptable risks. As a result, VOCs in the groundwater do not appear to be creating unacceptable risks in the surface water, sediment, or surface soil.

5.3.2 Compliance with ARARs

Under all five RAAs, the primary groundwater COC, TCE, has the potential to meet Federal and State chemical-specific ARARs through passive and/or active remedial approaches. Under RAAs 1, 2, and 3, groundwater models support the conclusion that TCE may eventually meet ARARs via the passive remedial approach of natural attenuation. Under RAAs 1 and 2, however, natural attenuation will not be adequately monitored, nor its effectiveness evaluated. TCE may as well, eventually meet ARARs via the active remedial approaches introduced under RAAs 4 and 5. Very few, if any, active remedial actions can document that TCE contaminated groundwaters have been remediated to drinking water standards.

RAAs 4 and 5 can be designed to meet applicable location- and action-specific ARARs. No location-specific ARARs apply to RAAs 1, 2, and 3. RAA 1 will not comply with the action-specific groundwater corrective action ARAR (15A NCAC 2L.0106 - .0113); while RAA 2 will not comply with the action-specific ARAR (15A NCAC 2L.0113) without a variance. RAA 3 would have to comply with the action-specific groundwater corrective action ARAR (15A NCAC 2L.0106(l)).

5.3.3 Long-Term Effectiveness and Permanence

RAAs 3, 4, and 5 appear to provide the greatest degree of long-term effectiveness and permanence. Of all the alternatives evaluated, RAA 1 will allow the most residual risk to remain at the site because it involves taking no action. The other RAAs allow less residual risk to remain because they

involve, at a minimum, institutional controls. Compared to RAA 2, however, RAAs 3, 4, and 5 mitigate residual risk to a greater extent because they involve monitored natural attenuation (RAA 3) and active groundwater remediation (RAAs 4 and 5). Regardless, the magnitude of residual risk associated with leaving TCE untreated at the site is minimal (as discussed in Section 5.3.1).

The long-term effectiveness of RAAs 1, 2, and 3 rely on the effectiveness of natural attenuation at reducing VOC contamination. As previously noted, the extent to which natural attenuation may reduce contaminant levels, and the amount of time it will take, are difficult to predict. However, RAA 3 allows for the progress to be monitored and predicted. Groundwater modeling results indicate that a 41 percent reduction of the maximum TCE concentration is expected via the effects of natural attenuation over a 30-year time period. RAA 4, the extraction and on-site treatment system, is assumed to operate for 30 years. Even though vendor information indicates that the system would take one year to reach clean-up goals for RAA 5, the in-situ volatilization system, is also assumed to operate for 10 years. This estimate is based on past performance of at similar sites that have implemented this technology. Overall, the cleanup times under RAAs 3, 4, and 5 are all difficult to predict.

Active remediation may be considered a more reliable means for treating contaminants than passive remediation; however, RAAs 4 and 5 will only be adequate and reliable to a certain extent. Technologies for completely extracting contaminants from groundwater are not proven. Contaminants may sorb to solid particles or escape into subsurface pore spaces or fissures where they become difficult to extract. Similarly, the technology associated with RAA 5 may spread contaminants into the vadose zone. As a result, active remediation methods may not be completely reliable for extracting contaminants from the groundwater.

RAAs 2, 3, 4, and 5 all involve groundwater/surface water monitoring programs and aquifer use restrictions as institutional controls. RAA 3 includes the most extensive monitoring program in order to identify the type and progress of natural attenuation processes that may be occurring. These types of controls have been proven in the past to be adequate or reliable means to manage the hazardous substances remaining on site. RAA 1, however, does not provide adequate or reliable controls. As a result, RAAs 2, 3, 4, and 5 mitigate human health exposure through the use of institutional controls, but RAA 1 does not. Also, the effectiveness of RAAs 3, 4, and 5 can be determined (via remedial action and monitoring) more often than the effectiveness of RAAs 1 and 2 can be determined.

All five RAAs require 5-year reviews to ensure that adequate protection of human health and the environment is maintained. For alternatives 2, 3, 4, and 5, this review will no longer be necessary once ARARs are achieved.

5.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

A reduction in the toxicity, mobility, and volume of groundwater contamination through treatment is anticipated via RAAs 3, 4, and 5. The treatment processes (both passive and/or active) associated with these alternatives will reduce toxicity and volume, while the effects that RAAs 4 and 5 have on groundwater flow will reduce mobility. The treatment processes associated with these alternatives are also expected to have irreversible effects. Unlike RAAs 4 and 5, RAAs 1, 2, and 3 do not involve physical treatment processes. However, RAAs 1, 2, and 3 involve passive treatment processes in the form of natural attenuation processes. Thus, groundwater contamination may

undergo toxicity and volume reduction under RAAs 1, 2, and 3, but offer no reduction in plume mobility.

The RAAs differ significantly in the kind of residuals they create after treatment. Structural residuals (monitoring wells) will remain at the site under all five of the RAAs. RAAs 1, 2, and 3; however, create no treatment residuals. RAAs 4 and 5, on the other hand, create treatment residuals. The residuals associated with RAA 4 (sludge, off-gases, and treated groundwater) are more voluminous than the treatment residuals associated with RAA 5 (condensed vapor and spent carbon).

RAAs 4 and 5 satisfy the statutory preference for treatment via active processes, while RAA 3 satisfies the preference for treatment via the confirmed natural attenuation processes. Since treatment cannot be confirmed under RAAs 1 and 2, the statutory preference for treatment cannot be justified.

5.3.5 Short-Term Effectiveness

Implementation of RAAs 1, 2, and 3 does not pose substantial risks to the community or workers. Implementation of RAAs 4 and 5 may pose additional risk to community and/or workers because they involve construction and operation of on-site treatment facilities.

The time for the natural attenuation processes associated with RAAs 1, 2, and 3 to be complete is unknown and difficult to estimate. Likewise, the time for RAAs 4 and 5 to be complete is unknown. Based on existing site and technology information, it appears that RAA 5 may require the least treatment time, followed by RAAs 3 and 4.

5.3.6 Implementability

Since the no action alternative is required by the NCP, RAA 1 is the easiest alternative to implement. RAAs 2 and 3 are the next most implementable alternatives, followed by RAAs 4 and 5. RAAs 4 and 5 are the least implementable because they involve installation of wells and piping networks, and the construction of a treatment system.

RAA 1 requires no operation or maintenance; while RAA 2 requires minimal operation and maintenance for the semiannual groundwater/surface water sampling and periodic well replacement. RAA 3 requires a slight increase in maintenance, as the monitoring requirements include both TCL VOCs and natural attenuation parameters. Due to the treatment systems, RAAs 4 and 5 require the most operation and maintenance. Compared to RAA 4, RAA 5 requires much less system O&M because the groundwater being treated is not lifted above the ground surface.

Under RAAs 4 and 5, there is the potential for inorganic precipitation and oxidation to clog the well screens necessitating frequent maintenance and possibly equipment replacement. Under RAA 5, this potential is greatest because metal precipitation and oxidation will be enhanced by the injection of oxygen.

Under all five of the RAAs, additional remedial actions could potentially be implemented with relative ease, if necessary.

There are no equipment requirements associated with RAA 1. RAAs 2, 3, and 4 involve conventional equipment and services that should be readily available. The equipment associated

with RAA 5 is not as conventional as the equipment associated with RAAs 2, 3, and 4; and is only available through a limited number of vendors.

RAAs 1 and 2 may require a waiver since contaminated groundwater will be left on site indefinitely at concentrations that exceed ARARs; while RAAs 4 and 5 will both require extensive coordination with the Base Public Works/Planning Department. Additionally, RAAs 2, 3, 4, and 5 will require semiannual submission of reports that document sampling and treatment results.

5.3.7 Cost

In terms of NPW, the no action alternative (RAA 1) would be the least expensive alternative to implement. The estimated NPW values in increasing order are: $0 (RAA 1), $338,000 (RAA 2), $902,000 (RAA 3), $1,264,000 (RAA 4), and $1,293,000 (RAA 5).

5.4 Reference

USEPA, 1988. United States Environmental Protection Agency. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. Office of Emergency and Remedial Response. Washington, D.C. EPA/540/G-89/004.

SECTION 5.0 TABLES

TABLE 5-1

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
OVERALL PROTECTIVENESS					
• Human Health	No measurable reduction in potential human health risks.	Through monitoring, institutional controls will reduce potential human health risks.	Provides overall protection of human health through natural attenuation, monitoring, and aquifer use restrictions.	Institutional controls and groundwater extraction/treatment will reduce potential human health risks.	Institutional controls, and in-well aeration will reduce potential human health risks.
• Environmental Protection	No measurable reduction in potential risks to ecological receptors.	No measurable reduction in potential risks to ecological receptors.	Provides overall protection of the environment through natural attenuation and monitoring.	Institutional controls and active groundwater treatment will reduce risks to ecological receptors.	Institutional controls and active groundwater treatment will reduce risks to ecological receptors.
COMPLIANCE WITH ARARs					
• Chemical-Specific ARARs	Contaminants may eventually meet the Federal and State ARARs through natural attenuation processes.	Contaminants may eventually meet the Federal and State ARARs through natural attenuation processes.	Natural attenuation is expected to achieve the ARARs over time.	Groundwater contamination may eventually meet Federal and State ARARs through active treatment.	Groundwater contamination may eventually meet Federal and State ARARs through active treatment.
• Location-Specific ARARs	Not applicable.	Not applicable.	Not applicable.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.
• Action-Specific ARARs	Will not meet groundwater corrective action State ARARs.	Will not meet groundwater corrective ction State ARAR without a variance.	Can be designed to meet action-specific ARARs.	Can be designed to meet action-specific ARARs.	Can be designed to meet action-specific ARARs.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
LONG-TERM EFFECTIVENESS AND PERMANENCE					
• Magnitude of Residual Risk	The residual risk from untreated contaminants will be minimal. However, RAA 1 provides no active means for reducing residual risk.	Although residual risk from untreated contaminants will be minimal, it will remain on site under RAA 2. However, institutional controls should mitigate any residual risks that may exist.	Residual risks will be minimal; however, natural attenuation combined with monitoring and institutional controls should mitigate remaining residual risk.	Groundwater extraction/treatment should mitigate residual risk. However, due to the technical limitations associated with groundwater remediation, extraction/treatment is not expected to eliminate residual risk.	In-well aeration should mitigate residual risk. However, due to the technical limitations associated with groundwater remediation, in-well aeration is not expected to eliminate residual risk.
• Adequacy and Reliability of Controls	There are no controls associated with this alternative.	The monitoring program is adequate and reliable for determining the alternative's effectiveness. If enforced over time, aquifer use restrictions are adequate and reliable for preventing human exposure to groundwater.	Monitoring and aquifer use restrictions will be adequate and reliable controls for preventing exposure to the contamination, as well as, maintaining this alternative's effectiveness.	Once designed/sized in accordance with site-specific characteristics, extraction/treatment should be both adequate and reliable. The monitoring program is adequate and reliable for determining effectiveness. Aquifer use restrictions are adequate and reliable for preventing human exposure to groundwater.	Due to the limited commercial track record, the adequacy and reliability of in-well aeration is uncertain. The monitoring program is adequate and reliable for determining the alternative's effectiveness. Aquifer use restrictions can be adequate and reliable for preventing human exposure to groundwater.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
LONG-TERM EFFECTIVENESS AND PERMANENCE (Continued)					
• Need for 5-year reviews	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.	Reviews will be required to ensure adequate protection of human health and the environment.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT					
• Treatment Process Used	There is no physical treatment process associated with this alternative.	There is no physical treatment process associated with this alternative.	There is no physical treatment process associated with this alternative; however, natural attenuation will provide passive treatment.	The treatment process includes neutralization, precipitation, flocculation, sedimentation, and filtration as pretreatment for the air stripper; air stripping for VOC removal; and secondary treatment of air emission and groundwater discharge via carbon adsorption.	The treatment process includes in-well aeration and off-gas carbon adsorption. This process strips VOCs from the groundwater and removes contaminants from the off-gas.
• Amount Destroyed or Treated	No destruction through treatment.; however, natural attenuation processes are expected to reduce contaminant concentrations.	No destruction through treatment.; however, natural attenuation processes are expected to reduce contaminant concentrations.	Natural attenuation is expected to treat and/or destroy the majority of the contamination.	Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be treated.	Due to the technical limitations associated with groundwater remediation, most of the contamination, but not all, is expected to be treated.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (Continued)					
• Reduction of Toxicity, Mobility, or Volume Through Treatment	Some reduction in toxicity, mobility, and volume through natural attenuation is expected over time.	Some reduction in toxicity, mobility, and volume through natural attenuation is expected over time.	Some reduction in toxicity, mobility, and volume through natural attenuation is expected over time.	The groundwater treatment processes are expected to reduce toxicity and volume of contaminants in the groundwater, and the extraction wells will reduce the mobility of the plume.	The in-well aeration system is expected to reduce the toxicity, mobility, and volume of the plume.
• Irreversibility of the Treatment	Not applicable.	Not applicable.	Not applicable.	Air stripping will have irreversible results.	In-situ air stripping and off-gas carbon adsorption will have irreversible results.
• Residuals Remaining After Treatment	Not applicable.	Not applicable.	Not applicable.	Treatment residuals may include sludge, spent carbon, and treated groundwater. The sludge should be non-hazardous, the spent carbon will require disposal or regeneration, and the treated groundwater is expected to be within acceptable groundwater discharge limits.	Treatment residuals will include the small amount of liquid left in the knockout tanks and spent carbon. The liquid should be non-hazardous, but the spent carbon will contain adsorbed contaminants requiring disposal or regeneration.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT (Continued)					
• Statutory Preference for Treatment	Since no means are provided to measure the effects/progress of natural attenuation, the statutory preference for treatment cannot be justified.	Since no means are provided to measure the effects/progress of natural attenuation, the statutory preference for treatment cannot be justified.	If the natural attenuation processes are confirmed through monitoring, the statutory preference for treatment will be satisfied.	Satisfied.	Satisfied.
SHORT-TERM EFFECTIVENESS					
• Community Protection	Potential risks to the community will not be increased.	Potential risks to the community will not be increased during implementation.	Potential risks to the community will not be significantly increased.	Due to well and piping requirements, potential risks to the community will be increased during installation of the extraction/treatment system. Proper site controls will be necessary during system installation and operation.	Potential risks to the community will be minimized through adequate site controls established during installation of the in-well aeration system. Proper continuance of the site controls may be necessary throughout system operation.
• Worker Protection	No risks to workers.	No risks to workers.	No significant risks to workers; however, adequate personal protective equipment may be necessary.	Potential risks to workers will be increased; worker protection is required.	Potential risks to workers will be increased; worker protection is required.
• Environmental Impact	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
SHORT-TERM EFFECTIVENESS (Continued)					
• Time Until Action is Complete	Unknown.	Unknown; 30 years of monitoring has been assumed for cost estimating purposes.	Unknown; 30 years of monitoring has been assumed for cost estimating purposes.	Unknown; 30 years has been assumed for cost estimating purposes.	Unknown; 10 years of treatment and 30 years of monitoring has been assumed for cost estimating purposes.
IMPLEMENTABILITY					
• Ability to Construct and Operate	Not applicable.	Based on past experience, groundwater/surface water sampling and aquifer use restrictions are easily implemented.	Based on past experience, groundwater/surface water sampling and aquifer use restrictions are easily implemented.	Based on past experience, an extraction/treatment system will be easy to construct and operate. Disposal of treatment residuals and inorganics precipitation on the well screens may complicate system operation. The fact that groundwater must be lifted above the ground surface also complicates system operation.	The system should be easy to construct and operate. Carbon replacement and inorganics precipitation on the well screens may make system operation more challenging. The fact that groundwater will remain below the ground surface simplifies system operation.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
IMPLEMENTABILITY (Continued)					
• Reliability of Technology	Not applicable.	Groundwater and surface water sampling are reliable monitoring technologies.	Groundwater and surface water sampling techniques, together with documentation of natural attenuation processes, provide for a reliable, remedial technology.	Inorganics may precipitate on the well screens creating the need for well replacement. Also, the long operation time for the system may necessitate equipment replacement.	In-well aeration has not been widely demonstrated so its reliability is uncertain. However, there are several successful full scale applications. Inorganics may precipitate on the well screens necessitating well replacement.
• Ease of Undertaking Additional Remedial Actions	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.	Additional remedial actions can be easily implemented.
• Ability to Monitor Effectiveness	No monitoring plan. Failure to detect contamination could result in human and/or environmental exposure.	Monitoring plan designed to detect contaminants before significant exposure can occur; however, are not designed under RAA 2 to monitor the progress of natural attenuation.	Monitoring plan designed to detect contaminants before significant exposure can occur. Natural attenuation parameters and groundwater modeling establish predictable alternative effectiveness.	Monitoring plan designed to detect contaminants before significant exposure can occur.	Monitoring plan designed to detect contaminants before significant exposure can occur.
• Availability of Services and Equipment	No services or equipment required.	Services and equipment are readily available.	Services and equipment are readily available.	Services and equipment are readily available.	Services and equipment are available through several vendors.

TABLE 5-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0303
SITE 36, CAMP GEIGER AREA DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA 1 No Action	RAA 2 Institutional Controls	RAA 3 Monitored Natural Attenuation	RAA 4 Extraction and On-Site Treatment	RAA 5 In-Situ Volatilization (In-Well Aeration)
IMPLEMENTABILITY (Continued)					
• Requirements for Agency Coordination	May require a waiver of ARARs since contaminated groundwater will be left on site.	Must submit semiannual reports to document sampling.	No significant requirements; however, semiannual reports will document results.	Substantive requirements of air and water discharge permits must be met. Must submit semiannual reports to document sampling.	Substantive requirements of air and water discharge permits must be met. Must submit semiannual reports to document sampling.
COST (Approximate Net Present Worth)	**$0**	**$338,000**	**$902,000**	**$1,264,000**	**$1,293,000**

TABLE 5-2

ESTIMATED COSTS FOR GROUNDWATER AND SURFACE WATER RAA No. 2

GROUNDWATER RAA No. 2: INSTITUTIONAL CONTROLS
SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS
Jun-98

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER AND SURFACE WATER MONITORING O&M							
Labor	Hours	80	$40	$3,200		2 sampling events/yr, 2 days/event, 10 hrs/day/person, 2 people	Engineering Estimate - Previous Projects
Travel	Sample Event	2	$1,508	$3,016		Includes minivan rental and airfare for 2 people	Engineering Estimate - Previous Projects
Per Diem	Sample Event	2	$292	$584		Includes lodging and meals for 2 people	Engineering Estimate - Previous Projects
VOA	Sample	18	$179	$3,227		7 samples/1 duplicate sample /1 MS/MSD sample, twice yearly	Basic Ordering Agreement
Equipment & Supplies	Sample Event	2	$600	$1,200		Ice, DI water, expendables, pump, etc.	Engineering Estimate
Sample Shipping	Sample Event	2	$332	$664		2 coolers per day for 2 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$3,408	$3,408		Equal annual cost of replacing 7 wells every 5 years for 30 years	Engineering Estimate; Table 5-2A
Well Redevelopment	Year	1	$873	$873			Engineering Estimate; Table 5-3B
Total Groundwater and Surface Water Monitoring O&M Costs					$22,171		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$0	
TOTAL ANNUAL O&M COSTS	$22,000	30 years of semi-annual monitoring
PRESENT WORTH VALUE	$338,000	Based on a discount rate of 5%

TABLE 5-2A
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER MONITORING WELL REPLACEMENT COSTS

GENERAL ASSUMPTIONS

3 shallow monitoring wells (15-ft deep) will be replaced

3 intermediate monitoring wells (30-ft deep) will be replaced

1 Deep monitoring well (60-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$31.50	195	$6,142.50
2" PVC sch. 40 riser	LF	$1.25	146	$182.50
2" PVC sch. 40 screen	Each	$20.00	7	$140.00
Protective cover	Each	$400.00	7	$2,800.00
Drums	Each	$42.00	40	$1,680.00
Well development	Hour	$65.00	21	$1,365.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	9	$855.00
Geologist labor	Hour	$40.00	90	$3,600.00
Geologist travel	Each	$2,400.00	1	$2,400.00
Geologist per diem	Day	$73.00	9	$657.00

Well Replacement Costs	$20,522
Total Present Worth (5% discount rate, 5 replacement events, 30yr	$52,343
Equal Annual Cost (5% discount rate, 30 years)	$3,408

TABLE 5-2B
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER O & M MONITORING WELL REDEVELOPMENT

GENERAL ASSUMPTIONS

Redevelop 10 monitoring wells every 5 years for 30 years

Item	Units	Unit Cost	No. of Units	Total
Labor (2 people)	Hr	$40.00	100	$4,000.00
Equipment	Ls	$200.00	1	$200.00
Travel	Day	$65.00	5	$325.00
Per Diem (2 people x $73.00/day)	Day	$146.00	5	$730.00

Redevelopment Costs Per Event	$5,255
Total Present Worth (5% discount rate, 5 redevelopment events, 30y	$13,403
Equal Annual Cost (5% discount rate, 30 years)	$873

TA 5-3

ESTIMATED COSTS FOR GROUNDWATER RAA No. 3

GROUNDWATER RAA No. 3: MONITORED NATURAL ATTENUATION
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

3 SURFACE WATER SAMPLES
MONITORING 11 EXISTING WELLS

Jun-98

DIRECT AND INDIRECT CAPITAL COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
NATURAL ATTENUATION STUDIES							
Initial Field Effort	LS	1	$ 23,239	$23,239		Collection of soil, soil gas, and groundwater samples	Engineering Estimates - Table 5-3B
Modeling, Data Evaluation and Analysis	LS	1	$25,000	$25,000			Engineering Estimates - Previous Projects
Work Plan Development	LS	1	$10,000	$10,000			Engineering Estimates - Previous Projects
Reporting	LS	1	$10,000	$10,000			Engineering Estimates - Previous Projects
Contingency	LS	1	$3,486	$3,486		15% of direct capital costs	Engineering Estimates - Previous Projects
Total Natural Attenuation Study Capital Costs					$71,725		
TOTAL DIRECT AND INDIRECT CAPITAL COSTS					$ 71,725		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER MONITORING O&M							
Labor	Hours	48	$40	$1,920		2 days/event, 10 hrs/day/person, 2 people, 4 hrs travel/person	Engineering Estimate - Table 5-3C
Travel	Sample Event	1	$1,508	$1,508		Includes minivan rental and airfare for 2 people	Engineering Estimate - Table 5-3C
Per Diem	Sample Event	1	$292	$292		Includes lodging and meals for 2 people	Engineering Estimate - Table 5-3C
Laboratory Analysis & Data Validation							
Intrinsic Remed. Parameters	Sample	14	$ 631.79	$8,845		11 samples/2 duplicate samples /1 MS/MSD samples	Basic Ordering Agreement - Table 5-3D
Equip. & Supplies	Sample Event	1	$552	$552		Ice, DI water, expendables, pump, etc.	Engineering Estimate - Table 5-3C
Shipping	Sample Event	1	$332	$332		2 coolers per day for 2 days; $83/cooler	Engineering Estimate - Table 5-3C
Reporting	Sample Event	1	$3,000	$3,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$4,848	$4,848		Equal annual cost of replacing 11 wells every 5 years for 30 years	Engineering Estimate - Table 5-3A
Well Redevelopment	Year	1	$873	$873			
Model Updates & Reporting	Year	1	$20,000	$20,000			
Total Groundwater Monitoring O&M Costs (1 to 5 years)					$86,668	Quarterly sampling will be performed for the first 5 years	
Total Groundwater Monitoring O&M Costs (6 to 30 years)					$53,770	Semi-annual sampling will be performed for the remaining 15 yrs	

TABLE . .CON'T)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 3

GROUNDWATER RAA No. 3: MONITORED NATURAL ATTENUATION
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MCB, CAMP LEJEUNE, NORTH CAROLINA

3 SURFACE WATER SAMPLES
MONITORING 11 EXISTING WELLS
Jun-98

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$ 72,000	
TOTAL ANNUAL O&M COSTS (1 - 5 YEARS) TOTAL ANNUAL O&M COSTS (6 - 30 YEARS)	$87,000 $54,000	
PRESENT WORTH VALUE	$902,000	Based on a discount rate of 5%

TABLE 5-3A
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER MONITORING WELL REPLACEMENT COSTS

GENERAL ASSUMPTIONS

6 shallow monitoring wells (15-ft deep) will be replaced

4 intermediate monitoring wells (30-ft deep) will be replaced

1 Deep monitoring well (60-ft deep) will be replaced

Item	Units	Unit Cost	No. of Units	Total
Mobilization	Each	$500.00	1	$500.00
Type II Well installation	LF	$31.50	270	$8,505.00
2" PVC sch. 40 riser	LF	$1.25	175	$218.75
2" PVC sch. 40 screen	LF	$11.00	87	$957.00
Protective cover	Each	$400.00	11	$4,400.00
Drums	Each	$42.00	60	$2,520.00
Well development	Hour	$65.00	15	$975.00
Temp. decon. pad	Each	$200.00	1	$200.00
Contractor per diem	Day	$95.00	15	$1,425.00
Geologist labor	Hour	$40.00	150	$6,000.00
Geologist travel	Each	$2,400.00	1	$2,400.00
Geologist per diem	Day	$73.00	15	$1,095.00

Well Replacement Costs	$29,196
Total Present Worth (5% discount rate, 5 replacement events, 30yrs)	$74,467
Equal Annual Cost (5% discount rate, 30 years)	$4,848

TABLE 5-3B
ESTIMATED COSTS FOR INITIAL FIELD EFFORT

Item	Units	Unit Cost	Quantity	Subtotal	Remarks
Geoprobe Rig	Day	$ 1,500.00	2	$ 3,000.00	Engineering Estimate
Equipment	LS	$ 551.79	1	$ 551.79	Table 5-3D
Water Analysis	Day	$ 631.79	15	$ 9,476.85	Table 5-3E
Soil Analysis	Day	$ 212.27	10	$ 2,122.70	Table 5-3E
Labor	Hour	$ 32.00	160	$ 5,120.00	Engineering Estimate
Travel	LS	$ 1,800.00	1	$ 1,800.00	Engineering Estimate
Per Diem (2 people)	Day	$146.00	8	$ 1,168.00	Engineering Estimate
			Total	$ 23,239.00	

TABLE 5-3C
COST ESTIMATE ASSUMPTIONS FOR
GROUNDWATER MONITORING O&M

GENERAL ASSUMPTIONS

- Groundwater will be sampled quarterly for the first 5 years, then semiannually thereafter
- 11 wells will be sampled for intrinsic remediation parameters

LABOR		48	hours/event
No. of people:		2	
Days required:		2	
Hours per day:		10	
Travel Time/person		4	
LABOR COST		$1,920	/event
	(yrs 1-5)	$7,680	/year
	(yrs 6-30)	$3,840	/year
TRAVEL		$1,508	/event
No. of people:		2	
Days required:		2	
Airfare (roundtrip		$689.00	
PIT-OAJ, full fare)			
Mini-van rental		$65.00	
PER DIEM		$292.00	/event
No. of people:		2	
Days required:		2	
Lodging (per night)		$47.00	
Meals (per day)		$26.00	

ITEM	UNIT RATE	UNIT	No. OF UNITS	TOTAL
Conductivity Meter	$3.86	/Day	2	$7.72
pH Meter	$6.35	/Day	2	$12.70
Turbidity Meter	$9.67	/Day	2	$19.34
Hydrogen Ion Meter	$80.00	/Day	2	$160.00
D.O. Meter	$13.23	/Day	2	$26.46
Perstaltic Pump	$6.62	/Day	2	$13.24
P.E. Tubing	$21.25	/100 feet	2	$42.50
Silicon Tubing	$2.75	/foot	2	$5.50
P.E. Squeeze Bottles	$.06	/Day	2	$.12
Garbage Bags	$.16	Each	5	$.80
Inner Gloves	$8.97	/Box	1	$8.97
Paper Towels	$.81	Roll	4	$3.24
Markers	$.60	Each	2	$1.20
Equipment Shipping	$50.00	/Package	5	$250.00
			TOTAL:	$551.79

TABLE 5-3D
ESTIMATED ANALYTICAL PARAMETER COSTS FOR INTRINSIC REMEDIATION MONITORING

Parameters	Unit Price(1)	Validation Price	Total
Groundwater			
Diss. Oxygen	Field (2)	--	--
Nitrate & Nitrite	$ 20.03	$ 6.67	$ 26.70
Iron (II)	$ 45.00	$ 7.00	$ 52.00
Iron (III)	$ 45.00	$ 7.00	$ 52.00
Sulfate	$ 13.39	$ 6.33	$ 19.72
Sulfide	$ 17.41	$ 6.33	$ 23.74
Methane	$ 140.00	$ 13.50	$ 153.50
ReDox	Field	--	--
Major Cations	$ 55.00	$ 15.00	$ 70.00
pH	Field	--	--
Temperature	Field	--	--
TOC (water)	$ 24.13	$ 6.33	$ 30.46
Alkalinity	$ 9.93	$ 6.17	$ 16.10
Chloride	$ 12.84	$ 6.33	$ 19.17
VOAs	147.73	20.67	$ 168.40
	TOTAL		$ 631.79
Soil Analysis			
VOCs	$ 160.44	$ 20.50	$ 180.94
TOC	$ 25.00	$ 6.33	$ 31.33
Moisture (3)	--	--	--
	TOTAL		$ 212.27

NOTES

(1) Costs based on laboratory quotes and LANTDIV bidding prices.

(2) The cost for field analysis is included in equipment and labor costs for groundwater sampling.

(3) No charge, as moisture content is included in other analyses

(4) On-site mobile laboratory used for soil gas analysis

TABLE 5-3E
COST ESTIMATE ASSUMPTIONS FOR GROUNDWATER
O & M MONITORING WELL REDEVELOPMENT

GENERAL ASSUMPTIONS

Redevelop 11 monitoring wells every 5 years for 30 years

Item	Units	Unit Cost	No. of Units	Total
Labor (2 people)	Hr	$40.00	100	$4,000.00
Equipment	Ls	$200.00	1	$200.00
Travel	Day	$65.00	5	$325.00
Per Diem (2 people x $73.00/day)	Day	$146.00	5	$730.00

Redevelopment Costs Per Event	$5,255
Total Present Worth (5% discount rate, 5 redevelopment events, 30yrs)	$13,403
Equal Annual Cost (5% discount rate, 30 years)	$873

TABLE 5-4
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

2 EXTRACTION WELLS
10 GPM TREATMENT FACILITY
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS
Jun-98

CAPITAL COSTS (DIRECT AND INDIRECT)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$12,000	$12,000		Work Plan, Erosion and Sediment Control Plan, and H & S Plan	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$9,000	$9,000		Includes mobilization for all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$7,500	$7,500		Includes decon/laydown area	Engineering Estimate- Previous Projects
Contract Administration	LS	1	$9,000	$9,000			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$5,500	$5,500			Engineering Estimate- Previous Projects
Total General Costs					$43,000		
SITE WORK							
Site Work During System Installation:							
Clearing	Acre	0.6	$8,000	$4,800		Clear and grub, chip stumps	Means Site 1996, 021-104 & Estimate
Piping Trench for the Collection Line	LF	300	$4	$1,200		Includes excavation, removal, backfill, and tamping	Means Site 1996, A12.73-110 & Estimate
Piping Trench for the Discharge Line	LF	200	$4	$800		Includes excavation, removal, backfill, and tamping	Means Site 1996, A12.73-110 & Estimate
Excavation for Treatment Area Slab	CY	75	$12	$900		Roughly 30' x 30' x 2'excavation	Means Site 1996, 022-200 & Estimate
Backfill Around Treatment Area Slab	CY	45	$5	$225		Roughly 5' x 2' x 120' around plant	Means Site 1996, 022-226 & Estimate
Gravel Driveway & Road Improvement	LF	900	$15	$13,500		3" Thick Aggregate Road, incl. materials and labor	Engineering Estimate- Previous Projects
Water Connection at Treatment Area	LF	1000	$8	$8,000		Includes trenching & laying a 1" copper line	Means Site 1996, 026-662 & 022-258
Overhead Electrical to Treatment Area	LF	850	$25	$21,250		Includes overhead routing and poles	Means Site 1994, 167-100 & Estimate
Erosion Protection at Discharge Point	CY	5	$62	$310		For erosion protection around headwall	Engineering Estimate- Previous Projects
Site Restoration:							
Topsoil Spreading in Cleared Areas	SY	2900	$3	$8,700			Means Site 1996, 022-286 & Estimate
Top Dressing Around Treatment Plant	CY	50	$40	$2,000			Means Site 1996, 022-286 & Estimate
Fine Grading and Seeding for Revegetation	SY	2900	$2	$5,800			Means Site 1996, 022-286 & Estimate
Total Site Work Costs					$67,485		

TABLE 5-4 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

2 EXTRACTION WELLS
10 GPM TREATMENT FACILITY
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS
Jun-98

CAPITAL COSTS (DIRECT AND INDIRECT)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
CONCRETE/STRUCTURAL							
Metals Pretreatment Bldg.	LS	1	$20,000	$20,000		Prefabricated metal enclosure, installed	Engineering Estimate- Previous Projects
Slab for Treatment Area	EA	1	$4,500	$4,500		25' x 25' on-grade slab	Engineering Estimate- Previous Projects
Headwall for Discharge Point	EA	1	$1,711	$1,711		Includes excavation, backfill, concrete, and forms	Means Site 1996, A12.3-750 & Estimate
Total Concrete/Structural Costs					$6,211		
EXTRACTION WELLS							
Shallow Extraction Well Installation	LF	80	$450	$36,000		6" stainless steel	Engineering Estimate- Previous Projects
Well Development	EA	2	$375	$750			Engineering Estimate- Previous Projects
Total Extraction Well Costs					$36,750		
PIPING SYSTEM							
2" PVC Line for Recovery	LF	300	$5	$1,500		Includes materials and installation (also includes down-hole line)	Means Site 1996, 026-678 & Estimate
2" PVC Line for Discharge to Creek	LF	200	$5	$1,000		Includes materials and installation (also includes down-hole line)	Means Site 1996, 026-678 & Estimate
4" PVC Containment Line for Recovery	LF	300	$8	$2,400		Includes materials and installation (also includes down-hole line)	Means Site 1996, 026-678 & Estimate
Fittings	LS	1	$735	$735		Assume 15% of Total Piping Cost	Engineering Estimate- Previous Projects
Total Piping System Costs					$5,635		
TREATMENT EQUIPMENT							
Package VOC and Solids Removal System	EA	1	$27,500	$27,500		Includes air stripper, solids filter, electric submersible pumps, all controls, and shipping (system skid mounted & enclosed)	Vendor Quote
Metals Pretreatment System	EA	1	$36,000	$36,000		Includes surge tank, clarifier, filter press, etc.	Engineering Estimate- Previous Projects
Flowmeter	EA	1	$1,500	$1,500			Engineering Estimate- Previous Projects
Installation of Equipment	LS	1	$4,000	$4,000		Incl. unloading crane, pump installation, hookups, and startup	Vendor Estimate
Piping and Fittings	LS	1	$7,250	$7,250		Assume 25% of equipment cost	Engineering Estimate- Previous Projects
Carbon Treatment Unit	EA	2	$1,000	$2,000			Engineering Estimate- Previous Projects
Total Treatment Plant Equipment Costs					$80,250		
TOTAL DIRECT CAPITAL COSTS					$239,331		

TABLE 5-4 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

2 EXTRACTION WELLS
10 GPM TREATMENT FACILITY
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS
Jun-98

CAPITAL COSTS (DIRECT AND INDIRECT)

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$28,720	$28,720		12% of Total Direct Cost	Engineering Estimate
Pump Test	EA	1	$15,000	$15,000			Engineering Estimate- Previous Projects
3D Groundwater Modeling	Hours	300	$40	$12,000			Engineering Estimate- Previous Projects
Design and Construction Administration	LS	1	$35,900	$35,900		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$35,900	$35,900		15% of Total Direct Cost	Engineering Estimate
Start-up Costs	LS	1	$35,900	$35,900		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$163,419		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER AND SURFACE WATER MONITORING O&M (Based on semiannual sampling for 30 year							
Labor	Hours	80	$40	$3,200		2 sample events, 2 days each, 10hrs/day/person, 2 people	Engineering Estimate
Travel	Sample Event	2	$1,508	$3,016		Includes travel-airfare for 2 people and truck rental	Engineering Estimate
Per Diem	Sample Event	2	$292	$584		2 days/sample event, $73 day/person, 2 people	Engineering Estimate
Laboratory Analysis & Data Validation							
VOCs	Sample	18	$179	$3,222		7 samples / 1 duplicate / 1 MS/MSD / twice yearly	Basic Ordering Agreement
Supplies and Equipment	Sample Event	2	$600	$1,200		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate
Sample Shipping	Sample Event	2	$332	$664		2 coolers per day for 2 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$3,408	$3,408		Equal annual cost of replacing 7 wells every 5 years for 30 years	Engineering Estimate; Table 5-2A
Well Redevelopment	Year	1	$873	$873			Engineering Estimate; Table 5-2B
Total Groundwater and Surface Water Monitoring O&M Costs					$22,166		

TABLE 5-4 (CONTINUED)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 4

GROUNDWATER RAA No. 4: EXTRACTION AND ON-SITE TREATMENT
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

2 EXTRACTION WELLS
10 GPM TREATMENT FACILITY
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS
Jun-98

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
TREATMENT SYSTEM O&M (Based on 30 years of system operation)							
Labor for Plant O&M	Week	52	$120	$6,240		4 hrs/wk, 52 weeks/yr, at $30/hr	Engineering Estimate
Labor for Sampling	Month	12	$240	$2,880		8 hr/month, 12 months/yr, at $30/hr	Engineering Estimate
Air Sampling - Analysis	Sample	24	$200	$4,800			Engineering Estimate
Effluent Sampling - Analysis	Sample	24	$300	$7,200			Engineering Estimate
Carbon Regeneration/Replacement	EA	2	$1,000	$2,000			Engineering Estimate
Sludge Disposal	Month	12	$300	$3,600		2 drums/month at $150/drum disposal costs	Engineering Estimate
Electricity	Month	12	$150	$1,800		24 hr/day, 365 days/year operation	Means Site 1996, 010-034 & Estimate
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
Total Treatment System O&M Costs					$33,520		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	**$403,000**	
TOTAL ANNUAL O&M COSTS	**$56,000**	Assuming 30 Years of Operation & Semi-annual Monitoring
PRESENT WORTH VALUE	**$1,264,000**	Based on a discount rate of 5%

TABLE 5-5
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: IN-SITU VOLATILIZATION (IN-WELL AERATION)
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

9 AERATION WELLS
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
DIRECT CAPITAL COSTS:							
GENERAL							
Preconstruction Submittals	LS	1	$15,000	$15,000		Work Plan, Erosion and Sediment Control Plan, and H & S Plan	Engineering Estimate- Previous Projects
Mobilization/Demobilization	LS	1	$12,000	$12,000		Includes mobilization for all subcontractors	Engineering Estimate- Previous Projects
Decontamination Pad	LS	1	$10,000	$10,000		Includes decon/laydown area	Engineering Estimate- Previous Projects
Contract Administration	LS	1	$12,500	$12,500			Engineering Estimate- Previous Projects
Post-Construction Submittals	LS	1	$7,000	$7,000			Engineering Estimate- Previous Projects
Pilot Study	EA	1	$300,000	$300,000			Engineering Estimate- Previous Projects
Total General Costs					$356,500		
SITE WORK							
Site Work During System Installation:							
Clearing	Acre	0.4	$8,000	$3,200		Clear and grub, and chip stumps	Means Site 1996, 021-104 & Estimate
Overhead Electrical to Treatment Area	LF	850	$25	$21,250		Cost for installation	Means Site 1994, 167-1900 & Estimate
Site Restoration:							
Topsoil Spreading in Cleared Areas	SY	1900	$3	$5,700			Means Site 1996, 022-286 & Estimate
Fine Grading and Seeding for Revegetation	SY	1900	$2	$3,800			Means Site 1996, 022-286 & Estimate
Roadway Improvements	LF	900	$15	$13,500			Engineering Estimate- Previous Projects
Total Site Work Costs					$33,950		
AERATION SYSTEM							
NoVOCs™ System	EA	1	$190,000	$190,000	$190,000	Well drilling, installation, and development; mechanical, electrical, and treatment equipment; labor for design specifications and drawings; oversight of installation and startup; technical support	Vendor Quote
TOTAL DIRECT CAPITAL COSTS:					$580,450		

TABLE 5-5 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: IN-SITU VOLATILIZATION (IN-WELL AERATION)
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

9 AERATION WELLS
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$69,654	$69,654		12% of Total Direct Cost	Engineering Estimate
Design and Construction Administration	LS	1	$87,068	$87,068		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$87,068	$87,068		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$243,789		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
GROUNDWATER AND SURFACE WATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	80	$40	$3,200		2 sample events, 2 days, 10 hrs/day/person, 2 people	Engineering Estimate
Travel	Sample Event	2	$1,508	$3,016		Includes travel-airfare for 2 people and truck rental	Engineering Estimate
Per Diem	Sample Event	2	$292	$584		2 days/sample event, $66/day/person, 2 people	Engineering Estimate
Laboratory Analysis & Data Validation							
VOCs	Sample	18	$179	$3,222		7 samples / 1 duplicate / 1 MS/MSD twice yearly	Basic Ordering Agreement
Supplies & Equipment	Sample Event	2	$600	$1,200		Ice, DI water, expendables, pump, meters, etc.	Engineering Estimate
Sample Shipping	Sample Event	2	$332	$664		2 coolers per day for 2 days; $83/cooler	Engineering Estimate
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate
Well Replacement	Year	1	$3,408	$3,408		Equal annual cost of replacing 7 wells every 5 years for 30 years	Engineering Estimate; Table 5-2A
Well Redevelopment	Year	1	$873	$873			Engineering Estimate; Table 5-2B
TOTAL GROUNDWATER AND SURFACE WATER MONITORING O&M COSTS					$22,166		

TABLE 5-5 (Continued)
ESTIMATED COSTS FOR GROUNDWATER RAA No. 5

GROUNDWATER RAA No. 5: IN-SITU VOLATILIZATION (IN-WELL AERATION)
OU No 6, SITE 36 - CAMP GEIGER AREA DUMP
MCB CAMP LEJEUNE, NC

9 AERATION WELLS
MONITORING 7 EXISTING WELLS
SAMPLING 3 SURFACE WATER STATIONS

ANNUAL O&M COSTS

Jun-98

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	BASIS OR COMMENTS	SOURCE
TREATMENT SYSTEM O&M (Based on 10 years of system operation)							
Utilities	Yr	1	$4,400	$4,400		Electric service at $0.10/Kwh and phone service	Vendor Quote
Maintenance	Yr	1	$800	$800		Routine repairs and preventative maintenance	Vendor Quote
Labor	Week	52	$120	$6,240		4 hrs/wk, 52 wks/year, at $30.00/hr	Vendor Quote
Off-gas Treatment	Yr	1	$500	$500		Carbon replacement	Vendor Quote
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL TREATMENT SYSTEM O&M COSTS					$16,940		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$824,000	
TOTAL ANNUAL O&M COSTS - GROUNDWATER	$22,000	Assuming 30 Years of Semi-annual Sampling
TOTAL ANNUAL O&M COSTS - TREATMENT SYSTEM	$17,000	Assuming 10 Years of Treatment
PRESENT WORTH VALUE	$1,293,000	Based on a discount rate of 5%

APPENDIX A
RISK-BASED ACTION LEVEL CALCULATIONS AND UPDATED HUMAN HEALTH RISKS - SEDIMENT

Baker

Baker Environmental, Inc.

Updated Human Health Risks

Sediment

Groundwater Exposure Risk-Base... ...on Levels
CTO-303 Site 36, Camp Geiger Area Dump
Feasibility Study
MCB, Camp Lejeune, North Carolina.
Future Residential Adult

COPC	Noncarcinogenic Action Level (mg/L)	Ingestion	Dermal Contact	Inhalation	Noncarcinogenic Risk	Carcinogenic Action Level (mg/L)	Ingestion	Dermal Contact	Inhalation	Carcinogenic Risk
Iron	11	1.0E+00	8.7E-04	NA	1.0E+00	NA	0.0E+00	0.0E+00	NA	0.0E+00
Tetrachloroethene	0.37	1.0E+00	1.3E-03	---	1.0E+00	1.4E-01	8.5E-05	1.4E-05	1.1E-06	1.0E-04
Trichloroethene	0.22	1.0E+00	2.8E-04	---	1.0E+00	6.6E-01	8.5E-05	4.9E-06	1.5E-05	1.0E-04

Action Level (mg/L) = (C ingestion + C dermal contact + C inhalation)

C ingestion (mg/L) = TR or HI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD
C dermal contact (mg/L) = TR or HI * BW * ATc or ATnc * DY / SA * PC * ET * EF * ED * CF * CSF or 1/RfD
C inhalation (mg/L) = TR or HI * ATc or ATnc * DY / ED * ET * shower concentration * CSF or 1/RfC

Where:	Inputs
C = conc. in water from ingestion exposure (mg/l)	calculated
IRw = adult daily water ingestion rate (L/Day)	2
EF = adult exposure frequency (days/yr)	350
ED = adult exposure duration (yr)	30
BW = adult body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = days per year (day/year)	365
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific

Where:	Inputs
C = conc. in water from d. contact exposure (mg/l)	Calculated
SA = adult skin surface available for contact (cm2)	23000
PC = contaminant specific dermal permability (cm/hr)	Specific
ET = adult exposure time (hours/day)	0.25
EF = adult exposure frequency (days/yr)	350
ED = adult exposure duration (years)	30
CF = volumetric conversion factor for water (1liter/1000 cm3)	0.001
TR = Total lifetime risk - carcinogenic effects	0.0001
HI = Hazard Index - noncarcinogenic effects	1

The shower concentration is calculated from the Foster et al. shower model
RfC = inhalation reference concentration

Ingestion

COPC	Concentration (mg/l)	Ingestion Rate (L/day) Adult	Exposure Frequency (day/year) Adult	Exposure Duration (year) Adult	Body Weight (kg) Adult	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day) Adult	Reference Dose (mg/kg-day)	Noncarcinogenic Risk Adult	Average Carc Time (days)	Carc Dose (mg/kg-day) Adult	Cancer Potency Factor (mg/kg-day)	Carcinogenic Risk Adult
Iron	11.000	2	350	30	70	10950	3.0E-01	3.0E-01	1.0E+00	25550	0.0E+00	0.0E+00	0.0E+00
Tetrachloroethene	0.370	2	350	30	70	10950	1.0E-02	1.0E-02	1.0E+00	25550	1.6E-03	5.2E-02	8.5E-05
Trichloroethene	0.220	2	350	30	70	10950	6.0E-03	6.0E-03	1.0E+00	25550	7.7E-03	1.1E-02	8.5E-05

Dermal Contact

COPC	Concentration (mg/l)	Surface Area (cm2) Adult	Dermal Permeability (cm/hr)	Exposure Time (hours/day) Adult	Exposure Frequency (days/yr) Adult	Exposure Duration (years) Adult	Volumetric Conversion (L/m3)	Body Weight (kg) Adult	Average Noncarc Time (years)	Noncarc Dose (mg/kg-day) Adult	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarc Risk Adult	Average Carc Time (days)	Carc Dose (mg/kg-day) Adult	Cancer Potency Factor (mg/kg-day)	Carcinogenic Risk Adult
Iron	11.000	23000	1.00E-03	0.25	350	30	0.001	70	10950	8.7E-04	6.0E-02	1.4E-02	25550	3.7E-04	0.0E+00	0.0E+00
Tetrachloroethene	0.370	23000	4.50E-02	0.25	350	30	0.001	70	10950	1.3E-03	8.0E-03	1.6E-01	25550	2.1E-04	6.5E-02	1.4E-05
Trichloroethene	0.220	23000	1.60E-02	0.25	350	30	0.001	70	10950	2.8E-04	4.8E-03	5.8E-02	25550	3.6E-04	1.4E-02	4.9E-06

Inhalation

COPC	Concentration (mg/l)	Concentration mg/kg/shwr	Exposure Duration years	Exposure Frequency shwr/year	Avg. Time noncarc. days	Avg. Time carc. days	Noncarc. Dose mg/kg/d	Carc. Dose mg/kg/d	Inhalation Reference Conc mg/kg/d	Inhalation Potency Factor (mg/kg/d)^-1	Noncarc. Risk	Cancer Risk
NA for metals												
Tetrachloroethene	0.14	1.4E-03	30	350	10950	25550	1.3E-03	5.6E-04	0.0E+00	2.0E-03	---	1.1E-06
Trichloroethene	0.66	6.0E-03	30	350	10950	25550	5.8E-03	2.5E-03	0.0E+00	6.0E-03	---	1.5E-05

ɔundwater Exposure Risk-Base levels
O-303 Site 36, Camp Geiger A
ɜsibility Study
:B, Camp Lejeune, North Carolina
ure Residential Child

PC	Noncarcinogenic Action Level (mg/L)	Ingestion	Dermal Contact	Inhalation	Noncarcinogenic Risk	Carcinogenic Action Level (mg/L)	Ingestion	Dermal Contact	Inhalation	Carcinogenic Risk
ı	4.8	1.0E+00	7.7E-04	NA	1.0E+00	NA	0.0E+00	0.0E+00	NA	0.0E+00
rachloroethene	0.16	1.0E+00	1.2E-03	—	1.0E+00	3.1E-01	8.8E-05	1.2E-05	3.1E-06	1.0E-04
:hloroethene	0.098	1.0E+00	2.5E-04	—	1.0E+00	1.2E+00	6.9E-05	3.5E-06	3.1E-05	1.0E-04

ion Level (mg/L) = (C ingestion + C dermal contact + C inhalation)

ıgestion (mg/L) = TR or HI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD
:ermal contact (mg/L) = TR or HI * BW * ATc or ATnc * DY / SA * PC * ET * EF * ED * CF * CSF or 1/RfD
ɔhalation (mg/L) = TR or HI * ATc or ATnc * DY / ED * ET * shower concentration * CSF or 1/RfC

ere:	Inputs
C = conc. in water from ingestion exposure (mg/l)	calculated
IRw = daily water ingestion rate (L/Day)	1
EF = exposure frequency (days/yr)	350
ED = exposure duration (yr)	6
BW = body weight (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = days per year (day/year)	365
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific

Where:	Inputs
C = conc. in water from d. contact exposure (mg/l)	Calculated
SA = skin surface available for contact (cm2)	10000
PC = contaminant specific dermal permability (cm/hr)	Specific
ET = exposure time (hours/day)	0.25
EF = exposure frequency (days/yr)	350
ED = exposure duration (years)	6
CF = volumetric conversion factor for water (1liter/1000 cm3)	0.001
TR = Total lifetime risk - carcinogenic effects	0.0001
HI = Hazard Index - noncarcinogenic effects	1

The shower concentration is calculated from the Foster et al. shower model
RfC = inhalation reference concentration

estion

PC	Concentration (mg/l)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day)	Reference Dose (mg/kg-day)	Noncarcinogenic Risk	Average Carc Time (days)	Carc Dose (mg/kg-day)	Cancer Potency Factor (mg/kg-day)	Carcinogenic Risk
ı	4.800	1	350	6	15	2190	3.1E-01	3.0E-01	1.0E+00	25550	0.0E+00	0.0E+00	0.0E+00
rachloroethene	0.160	1	350	6	15	2190	1.0E-02	1.0E-02	1.0E+00	25550	1.7E-03	5.2E-02	8.8E-05
:hloroethene	0.098	1	350	6	15	2190	6.3E-03	6.0E-03	1.0E+00	25550	6.3E-03	1.1E-02	6.9E-05

:rmal Contact

PC	Concentration (mg/l)	Surface Area (cm2)	Dermal Permeability (cm/hr)	Exposure Time (hours/day)	Exposure Frequency (days/yr)	Exposure Duration (years)	Volumetric Conversion (L/m3)	Body Weight (kg)	Average Noncarc Time (years)	Noncarc Dose (mg/kg-day)	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarc Risk	Average Carc Time (days)	Carc Dose (mg/kg-day)	Cancer Potency Factor (mg/kg-day)	Carcinogenic Risk
ı	4.800	10000	1.00E-03	0.25	350	6	0.001	15	2190	7.7E-04	6.0E-02	1.3E-02	25550	6.6E-05	0.0E+00	0.0E+00
rachloroethene	0.160	10000	4.50E-02	0.25	350	6	0.001	15	2190	1.2E-03	8.0E-03	1.4E-01	25550	1.9E-04	6.5E-02	1.2E-05
:hloroethene	0.098	10000	1.60E-02	0.25	350	6	0.001	15	2190	2.5E-04	4.8E-03	5.2E-02	25550	2.5E-04	1.4E-02	3.5E-06

alation

PC	Concentration (mg/l)	Concentration mg/kg/shwr	Exposure Duration years	Exposure Frequency shwr/year	Avg. Time noncarc. days	Avg. Time carc. days	Noncarc. Dose mg/kg/d	Carc. Dose mg/kg/d	Inhalation Reference Conc. mg/kg/d	Inhalation Potency Factor (mg/kg/d)^-1	Noncarc. Risk	Cancer Risk
for metals												
rachloroethene	0.31	1.8E-02	6	350	2190	25550	1.8E-02	1.5E-03	0.0E+00	2.0E-03	—	3.1E-06
:hloroethene	1.15	6.3E-02	6	350	2190	25550	6.1E-02	5.2E-03	0.0E+00	6.0E-03	—	3.1E-05

ıbsurface Soil Exposure Based Action Levels
TO-303 Site 36, Camp Geiger Area Dump
ıasibility Study
CB, Camp Lejeune, North Carolina
ıture Residential Child

		Noncarcinogenic Risk =		1.0E+00
OPC	Action Level (mg/kg	Ingestion	Dermal Contact	Inhalation
›n	23,000	9.8E-01	5.6E-02	NA

:tion Level (mg/kg) = (C ingestion + C dermal contact + C inhalation)

ingestion (mg/kg) = TR or HI * BW * ATc or ATnc * DY / EF * ED * IR * CSF or 1/RfD
dermal contact (mg/kg) = TR or HI * BW * ATc or ATnc * DY / SA * AF * ABS * EF * ED * CF * CSF or 1/RfD
inhalation (mg/kg) = Not applicable for iron in subsurface soil = 0

here:	Inputs
C = conc. in soil from ingestion exposure (mg/kg)	calculated
CF = conversion for kg to mg	1E-06
EF = child exposure frequency (days/yr)	350
ED = child exposure duration (yr)	6
IR = child soil ingestion rate (mg/day)	200
BW = child body weight (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = days per year (days/year)	365
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific

Where:	Inputs
C = conc. in soil from d. contact exposure(mg/kg)	calculated
CF = conversion factor (kg/mg)	1E-06
SA = child exposed skin surface area (cm2)	2300
AF = soil to skin adherence factor (mg/cm2)	1
ABS = fraction absorbed (unitless)	specific
EF = child exposure frequency (events/yr)	350
ED = child exposure duration (years)	6
TR = Total lifetime risk - carcinogenic effects	0.0001
HI = Hazard Index - noncarcinogenic effects	1

gestion

OPC	Concentration (mg/kg)	Exposure Frequency (days/yr) Child	Exposure Duration (yr) Child	Conversion Factor (kg/mg)	Ingestion Rate (mg/day) Child	Body Weight (kg) Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day) Child	Reference Dose (mg/kg/day)	Noncarcinogenic Risk Child
›n	23000	350	6	1E-06	200	15	2190	2.9E-01	3.00E-01	9.8E-01

ermal Contact

OPC	Concentration (mg/kg)	Conversion Factor (kg/mg)	Surface Area (cm2) Child	Adherence Factor (mg/cm2)	Fraction Absorbed (%)	Exposure Frequency (events/yr) Child	Exposure Duration (yrs) Child	Body Weight (kg) Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day) Child	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarcinogenic Risk Child
›n	23000	1E-06	2300	1	0.001	350	6	15	2190	3.4E-03	6.0E-02	5.6E-02

Fish and Crab Tissue Exp. Risk-Based Action Levels
CTO-303 Site 36, Camp Geiger Area Dump
Feasibility Study
MCB, Camp Lejeune, North Carolina
Currrent and Future Recreational Fisherman

	Action Level (mg/kg)		Ingestion Risk	
COPC	Noncarcinogenic	Carcinogenic	Noncarcinogenic	Carcinogenic
Fish Tissue				
Arsenic	0.56	0.3	1.0E+00	1.0E-04
Mercury	0.56	NA	1.0E+00	NA
Crab Tissue				
Arsenic	0.56	0.3	1.0E+00	1.0E-04

Action Level (mg/kg) = TR or HI * BW * ATc or ATnc * DY / IR * FI * EF * ED * CSF or 1/RfD

Where:	Inputs
C = conc. in fish or crab tissue from ingestion exposure (mg/kg)	calculated
IR = adult ingestion rate (kg/meal)	0.284
FI = fraction ingested from contaminated source (unitless)	1
EF = adult exposure frequency (meals/yr)	48
ED = adult exposure duration (years)	30
BW = adult body weight (kg)	70
ATc = averaging time for carcinogen (years)	70
ATnc = averaging time for noncarcinogen (years)	30
DY = days per year (days/yr)	365
CSF = cancer slope factor (mg/kg-day)-1	specific
RfD = reference dose (mg/kg-day)	specific

Where:	Inputs
TR = Total lifetime risk - carcinogenic effects	0.0001
HI = Hazard Index - noncarcinogenic effects	1

Fish Ingestion

COPC	Concentration Noncarcinogenic (mg/kg)	Concentration Carcinogenic (mg/kg)	Ingestion Rate (kg/meal) Adult	Fraction Ingestion (%)	Exposure Frequency (meals/yr) Adult	Exposure Duration (years) Adult	Body Weight (kg) Adult	Average Carc Time (days)	Carc Dose (mg/kg-day) Adult	Slope Factor (mg/kg-day)-1	Carcinogenic Risk Adult	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day) Adult	Reference Dose (mg/kg-day)	Noncarcinogenic Risk Adult
Arsenic	0.560	0.300	0.284	1	48	30	70	25550	6.9E-05	1.5E+00	1.0E-04	10950	3.0E-04	3.0E-04	1.0E+00
Mercury	0.560	NA	0.284	1	48	30	70	25550	0.0E+00	0.0E+00	0.0E+00	10950	3.0E-04	3.0E-04	1.0E+00
TOTAL															

Crab Tisue Ingestion

COPC	Concentration Noncarcinogenic (mg/kg)	Concentration Carcinogenic	Ingestion Rate (kg/meal) Adult	Fraction Ingestion (%)	Exposure Frequency (meals/yr) Adult	Exposure Duration (years) Adult	Body Weight (kg) Adult	Average Carc Time (days)	Carc Dose (mg/kg-day) Adult	Slope Factor (mg/kg-day)-1	Carcinogenic Risk Adult	Average Noncarc Time (days)	Noncarc Dose (mg/kg-day) Adult	Reference Dose (mg/kg-day)	Noncarcinogenic Risk Adult
Arsenic	0.56	0.300	0.284	1	48	30	70	25550	6.9E-05	1.5E+00	1.0E-04	10950	3.0E-04	3.0E-04	1.0E+00
TOTAL															

Baker

Baker Environmental, Inc.

Updated Human Health Risks - Sediment

Fisherman

SEDIMENT INGESTION EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
FISHERMAN

Intake from ingestion of sediment is calculated as follows:

Intake (mg/kg-day) = C * IR * CF * EF * ED/ BW * ATC or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in sediment (mg/kg)	
CF = conversion for kg to mg	1E-06
EF = exposure frequency (days/yr)	48
ED = exposure duration (yr)	30
IR = soil ingestion rate (mg/day)	100
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = days per year (days/year)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Exposure Frequency (days/yr)	Exposure Duration (yr)	Ingestion Rate (mg/day)	Conversio Factor (kg/mg)	Body Weight (kg)	Average Carc Tim (days)	Carc Dose (mg/kg/da	Slope Factor (mg/kg/day)-1	Carcinogenic Risk	Percent Carcinogenic Risk	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day)	Reference Dose (mg/kg/day)	Noncarcinogenic Risk	Percent Noncarcinogenic Risk
Tetrachloroethene	0.004	48	30	100	1E-06	70	25550	3.2E-10	5.20E-02	1.7E-11	0%	10950	7.5E-10	1.00E-02	7.5E-08	0%
Diethylphthalate	1.110	48	30	100	1E-06	70	25550	8.9E-08	0.00E+00	0.0E+00	0%	10950	2.1E-07	8.00E-01	2.6E-07	0%
Anthracene	0.046	48	30	100	1E-06	70	25550	3.7E-09	0.00E+00	0.0E+00	0%	10950	8.6E-09	3.00E-01	2.9E-08	0%
Di-n-butylphthalate	0.218	48	30	100	1E-06	70	25550	1.8E-08	0.00E+00	0.0E+00	0%	10950	4.1E-08	1.00E-01	4.1E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	48	30	100	1E-06	70	25550	2.6E-08	1.40E-02	3.7E-10	0%	10950	6.2E-08	2.00E-02	3.1E-06	0%
Dieldrin	0.052	48	30	100	1E-06	70	25550	4.2E-09	1.60E+01	6.7E-08	10%	10950	9.8E-09	5.00E-05	2.0E-04	1%
4,4'-DDE	1.200	48	30	100	1E-06	70	25550	9.7E-08	3.40E-01	3.3E-08	5%	10950	2.3E-07	0.00E+00	0.0E+00	0%
Endrin	0.007	48	30	100	1E-06	70	25550	5.3E-10	0.00E+00	0.0E+00	0%	10950	1.2E-09	3.00E-04	4.1E-06	0%
4,4'-DDD	1.140	48	30	100	1E-06	70	25550	9.2E-08	2.40E-01	2.2E-08	3%	10950	2.1E-07	0.00E+00	0.0E+00	0%
Endosulfan sulfate	0.003	48	30	100	1E-06	70	25550	2.4E-10	0.00E+00	0.0E+00	0%	10950	5.6E-10	6.00E-03	9.4E-08	0%
4,4'-DDT	0.046	48	30	100	1E-06	70	25550	3.7E-09	3.40E-01	1.3E-09	0%	10950	8.6E-09	5.00E-04	1.7E-05	0%
Endrin ketone	0.011	48	30	100	1E-06	70	25550	8.9E-10	0.00E+00	0.0E+00	0%	10950	2.1E-09	3.00E-04	6.9E-06	0%
Endrin aldehyde	0.008	48	30	100	1E-06	70	25550	6.1E-10	0.00E+00	0.0E+00	0%	10950	1.4E-09	3.00E-04	4.8E-06	0%
alpha-Chlordane	0.013	48	30	100	1E-06	70	25550	1.0E-09	1.30E+00	1.4E-09	0%	10950	2.4E-09	6.00E-05	4.1E-05	0%
Arsenic	2.410	48	30	100	1E-06	70	25550	1.9E-07	1.50E+00	2.9E-07	42%	10950	4.5E-07	3.00E-04	1.5E-03	8%
Chromium	23.060	48	30	100	1E-06	70	25550	1.9E-06	0.00E+00	0.0E+00	0%	10950	4.3E-06	5.00E-03	8.7E-04	5%
Aluminum	19389.170	48	30	100	1E-06	70	25550	1.6E-03	0.00E+00	0.0E+00	0%	10950	3.6E-03	1.00E+00	3.6E-03	19%
Barium	68.510	48	30	100	1E-06	70	25550	5.5E-06	0.00E+00	0.0E+00	0%	10950	1.3E-05	7.00E-02	1.8E-04	1%
Beryllium	0.810	48	30	100	1E-06	70	25550	6.5E-08	4.30E+00	2.8E-07	40%	10950	1.5E-07	5.00E-03	3.0E-05	0%
Cadmium (soil)	3.750	48	30	100	1E-06	70	25550	3.0E-07	0.00E+00	0.0E+00	0%	10950	7.0E-07	1.00E-03	7.0E-04	4%
Cobalt	4.200	48	30	100	1E-06	70	25550	3.4E-07	0.00E+00	0.0E+00	0%	10950	7.9E-07	6.00E-02	1.3E-05	0%
Copper	19.880	48	30	100	1E-06	70	25550	1.6E-06	0.00E+00	0.0E+00	0%	10950	3.7E-06	4.00E-02	9.3E-05	0%
Iron	11661.090	48	30	100	1E-06	70	25550	9.4E-04	0.00E+00	0.0E+00	0%	10950	2.2E-03	3.00E-01	7.3E-03	38%
Lead	3422.990	48	30	100	1E-06	70	25550	2.8E-04	0.00E+00	0.0E+00	0%	10950	6.4E-04	0.00E+00	0.0E+00	0%
Manganese (soil)	45.170	48	30	100	1E-06	70	25550	3.6E-06	0.00E+00	0.0E+00	0%	10950	8.5E-06	1.40E-01	6.1E-05	0%
Mercury	0.660	48	30	100	1E-06	70	25550	5.3E-08	0.00E+00	0.0E+00	0%	10950	1.2E-07	3.00E-04	4.1E-04	2%
Nickel	25.810	48	30	100	1E-06	70	25550	2.1E-06	0.00E+00	0.0E+00	0%	10950	4.8E-06	2.00E-02	2.4E-04	1%
Selenium	0.710	48	30	100	1E-06	70	25550	5.7E-08	0.00E+00	0.0E+00	0%	10950	1.3E-07	5.00E-03	2.7E-05	0%
Thallium	0.650	48	30	100	1E-06	70	25550	5.2E-08	0.00E+00	0.0E+00	0%	10950	1.2E-07	8.00E-05	1.5E-03	8%
Vanadium	83.120	48	30	100	1E-06	70	25550	6.7E-06	0.00E+00	0.0E+00	0%	10950	1.6E-05	7.00E-03	2.2E-03	12%
Zinc	140.000	48	30	100	1E-06	70	25550	1.1E-05	0.00E+00	0.0E+00	0%	10950	2.6E-05	3.00E-01	8.8E-05	0%
TOTAL										7.0E-07					1.9E-02	

SEDIMENT DERMAL CONTACT EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
FISHERMAN

The intake from dermal contact to sediment is calculted as follows:

Intake (mg/kg-day) = C * CF * SA * AF * Abs * EF * ED/BW * ATc or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in soil (mg/kg)	
CF = conversion factor (kg/mg)	1.00E-06
SA = exposed skin surface area (cm2)	5800
AF = sediment to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
EF = exposure frequency (events/yr)	48
ED = expsosure duration (years)	30
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = day per year (day/yr)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	ABS Factor (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Carc Time (days)	Carc Dose (mg/kg/day)	Dermal Adjust Slope Factor (mg/kg-day)-1	Carcinogenic Risk	Percent Carcinogenic Risk	Average Noncarc Tim (days)	Noncarc Dose (mg/kg/day)	Dermally-Adjusted Reference Dose (mg/kg-day)	Noncarcinogeni Risk	Percent Noncarcinogeni Risk
Tetrachloroethene	0.004	1E-06	5800	1	0.01	48	30	70	25550	1.9E-10	6.50E-02	1.2E-11	0%	10950	4.4E-10	8.00E-03	5.4E-08	0%
Diethylphthalate	1.110	1E-06	5800	1	0.01	48	30	70	25550	5.2E-08	0.00E+00	0.0E+00	0%	10950	1.2E-07	4.00E-01	3.0E-07	0%
Anthracene	0.046	1E-06	5800	1	0.01	48	30	70	25550	2.1E-09	0.00E+00	0.0E+00	0%	10950	5.0E-09	1.50E-01	3.3E-08	0%
Di-n-butylphthalate	0.218	1E-06	5800	1	0.01	48	30	70	25550	1.0E-08	0.00E+00	0.0E+00	0%	10950	2.4E-08	5.00E-02	4.8E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	1E-06	5800	1	0.01	48	30	70	25550	1.5E-08	2.80E-02	4.3E-10	0%	10950	3.6E-08	1.00E-02	3.6E-06	0%
Dieldrin	0.052	1E-06	5800	1	0.01	48	30	70	25550	2.4E-09	3.20E+01	7.8E-08	25%	10950	5.7E-09	2.50E-05	2.3E-04	4%
4,4'-DDE	1.200	1E-06	5800	1	0.01	48	30	70	25550	5.6E-08	6.80E-01	3.8E-08	12%	10950	1.3E-07	0.00E+00	0.0E+00	0%
Endrin	0.007	1E-06	5800	1	0.01	48	30	70	25550	3.1E-10	0.00E+00	0.0E+00	0%	10950	7.2E-10	1.50E-04	4.8E-06	0%
4,4'-DDD	1.140	1E-06	5800	1	0.01	48	30	70	25550	5.3E-08	4.80E-01	2.6E-08	8%	10950	1.2E-07	0.00E+00	0.0E+00	0%
Endosulfan sulfate	0.003	1E-06	5800	1	0.01	48	30	70	25550	1.4E-10	0.00E+00	0.0E+00	0%	10950	3.3E-10	3.00E-03	1.1E-07	0%
4,4'-DDT	0.046	1E-06	5800	1	0.01	48	30	70	25550	2.1E-09	6.80E-01	1.5E-09	0%	10950	5.0E-09	2.50E-04	2.0E-05	0%
Endrin ketone	0.011	1E-06	5800	1	0.01	48	30	70	25550	5.1E-10	0.00E+00	0.0E+00	0%	10950	1.2E-09	1.50E-04	8.0E-06	0%
Endrin aldehyde	0.008	1E-06	5800	1	0.01	48	30	70	25550	3.5E-10	0.00E+00	0.0E+00	0%	10950	8.3E-10	1.50E-04	5.5E-06	0%
alpha-Chlordane	0.013	1E-06	5800	1	0.01	48	30	70	25550	6.1E-10	2.60E+00	1.6E-09	1%	10950	1.4E-09	3.00E-05	4.7E-05	1%
Aluminum	19389.170	1E-06	5800	1	0.001	48	30	70	25550	9.1E-05	0.00E+00	0.0E+00	0%	10950	2.1E-04	2.00E-01	1.1E-03	18%
Arsenic	2.41	1E-06	5800	1	0.001	48	30	70	25550	1.1E-08	7.50E+00	8.4E-08	27%	10950	2.6E-08	6.00E-05	4.4E-04	8%
Chromium	23.06	1E-06	5800	1	0.001	48	30	70	25550	1.1E-07	0.00E+00	0.0E+00	0%	10950	2.5E-07	1.00E-03	2.5E-04	4%
Barium	68.510	1E-06	5800	1	0.001	48	30	70	25550	3.2E-07	0.00E+00	0.0E+00	0%	10950	7.5E-07	1.40E-02	5.3E-05	1%
Beryllium	0.810	1E-06	5800	1	0.001	48	30	70	25550	3.8E-09	2.15E+01	8.1E-08	26%	10950	8.8E-09	1.00E-03	8.8E-06	0%
Cadmium (soil)	3.750	1E-06	5800	1	0.001	48	30	70	25550	1.8E-08	0.00E+00	0.0E+00	0%	10950	4.1E-08	2.00E-04	2.0E-04	4%
Cobalt	4.200	1E-06	5800	1	0.001	48	30	70	25550	2.0E-08	0.00E+00	0.0E+00	0%	10950	4.6E-08	1.20E-02	3.8E-06	0%
Copper	19.880	1E-06	5800	1	0.001	48	30	70	25550	9.3E-08	0.00E+00	0.0E+00	0%	10950	2.2E-07	8.00E-03	2.7E-05	0%
Iron	11661.090	1E-06	5800	1	0.001	48	30	70	25550	5.4E-05	0.00E+00	0.0E+00	0%	10950	1.3E-04	6.00E-02	2.1E-03	36%
Lead	3422.990	1E-06	5800	1	0.001	48	30	70	25550	1.6E-05	0.00E+00	0.0E+00	0%	10950	3.7E-05	0.00E+00	0.0E+00	0%
Manganese (soil)	45.170	1E-06	5800	1	0.001	48	30	70	25550	2.1E-07	0.00E+00	0.0E+00	0%	10950	4.9E-07	2.80E-02	1.8E-05	0%
Mercury	0.660	1E-06	5800	1	0.001	48	30	70	25550	3.1E-09	0.00E+00	0.0E+00	0%	10950	7.2E-09	6.00E-05	1.2E-04	2%
Nickel	25.810	1E-06	5800	1	0.001	48	30	70	25550	1.2E-07	0.00E+00	0.0E+00	0%	10950	2.8E-07	4.00E-03	7.0E-05	1%
Selenium	0.710	1E-06	5800	1	0.001	48	30	70	25550	3.3E-09	0.00E+00	0.0E+00	0%	10950	7.7E-09	1.00E-03	7.7E-06	0%
Thallium	0.650	1E-06	5800	1	0.001	48	30	70	25550	3.0E-09	0.00E+00	0.0E+00	0%	10950	7.1E-09	1.60E-05	4.4E-04	8%
Vanadium	83.120	1E-06	5800	1	0.001	48	30	70	25550	3.9E-07	0.00E+00	0.0E+00	0%	10950	9.1E-07	1.40E-03	6.5E-04	11%
Zinc	140.000	1E-06	5800	1	0.001	48	30	70	25550	6.5E-07	0.00E+00	0.0E+00	0%	10950	1.5E-06	6.00E-02	2.5E-05	0%
TOTAL												3.1E-07					5.8E-03	

Baker

Baker Environmental, Inc.

Updated Human Health Risks - Sediment

Residential Child

SEDIMENT INGESTION E[illegible] ASSESSMENT
OPERABLE UNIT NO. 6 (SI[illegible]
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
CURRENT AND FUTURE RESIDENTIAL CHILD

Intake from ingestion of sediment is calculated as follows:

Intake (mg/kg-day) = C * IR * CF * EF * ED/ BW * ATC or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in sediment (mg/kg)	
CF = conversion for kg to mg	1E-06
EF = exposure frequency for child (days/yr)	45
ED = exposure duration for child (yr)	6
IR = soil ingestion rate for child (mg/day)	200
BW = body weight for child (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = days per year (days/year)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Exposure Frequency (days/yr) Child	Exposure Duration (yr) Child	Ingestion Rate (mg/day) Child	Conversion Factor (kg/mg)	Body Weight (kg) Child	Average Carc Time (days)	Carc Dose (mg/kg/day) Child	Slope Factor (mg/kg/day)-1	Carcinogenic Risk Child	Percent Carcinogenic Risk Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day) Child	Reference Dose (mg/kg/day)	Noncarcinogenic Risk Child	Percent Noncarcinogenic Risk Child
Tetrachloroethene	0.004	45	6	200	1E-06	15	25550	5.6E-10	5.2E-02	2.9E-11	0%	2190	6.6E-09	1.0E-02	6.6E-07	0%
Diethylphthalate	1.110	45	6	200	1E-06	15	25550	1.6E-07	0.0E+00	0.0E+00	0%	2190	1.8E-06	8.0E-01	2.3E-06	0%
Anthracene	0.046	45	6	200	1E-06	15	25550	6.5E-09	0.0E+00	0.0E+00	0%	2190	7.6E-08	3.0E-01	2.5E-07	0%
Di-n-butylphthalate	0.218	45	6	200	1E-06	15	25550	3.1E-08	0.0E+00	0.0E+00	0%	2190	3.6E-07	1.0E-01	3.6E-06	0%
Bis(2-ethylhexyl)phthalat	0.328	45	6	200	1E-06	15	25550	4.6E-08	1.4E-02	6.5E-10	0%	2190	5.4E-07	2.0E-02	2.7E-05	0%
Dieldrin	0.052	45	6	200	1E-06	15	25550	7.3E-09	1.6E+01	1.2E-07	10%	2190	8.5E-08	5.0E-05	1.7E-03	1%
4,4'-DDE	1.200	45	6	200	1E-06	15	25550	1.7E-07	3.4E-01	5.7E-08	5%	2190	2.0E-06	0.0E+00	0.0E+00	0%
Endrin	0.007	45	6	200	1E-06	15	25550	9.3E-10	0.0E+00	0.0E+00	0%	2190	1.1E-08	3.0E-04	3.6E-05	0%
4,4'-DDD	1.140	45	6	200	1E-06	15	25550	1.6E-07	2.4E-01	3.9E-08	3%	2190	1.9E-06	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	45	6	200	1E-06	15	25550	4.2E-10	0.0E+00	0.0E+00	0%	2190	4.9E-09	6.0E-03	8.2E-07	0%
4,4'-DDT	0.046	45	6	200	1E-06	15	25550	6.5E-09	3.4E-01	2.2E-09	0%	2190	7.6E-08	5.0E-04	1.5E-04	0%
Endrin ketone	0.011	45	6	200	1E-06	15	25550	1.5E-09	0.0E+00	0.0E+00	0%	2190	1.8E-08	3.0E-04	6.0E-05	0%
Endrin aldehyde	0.008	45	6	200	1E-06	15	25550	1.1E-09	0.0E+00	0.0E+00	0%	2190	1.2E-08	3.0E-04	4.2E-05	0%
alpha-Chlordane	0.013	45	6	200	1E-06	15	25550	1.8E-09	1.3E+00	2.4E-09	0%	2190	2.1E-08	6.0E-05	3.6E-04	0%
Aluminum	19389.170	45	6	200	1E-06	15	25550	2.7E-03	0.0E+00	0.0E+00	0%	2190	3.2E-02	1.0E+00	3.2E-02	19%
Arsenic	2.410	45	6	200	1E-06	15	25550	3.4E-07	1.5E+00	5.1E-07	42%	2190	4.0E-06	3.0E-04	1.3E-02	8%
Chromium	23.060	45	6	200	1E-06	15	25550	3.2E-06	0.0E+00	0.0E+00	0%	2190	3.8E-05	5.0E-03	7.6E-03	5%
Barium	68.510	45	6	200	1E-06	15	25550	9.7E-06	0.0E+00	0.0E+00	0%	2190	1.1E-04	7.0E-02	1.6E-03	1%
Beryllium	0.810	45	6	200	1E-06	15	25550	1.1E-07	4.3E+00	4.9E-07	40%	2190	1.3E-06	5.0E-03	2.7E-04	0%
Cadmium (soil)	3.750	45	6	200	1E-06	15	25550	5.3E-07	0.0E+00	0.0E+00	0%	2190	6.2E-06	1.0E-03	6.2E-03	4%
Cobalt	4.200	45	6	200	1E-06	15	25550	5.9E-07	0.0E+00	0.0E+00	0%	2190	6.9E-06	6.0E-02	1.2E-04	0%
Copper	19.880	45	6	200	1E-06	15	25550	2.8E-06	0.0E+00	0.0E+00	0%	2190	3.3E-05	4.0E-02	8.2E-04	0%
Iron	11661.090	45	6	200	1E-06	15	25550	1.6E-03	0.0E+00	0.0E+00	0%	2190	1.9E-02	3.0E-01	6.4E-02	38%
Lead	3422.990	45	6	200	1E-06	15	25550	4.8E-04	0.0E+00	0.0E+00	0%	2190	5.6E-03	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	45	6	200	1E-06	15	25550	6.4E-06	0.0E+00	0.0E+00	0%	2190	7.4E-05	1.4E-01	5.3E-04	0%
Mercury	0.660	45	6	200	1E-06	15	25550	9.3E-08	0.0E+00	0.0E+00	0%	2190	1.1E-06	3.0E-04	3.6E-03	2%
Nickel	25.810	45	6	200	1E-06	15	25550	3.6E-06	0.0E+00	0.0E+00	0%	2190	4.2E-05	2.0E-02	2.1E-03	1%
Selenium	0.710	45	6	200	1E-06	15	25550	1.0E-07	0.0E+00	0.0E+00	0%	2190	1.2E-06	5.0E-03	2.3E-04	0%
Thallium	0.650	45	6	200	1E-06	15	25550	9.2E-08	0.0E+00	0.0E+00	0%	2190	1.1E-06	8.0E-05	1.3E-02	8%
Vanadium	83.120	45	6	200	1E-06	15	25550	1.2E-05	0.0E+00	0.0E+00	0%	2190	1.4E-04	7.0E-03	2.0E-02	12%
Zinc	140.000	45	6	200	1E-06	15	25550	2.0E-05	0.0E+00	0.0E+00	0%	2190	2.3E-04	3.0E-01	7.7E-04	0%
TOTAL										1.2E-06					1.7E-01	

SEDIMENT DERMAL CON[illegible]POSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SI[illegible]
REMEDIAL INVESTIGATION C[illegible]O-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
CURRENT AND FUTURE RESIDENTIAL CHILD

The intake from dermal contact to sediment is calculated as follows:

Intake (mg/kg-day) = C * CF * SA * AF * Abs * EF * ED/BW * ATc or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in soil (mg/kg)	
CF = conversion factor (kg/mg)	1.00E-06
SA = child exposed skin surface area (cm2)	2300
AF = sediment to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
EF = child exposure frequency (events/yr)	45
ED = child expsosure duration (years)	6
BW = child body weight (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = day per year (day/yr)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration Carcinogen (mg/kg)	Conversion Factor (kg/mg)	Surface Area (cm2) Child	Adherence Factor (mg/cm2)	ABS Factor (%)	Exposure Frequency (events/yr) Child	Exposure Duration (yrs) Child	Body Weight (kg) Child	Average Carc Time (days)	Carc Dose (mg/kg/day) Child	Dermal Adjust. Slope Factor (mg/kg-day)-1	Carcinogenic Risk Child	Percent Carcinogenic Risk Child	Average Noncarc Tim (days)	Noncarc Dose (mg/kg/day) Child	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarcinogenic Risk Child	Percent Noncarcinogenic Risk Child
Tetrachloroethene	0.004	1E-06	2300	1	0.01	45	6	15	25550	6.5E-11	6.5E-02	4.2E-12	0%	2190	7.6E-10	8.0E-03	9.5E-08	0%
Diethylphthalate	1.110	1E-06	2300	1	0.01	45	6	15	25550	1.8E-08	0.0E+00	0.0E+00	0%	2190	2.1E-07	4.0E-01	5.2E-07	0%
Anthracene	0.046	1E-06	2300	1	0.01	45	6	15	25550	7.5E-10	0.0E+00	0.0E+00	0%	2190	8.7E-09	1.5E-01	5.8E-08	0%
Di-n-butylphthalate	0.218	1E-06	2300	1	0.01	45	6	15	25550	3.5E-09	0.0E+00	0.0E+00	0%	2190	4.1E-08	5.0E-02	8.2E-07	0%
Bis(2-ethylhexyl)phthalat	0.328	1E-06	2300	1	0.01	45	6	15	25550	5.3E-09	2.8E-02	1.5E-10	0%	2190	6.2E-08	1.0E-02	6.2E-06	0%
Dieldrin	0.052	1E-06	2300	1	0.01	45	6	15	25550	8.4E-10	3.2E+01	2.7E-08	25%	2190	9.8E-09	2.5E-05	3.9E-04	4%
4,4'-DDE	1.200	1E-06	2300	1	0.01	45	6	15	25550	1.9E-08	6.8E-01	1.3E-08	12%	2190	2.3E-07	0.0E+00	0.0E+00	0%
Endrin	0.007	1E-06	2300	1	0.01	45	6	15	25550	1.1E-10	0.0E+00	0.0E+00	0%	2190	1.2E-09	1.5E-04	8.3E-06	0%
4,4'-DDD	1.140	1E-06	2300	1	0.01	45	6	15	25550	1.8E-08	4.8E-01	8.9E-09	8%	2190	2.2E-07	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	1E-06	2300	1	0.01	45	6	15	25550	4.9E-11	0.0E+00	0.0E+00	0%	2190	5.7E-10	3.0E-03	1.9E-07	0%
4,4'-DDT	0.046	1E-06	2300	1	0.01	45	6	15	25550	7.5E-10	6.8E-01	5.1E-10	0%	2190	8.7E-09	2.5E-04	3.5E-05	0%
Endrin ketone	0.011	1E-06	2300	1	0.01	45	6	15	25550	1.8E-10	0.0E+00	0.0E+00	0%	2190	2.1E-09	1.5E-04	1.4E-05	0%
Endrin aldehyde	0.008	1E-06	2300	1	0.01	45	6	15	25550	1.2E-10	0.0E+00	0.0E+00	0%	2190	1.4E-09	1.5E-04	9.6E-06	0%
alpha-Chlordane	0.013	1E-06	2300	1	0.01	45	6	15	25550	2.1E-10	2.6E+00	5.5E-10	1%	2190	2.5E-09	3.0E-05	8.2E-05	1%
Aluminum	19389.170	1E-06	2300	1	0.001	45	6	15	25550	3.1E-05	0.0E+00	0.0E+00	0%	2190	3.7E-04	2.0E-01	1.8E-03	18%
Arsenic	2.410	1E-06	2300	1	0.001	45	6	15	25550	3.9E-09	7.5E+00	2.9E-08	27%	2190	4.6E-08	6.0E-05	7.6E-04	8%
Chromium	23.060	1E-06	2300	1	0.001	45	6	15	25550	3.7E-08	0.0E+00	0.0E+00	0%	2190	4.4E-07	1.0E-03	4.4E-04	4%
Barium	68.510	1E-06	2300	1	0.001	45	6	15	25550	1.1E-07	0.0E+00	0.0E+00	0%	2190	1.3E-06	1.4E-02	9.3E-05	1%
Beryllium	0.810	1E-06	2300	1	0.001	45	6	15	25550	1.3E-09	2.1E+01	2.8E-08	26%	2190	1.5E-08	1.0E-03	1.5E-05	0%
Cadmium (soil)	3.750	1E-06	2300	1	0.001	45	6	15	25550	6.1E-09	0.0E+00	0.0E+00	0%	2190	7.1E-08	2.0E-04	3.5E-04	4%
Cobalt	4.200	1E-06	2300	1	0.001	45	6	15	25550	6.8E-09	0.0E+00	0.0E+00	0%	2190	7.9E-08	1.2E-02	6.6E-06	0%
Copper	19.880	1E-06	2300	1	0.001	45	6	15	25550	3.2E-08	0.0E+00	0.0E+00	0%	2190	3.8E-07	8.0E-03	4.7E-05	0%
Iron	11661.090	1E-06	2300	1	0.001	45	6	15	25550	1.9E-05	0.0E+00	0.0E+00	0%	2190	2.2E-04	6.0E-02	3.7E-03	36%
Lead	3422.990	1E-06	2300	1	0.001	45	6	15	25550	5.5E-06	0.0E+00	0.0E+00	0%	2190	6.5E-05	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	1E-06	2300	1	0.001	45	6	15	25550	7.3E-08	0.0E+00	0.0E+00	0%	2190	8.5E-07	2.8E-02	3.0E-05	0%
Mercury	0.860	1E-06	2300	1	0.001	45	6	15	25550	1.1E-09	0.0E+00	0.0E+00	0%	2190	1.2E-08	6.0E-05	2.1E-04	2%
Nickel	25.810	1E-06	2300	1	0.001	45	6	15	25550	4.2E-08	0.0E+00	0.0E+00	0%	2190	4.9E-07	4.0E-03	1.2E-04	1%
Selenium	0.710	1E-06	2300	1	0.001	45	6	15	25550	1.2E-09	0.0E+00	0.0E+00	0%	2190	1.3E-08	1.0E-03	1.3E-05	0%
Thallium	0.650	1E-06	2300	1	0.001	45	6	15	25550	1.1E-09	0.0E+00	0.0E+00	0%	2190	1.2E-08	1.6E-05	7.7E-04	8%
Vanadium	83.120	1E-06	2300	1	0.001	45	6	15	25550	1.3E-07	0.0E+00	0.0E+00	0%	2190	1.6E-06	1.4E-03	1.1E-03	11%
Zinc	140.000	1E-06	2300	1	0.001	45	6	15	25550	2.3E-07	0.0E+00	0.0E+00	0%	2190	2.6E-06	6.0E-02	4.4E-05	0%
TOTAL												1.1E-07					1.0E-02	

Baker

Baker Environmental, Inc.

Updated Human Health Risks - Sediment

Child Trespasser

SEDIMENT INGESTION EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
CHILD TRESPASSER

Intake from ingestion of sediment is calculated as follows:

Intake (mg/kg-day) = C * IR * CF * EF * ED/ BW * ATC or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in sediment (mg/kg)	
CF = conversion for kg to mg	1E-06
EF = exposure frequency for child (days/yr)	45
ED = exposure duration for child (yr)	6
IR = sediment ingestion rate for child (mg/day)	200
BW = body weight for child (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = days per year (days/year)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Exposure Frequency (days/yr) Child	Exposure Duration (yr) Child	Ingestion Rate (mg/day) Child	Conversio Factor (kg/mg)	Body Weight (kg) Child	Average Carc Tim (days)	Carc Dose (mg/kg/day) Child	Slope Factor (mg/kg/day)-1	Carcinogenic Risk Child	Percent Carcinogenic Risk Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day) Child	Reference Dose (mg/kg/day)	Noncarcinogenic Risk Child	Percent Noncarcinogenic Risk Child
Tetrachloroethene	0.004	45	6	200	1E-06	15	25550	5.6E-10	5.2E-02	2.9E-11	0%	2190	6.6E-09	1.0E-02	6.6E-07	0%
Diethylphthalate	1.110	45	6	200	1E-06	15	25550	1.6E-07	0.0E+00	0.0E+00	0%	2190	1.8E-06	8.0E-01	2.3E-06	0%
Anthracene	0.046	45	6	200	1E-06	15	25550	6.5E-09	0.0E+00	0.0E+00	0%	2190	7.6E-08	3.0E-01	2.5E-07	0%
Di-n-butylphthalate	0.218	45	6	200	1E-06	15	25550	3.1E-08	0.0E+00	0.0E+00	0%	2190	3.6E-07	1.0E-01	3.6E-06	0%
Bis(2-ethylhexyl)phthalate	0.328	45	6	200	1E-06	15	25550	4.6E-08	1.4E-02	6.5E-10	0%	2190	5.4E-07	2.0E-02	2.7E-05	0%
Dieldrin	0.052	45	6	200	1E-06	15	25550	7.3E-09	1.6E+01	1.2E-07	10%	2190	8.5E-08	5.0E-05	1.7E-03	1%
4,4'-DDE	1.200	45	6	200	1E-06	15	25550	1.7E-07	3.4E-01	5.7E-08	5%	2190	2.0E-06	0.0E+00	0.0E+00	0%
Endrin	0.007	45	6	200	1E-06	15	25550	9.3E-10	0.0E+00	0.0E+00	0%	2190	1.1E-08	3.0E-04	3.6E-05	0%
4,4'-DDD	1.140	45	6	200	1E-06	15	25550	1.6E-07	2.4E-01	3.9E-08	3%	2190	1.9E-06	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	45	6	200	1E-06	15	25550	4.2E-10	0.0E+00	0.0E+00	0%	2190	4.9E-09	6.0E-03	8.2E-07	0%
4,4'-DDT	0.046	45	6	200	1E-06	15	25550	6.5E-09	3.4E-01	2.2E-09	0%	2190	7.6E-08	5.0E-04	1.5E-04	0%
Endrin ketone	0.011	45	6	200	1E-06	15	25550	1.5E-09	0.0E+00	0.0E+00	0%	2190	1.8E-08	3.0E-04	6.0E-05	0%
Endrin aldehyde	0.008	45	6	200	1E-06	15	25550	1.1E-09	0.0E+00	0.0E+00	0%	2190	1.2E-08	3.0E-04	4.2E-05	0%
alpha-Chlordane	0.013	45	6	200	1E-06	15	25550	1.8E-09	1.3E+00	2.4E-09	0%	2190	2.1E-08	6.0E-05	3.6E-04	0%
Aluminum	19389.170	45	6	200	1E-06	15	25550	2.7E-03	0.0E+00	0.0E+00	0%	2190	3.2E-02	1.0E+00	3.2E-02	19%
Arsenic	2.410	45	6	200	1E-06	15	25550	3.4E-07	1.5E+00	5.1E-07	42%	2190	4.0E-06	3.0E-04	1.3E-02	8%
Chromium	23.060	45	6	200	1E-06	15	25550	3.2E-06	0.0E+00	0.0E+00	0%	2190	3.8E-05	5.0E-03	7.6E-03	5%
Barium	68.510	45	6	200	1E-06	15	25550	9.7E-06	0.0E+00	0.0E+00	0%	2190	1.1E-04	7.0E-02	1.6E-03	1%
Beryllium	0.810	45	6	200	1E-06	15	25550	1.1E-07	4.3E+00	4.9E-07	40%	2190	1.3E-06	5.0E-03	2.7E-04	0%
Cadmium (soil)	3.750	45	6	200	1E-06	15	25550	5.3E-07	0.0E+00	0.0E+00	0%	2190	6.2E-06	1.0E-03	6.2E-03	4%
Cobalt	4.200	45	6	200	1E-06	15	25550	5.9E-07	0.0E+00	0.0E+00	0%	2190	6.9E-06	6.0E-02	1.2E-04	0%
Copper	19.880	45	6	200	1E-06	15	25550	2.8E-06	0.0E+00	0.0E+00	0%	2190	3.3E-05	4.0E-02	8.2E-04	0%
Iron	11661.090	45	6	200	1E-06	15	25550	1.6E-03	0.0E+00	0.0E+00	0%	2190	1.9E-02	3.0E-01	6.4E-02	38%
Lead	3422.990	45	6	200	1E-06	15	25550	4.8E-04	0.0E+00	0.0E+00	0%	2190	5.6E-03	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	45	6	200	1E-06	15	25550	6.4E-06	0.0E+00	0.0E+00	0%	2190	7.4E-05	1.4E-01	5.3E-04	0%
Mercury	0.660	45	6	200	1E-06	15	25550	9.3E-08	0.0E+00	0.0E+00	0%	2190	1.1E-06	3.0E-04	3.6E-03	2%
Nickel	25.810	45	6	200	1E-06	15	25550	3.6E-06	0.0E+00	0.0E+00	0%	2190	4.2E-05	2.0E-02	2.1E-03	1%
Selenium	0.710	45	6	200	1E-06	15	25550	1.0E-07	0.0E+00	0.0E+00	0%	2190	1.2E-06	5.0E-03	2.3E-04	0%
Thallium	0.650	45	6	200	1E-06	15	25550	9.2E-08	0.0E+00	0.0E+00	0%	2190	1.1E-06	8.0E-05	1.3E-02	8%
Vanadium	83.120	45	6	200	1E-06	15	25550	1.2E-05	0.0E+00	0.0E+00	0%	2190	1.4E-04	7.0E-03	2.0E-02	12%
Zinc	140.000	45	6	200	1E-06	15	25550	2.0E-05	0.0E+00	0.0E+00	0%	2190	2.3E-04	3.0E-01	7.7E-04	0%
TOTAL										1.2E-06					1.7E-01	

SEDIMENT DERMAL CONTACT EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
CHILD TRESPASSER

The intake from dermal contact to sediment is calculated as follows:

Intake (mg/kg-day) = C * CF * SA * AF * Abs * EF * ED/BW * ATc or ATnc * DY

Risk = Intake *.CSF or /RfD

Where:	INPUTS
C = contaminant concentration in soil (mg/kg)	Specific
CF = conversion factor (kg/mg)	1.00E-06
SA = child exposed skin surface area (cm2)	2000
AF = sediment to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
EF = child exposure frequency (events/yr)	45
ED = child expsosure duration (years)	6
BW = child body weight (kg)	15
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	6
DY = day per year (day/yr)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration Carcinogen (mg/kg)	Conversion Factor (kg/mg)	Surface Area (cm2) Child	Adherenc Factor (mg/cm2)	ABS Factor (%)	Exposure Frequenc (events/yr Child	Exposure Duration (yrs) Child	Body Weight (kg) Child	Average Carc Time (days)	Carc Dose (mg/kg/day) Child	Dermal Adjust Slope Factor (mg/kg-day)-1	Carcinogenic Risk Child	Percent Carcinogenic Risk Child	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day) Child	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarcinogenic Risk Child	Percent Noncarcinogenic Risk Child
Tetrachloroethene	0.004	1E-06	2000	1	0.01	45	6	15	25550	5.6E-11	6.5E-02	3.7E-12	0%	2190	6.6E-10	8.0E-03	8.2E-08	0%
Diethylphthalate	1.110	1E-06	2000	1	0.01	45	6	15	25550	1.6E-08	0.0E+00	0.0E+00	0%	2190	1.8E-07	4.0E-01	4.6E-07	0%
Anthracene	0.046	1E-06	2000	1	0.01	45	6	15	25550	6.5E-10	0.0E+00	0.0E+00	0%	2190	7.6E-09	1.5E-01	5.0E-08	0%
Di-n-butylphthalate	0.218	1E-06	2000	1	0.01	45	6	15	25550	3.1E-09	0.0E+00	0.0E+00	0%	2190	3.6E-08	5.0E-02	7.2E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	1E-06	2000	1	0.01	45	6	15	25550	4.6E-09	2.8E-02	1.3E-10	0%	2190	5.4E-08	1.0E-02	5.4E-06	0%
Dieldrin	0.052	1E-06	2000	1	0.01	45	6	15	25550	7.3E-10	3.2E+01	2.3E-08	25%	2190	8.5E-09	2.5E-05	3.4E-04	4%
4,4'-DDE	1.200	1E-06	2000	1	0.01	45	6	15	25550	1.7E-08	6.8E-01	1.1E-08	12%	2190	2.0E-07	0.0E+00	0.0E+00	0%
Endrin	0.007	1E-06	2000	1	0.01	45	6	15	25550	9.3E-11	0.0E+00	0.0E+00	0%	2190	1.1E-09	1.5E-04	7.2E-06	0%
4,4'-DDD	1.140	1E-06	2000	1	0.01	45	6	15	25550	1.6E-08	4.8E-01	7.7E-09	8%	2190	1.9E-07	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	1E-06	2000	1	0.01	45	6	15	25550	4.2E-11	0.0E+00	0.0E+00	0%	2190	4.9E-10	3.0E-03	1.6E-07	0%
4,4'-DDT	0.046	1E-06	2000	1	0.01	45	6	15	25550	6.5E-10	6.8E-01	4.4E-10	0%	2190	7.6E-09	2.5E-04	3.0E-05	0%
Endrin ketone	0.011	1E-06	2000	1	0.01	45	6	15	25550	1.5E-10	0.0E+00	0.0E+00	0%	2190	1.8E-09	1.5E-04	1.2E-05	0%
Endrin aldehyde	0.008	1E-06	2000	1	0.01	45	6	15	25550	1.1E-10	0.0E+00	0.0E+00	0%	2190	1.2E-09	1.5E-04	8.3E-06	0%
alpha-Chlordane	0.013	1E-06	2000	1	0.01	45	6	15	25550	1.8E-10	2.6E+00	4.8E-10	1%	2190	2.1E-09	3.0E-05	7.1E-05	1%
Aluminum	19389.170	1E-06	2000	1	0.001	45	6	15	25550	2.7E-05	0.0E+00	0.0E+00	0%	2190	3.2E-04	2.0E-01	1.6E-03	18%
Arsenic	2.410	1E-06	2000	1	0.001	45	6	15	25550	3.4E-09	7.5E+00	2.5E-08	27%	2190	4.0E-08	6.0E-05	6.6E-04	8%
Chromium	23.060	1E-06	2000	1	0.001	45	6	15	25550	3.2E-08	0.0E+00	0.0E+00	0%	2190	3.8E-07	1.0E-03	3.8E-04	4%
Barium	68.510	1E-06	2000	1	0.001	45	6	15	25550	9.7E-08	0.0E+00	0.0E+00	0%	2190	1.1E-06	1.4E-02	8.0E-05	1%
Beryllium	0.810	1E-06	2000	1	0.001	45	6	15	25550	1.1E-09	2.1E+01	2.5E-08	26%	2190	1.3E-08	1.0E-03	1.3E-05	0%
Cadmium (soil)	3.750	1E-06	2000	1	0.001	45	6	15	25550	5.3E-09	0.0E+00	0.0E+00	0%	2190	6.2E-08	2.0E-04	3.1E-04	4%
Cobalt	4.200	1E-06	2000	1	0.001	45	6	15	25550	5.9E-09	0.0E+00	0.0E+00	0%	2190	6.9E-08	1.2E-02	5.8E-06	0%
Copper	19.880	1E-06	2000	1	0.001	45	6	15	25550	2.8E-08	0.0E+00	0.0E+00	0%	2190	3.3E-07	8.0E-03	4.1E-05	0%
Iron	11661.090	1E-06	2000	1	0.001	45	6	15	25550	1.6E-05	0.0E+00	0.0E+00	0%	2190	1.9E-04	6.0E-02	3.2E-03	36%
Lead	3422.990	1E-06	2000	1	0.001	45	6	15	25550	4.8E-06	0.0E+00	0.0E+00	0%	2190	5.6E-05	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	1E-06	2000	1	0.001	45	6	15	25550	6.4E-08	0.0E+00	0.0E+00	0%	2190	7.4E-07	2.8E-02	2.7E-05	0%
Mercury	0.660	1E-06	2000	1	0.001	45	6	15	25550	9.3E-10	0.0E+00	0.0E+00	0%	2190	1.1E-08	6.0E-05	1.8E-04	2%
Nickel	25.810	1E-06	2000	1	0.001	45	6	15	25550	3.6E-08	0.0E+00	0.0E+00	0%	2190	4.2E-07	4.0E-03	1.1E-04	1%
Selenium	0.710	1E-06	2000	1	0.001	45	6	15	25550	1.0E-09	0.0E+00	0.0E+00	0%	2190	1.2E-08	1.0E-03	1.2E-05	0%
Thallium	0.650	1E-06	2000	1	0.001	45	6	15	25550	9.2E-10	0.0E+00	0.0E+00	0%	2190	1.1E-08	1.6E-05	6.7E-04	8%
Vanadium	83.120	1E-06	2000	1	0.001	45	6	15	25550	1.2E-07	0.0E+00	0.0E+00	0%	2190	1.4E-06	1.4E-03	9.8E-04	11%
Zinc	140.000	1E-06	2000	1	0.001	45	6	15	25550	2.0E-07	0.0E+00	0.0E+00	0%	2190	2.3E-06	6.0E-02	3.8E-05	0%
TOTAL												9.4E-08					8.8E-03	

Baker

Baker Environmental, Inc.

Updated Human Health Risks - Sediment

Residential Adult

SEDIMENT INGESTION EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
CURRENT AND FUTURE RESIDENTIAL ADULT

Intake from ingestion of sediment is calculated as follows:

Intake (mg/kg-day) = C * IR * CF * EF * ED/ BW * ATC or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in sediment (mg/kg)	
CF = conversion for kg to mg	1E-06
EF = exposure frequency (days/yr)	45
ED = exposure duration (yr)	30
IR = soil ingestion rate (mg/day)	100
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = days per year (days/year)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Exposure Frequency (days/yr)	Exposure Duration (yr)	Ingestion Rate (mg/day)	Conversion Factor (kg/mg)	Body Weight (kg)	Average Carc Time (days)	Carc Dose (mg/kg/day)	Slope Factor (mg/kg/day)-1	Carcinogenic Risk	Percent Carcinogenic Risk	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day)	Reference Dose (mg/kg/day)	Noncarcinogenic Risk	Percent Noncarcinogenic Risk
Tetrachloroethene	0.004	45	30	100	1E-06	70	25550	3.0E-10	5.2E-02	1.6E-11	0%	10950	7.0E-10	1.0E-02	7.0E-08	0%
Diethylphthalate	1.110	45	30	100	1E-06	70	25550	8.4E-08	0.0E+00	0.0E+00	0%	10950	2.0E-07	8.0E-01	2.4E-07	0%
Anthracene	0.046	45	30	100	1E-06	70	25550	3.5E-09	0.0E+00	0.0E+00	0%	10950	8.1E-09	3.0E-01	2.7E-08	0%
Di-n-butylphthalate	0.218	45	30	100	1E-06	70	25550	1.6E-08	0.0E+00	0.0E+00	0%	10950	3.8E-08	1.0E-01	3.8E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	45	30	100	1E-06	70	25550	2.5E-08	1.4E-02	3.5E-10	0%	10950	5.8E-08	2.0E-02	2.9E-06	0%
Dieldrin	0.052	45	30	100	1E-06	70	25550	3.9E-09	1.6E+01	6.3E-08	10%	10950	9.2E-09	5.0E-05	1.8E-04	1%
4,4'-DDE	1.200	45	30	100	1E-06	70	25550	9.1E-08	3.4E-01	3.1E-08	5%	10950	2.1E-07	0.0E+00	0.0E+00	0%
Endrin	0.007	45	30	100	1E-06	70	25550	5.0E-10	0.0E+00	0.0E+00	0%	10950	1.2E-09	3.0E-04	3.9E-06	0%
4,4'-DDD	1.140	45	30	100	1E-06	70	25550	8.6E-08	2.4E-01	2.1E-08	3%	10950	2.0E-07	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	45	30	100	1E-06	70	25550	2.3E-10	0.0E+00	0.0E+00	0%	10950	5.3E-10	6.0E-03	8.8E-08	0%
4,4'-DDT	0.046	45	30	100	1E-06	70	25550	3.5E-09	3.4E-01	1.2E-09	0%	10950	8.1E-09	5.0E-04	1.6E-05	0%
Endrin ketone	0.011	45	30	100	1E-06	70	25550	8.3E-10	0.0E+00	0.0E+00	0%	10950	1.9E-09	3.0E-04	6.5E-06	0%
Endrin aldehyde	0.008	45	30	100	1E-06	70	25550	5.7E-10	0.0E+00	0.0E+00	0%	10950	1.3E-09	3.0E-04	4.5E-06	0%
alpha-Chlordane	0.013	45	30	100	1E-06	70	25550	9.8E-10	1.3E+00	1.3E-09	0%	10950	2.3E-09	6.0E-05	3.8E-05	0%
Aluminum	19389.170	45	30	100	1E-06	70	25550	1.5E-03	0.0E+00	0.0E+00	0%	10950	3.4E-03	1.0E+00	3.4E-03	19%
Arsenic	2.410	45	30	100	1E-06	70	25550	1.8E-07	1.5E+00	2.7E-07	42%	10950	4.2E-07	3.0E-04	1.4E-03	8%
Chromium	23.060	45	30	100	1E-06	70	25550	1.7E-06	0.0E+00	0.0E+00	0%	10950	4.1E-06	5.0E-03	8.1E-04	5%
Barium	68.510	45	30	100	1E-06	70	25550	5.2E-06	0.0E+00	0.0E+00	0%	10950	1.2E-05	7.0E-02	1.7E-04	1%
Beryllium	0.810	45	30	100	1E-06	70	25550	6.1E-08	4.3E+00	2.6E-07	40%	10950	1.4E-07	5.0E-03	2.9E-05	0%
Cadmium (soil)	3.750	45	30	100	1E-06	70	25550	2.8E-07	0.0E+00	0.0E+00	0%	10950	6.6E-07	1.0E-03	6.6E-04	4%
Cobalt	4.200	45	30	100	1E-06	70	25550	3.2E-07	0.0E+00	0.0E+00	0%	10950	7.4E-07	6.0E-02	1.2E-05	0%
Copper	19.880	45	30	100	1E-06	70	25550	1.5E-06	0.0E+00	0.0E+00	0%	10950	3.5E-06	4.0E-02	8.8E-05	0%
Iron	11681.090	45	30	100	1E-06	70	25550	8.8E-04	0.0E+00	0.0E+00	0%	10950	2.1E-03	3.0E-01	6.8E-03	38%
Lead	3422.990	45	30	100	1E-06	70	25550	2.6E-04	0.0E+00	0.0E+00	0%	10950	6.0E-04	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	45	30	100	1E-06	70	25550	3.4E-06	0.0E+00	0.0E+00	0%	10950	8.0E-06	1.4E-01	5.7E-05	0%
Mercury	0.660	45	30	100	1E-06	70	25550	5.0E-08	0.0E+00	0.0E+00	0%	10950	1.2E-07	3.0E-04	3.9E-04	2%
Nickel	25.810	45	30	100	1E-06	70	25550	1.9E-06	0.0E+00	0.0E+00	0%	10950	4.5E-06	2.0E-02	2.3E-04	1%
Selenium	0.710	45	30	100	1E-06	70	25550	5.4E-08	0.0E+00	0.0E+00	0%	10950	1.3E-07	5.0E-03	2.5E-05	0%
Thallium	0.650	45	30	100	1E-06	70	25550	4.9E-08	0.0E+00	0.0E+00	0%	10950	1.1E-07	8.0E-05	1.4E-03	8%
Vanadium	83.120	45	30	100	1E-06	70	25550	6.3E-06	0.0E+00	0.0E+00	0%	10950	1.5E-05	7.0E-03	2.1E-03	12%
Zinc	140.000	45	30	100	1E-06	70	25550	1.1E-05	0.0E+00	0.0E+00	0%	10950	2.5E-05	3.0E-01	8.2E-05	0%
TOTAL										6.5E-07					1.8E-02	

SEDIMENT DERMAL CONTACT EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
CURRENT AND FUTURE RESIDENTIAL ADULT

The intake from dermal contact to sediment is calculated as follows:

Intake (mg/kg-day) = C * CF * SA * AF * Abs * EF * ED/BW * ATc or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in soil (mg/kg)	
CF = conversion factor (kg/mg)	1.00E-06
SA = exposed skin surface area (cm2)	5800
AF = sediment to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
EF = exposure frequency (events/yr)	45
ED = exposure duration (years)	30
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = day per year (day/yr)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	ABS Factor (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Carc Time (days)	Carc Dose (mg/kg/day)	Dermal Adjust. Slope Factor (mg/kg-day)-1	Carcinogenic Risk	Percent Carcinogenic Risk	Average Noncarc Tim (days)	Noncarc Dose (mg/kg/day)	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarcinogenic Risk	Percent Noncarcinogeni Risk
Tetrachloroethene	0.004	1E-06	5800	1	0.01	45	30	70	25550	1.8E-10	6.5E-02	1.1E-11	0%	10950	4.1E-10	8.0E-03	5.1E-08	0%
Diethylphthalate	1.110	1E-06	5800	1	0.01	45	30	70	25550	4.9E-08	0.0E+00	0.0E+00	0%	10950	1.1E-07	4.0E-01	2.8E-07	0%
Anthracene	0.046	1E-06	5800	1	0.01	45	30	70	25550	2.0E-09	0.0E+00	0.0E+00	0%	10950	4.7E-09	1.5E-01	3.1E-08	0%
Di-n-butylphthalate	0.218	1E-06	5800	1	0.01	45	30	70	25550	9.5E-09	0.0E+00	0.0E+00	0%	10950	2.2E-08	5.0E-02	4.5E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	1E-06	5800	1	0.01	45	30	70	25550	1.4E-08	2.8E-02	4.0E-10	0%	10950	3.4E-08	1.0E-02	3.4E-06	0%
Dieldrin	0.052	1E-06	5800	1	0.01	45	30	70	25550	2.3E-09	3.2E+01	7.3E-08	25%	10950	5.3E-09	2.5E-05	2.1E-04	4%
4,4'-DDE	1.200	1E-06	5800	1	0.01	45	30	70	25550	5.3E-08	6.8E-01	3.6E-08	12%	10950	1.2E-07	0.0E+00	0.0E+00	0%
Endrin	0.007	1E-06	5800	1	0.01	45	30	70	25550	2.9E-10	0.0E+00	0.0E+00	0%	10950	6.7E-10	1.5E-04	4.5E-06	0%
4,4'-DDD	1.140	1E-06	5800	1	0.01	45	30	70	25550	5.0E-08	4.8E-01	2.4E-08	8%	10950	1.2E-07	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	1E-06	5800	1	0.01	45	30	70	25550	1.3E-10	0.0E+00	0.0E+00	0%	10950	3.1E-10	3.0E-03	1.0E-07	0%
4,4'-DDT	0.046	1E-06	5800	1	0.01	45	30	70	25550	2.0E-09	6.8E-01	1.4E-09	0%	10950	4.7E-09	2.5E-04	1.9E-05	0%
Endrin ketone	0.011	1E-06	5800	1	0.01	45	30	70	25550	4.8E-10	0.0E+00	0.0E+00	0%	10950	1.1E-09	1.5E-04	7.5E-06	0%
Endrin aldehyde	0.008	1E-06	5800	1	0.01	45	30	70	25550	3.3E-10	0.0E+00	0.0E+00	0%	10950	7.8E-10	1.5E-04	5.2E-06	0%
alpha-Chlordane	0.013	1E-06	5800	1	0.01	45	30	70	25550	5.7E-10	2.6E+00	1.5E-09	1%	10950	1.3E-09	3.0E-05	4.4E-05	1%
Aluminum	19389.170	1E-06	5800	1	0.001	45	30	70	25550	8.5E-05	0.0E+00	0.0E+00	0%	10950	2.0E-04	2.0E-01	9.9E-04	18%
Arsenic	2.410	1E-06	5800	1	0.001	45	30	70	25550	1.1E-08	7.5E+00	7.9E-08	27%	10950	2.5E-08	6.0E-05	4.1E-04	8%
Chromium	23.060	1E-06	5800	1	0.001	45	30	70	25550	1.0E-07	0.0E+00	0.0E+00	0%	10950	2.4E-07	1.0E-03	2.4E-04	4%
Barium	68.510	1E-06	5800	1	0.001	45	30	70	25550	3.0E-07	0.0E+00	0.0E+00	0%	10950	7.0E-07	1.4E-02	5.0E-05	1%
Beryllium	0.810	1E-06	5800	1	0.001	45	30	70	25550	3.5E-09	2.1E+01	7.6E-08	26%	10950	8.3E-09	1.0E-03	8.3E-06	0%
Cadmium (soil)	3.750	1E-06	5800	1	0.001	45	30	70	25550	1.6E-08	0.0E+00	0.0E+00	0%	10950	3.8E-08	2.0E-04	1.9E-04	4%
Cobalt	4.200	1E-06	5800	1	0.001	45	30	70	25550	1.8E-08	0.0E+00	0.0E+00	0%	10950	4.3E-08	1.2E-02	3.6E-06	0%
Copper	19.880	1E-06	5800	1	0.001	45	30	70	25550	8.7E-08	0.0E+00	0.0E+00	0%	10950	2.0E-07	8.0E-03	2.5E-05	0%
Iron	11661.090	1E-06	5800	1	0.001	45	30	70	25550	5.1E-05	0.0E+00	0.0E+00	0%	10950	1.2E-04	6.0E-02	2.0E-03	36%
Lead	3422.990	1E-06	5800	1	0.001	45	30	70	25550	1.5E-05	0.0E+00	0.0E+00	0%	10950	3.5E-05	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	1E-06	5800	1	0.001	45	30	70	25550	2.0E-07	0.0E+00	0.0E+00	0%	10950	4.6E-07	2.8E-02	1.6E-05	0%
Mercury	0.660	1E-06	5800	1	0.001	45	30	70	25550	2.9E-09	0.0E+00	0.0E+00	0%	10950	6.7E-09	6.0E-05	1.1E-04	2%
Nickel	25.810	1E-06	5800	1	0.001	45	30	70	25550	1.1E-07	0.0E+00	0.0E+00	0%	10950	2.6E-07	4.0E-03	6.6E-05	1%
Selenium	0.710	1E-06	5800	1	0.001	45	30	70	25550	3.1E-09	0.0E+00	0.0E+00	0%	10950	7.3E-09	1.0E-03	7.3E-06	0%
Thallium	0.650	1E-06	5800	1	0.001	45	30	70	25550	2.8E-09	0.0E+00	0.0E+00	0%	10950	6.6E-09	1.6E-05	4.1E-04	8%
Vanadium	83.120	1E-06	5800	1	0.001	45	30	70	25550	3.6E-07	0.0E+00	0.0E+00	0%	10950	8.5E-07	1.4E-03	6.1E-04	11%
Zinc	140.000	1E-06	5800	1	0.001	45	30	70	25550	6.1E-07	0.0E+00	0.0E+00	0%	10950	1.4E-06	6.0E-02	2.4E-05	0%
TOTAL												2.9E-07					5.4E-03	

Baker

Baker Environmental, Inc.

Updated Human Health Risks - Sediment

Adult Trespasser

SEDIMENT INGESTION EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
ADULT TRESPASSER

Intake from ingestion of sediment is calculated as follows:

Intake (mg/kg-day) = C * IR * CF * EF * ED/ BW * ATC or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in sediment (mg/kg)	
CF = conversion for kg to mg	1E-06
EF = exposure frequency (days/yr)	45
ED = exposure duration (yr)	30
IR = soil ingestion rate (mg/day)	100
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = days per year (days/year)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Exposure Frequency (days/yr)	Exposure Duration (yr)	Ingestion Rate (mg/day)	Conversion Factor (kg/mg)	Body Weight (kg)	Average Carc Tim (days)	Carc Dose (mg/kg/day)	Slope Factor (mg/kg/day)-1	Carcinogeni Risk	Percent Carcinogenic Risk	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day)	Reference Dose (mg/kg/day)	Noncarcinogenic Risk	Percent Noncarcinogenic Risk
Tetrachloroethene	0.004	45	30	100	1E-06	70	25550	3.0E-10	5.2E-02	1.6E-11	0%	10950	7.0E-10	1.0E-02	7.0E-08	0%
Diethylphthalate	1.110	45	30	100	1E-06	70	25550	8.4E-08	0.0E+00	0.0E+00	0%	10950	2.0E-07	8.0E-01	2.4E-07	0%
Anthracene	0.046	45	30	100	1E-06	70	25550	3.5E-09	0.0E+00	0.0E+00	0%	10950	8.1E-09	3.0E-01	2.7E-08	0%
Di-n-butylphthalate	0.218	45	30	100	1E-06	70	25550	1.6E-08	0.0E+00	0.0E+00	0%	10950	3.8E-08	1.0E-01	3.8E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	45	30	100	1E-06	70	25550	2.5E-08	1.4E-02	3.5E-10	0%	10950	5.8E-08	2.0E-02	2.9E-06	0%
Dieldrin	0.052	45	30	100	1E-06	70	25550	3.9E-09	1.6E+01	6.3E-08	10%	10950	9.2E-09	5.0E-05	1.8E-04	1%
4,4'-DDE	1.200	45	30	100	1E-06	70	25550	9.1E-08	3.4E-01	3.1E-08	5%	10950	2.1E-07	0.0E+00	0.0E+00	0%
Endrin	0.007	45	30	100	1E-06	70	25550	5.0E-10	0.0E+00	0.0E+00	0%	10950	1.2E-09	3.0E-04	3.9E-06	0%
4,4'-DDD	1.140	45	30	100	1E-06	70	25550	8.6E-08	2.4E-01	2.1E-08	3%	10950	2.0E-07	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	45	30	100	1E-06	70	25550	2.3E-10	0.0E+00	0.0E+00	0%	10950	5.3E-10	6.0E-03	8.8E-08	0%
4,4'-DDT	0.046	45	30	100	1E-06	70	25550	3.5E-09	3.4E-01	1.2E-09	0%	10950	8.1E-09	5.0E-04	1.6E-05	0%
Endrin ketone	0.011	45	30	100	1E-06	70	25550	8.3E-10	0.0E+00	0.0E+00	0%	10950	1.9E-09	3.0E-04	6.5E-06	0%
Endrin aldehyde	0.008	45	30	100	1E-06	70	25550	5.7E-10	0.0E+00	0.0E+00	0%	10950	1.3E-09	3.0E-04	4.5E-06	0%
alpha-Chlordane	0.013	45	30	100	1E-06	70	25550	9.8E-10	1.3E+00	1.3E-09	0%	10950	2.3E-09	6.0E-05	3.8E-05	0%
Aluminum	19389.170	45	30	100	1E-06	70	25550	1.5E-03	0.0E+00	0.0E+00	0%	10950	3.4E-03	1.0E+00	3.4E-03	19%
Arsenic	2.410	45	30	100	1E-06	70	25550	1.8E-07	1.5E+00	2.7E-07	42%	10950	4.2E-07	3.0E-04	1.4E-03	8%
Chromium	23.060	45	30	100	1E-06	70	25550	1.7E-06	0.0E+00	0.0E+00	0%	10950	4.1E-06	5.0E-03	8.1E-04	5%
Barium	68.510	45	30	100	1E-06	70	25550	5.2E-06	0.0E+00	0.0E+00	0%	10950	1.2E-05	7.0E-02	1.7E-04	1%
Beryllium	0.810	45	30	100	1E-06	70	25550	6.1E-08	4.3E+00	2.6E-07	40%	10950	1.4E-07	5.0E-03	2.9E-05	0%
Cadmium (soil)	3.750	45	30	100	1E-06	70	25550	2.8E-07	0.0E+00	0.0E+00	0%	10950	6.6E-07	1.0E-03	6.6E-04	4%
Cobalt	4.200	45	30	100	1E-06	70	25550	3.2E-07	0.0E+00	0.0E+00	0%	10950	7.4E-07	6.0E-02	1.2E-05	0%
Copper	19.880	45	30	100	1E-06	70	25550	1.5E-06	0.0E+00	0.0E+00	0%	10950	3.5E-06	4.0E-02	8.8E-05	0%
Iron	11661.090	45	30	100	1E-06	70	25550	8.8E-04	0.0E+00	0.0E+00	0%	10950	2.1E-03	3.0E-01	6.8E-03	38%
Lead	3422.990	45	30	100	1E-06	70	25550	2.6E-04	0.0E+00	0.0E+00	0%	10950	6.0E-04	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	45	30	100	1E-06	70	25550	3.4E-06	0.0E+00	0.0E+00	0%	10950	8.0E-06	1.4E-01	5.7E-05	0%
Mercury	0.660	45	30	100	1E-06	70	25550	5.0E-08	0.0E+00	0.0E+00	0%	10950	1.2E-07	3.0E-04	3.9E-04	2%
Nickel	25.810	45	30	100	1E-06	70	25550	1.9E-06	0.0E+00	0.0E+00	0%	10950	4.5E-06	2.0E-02	2.3E-04	1%
Selenium	0.710	45	30	100	1E-06	70	25550	5.4E-08	0.0E+00	0.0E+00	0%	10950	1.3E-07	5.0E-03	2.5E-05	0%
Thallium	0.650	45	30	100	1E-06	70	25550	4.9E-08	0.0E+00	0.0E+00	0%	10950	1.1E-07	8.0E-05	1.4E-03	8%
Vanadium	83.120	45	30	100	1E-06	70	25550	6.3E-06	0.0E+00	0.0E+00	0%	10950	1.5E-05	7.0E-03	2.1E-03	12%
Zinc	140.000	45	30	100	1E-06	70	25550	1.1E-05	0.0E+00	0.0E+00	0%	10950	2.5E-05	3.0E-01	8.2E-05	0%
TOTAL										6.5E-07					1.8E-02	

SEDIMENT DERMAL CONTACT EXPOSURE ASSESSMENT
OPERABLE UNIT NO. 6 (SITE 36)
REMEDIAL INVESTIGATION CTO-0303
MCB CAMP LEJEUNE, NORTH CAROLINA
ADULT TRESPASSER

The intake from dermal contact to sediment is calculted as follows:

Intake (mg/kg-day) = C * CF * SA * AF * Abs * EF * ED/BW * ATc or ATnc * DY

Risk = Intake * CSF or /RfD

Where:	INPUTS
C = contaminant concentration in soil (mg/kg)	
CF = conversion factor (kg/mg)	1.00E-06
SA = exposed skin surface area (cm2)	5000
AF = sediment to skin adherence factor (mg/cm2)	1
Abs = fraction absorbed (unitless) (contaminant specific)	Specific
EF = exposure frequency (events/yr)	45
ED = exposure duration (years)	30
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	30
DY = day per year (day/yr)	365
CSF = cancer slope factor (mg/kg-day)-1	Specific
RfD = reference dose (mg/kg-day)	Specific

COPC	Concentration (mg/kg)	Conversion Factor (kg/mg)	Surface Area (cm2)	Adherence Factor (mg/cm2)	ABS Factor (%)	Exposure Frequency (events/yr)	Exposure Duration (yrs)	Body Weight (kg)	Average Carc Time (days)	Carc Dose (mg/kg/day)	Dermal Adjust Slope Factor (mg/kg-day)-1	Carcinogenic Risk	Percent Carcinogenic Risk	Average Noncarc Time (days)	Noncarc Dose (mg/kg/day)	Dermal Adjust. Reference Dose (mg/kg-day)	Noncarcinogeni Risk	Percent Noncarcinogenic Risk
Tetrachloroethene	0.004	1E-06	5000	1	0.01	45	30	70	25550	1.5E-10	6.5E-02	9.8E-12	0%	10950	3.5E-10	8.0E-03	4.4E-08	0%
Diethylphthalate	1.110	1E-06	5000	1	0.01	45	30	70	25550	4.2E-08	0.0E+00	0.0E+00	0%	10950	9.8E-08	4.0E-01	2.4E-07	0%
Anthracene	0.046	1E-06	5000	1	0.01	45	30	70	25550	1.7E-09	0.0E+00	0.0E+00	0%	10950	4.1E-09	1.5E-01	2.7E-08	0%
Di-n-butylphthalate	0.218	1E-06	5000	1	0.01	45	30	70	25550	8.2E-09	0.0E+00	0.0E+00	0%	10950	1.9E-08	5.0E-02	3.8E-07	0%
Bis(2-ethylhexyl)phthalate	0.328	1E-06	5000	1	0.01	45	30	70	25550	1.2E-08	2.8E-02	3.5E-10	0%	10950	2.9E-08	1.0E-02	2.9E-06	0%
Dieldrin	0.052	1E-06	5000	1	0.01	45	30	70	25550	2.0E-09	3.2E+01	6.3E-08	25%	10950	4.6E-09	2.5E-05	1.8E-04	4%
4,4'-DDE	1.200	1E-06	5000	1	0.01	45	30	70	25550	4.5E-08	6.8E-01	3.1E-08	12%	10950	1.1E-07	0.0E+00	0.0E+00	0%
Endrin	0.007	1E-06	5000	1	0.01	45	30	70	25550	2.5E-10	0.0E+00	0.0E+00	0%	10950	5.8E-10	1.5E-04	3.9E-06	0%
4,4'-DDD	1.140	1E-06	5000	1	0.01	45	30	70	25550	4.3E-08	4.8E-01	2.1E-08	8%	10950	1.0E-07	0.0E+00	0.0E+00	0%
Endosulfan sulfate	0.003	1E-06	5000	1	0.01	45	30	70	25550	1.1E-10	0.0E+00	0.0E+00	0%	10950	2.6E-10	3.0E-03	8.8E-08	0%
4,4'-DDT	0.046	1E-06	5000	1	0.01	45	30	70	25550	1.7E-09	6.8E-01	1.2E-09	0%	10950	4.1E-09	2.5E-04	1.6E-05	0%
Endrin ketone	0.011	1E-06	5000	1	0.01	45	30	70	25550	4.2E-10	0.0E+00	0.0E+00	0%	10950	9.7E-10	1.5E-04	6.5E-06	0%
Endrin aldehyde	0.008	1E-06	5000	1	0.01	45	30	70	25550	2.9E-10	0.0E+00	0.0E+00	0%	10950	6.7E-10	1.5E-04	4.5E-06	0%
alpha-Chlordane	0.013	1E-06	5000	1	0.01	45	30	70	25550	4.9E-10	2.6E+00	1.3E-09	1%	10950	1.1E-09	3.0E-05	3.8E-05	1%
Aluminum	19389.170	1E-06	5000	1	0.001	45	30	70	25550	7.3E-05	0.0E+00	0.0E+00	0%	10950	1.7E-04	2.0E-01	8.5E-04	18%
Arsenic	2.410	1E-06	5000	1	0.001	45	30	70	25550	9.1E-09	7.5E+00	6.8E-08	27%	10950	2.1E-08	6.0E-05	3.5E-04	8%
Chromium	23.060	1E-06	5000	1	0.001	45	30	70	25550	8.7E-08	0.0E+00	0.0E+00	0%	10950	2.0E-07	1.0E-03	2.0E-04	4%
Barium	68.510	1E-06	5000	1	0.001	45	30	70	25550	2.6E-07	0.0E+00	0.0E+00	0%	10950	6.0E-07	1.4E-02	4.3E-05	1%
Beryllium	0.810	1E-06	5000	1	0.001	45	30	70	25550	3.1E-09	2.1E+01	6.6E-08	26%	10950	7.1E-09	1.0E-03	7.1E-06	0%
Cadmium (soil)	3.750	1E-06	5000	1	0.001	45	30	70	25550	1.4E-08	0.0E+00	0.0E+00	0%	10950	3.3E-08	2.0E-04	1.7E-04	4%
Cobalt	4.200	1E-06	5000	1	0.001	45	30	70	25550	1.6E-08	0.0E+00	0.0E+00	0%	10950	3.7E-08	1.2E-02	3.1E-06	0%
Copper	19.880	1E-06	5000	1	0.001	45	30	70	25550	7.5E-08	0.0E+00	0.0E+00	0%	10950	1.8E-07	8.0E-03	2.2E-05	0%
Iron	11661.090	1E-06	5000	1	0.001	45	30	70	25550	4.4E-05	0.0E+00	0.0E+00	0%	10950	1.0E-04	6.0E-02	1.7E-03	36%
Lead	3422.990	1E-06	5000	1	0.001	45	30	70	25550	1.3E-05	0.0E+00	0.0E+00	0%	10950	3.0E-05	0.0E+00	0.0E+00	0%
Manganese (soil)	45.170	1E-06	5000	1	0.001	45	30	70	25550	1.7E-07	0.0E+00	0.0E+00	0%	10950	4.0E-07	2.8E-02	1.4E-05	0%
Mercury	0.660	1E-06	5000	1	0.001	45	30	70	25550	2.5E-09	0.0E+00	0.0E+00	0%	10950	5.8E-09	6.0E-05	9.7E-05	2%
Nickel	25.810	1E-06	5000	1	0.001	45	30	70	25550	9.7E-08	0.0E+00	0.0E+00	0%	10950	2.3E-07	4.0E-03	5.7E-05	1%
Selenium	0.710	1E-06	5000	1	0.001	45	30	70	25550	2.7E-09	0.0E+00	0.0E+00	0%	10950	6.3E-09	1.0E-03	6.3E-06	0%
Thallium	0.650	1E-06	5000	1	0.001	45	30	70	25550	2.5E-09	0.0E+00	0.0E+00	0%	10950	5.7E-09	1.6E-05	3.6E-04	8%
Vanadium	83.120	1E-06	5000	1	0.001	45	30	70	25550	3.1E-07	0.0E+00	0.0E+00	0%	10950	7.3E-07	1.4E-03	5.2E-04	11%
Zinc	140.000	1E-06	5000	1	0.001	45	30	70	25550	5.3E-07	0.0E+00	0.0E+00	0%	10950	1.2E-06	6.0E-02	2.1E-05	0%
TOTAL												2.5E-07					4.7E-03	

APPENDIX B
TWO DIMENSIONAL GROUNDWATER MODELS

1.0 Groundwater Flow and Transport Simulations

Two-dimensional groundwater flow and transport were simulated at Site 36. The purpose of these simulations was to assist in location of extraction wells and observe potential effects of natural attenuation on particular organic compounds. A finite-difference model was used to simulate flow. A method-of-characteristics model (in conjunction with the finite-difference model) was used to simulate transport. This Appendix provides Surfer™ contour plots of the simulations, a discussion of each simulation, and assumptions used in the models.

1.1 Discussion of Simulations

Figures 1 and 2 illustrate different groundwater flow simulations. Figure 1 is a simulation of natural static flow conditions, designed to be representative of conditions observed during the RI. Figure 2 illustrates groundwater flow with two, 5 gallons per minute (gpm) extraction wells introduced into the natural static flow model. Output files of this simulation, not included herein, indicate that the extraction wells will draw in creek water. Other extraction simulations indicate qualitatively, that any extraction wells close to Brinson Creek that effect the contaminant plume will also affect the creek.

Present contaminant concentration distributions were introduced into the extraction model to simulate future contaminant distribution. Figure 3 illustrates the approximated extent of 1,2-Dichloroethene (DCE) in groundwater based on RI analytical data. The transport of DCE was simulated due to its relatively high-mobility characteristic. Figure 4 illustrates the approximated extent of trichloroethene (TCE) in groundwater based on RI analytical data. The transport of TCE was simulated due to its relatively low-mobility characteristic.

Figures 5 and 6 illustrate the simulation of natural attenuation of DCE and TCE over a 30 year period. This is a simulation of RAA No. 2, Institutional Controls. These simulations seem to confirm the RI conceptual model point that the plume is migrating to Brinson Creek. These figures suggest that after 30 years, the contaminants will still likely be present in groundwater.

Figures 7 and 8 illustrate DCE and TCE concentration distributions influenced by extraction as illustrated on Figure 2. This is a simulation of RAA No. 3; Extraction and On-Site Treatment. Figures 7 and 8 suggest that the extraction well configuration will contain both the DCE and TCE plumes, and reduce their concentrations in groundwater.

1.2 Modeling Assumptions and Items of Note

This section presents a list of assumptions was used in the flow and transport simulations, and other items of note.

1) The aquifer is isotropic.
2) The aquifer is homogeneous in composition.
3) Steady-state conditions are used in the simulations.
4) The left and bottom model boundaries are no-flow boundaries, represented by groundwater flow line.
5) Hydrologic boundaries (non-physical) do not change over the simulation periods.
6) An effective porosity of 30% was used in the simulations.
7) Longitudinal dispersivity was assumed to be one-tenth the contaminant flow distance. Transverse dispersivity was assumed to be one-tenth longitudinal dispersivity.
8) The distribution coefficients used at Site 36 are as follows: DCE = 0.2107
   TCE = 0.5418
9) The transmissivity distribution (Figure 9) was based on hydraulic conductivity values determined from slug test data conducted on several shallow wells.
10) The thickness distribution (Figure 9) was based on field observations.
11) A source area is no longer present, or affecting the site.
12) Input units used are feet and seconds.
13) The dots bordering the site on Figures 1-8 represent the 20x20 grid boundary.

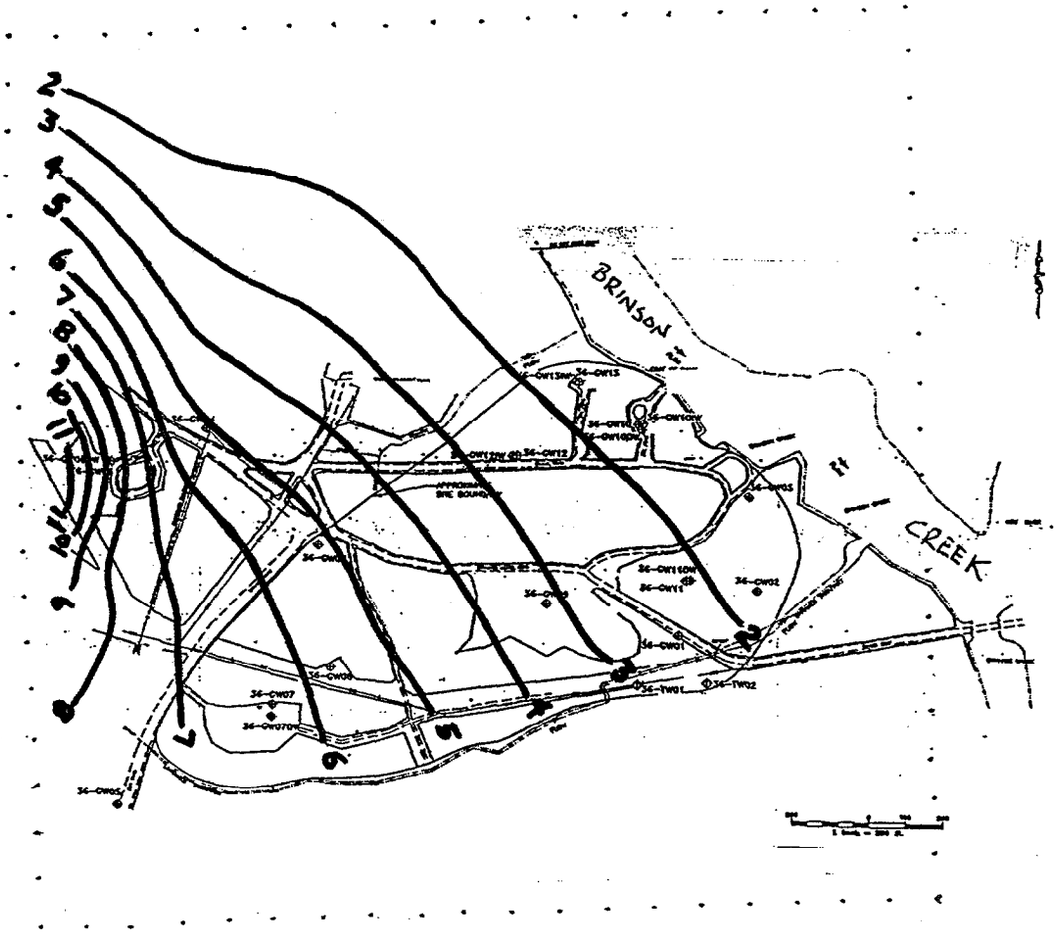


FIGURE 1
ONE-YEAR SIMULATION OF STATIC CONDITIONS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

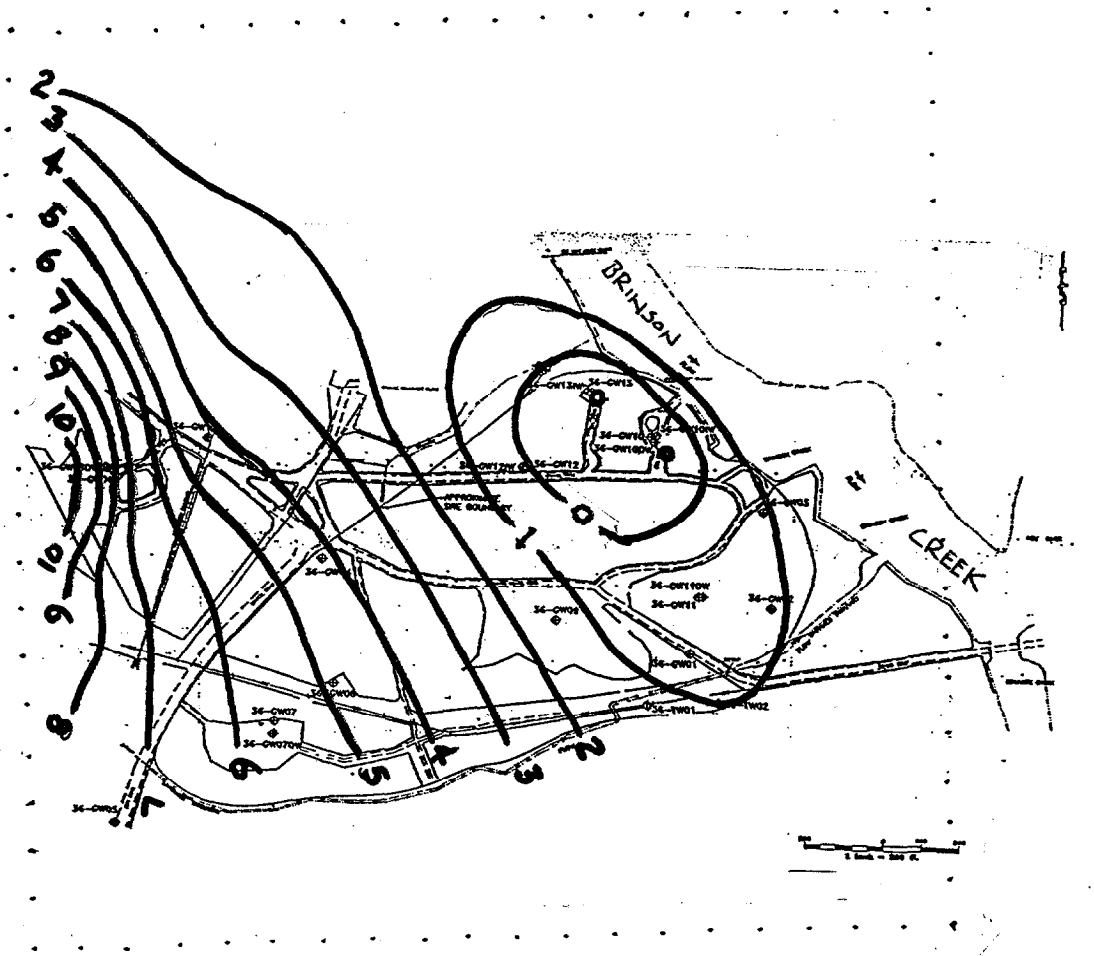


FIGURE 2
FIVE-YEAR SIMULATION OF TWO
5 GPM EXTRACTION WELLS
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

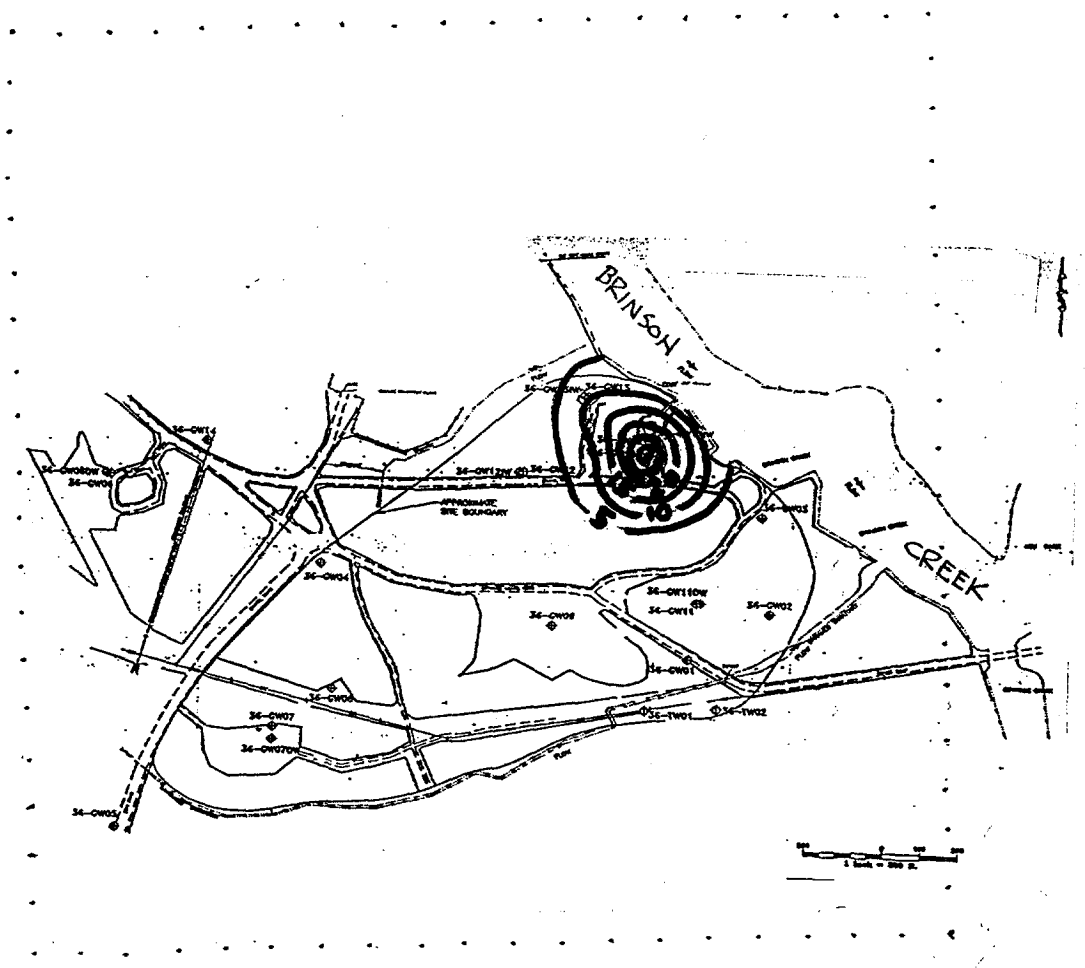


FIGURE 3
PRESENT CONCENTRATION DISTRIBUTION OF
1,2-DICHLOROETHENE (PPB)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

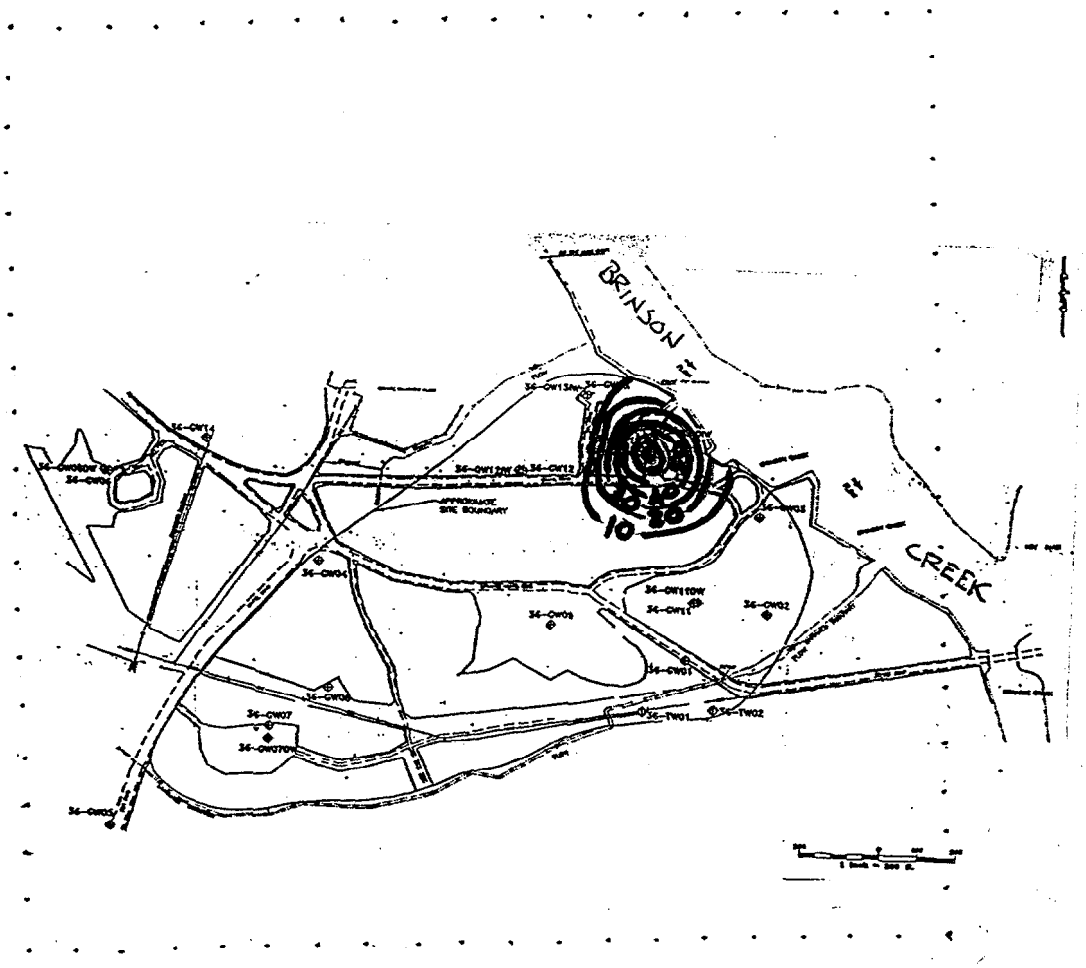


FIGURE 4
PRESENT CONCENTRATION DISTRIBUTION OF
TRICHLOROETHENE (PPB)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

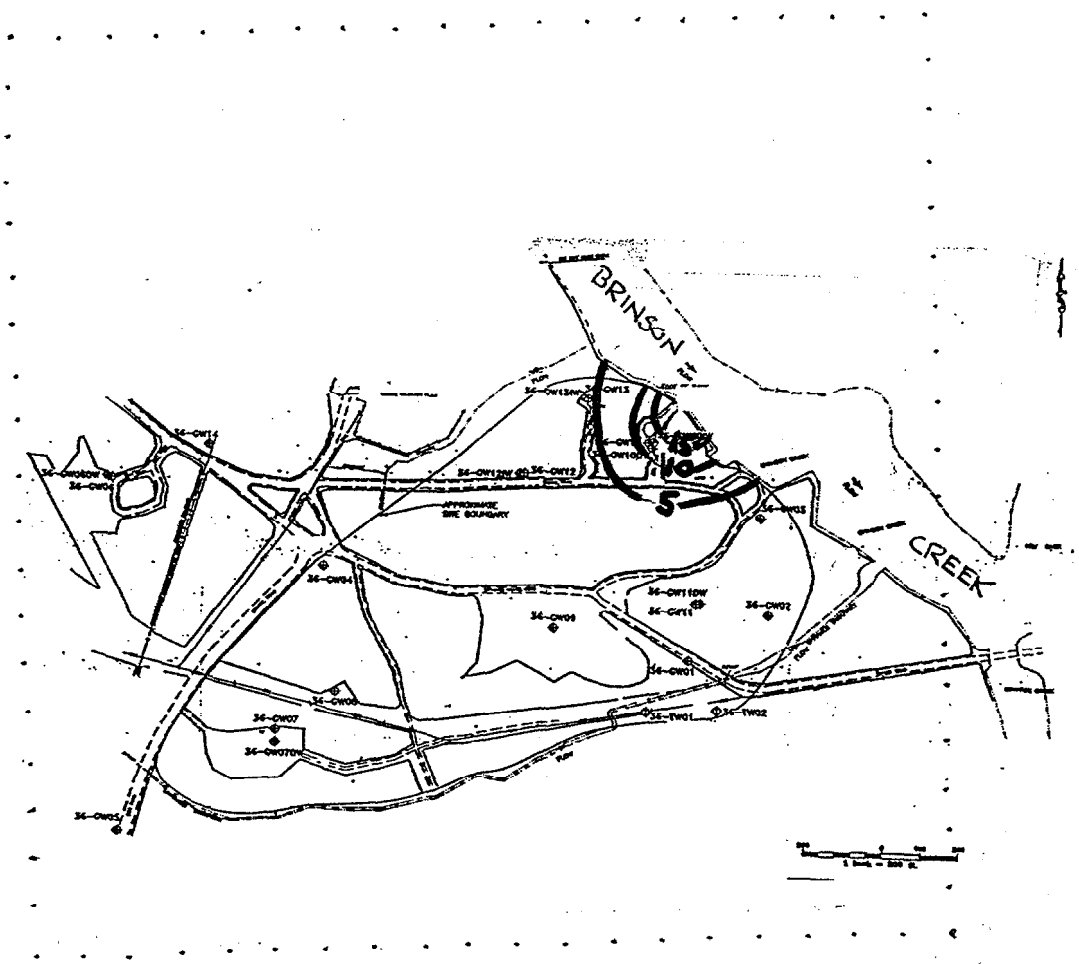


FIGURE 5
30-YEAR SIMULATION OF NATURAL ATTENUATION
1,2-DICHLOROETHENE (PPB)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

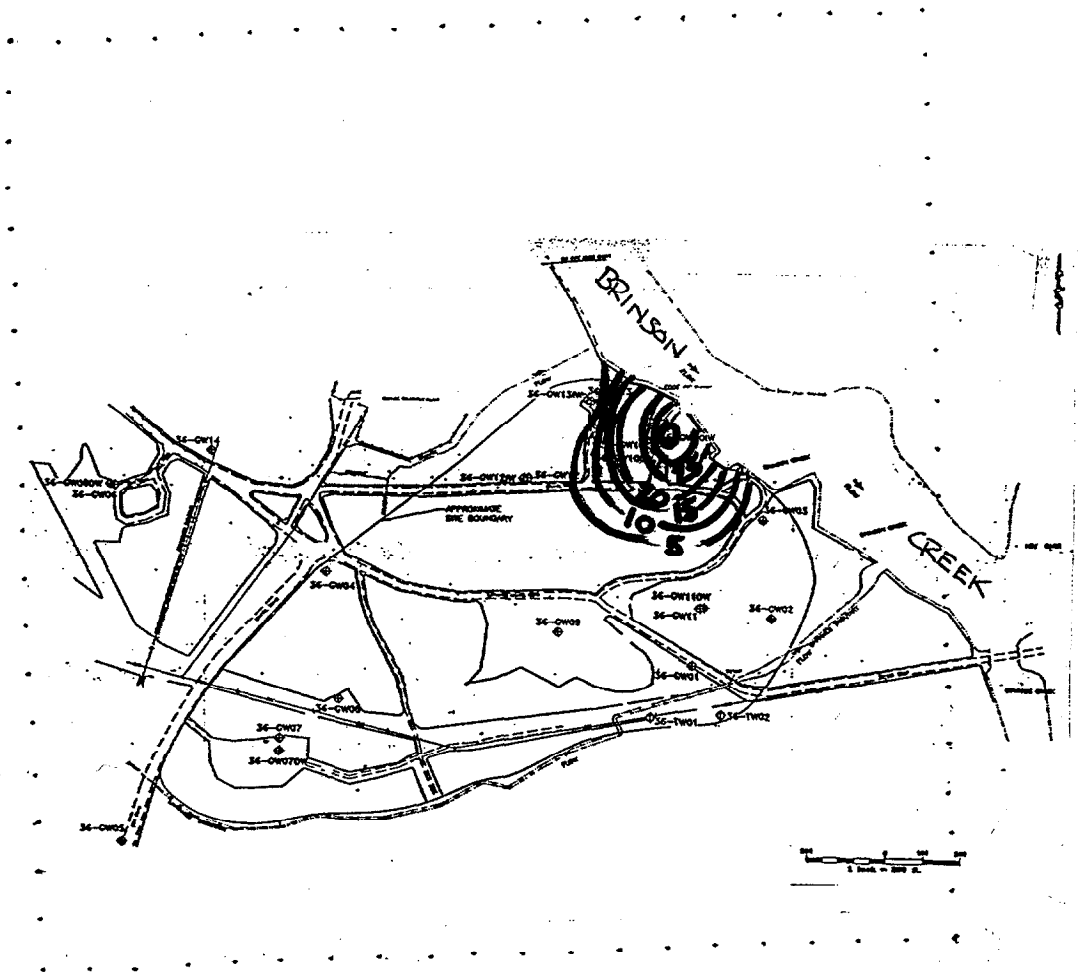


FIGURE 6
30-YEAR SIMULATION OF NATURAL ATTENUATION
TRICHLOROETHENE (PPB)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

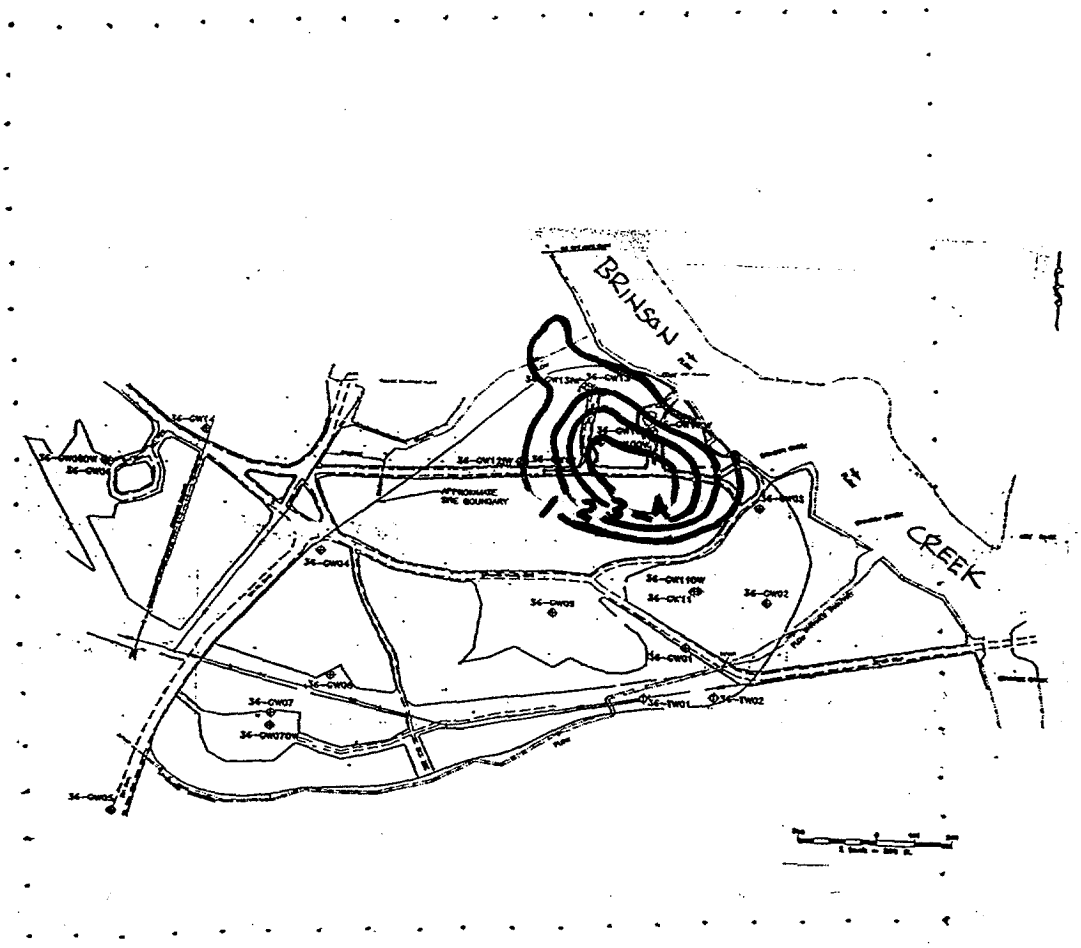


FIGURE 7
5-YEAR SIMULATION OF EXTRACTION
1,2-DICHLOROETHENE (PPB)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

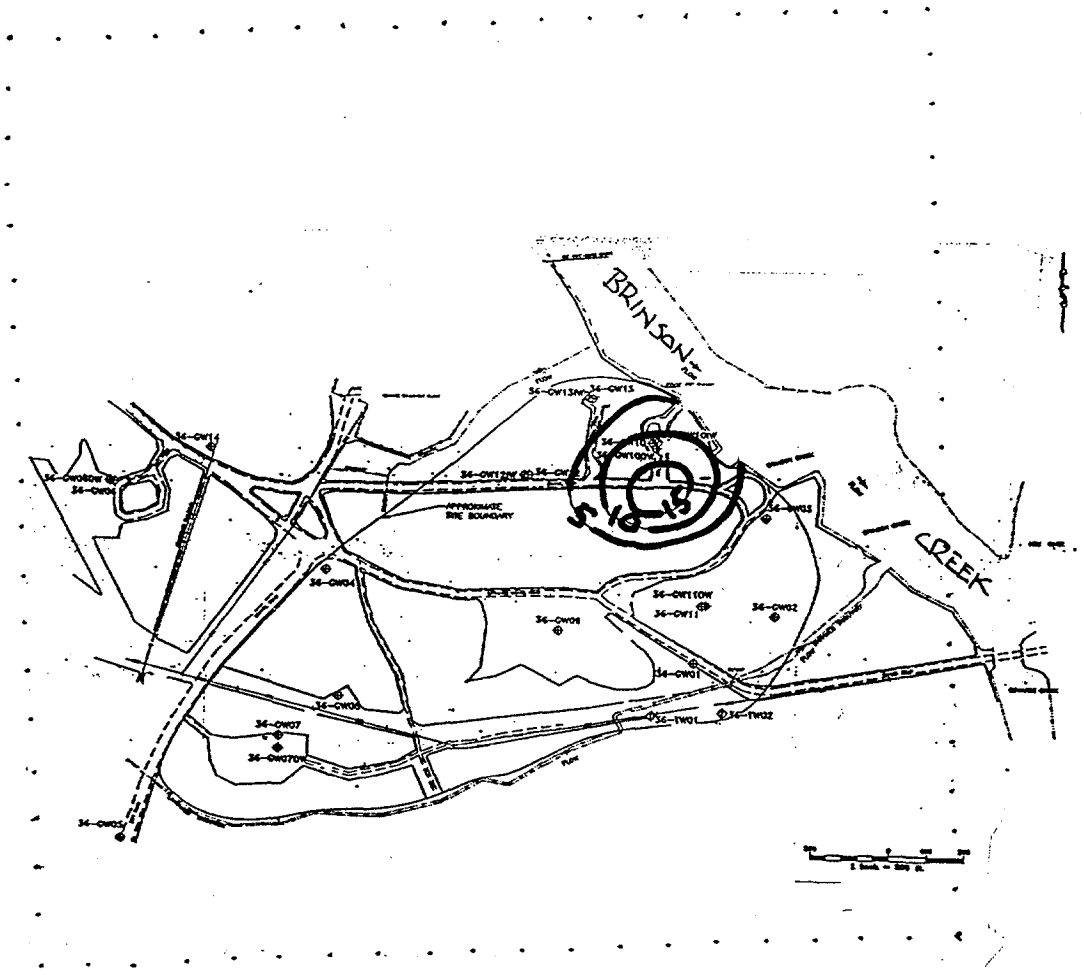


FIGURE 8
5-YEAR SIMULATION OF EXTRACTION
TRICHLOROETHENE (PPB)
SITE 36, CAMP GEIGER AREA DUMP
FEASIBILITY STUDY, CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

ICKNESS

.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	33.	33.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	33.	33.	33.	32.	31.	30.	29.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	34.	34.	33.	32.	31.	30.	29.	29.	0.	0.	0.	0.	0.	0.	0.	0.	0.
0.	34.	34.	33.	32.	31.	30.	29.	29.	28.	28.	0.	0.	0.	0.	0.	0.	0.
0.	35.	35.	34.	32.	31.	30.	30.	29.	28.	28.	27.	0.	0.	0.	0.	0.	0.
0.	35.	35.	34.	33.	32.	31.	30.	29.	28.	28.	27.	27.	0.	0.	0.	0.	0.
0.	36.	36.	34.	33.	32.	31.	30.	29.	28.	29.	27.	27.	34.	0.	0.	0.	0.
0.	36.	36.	35.	33.	33.	31.	30.	29.	28.	27.	27.	26.	34.	24.	0.	0.	0.
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0.	36.	36.	35.	33.	32.	31.	30.	29.	28.	27.	27.	27.	27.	27.	24.	24.	23.
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.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.000	.0

FIGURE 9
THICKNESS AND TRANSMISSIVITY
DISTRIBUTIONS OVER THE SITE 36 GRID
FEASIBILITY STUDY CTO-0303
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

APPENDIX C
IN-WELL AERATION TECHNICAL INFORMATION

BIOREMEDIATION BY GROUNDWATER CIRCULATION USING THE VACUUM-VAPORIZER-WELL (UVB) TECHNOLOGY: BASICS AND CASE STUDY

W. Buermann and G. Bott-Breuning

INTRODUCTION

Not only in the industrialized countries, but worldwide, the numbe of known groundwater and soil air contaminations by hydrocarbons benzene, toluene, ethylbenzene, and xylenes (BTEX); pesticides; nitrates etc., increases. Efficient, low-cost remediation techniques are needed.

A new method for the in situ remediation of groundwater and soi air is the vacuum-vaporizer-well (UVB) technology (German: Unterdruck Verdampfer-Brunnen [UVB]; invented by B. Bernhardt; patents: IEG mbH D-7410 Reutlingen). The disadvantages of groundwater remediatior applying current pumping methods (groundwater lowering, limited yield insufficient remediation) may be avoided if pumping and recharge tak place in the same well. The UVB technology applies this circulation wel concept.

The basics of hydromechanical theory are outlined in some detai (Buermann 1990, Bürmann 1991). Results of the field measurement conducted in Karlsruhe, Germany, to verify the UVB technology have been published briefly (Bürmann 1992, Bürmann & Wagner 1992) and are presented.

A case study on the bioremediation of pesticide (triazines)-contaminated groundwater is presented. Activated carbon is placed within the UVE well as a biofilter. A decrease in triazine concentrations in the ground-water is documented. An increase in the number of bacteria in the aquifer was observed and suggests a stimulation of biological processes. Development of metabolites within the activated carbon filter provides evidence of triazine biotransformation.

1-56670-084-1/94/$0.00 + $.50

Operation of the Vacuum-Vaporizer-Well: UVB Technology. The UVB produces a circulation flow within the surrounding groundwater, directed from the upper to the lower screening, as seen in Figure 1. Water is sucked into the lower screening, transported upwards inside the UVB by the water pump (air lift pump), and cleaned by fresh air in the stripping zone under below-atmospheric pressure before flowing out of the UVB through the upper screening. This all takes place without the water leaving the aquifer. If necessary, the groundwater is cleaned on site and directed back to the well. Soil air from the unsaturated zone of the aquifer may be sucked into the UVB through the upper screening and thus also may be cleaned. The contaminants in the stripping air are adsorbed by activated carbon. To avoid precipitation, the stripping air loop is closed. Thus contaminants that are not adsorbed can be kept from escaping into the atmosphere (Herrling et al. 1992).

In resting groundwater, circulation creates a permanent flow and consequently cleans the soil within the zone of the well, as all the circulating water flows through the well. Natural groundwater flow, which exists in most cases, deforms the circulation flow so that a portion of the water flowing toward the intake zone of the well may pass the well several times, due to the continual circulation flow, whereas the remainder of the water flows through the well only once. Therefore, the cleaning equipment of the UVB must be dimensioned so that one flow through the well is sufficient to ensure decontamination of the water.

Groundwater Flow around the UVB. The circulation flow depends on the natural groundwater flow, the water flowrate through the well, the water-saturated thickness of the aquifer (corresponding to the length of the well), the lengths of the lower and upper screenings, the outer radius of the well, and the horizontal and vertical conductivities of the aquifer (Buermann 1990).

The circulation flow may be influenced only by the design of the well itself, and in particular by the water flowrate. If existing wells must be used, water flowrate is the only means of control of the circulation flow.

In resting groundwater, the investigations give a theoretically unlimited zone of effect of the well. For a realistic judgment of the zone of effect, a radius around the well is chosen that contains a specific percentage of the total quantity of water flowing inside the well. The influence of the screening length is small. For realistic values of the anisotropy of the aquifer, the radius of effect is approximately 1.5 to 2 times the water-saturated aquifer thickness.

The circulation flow in moving groundwater shows two separating streamlines, at the bottom and at the top of the aquifer, similar to the

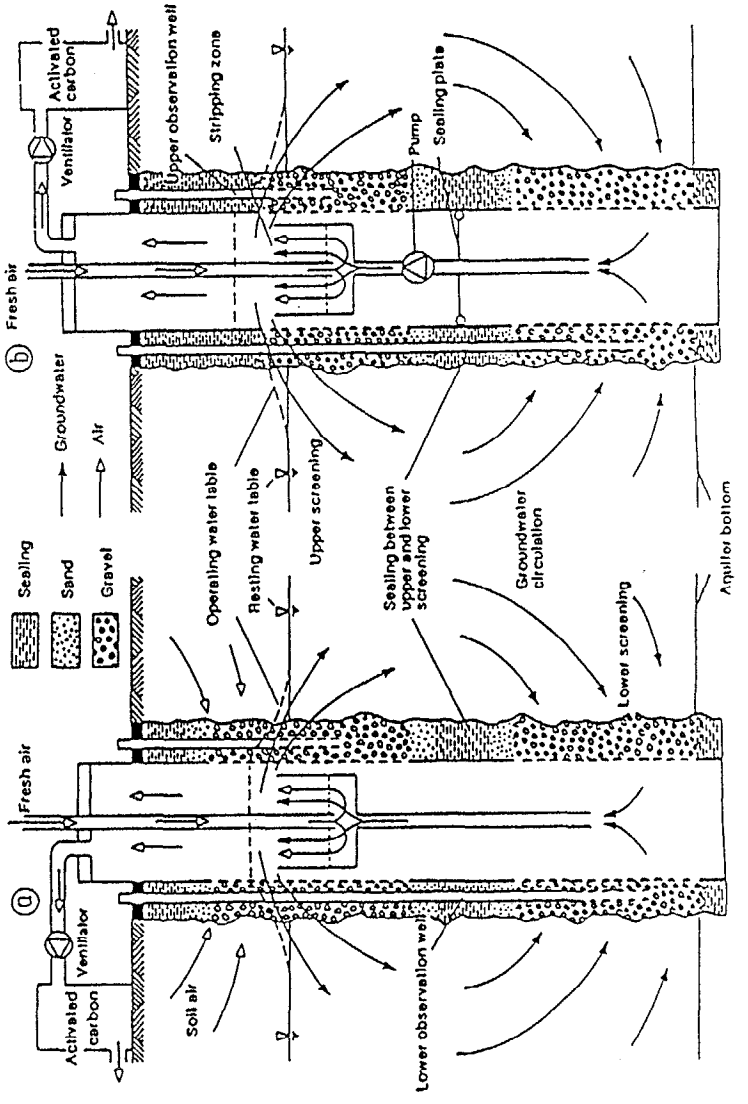

FIGURE 1. Typical [illegible] (UVB)

perfect well (Figure 2). In a well with upward flow, the lower separating streamline corresponds to the withdrawal well and the upper one to the infiltration well. Between these two separating streamlines at the lower and upper boundaries of the aquifer lies the separating stream surface of the flow around the well in the natural groundwater. This surface consists of spatial streamlines and shows a different contour in each horizontal section.

The dimension of the separating stream surface is characterized by the distance of the stagnation point S from the well. Figure 3 shows the water flowrate over the stagnation point distance of the upper separating streamline. The lower stagnation point distance gives the same curves for equal lengths in the lower and upper screening, and the curves remain essentially the same even for very different screening lengths. The smaller the ratio of vertical and horizontal conductivity, the greater the stagnation point distance and the influence zone of the well.

The water flowrate through the well rises more than proportional with the stagnation point distance. Therefore, instead of one single well of a large water flowrate, several wells of small rates may be useful.

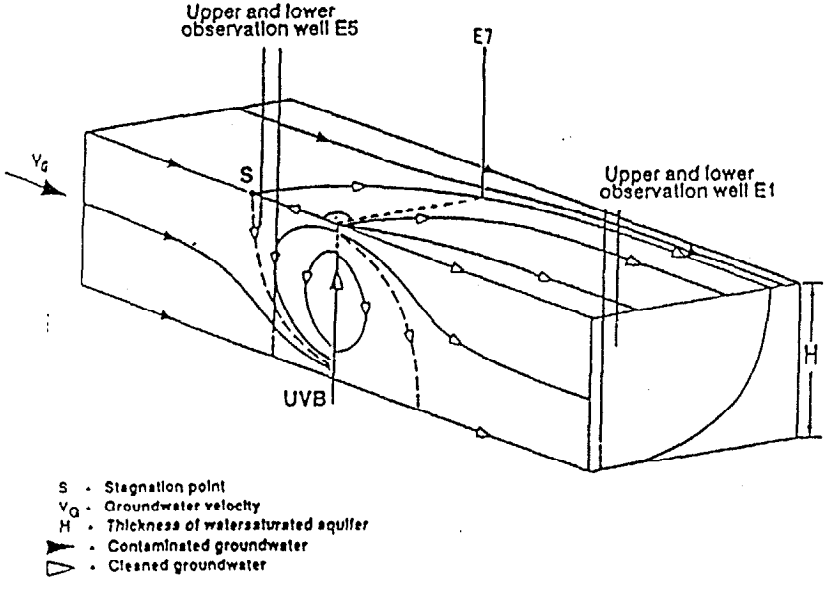

FIGURE 2. Typical flow pattern of the vacuum-vaporizer-well (UVB) in natural groundwater flow.

CASE STUDY OF A BIOLOGICAL REMEDIATION

The UVB technology offers not only an innovative method of physically remediating contaminated sites, but also makes in situ biological remediation of groundwater possible. As a case study, a combined physical and biological remediation of groundwater containing pesticides (triazines) is presented (Figure 4).

The darcy velocity of the natural groundwater flow of 0.17 m/d, the water-saturated thickness of the aquifer of 6.6 m, the anisotropy k_V/k_H of 0.1, the screening length of 2 m, and the water flowrate inside the UVB of 4 m^3/h give the stagnation point distance of about 13 m in Figure 3.

Principle of Bioremediation. The principle behind every bioremediation is optimizing the environmental conditions for the naturally existing, already adapted microorganisms. Oxygen often is a limiting factor for aerobic degradation. The part of the aquifer where the UVB creates a continuous circular flow is regarded as an in situ bioreactor and is constantly supplied with oxygen-enriched water. Additional nutrients needed by the bacteria can easily be injected into the circulation flow that

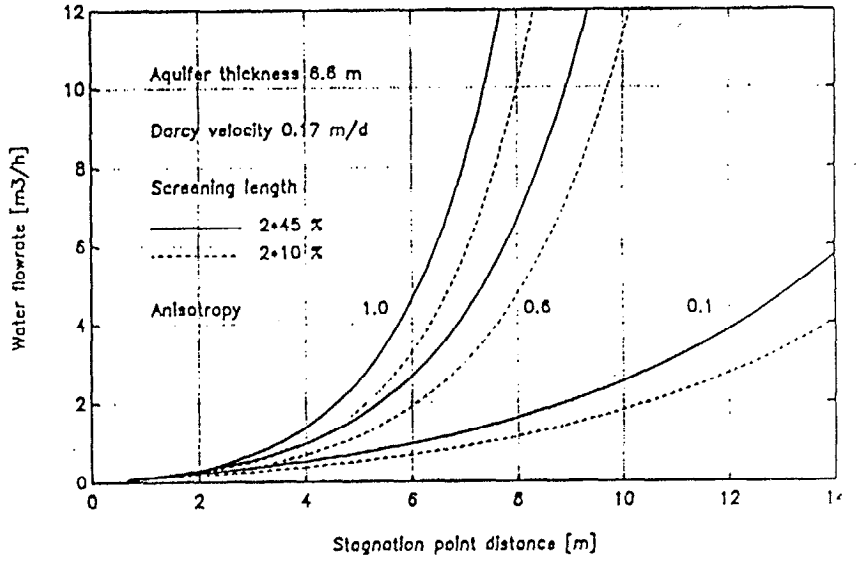

FIGURE 3. Water flowrate over stagnation point distance of the vacuum-vaporizer-well (UVB) in natural groundwater flow.

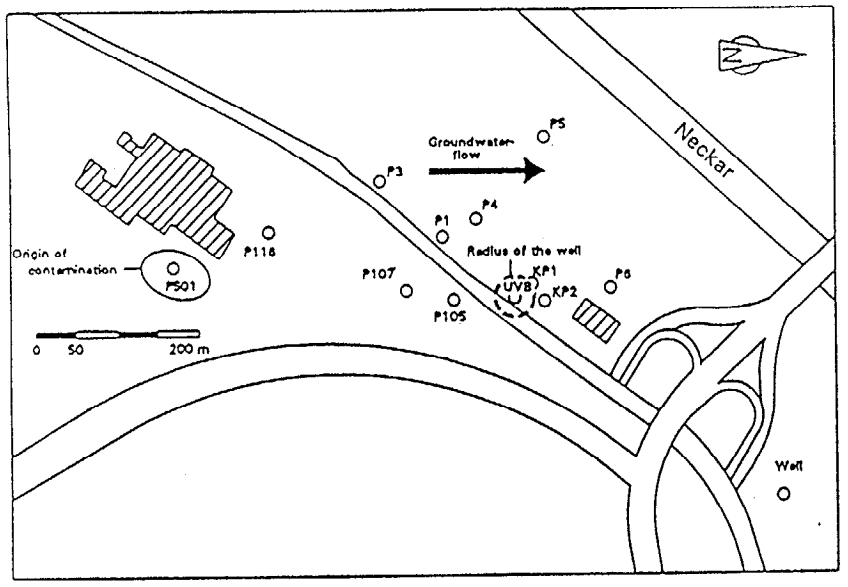

FIGURE 4. Schematic map of the contaminated site.

the UVB creates within the aquifer. These nutrients enable optimal conditions to be created for the microorganisms bound on grain surfaces.

In the case study presented in this paper, activated carbon was used as a biofilter within the UVB. The two variations shown in Figure 5 were tested. In both cases the contaminants and the triazine-degrading bacteria are adsorbed onto the activated carbon by constant circulation of contaminated groundwater in the well. This accumulation is a special advantage in cases with low contaminant concentrations or few bacteria in the groundwater. Adding specific nutrient supply for the bacteria to the biofilter is possible.

Results of the Triazine Remediation. In Figure 6, the concentration curves of the total triazines (atrazine, propazine, simazine, and triazine metabolites) entering and leaving the biofilter are depicted. The amount of triazines in the groundwater entering the activated carbon is higher than that leaving the biofilter. This decontamination is the result of adsorption of triazines onto and biological degradation processes within the activated carbon.

During biodegradation of triazines, various intermediates are formed (Cook 1987). These were detected in the aquifer before remediation with the UVB technique began. Figure 7 shows the concentration curve of one

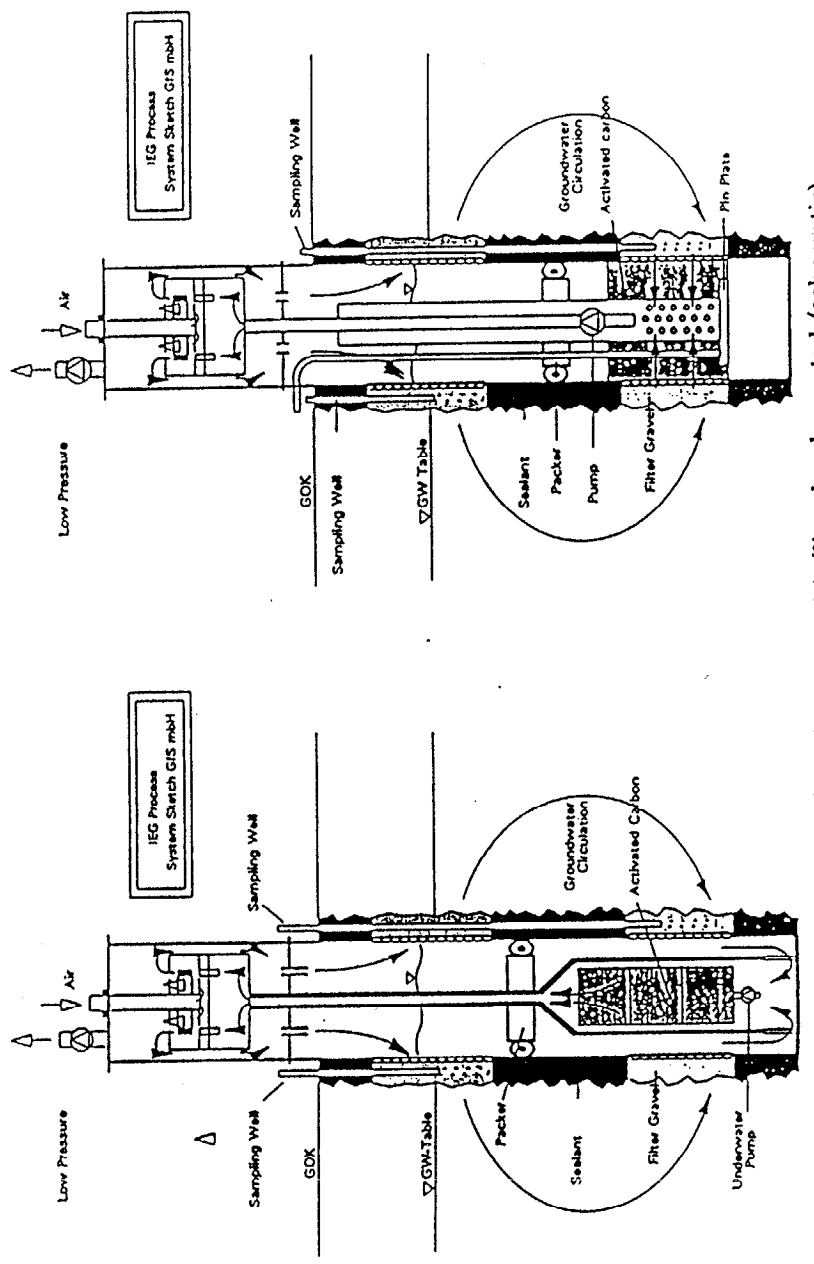

FIGURE 5. Version 1 (left) and version 2 (right) with the biofilter implemented (schematic).

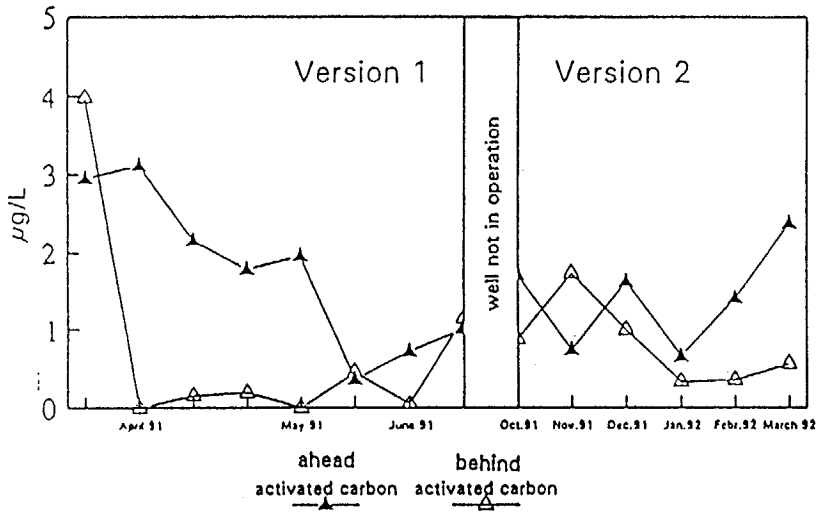

FIGURE 6. Concentration curve of triazines in groundwater entering and leaving the biofilter.

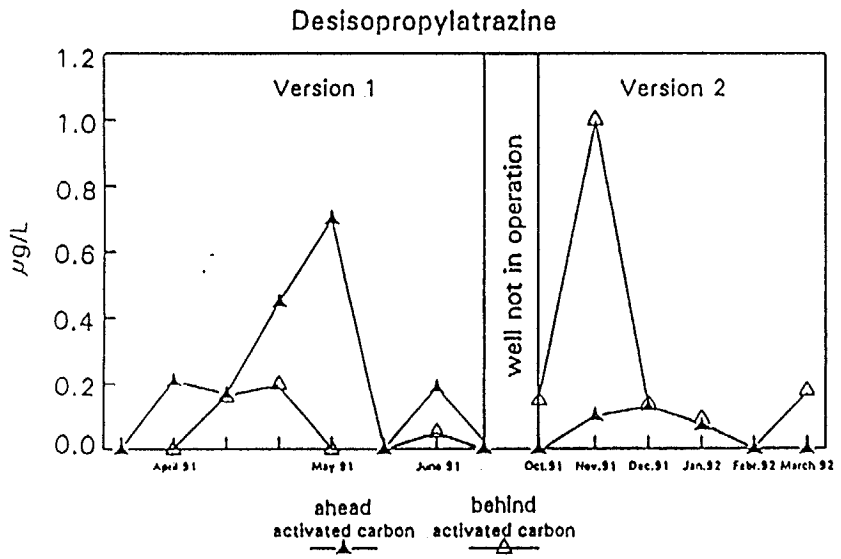

FIGURE 7. Metabolite concentration (desisopropylatrazine) in groundwater entering and leaving the biofilter.

of these metabolites, desisopropylatrazine, in groundwater before and after treatment by the activated carbon. The higher metabolite concentration behind the activated carbon indicates that further biological transformation of triazines occurs in the biofilter. This intermediate is further reduced by biodegradation. Figure 8 depicts the decrease of triazine concentrations in groundwater of the monitoring well KP1.

In addition to using intermediates as an indication of biodegradation it is possible to count the number of bacteria in a sample. This was carried out by the colony-forming-units (CFU) method, in which bacteria are cultivated under aerobic conditions on a defined standard nutrient supplier. Table 1 shows the development of the number of bacteria in samples taken from various wells. Within 3 months the number of bacteria in monitoring well KP1 increased by a factor of 1,000, and the triazine concentration decreased accordingly. A biofilm developed on the activated carbon from April to June 1991. It was analyzed qualitatively and quantitatively. The number of CFUs was 7.7×10^4/g activated carbon, which is an enrichment compared to the number of bacteria (470 CFU/ml groundwater) ahead of the activated carbon biofilter.

CONCLUSIONS

The combined physical and biological remediation of triazine-contaminated groundwater using the UVB technology shows good success

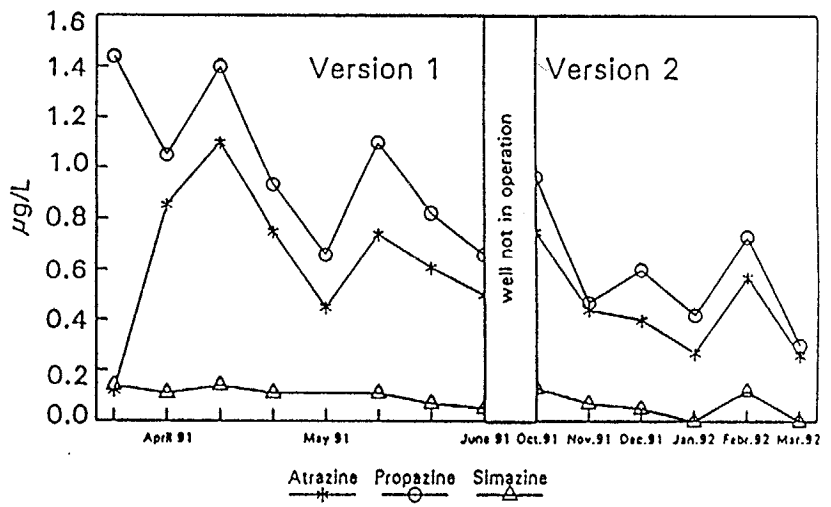

FIGURE 8. Triazine concentrations in the groundwater at monitoring well KP1.

TABLE 1. Development of bacteria (CFU/mL groundwater).

Date	Entering Activated Carbon	Leaving Activated Carbon	Monitoring Well KP1	Monitoring Well KP2
October 1991	$4.7*10^2$		$2.5*10^3$	
January 1992	$1.8*10^3$	$3.1*10^4$	$3.5*10^6$	$7.5*10^3$

in decreasing the triazine concentrations during remediation to date. The simultaneous increase in the number of bacteria in the aquifer suggests stimulation of biological processes. The development of metabolites and the increasing remediation rate within the activated carbon are evidence of biological triazine transformation. Further investigations include determination of degradation rate, looking for proof of specific triazine-degrading bacteria both in the aquifer and in the biofilter, and optimizing the biofilter.

ACKNOWLEDGMENTS

The authors gratefully acknowledge IEG mbH, D-7410 Reutlingen, for funding the investigations, and in particular, B. Bernhardt, IEG mbH, and many others for their work and their numerous helpful discussions and contributions concerning the UVB technology.

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EG&G ENVIRONMENTAL

A TECHNOLOGY AND SYSTEMS INTEGRATION COMPANY

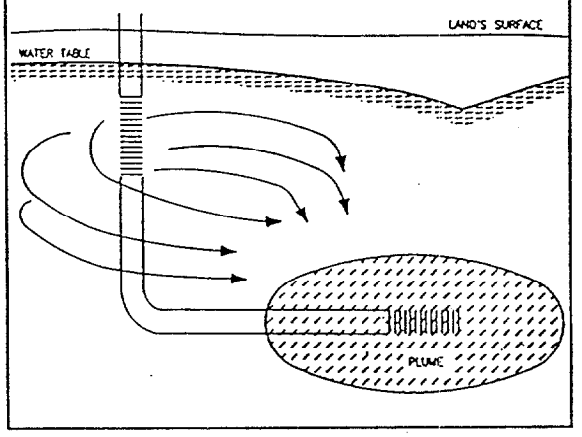
NoVOCs SYSTEM: IN-WELL STRIPPING OF VOCs FROM GROUNDWATER

THE CONCEPT

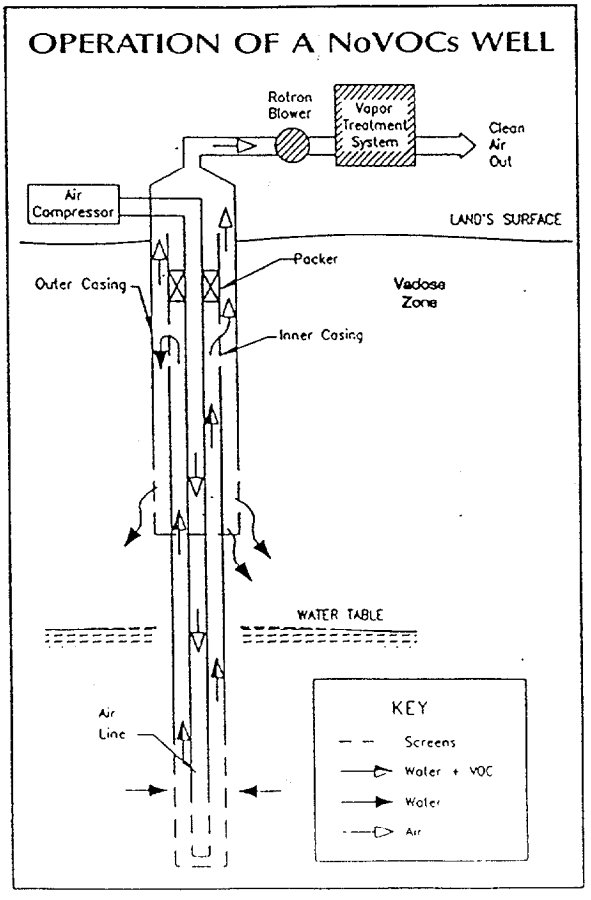
EG&G Environmental, Inc., through its NoVOCs division, offers a cost-effective new technology for removing volatile organic compounds (VOCs) from contaminated groundwater (US Patent No. 5,180,503). Traditional remedies for removing petroleum hydrocarbons and chlorinated solvents in the groundwater have relied upon extraction wells to bring contaminated water to the surface, followed by one of several treatment alternatives to remove contaminants from the aqueous phase. These options include: air stripping, activated carbon, and UV-peroxide oxidation.

In-well stripping, however, simplifies the process and results in significant savings by eliminating separate above-ground aqueous phase treatment.

HORIZONTAL NoVOCs WELL



OPERATION OF A NoVOCs WELL



In-well stripping operates on the same principle as the aerator in an aquarium. A compressor is used to deliver air or an inert gas such as nitrogen to the water column within an extraction well. The resulting bubbles in the water constitute an air lift pump. Because the water with bubbles has a lower density than water outside the well, a pressure gradient is established which causes water outside the well to flow into it through the lower screened section. The bubble-water mixture rises in the well. At the same time, VOCs in the water volatilize into the bubbles. The bubble-water mixture is allowed to rise to a point where optimum volatilization has occurred. The casing is screened at that point and sealed with a deflector plate.

When the mixture encounters the deflector plate, the bubbles break and combine. Water then flows through the upper screen and is allowed to reinfiltrate into the vadose (above water table) zone. A larger casing placed over the top of the well is maintained under vacuum; it allows coalesced bubbles to be drawn off for treatment above ground. Reinfiltrating water creates a torroidal circulation pattern around the well so that waters can be treated through multiple cycles to achieve the desired level of removal.

EG&G ENVIRONMENTAL

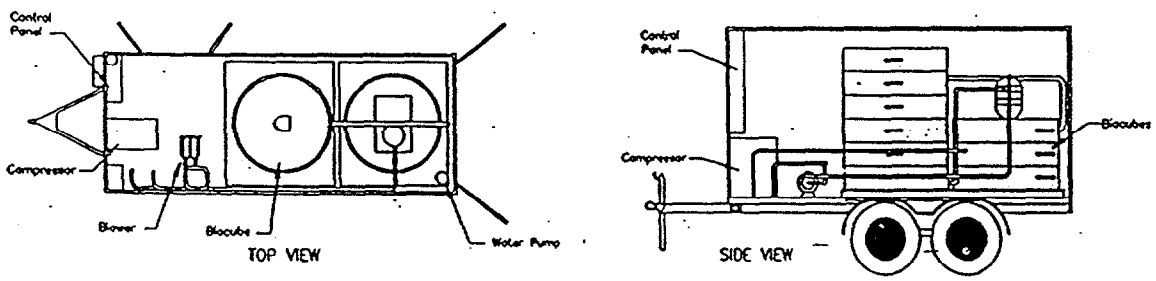
ADVANTAGES

In-well stripping offers a number of advantages over traditional pump and treat technologies:

- *Reduces Capital Costs*
- *Reduces Operating Costs Associated With Pumping Vapor, Not Water, to the Surface*
- *Accelerates Restoration Due to Disruption of Free Phase Product in the Capillary Fringe*
- *Enhances Bioremediation of Hydrocarbons as a Result of Aeration/Recirculation of Treated Water*
- *Eliminates Need for Reinjection Wells, Discharge Lines and Discharge Fees*
- *Facilitates Coupling with Soil Vapor Extraction Systems*
- *Minimizes Installation Time/Cost Through Use of Integrated System Mobile Unit*

In-well technology is available with a full set of related services, including consultation, design, installation, operation and monitoring. Designs include new installation and retrofits for existing extraction wells.

MOBILE UNIT FOR HYDROCARBON RECOVERY WITH NoVOCs SYSTEM



ABOUT EG&G ENVIRONMENTAL, INC.

EG&G Environmental is a wholly-owned subsidiary of EG&G, Inc., a Fortune 200 company. EG&G Environmental was formed in January 1994 to harness the recognized strengths of the parent corporation, build on them, and apply them in environmental problem solving. EG&G Environmental offers services and products in four strategic areas: *1) Consulting Services; 2) Technology Products; 3) Systems Integration; and 4) Integrated Environmental Management.*

For further information on in-well stripping technology or other products and services from EG&G Environmental, contact the Pittsburgh headquarters office or the Richland, Washington office.

EG&G ENVIRONMENTAL
FOSTER PLAZA 6, SUITE 400
681 ANDERSEN DRIVE
PITTSBURGH, PA 15220
(412) 920-5401
FAX (412) 920-5402

EG&G ENVIRONMENTAL
RT 1, BOX 5038, GROVER LANE
W. RICHLAND, WA 99352
(509) 967-2347
FAX (509) 967-5709

APPENDIX D
NC DEHNR RISK ANALYSIS FRAMEWORK

A Determination of Target Contaminant Concentrations in Groundwater
NC DEHNR Risk Analysis Framework
Site 36 - MCB Camp Lejeune

For the chlorinated solvent compounds observed at Site 36, the following table provides a comparison of the surface water quality standard for Brinson Creek to the maximum observed concentration.

Compound	North Carolina Surface Water Discharge Standard (mg/L)	Site 36 Maximum Detected Groundwater Concentration (mg/L)
1,2-Dichloroethene	7.0	0.037
Trichloroethene	0.0924	0.097
Tetrachloroethene	0.00885	0.002
1,1,2,2-Tetrachloroethane	0.0108	0.010

This table shows that the maximum observed concentrations of 1,2-Dichloroethene, Tetrachloroethene, and 1,1,2,2-Tetrachloroethane are below the surface water quality standards. Thus, these compounds in the groundwater at Site 36 should not degrade the water quality with respect to North Carolina Standards. Only Trichloroethene (TCE) exceeded the surface water quality standard; consequently, the target concentration model was run for TCE.

The model entitled G3CTM was used to calculate target concentrations in groundwater per the NC DEHNR Risk Analysis Framework. The model output indicates that the maximum TCE concentration in groundwater protective of surface water quality is 1.757 mg/L. A comparison of 1.757 mg/L to the maximum detected concentration of TCE at Site 36 (0.097 mg/L) indicates that the concentrations of TCE entering Brinson Creek from the solvent compound plume should not be above the surface water quality standard.

The following information is provided within this package:

- The output from the 3GCTM model
- A backup for the determination of the model input parameters
- The framework worksheets

DATAFILE NAME: C:\303\FS\NC.OUT
North Carolina Department of Environment, Health, and Natural Resources
Risk Assessment, Category G-3, Method II
G-3 Groundwater Contaminant Transport model

INPUT PARAMETERS:

CONTAMINANT CHEMICAL NAME	Trichloroethene
SURFACE WATER CHEMICAL STANDARD(mg/l)	0.081
DISTANCE FROM P.L.E. TO SURFACE WATER BODY (Feet) (P.L.E. = PLUME LEADING EDGE)	10
AQUIFER HYDRAULIC CONDUCTIVITY (Feet/Day)	7.1
AQUIFER GROUNDWATER GRADIENT (Feet/Feet)	0.005
AQUIFER EFFECTIVE POROSITY (unitless)	0.3
AQUIFER DISPERSION COEFFICIENT (Feet^2/Day)	0.118
CHEMICAL RETARDATION FACTOR (unitless)	2.81
CHEMICAL BIODEGRADATION DECAY RATE (1/Day)	0.0
LENGTH OF CONTAMINANT PLUME (Feet)	400
THICKNESS OF SURFICIAL AQUIFER (Feet)	25
WIDTH OF CONTAMINANT PLUME(Feet)	350
7Q10 OF RIVER OR STREAM (Feet^3/Second)	0.07
UP-STREAM CHEMICAL CONCENTRATION (mg/l)	0.0
SURFACE WATER CHEMICAL STANDARD(mg/l)	0.0924

MODELING RESULTS:

Maximum Groundwater Contaminant Concentration at Surface Water Boundary
occurs at Time = 2.309 years
with Groundwater Concentration C/Csource = 0.9991E+00
where Csource = Maximum Source Concentration

Maximum Groundwater Source Concentration = 1.757 mg/l
for the chemical TRICHLOROETHENE

APPENDIX 1:
WORKSHEETS FOR DERIVATION OF METHODS I, II AND III GROUNDWATER AND SOIL TARGET CONCENTRATIONS

WORKSHEET A1.1. SELECTION OF GROUNDWATER CATEGORIES (G-1, G-2 & G-3) AND CALCULATION OF TARGET CONCENTRATIONS FOR METHODS I, II & III FOR EACH CONTAMINANT AT A SITE.

1) Is groundwater current or potential drinking water?

   YES Enter G-1 at line A and go to 2.....A _____

   (NO) Go to 2. BASE-WIDE SUPPLY. SURFICIAL AQUIFER IMPRACTICAL FOR SUPPLY

2) Does exposure to contaminated groundwater occur through activities such as swimming in a swimming pool, gardening, irrigation, etc.?

   YES Enter G-1 at line B and go to 3.....B _____

   (NO) Go to 3.

3) Is contaminated groundwater at a vertical depth of 15 feet or less from soil surface or building substructure, <u>and</u>, within 30 horizontal feet or less of either an existing building, or a preferential pathway to a building?

   YES Enter G-2 at line C and go to 4.....C _____

   (NO) Go to 4 NO BLDG'S ON SITE. NO UNDERGROUND STRUCTURES NEAR PLUME.

4) Is there current or potential movement of groundwater contaminants to surface water?

   (YES) Enter G-3 at line D and go to 5.....D G-3

   NO Provide documentation that demonstrates no impact to surface water body will occur. Go to 5.

5) Is your site in the G-1, G-2 or G-3 category? See lines 1A, 2B, 3C and 4D above.

   (YES) Go to 6

   NO Go to 16.

6) Enter groundwater contaminants found at site into Column I of Table A1.1. Go to 7.

7) Enter maximum groundwater levels detected at site into Column II of Table A1.1 and go to 8.

8) *(Begin with the first contaminant and work through the following steps for each contaminant in Table A1.1 until all have been through the process.)*

Is your site in the G-1 Category? See lines 1A and 2B above. If G-1 is entered on either line, then site is in G-1 Category.

YES Is there a Method I G-1 Target Concentration in Table 3.1?

YES Is clean-up to the Method I G-1 Target Concentration feasible?

YES Enter Method I G-1 Target Concentration from Table 3.1 with a (I) beside it to indicate that Method I was used to determine this level into Column III of Table A1.1. Go to 10.

NO Use Method II to determine the groundwater Target Concentration (Chapter 3, Procedure for Determining Method II G-1 Target Concentrations). Go to 9.

NO Use Method II to determine the groundwater Target Concentration (Chapter 3, Procedure for Determining Method II G-1 Target Concentrations). Go to 9.

NO Go to 10.

9) Is clean-up to Method II G-1 Target Concentration feasible?

YES Enter the calculated Target Concentration into Column III of Table A1.1 with (II) beside it to indicate that Method II was used in determining this concentration. Go to 10.

NO Submit a request for approval to the Director or his designee to approve termination of corrective action according to 15A NCAC 2L .0104 and .0106(n). Go to 10.

10) Is your site in the G-2 Category? See line 3C above.

YES Is there a Method I G-2 Target Concentration in Table 3.1?

YES Is clean-up to Method I G-2 Target Concentration feasible?

YES Enter Method I G-2 Target Concentration with a (I) beside it into Column IV and go to 13.

NO Use Method II G-2 to determine the Target Concentration (Chapter 3, Procedure for Determining Method II G-2 Target Concentrations) Go to 11.

NO Use Method II G-2 to determine the Target Concentration (Chapter 3 Procedure for Determining Method II G-2 Target Concentrations) Go to 11.

NO Go to 13.

11) Is clean-up to Method II Target Concentration feasible?

YES Enter Target Concentration into Column IV with (II) beside it to indicate that Method II was used in determining this concentration. Go to 13.

NO Use Method III G-2 to determine the Target Concentration (Chapter 3, Method III Target Concentration Determination) replacing default transport model with more site-specific model. Go to 12.

12) Is clean-up to Method III Target Concentration feasible?

YES Enter Target Concentration into Column IV with (III) beside it to indicate that Method III was used in determining this concentration. Go to 13.

NO Submit a request for approval to the Director or his designee to conduct a site specific risk assessment. If approval is granted this worksheet may not be used.

13) Is your site in the G-3 Category? See line 4D above.

YES Does your site meet the following criteria:

- Groundwater plume is NOT in fractured bedrock; Y
- Groundwater plume's leading edge is greater than 250 feet from the surface water body; Y
- Groundwater plume length is less than 100 feet; Y
- Potentially impacted surface water is NOT classified as trout waters or water supplies (WS-I through WS-V) or future water supply (FWS); or Y
- Groundwater saturated thickness above bedrock is greater than 15 feet? Y

YES Is there a Method I G-3 Target Concentration in Table 3.2?

YES Is clean-up to Method I G-3 Target Concentration feasible?

YES Enter Method I G-3 Target Concentration with a (I) beside it into Column V and go to 17.

NO Use Method II G-3 to determine the Target Concentration (Chapter 3, Procedure for Determining Method II G-3 Target Concentrations) Go to 14.

NO Use Method II G-3 to determine the Target Concentration (Chapter 3 Procedure for Determining Method II G-3 Target Concentrations) Go to 14.

NO Use Method II G-3 to determine the Target Concentration (Chapter 3 Procedure for Determining Method II G-3 Target Concentrations) Go to 14.

NO Go to 17.

14) Is clean-up to Method II Target Concentration feasible?

YES Enter Target Concentration into Column V with (II) beside it to indicate that Method II was used in determining this concentration. Go to 17.

NO Use Method III G-3 to determine the Target Concentration (Chapter 3, Method III Target Concentration Determination) replacing default transport model with more site-specific model. Go to 15.

15) Is clean-up to Method III Target Concentration feasible?

YES Enter Target Concentration into Column V with (III) beside it to indicate that Method III was used in determining this concentration. Go to 17.

NO Submit a request for approval to the Director or his designee to conduct a site specific risk assessment. If approval is granted this worksheet may not be used.

16) Enter the lower of the following two parameters:

- 1000 times the groundwater quality standard (or interim standard) for the contaminant or
- 50% of the solubility of the contaminant

into Column VI and put "CCL" in Column VII. Go to 17.

17) Was this the last contaminant in Column I of Table A1.1?

YES Go to 18.

NO Is site is in G-1, G-2 or G-3 categories?

YES Go to 8 and continue to work through process until all contaminants have Target Concentrations.

NO Go to 16 and continue to work through process until all contaminants have Target Concentrations.

18) Compare the Target Concentrations listed in Columns III, IV and V.

Take the lowest of the Target Concentrations for each contaminant from those columns and enter this concentration into Column VI to obtain the required groundwater Target Concentration. Enter groundwater category and method symbol into Column VII. Go to 19.

19) Compare the Target Concentrations in Column VI to the maximum groundwater levels detected in Column II to determine if clean-up for a particular contaminant is necessary.

Highlight the contaminants in Column I whose maximum groundwater levels are above the Target Concentrations from Column VI. The highlighted contaminants must be remediated.

TABLE A1.1. WORK TABLE FOR DETERMINING GROUNDWATER TARGET CONCENTRATIONS.

See Worksheet A1.1 For Instructions On Completing This Work Table.

DATE:

SITE:

COUNTY:

MAILING ADDRESS:

INCIDENT NUMBER: _____

RESPONSIBLE PARTY: _____

PHONE NUMBER: _____

All concentrations are in mg/L.

I	II	III	IV	V(II)	VI	VII
Contaminants Found in Groundwater	Maximum Groundwater Concentration at Site	Target Concentrations by Groundwater Category			Required Groundwater Target Concentration*	Groundwater Category and Method
		G-1	G-2	G-3		
1,2-DCE	0.037	–	–	140.0	–	II G-3
TCE	0.097	–	–	0.081	0.162	↓
PCE	0.002	–	–	0.009	–	↓
1,1,2,2-PCE	0.010	–	–	0.0108	–	II G-3

* Lowest of the three target concentrations in Columns III through V unless none of the categories applied. If none of the categories apply, then enter the concentration for CCL where: CCL = the lower of 1000 times Groundwater quality standard (or interim groundwater quality standard) and 50% of the aqueous solubility of the contaminant.

NC DEHNR Risk Analysis Framework - Backup Information

As a part of the NC DEHNR Risk Analysis Framework, a model is included to determine maximum allowable contaminant concentrations in groundwater that are protective of surface water quality. The model, known as G3CTM, requires several input parameters. The paragraphs which follow provide the rationale for determining the input parameters.

Selection of Surface Water Quality Standards

Several chlorinated solvent compounds have been identified in groundwater at Site 36. The maximum observed concentrations of these compounds are as follows:

Compound	Site 36 Max. Observed Concentration (mg/L)
1,2-Dichloroethene	0.037
Trichloroethene	0.097
Tetrachloroethene	0.002
1,1,2,2-Tetrachloroethane	0.010

Brinson Creek is Classified as SC NSW. "SC" refers to tidal salt waters. "NSW" refers to nuturient sensitive waters.

The following published water quality standards have been established by the NC DEHNR[1] for all surface waters:

Compound	NC Standard (mg/L)
1,2-Dichloroethene	--
Trichloroethene	0.0924
Tetrachloroethene	--
1,1,2,2-Tetrachloroethane	0.0108

[1] From NC DEHNR 15A NCAC 2B .0208(a)(2)(B). This relates carcinogen standards protective of human health through the consumption of fish and shell fish. Drinking water standards are not applicable as Brinson Creek is non-potable. Sections .0212 (SC specific) and .0214 (NSW specific) do not specify any additional organic compounds.

When there is no published standard for a specific compound, the NC DEHNR Surface Water Section will calculate standards for a specific stream. For Brinson creek the calculated standards are as follows:

Compound	Calculated NC Standard (mg/L)
1,2-Dichloroethene	7.0
Tetrachloroethene	0.00885

Thus, a summary of standards:

Compound	North Carolina Standard (mg/L)
1,2-Dichloroethene	7.00
Trichloroethene	0.0924
Tetrachloroethene	0.000885
1,1,2,2-Tetrachloroethane	0.0108

A comparison of the observed maximum compound concentrations in groundwater at Site 36 to the above standards indicates that the maximum concentrations of 1,2-Dichloroethene (DCE), Tetrachloroethene (PCE), and 1,1,2,2-Tetrachloroethane (TCA) in groundwater are below surface water standards. Thus, maximum allowable concentrations of DCE, PCE, and TCA in groundwater need not be determined.

Distance of PLE from the Surface Water Body

The leading edge of the plume (PLE) may already be at Brinson Creek. The minimum input is 10 feet.

Hydrualic Conductivity (K)

The average K for the surfical aquifer is 4.2 feet/day based on slug test conducted at several shallow wells. The lower portion of the surficial aquifer typically exhibits a higher K. At nearby Site 35, a value is 10 feet/day was determined, based on slug tests. The average of the two values is 7.1 feet/day.

Groundwater Gradient

The value of 0.005 feet/foot was determined based on the spacing of contour line on a groundwater flow map from the RI.

Effective Porosity

Assumed to be approximately 30 %.

Dispersion Coefficient

A coefficient of 0.118 was determined from an equation provided in the framework.

Retardation Factor

As determined in the RI the retardation factor for TCE at Site 36 is 2.81.

Biodegradation Decay Rate

As per the framework document, no decay rate is allow for "some" chlorinated solvents. The document did not specify which solvents. To be conservative, no decay rate will be used for TCE.

Length of the Plume

The maximum length as measured from Figure 36-6 of the FS is approximately 400 feet.

Thickness of the Aquifer

Based on boring logs the thickness of the surficial aquifer is approximately 25 feet.

Width of the Plume

The maximum width as measured from Figure 36-6 of the FS is approximately 350 feet.

Stream 7Q10

A 7Q10 value for Brinson Creek is 0.07 cfs. This value was provided by Curtis Weaver of the USGS.

Upstream Chemical Concentration

Based on surface water sample analytical results, this value is zero.

APPENDIX E
VENDOR QUOTES

Ejector Systems Incorporated
910 National Avenue, Addison, IL 60101-9812

QUOTATION

Baker Environmental
Airport Office Park, Bldg. 3
Coraopolis, PA
15108
Attn: Mark DeJohn
Phone: 412-269-6007
FAX: 412-269-2002

Quote # 960655-00
Date: 04/04/96
Terms: Net 30 days
Freight: prepaid and added
FOB Addison
Quotation is valid for 60 days

Quote Specifications:

REF: F.S. PRoject # 303; Camp LeJune Site 36.

SYSTEM ELECTRICAL:
1/60/230 3 wire plus ground service,
brought to NEMA 3R exterior panel
Motors will be totally enclosed fan cooled

PUMPING SYSTEM DESIGN CRITERIA:

Qty	Diameter	Well Depth	GTS	Flow/Well
2	6 inch	40 feet	5ft.	5 gpm

TOTAL FLOW: 10 gpm @ 55 F LNAPL: NOT PRESENT

WATER TREATMENT DESIGN CRITERIA:

Dissolved Product: Contaminant	Concentration (ppb)	Discharge Limit (ppb)	After ESI Air Stripper (ppb)
TCE	97	2	< 1
PCE	2	.7	.5

We offer the following:

1 ESI Model 9443
REMEDIATION SYSTEM 24,713.00
INCLUDING:
* INSULATED ENCLOSURE: 8'W x 8'L x 8.5'H
with LIGHT, HEATER and THERMOSTAT
Equipment is mounted on a 8'W x 8'L steel platform with coated plywood deck. The enclosure consists of structural steel members and pre-assembled panels with aluminum skin. The enclosure incorporates one locking hinged door.
The side panels will be easily removable for additional access to the equipment for easier maintenance.
The breaker panel and control panel will be mounted on a vertical steel bracket attached to platform end.
The bracket, panels and all conduits will allow for the removal of the enclosure side panels by one person.
A single power connection will be provided by others.

* AIR MISER STRIPPING MODULE
6 tube air stripper with 2.5 HP / 3450 RPM blower motor
with: Effluent Transfer Pump
with: High/Low Blower Pressure Switch
with: High Sump Level Switch
with: Sample Ports
* 2" NPT inlet port with 40" WC suction lift

708-543-2214
1-800-OIL-LEAK
Fax 708 543-2014

Ejector Systems Incorporated
910 National Avenue, Addison, IL 60101-9812

* PVC water tubes (6 standard)
* 8" diameter tubes with removable ends for total cleaning access
* non-clogging nylon air diffusers
* regenerative blower with 1-1/2" exhaust
* locally mounted air pressure gauge
* temperature increase, relative humidity drop extends vapor-phase GAC life
* integral effluent sump with 2" NPT outlet

* ELECTRIC SUBMERSIBLE PUMP SYSTEM FOR 2 WELLS:
  * Grundfos Model 5E8 pump (5 gpm @ 130'TDH)
  * Panel-mounted controls
  * cable anchor with well mount
  * downwell hose, wires and jacketed motor leads
  * all additional straps, clamps and fittings for pump installation

* INTERLOCK CONTROL PANEL
  * latching pump shut-off relay w/manual reset and 2 dry contacts
  * definite-purpose contactor for electric pump shut off
* NEMA 3R EXTERIOR MOUNTED CONTROLS
  * breaker panel with individual branch breakers for all major components
  * control panel with magnetic starters, high level shut off system controls, and all additional control circuits required for the system

>>>>>Optional Equipment;(NOT INCLUDED)<<<<<

* SUSPENDED SOLIDS BAG FILTER.....$ 804.00
  * 2.1 sq. ft. surface area
  * 65 gpm flow capacity
  * 100 psi coated pressure tank
  * 25 micron filtration
  * differential gauge
  * by-pass line
  * 3 replacement bags included
  * quick opening clamp cover

==========
NET TOTAL: 24,713.00

Yours truly,
EJECTOR SYSTEMS, INC.

David Ogilvie
Sales Engineer

708-543-2214
1-800-OIL-LEAK
Fax 708-543-2014

EG&G

EG&G ENVIRONMENTAL
FOSTER PLAZA 6, SUITE 400
681 ANDERSEN DRIVE
PITTSBURGH, PA 15220
PHONE: (412) 920-5401

April 9, 1996

Ms. Cathy Chavara
Baker Environmental, Inc.
Airport Office Park
420 Rouser Road
Coraopolis, PA 15108

Re: North Carolina Site
Our ref. no.: 7002-100

Dear Cathy,

Please find attached our budgetary NoVOCs™ proposal for the referenced site for your use in a feasibility study.

We trust that the enclosed technical data and prices are sufficient for your purposes at this time.

Should you require additional information, or should you have any questions, please call me at 920-1340 or Terry Hawk at 728-8120. Terry will be away from the office until April 15.

We look forward to the prospect of working with you on this project. Thank you for the opportunity to present our proposal.

Very truly yours,

M M Baurz

for Wayne J. DiBartola
Vice President

cc: J. English, EG&GE
T. Hawk, EG&GE

NORTH CAROLINA GROUNDWATER CONTAMINATION SITE
PRELIMINARY NoVOCs™ DESIGN AND PRICE ESTIMATE

EG&G Environmental, Inc., (EG&GE) has prepared a preliminary design and price estimate for a NoVOCs™ system for a groundwater contamination site in North Carolina. The system would consist of nine NoVOCs™ wells and associated air handling and off-gas treatment equipment. The system would be operated to remediate a groundwater plume containing trichloroethylene (TCE) and tetrachloroethylene (PCE).

The following summarizes the design basis and features for the proposed system. This design is based on information provided to EG&GE by Baker Environmental, Inc., (Baker). Section 1.0 summarizes this design information. The specifications and price of the system are presented in Sections 2.0 and 3.0, respectively.

1.0 DESIGN INFORMATION

Information needed to design a NoVOCs™ groundwater treatment system includes characteristics of the contaminant plume, cleanup goals, and geohydrologic characteristics. Design information relevant to this site is described below.

1.1 Plume Characteristics

Plume characteristics were provided to EG&GE by Baker. The plume is reportedly 450 ft long by 350 ft wide by 16 ft deep.

1.2 Contaminant Concentrations and Cleanup Goals

The groundwater monitoring data provided indicate a maximum TCE concentration of 97 μg/L and a maximum PCE concentration of 2 μg/L. Cleanup goals for TCE and PCE are 5 μ/L and 0.7 μg/L, respectively.

1.3 Geohydrologic Characteristics

Geohydrologic characteristics needed to design the NoVOCs™ system are stratigraphy, depth to groundwater, horizontal hydraulic conductivity, anisotropy ratio (ratio of horizontal to vertical hydraulic conductivity), hydraulic gradient, and porosity. Geohydrologic data used for the design are summarized in Table 1.

Table 1. Summary of Geohydrologic Data Used for Design

Parameter	Value	Source
Stratigraphy	0 - 20 ft -- overlapping layers of fine sand and clay. 20 - 36 ft -- surficial aquifer consisting of shell fragments with fine sand, silt, and clay.	Cross-section provided by Baker.
Depth to groundwater	6 to 8 ft.	Provided by Baker.
Horizontal hydraulic conductivity	2.4 ft/day (8.5 x 10^{-4} cm/sec)	Provided by Baker.
Anisotropy ratio	10	Assumed based on stratigraphy.
Hydraulic gradient	0.002 ft/ft	Provided by Baker.
Porosity	0.2	Assumed based on stratigraphy.

2.0 System Design

The NoVOCs™ system for this site would consist of nine wells, each installed to a depth of 36 ft bgs. The wells would be located throughout the entire plume area. The wells would have a design pumping rate of 1.5 gpm and a design air-water ratio (AWR) of 100. This pumping rate and aquifer conditions would result in treatment zone dimensions of approximately 130 ft by 110 ft. An AWR of 100 would result in concentration reductions of 95% for TCE and 97% for PCE with each treatment cycle. The system is designed to reach cleanup goals with a single treatment cycle in order to minimize the cleanup time. The air injection rate at each well would be 20 cfm.

Figure 1 shows a general schematic of the NoVOCs™ well design for this site. The wells would be constructed of 6-in. PVC. An eductor design would be used so that treated water could be recharged below the water table at the top of the surficial aquifer unit. Each well would be constructed with two monitoring points. The lower monitoring point would be screened over the same interval as the NoVOCs™ inlet screen to sample water flowing into the well. The upper monitoring point would be placed in the annulus between the eductor and outer casing to sample the treated water and to monitor head in the recharge zone.

Required air handling and related equipment is summarized in Table 2. All equipment would be located in a trailer placed at a central location. Wells would be connected to the blowers by air lines buried underground. Off-gas would be treated using granular activated carbon (GAC).

Table 2. Equipment for Air Handling System

Air Injection Equipment
EN 6 5-HP explosion-proof regenerative blower
Inlet filter
Bleed-off muffler
Pressure relief valve
Venturi flow meter with gauge
Pressure gauge (blower discharge pressure)
Pressure gauge (blower inlet vacuum/filter restriction)
Valves and plumbing
Vacuum Equipment
EN 6 5-HP explosion-proof regenerative blower
Moisture separator with high level shut down
Vacuum relief valve
Venturi flow meter with gauge
Pressure gauge (blower discharge pressure)
Pressure gauge (blower inlet vacuum)
Valves and plumbing
Off-Gas Treatment Equipment
Two 150-lb radial-flow GAC units
Mechanical/Electrical Equipment
Equipment trailer with lights and ventilation blower
Electrical control panel
Control panel security cover
Auto-dialer alarm
Conduit and wiring

3.0 PRICE

The estimated price for the NoVOCs™ system described above is $190,000. This estimate is based on the best available design information and includes:

- well drilling, installation, and development;
- mechanical, electrical, and off-gas treatment equipment; and
- labor to provide design specifications and drawings, oversee well installation and system startup, and provide technical support as needed during operation.

The estimate includes the cost for containerizing drill cuttings and development water, but does not include disposal costs for these materials. Also, we assumed that 220 volt, 3 phase power and telephone service would be available at the site for the air handling system. The maximum power required by this system would be approximately 6 kw.

The estimated operating and maintenance (O&M) costs for the NoVOCs™ system are summarized in Table 3. Utility costs consist of electrical costs at $0.10/kwh and telephone

service. Maintenance costs include routine repairs and preventative maintenance. Labor costs include monthly inspections. Off-gas treatment costs are for regeneration of spent GAC. The GAC usage rates are based on maximum concentrations of contaminants in groundwater. The O&M costs do not include sampling and analysis to monitor cleanup progress.

Table 3. Summary of O&M Costs

Cost Element	Estimated Annual Cost
Utilities	$4,400
Maintenance	$800
Labor	$6,000
Off-gas Treatment	$500
Total	$11,700

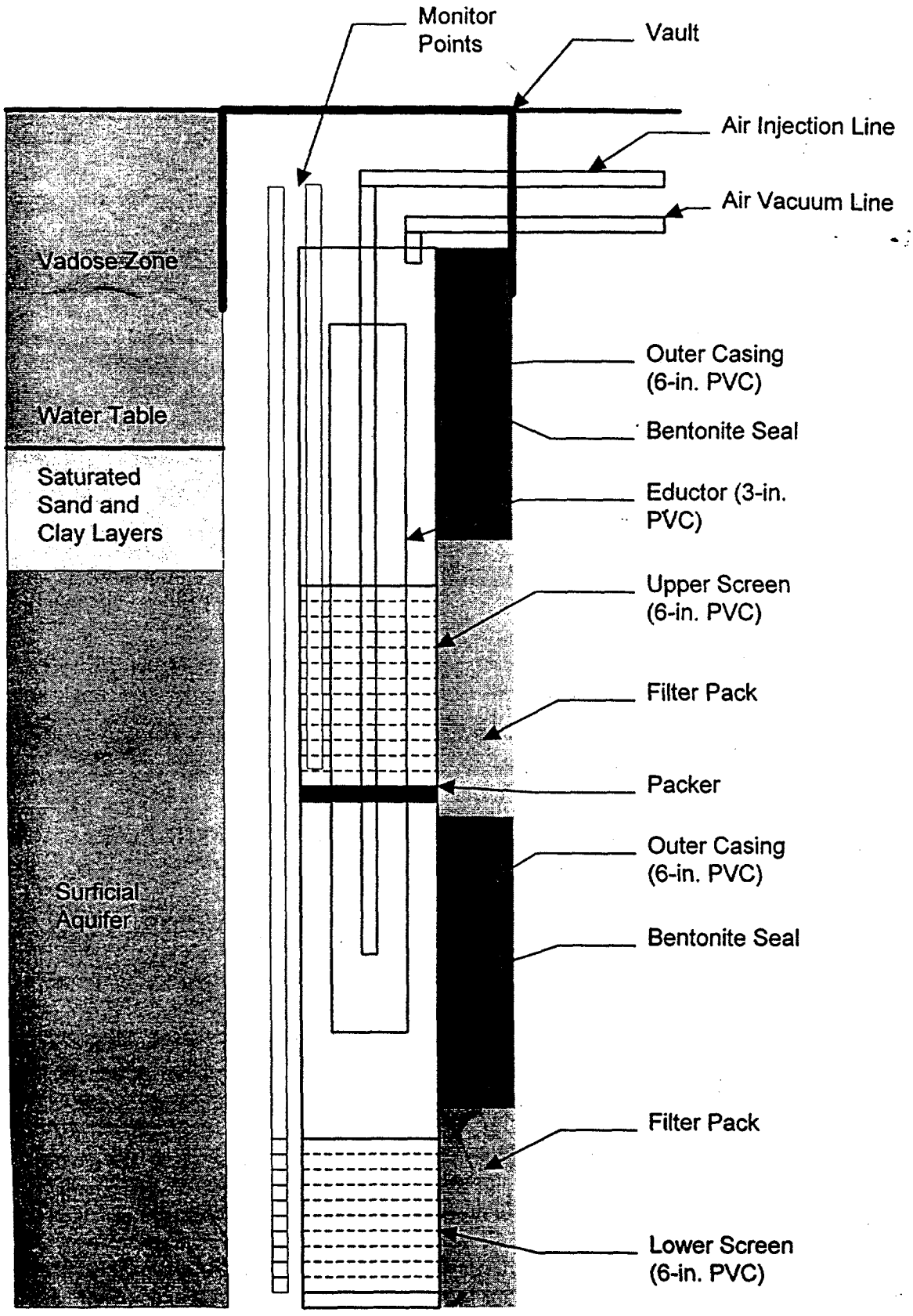


Figure 1. General Schematic of Well Design (Not to Scale)

FAX

EG&G Environmental

Date April 12, 1996

Number of pages including cover sheet 2

To:

Mark DeJohn
Baker Environmental

Phone
Fax Phone 269-2002
CC:

From:

Wayne J. DiBartola
EG&G Environmental, Inc.
Foster Plaza 6, Suite 400
681 Andersen Drive
Pittsburgh, PA 15220
Phone (412) 920-5401
Fax Phone (412) 920-5402

REMARKS:

☐ Urgent ☐ For your review ☐ Reply ASAP ☐ Please comment

Mark,

Per your request, please find following well arrangement sketch.

If you need anything more, call me.

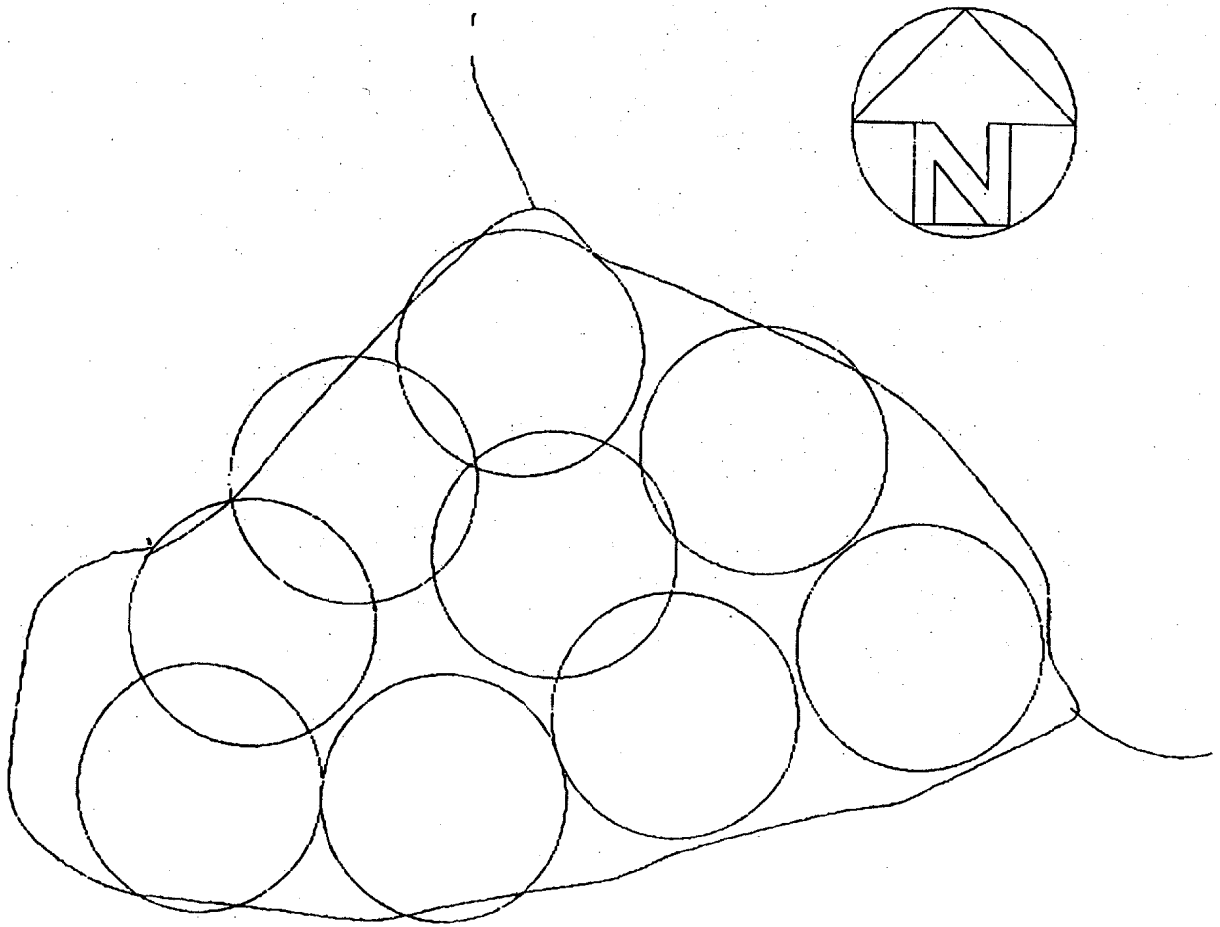
Regards,

Wayne DiBartola

JOE ENGLISH

ADDT'L Q & A

ESTIMATED CLEANUP TIME - ACCORDING TO WAYNE, ~ 1 YEAR
WELL LOCATIONS - SEE ATTACHED SKETCH



Approximate NoVOCs Well Locations

1" = 100'