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FINAL

FEASIBILITY STUDY REPORT
OPERABLE UNIT NO. 7
SITE 1

MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA
VOLUME I OF II

CONTRACT TASK ORDER 0231

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DEPARTMENT OF THE NAVY
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LIST OF ACRONYMS AND ABBREVIATIONS

ADL	administrative deadline lot
AOCs	areas of concern
ARARs	applicable or relevant and appropriate requirements
AWQC	Ambient Water Quality Criteria
Baker	Baker Environmental, Inc.
bgs	below ground surface
BEHP	bis (2-ethyl hexyl) phthalate
BRA	baseline human health risk assessment
CAA	Clean Air Act
CAMA	Coastal Area Management Act
Carc.	carcinogenic effects
CFR	Code of Federal Regulations
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLEJ	Camp Lejeune
CLP	contract laboratory program
COD	chemical oxygen demand
COCs	contaminants of concern
COPC	contaminants of potential concern
CSA	Comprehensive Site Assessment
CSF	carcinogenic slope factor
CWA	Clean Water Act
1,2-DCE	1,2-dichloroethene
DOD	Department of the Defense
DoN	Department of the Navy
DOT	Department of Transportation
DQO	data quality objective
EMD	Environmental Management Division (Camp Lejeune)
EPIC	Environmental Photographic Interpretation Center
ERA	ecological risk assessment
ER-L	effects range-low
ESE	Environmental Science and Engineering, Inc.
F	degrees Fahrenheit
FAWQC	Federal Ambient Water Quality Criteria
FFA	Federal Facilities Agreement
FSAP	Field Sampling and Analysis Plan
ft	feet
ft/ft	foot per foot

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

gpm	gallons per minute
GW	groundwater well
HA	health advisories
HI	Hazard Index
HPIA	Hadnot Point Industrial Area
HQ	hazard quotient
HQW	high quality water
i	hydraulic gradient
IAS	Initial Assessment Study
IAS	in situ air sparging
ICRs	incremental lifetime cancer risks
IDW	investigative derived wastes
IR	ingestion rate
IRA	interim remedial action
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program
K	hydraulic conductivity
kg	kilograms
LANTDIV	Naval Facilities Engineering Command, Atlantic Division
LAW	Law Engineering
MCB	Marine Corps Base
MCL	maximum contaminant level
mgd	million gallons per day
mg/kg	milligram per kilogram
mg/L	milligram per liter
ml	milliliter
msl	mean sea level
MTBE	methyl-tertiary-butyl-ether
MW	monitoring well
NAAQS	National Ambient Air Quality Standards
NCAC	North Carolina Administrative Code
NC DOT	North Carolina Department of Transportation
NC DEHNR	North Carolina Department of Environment, Health, and Natural Resources
NCMFC	North Carolina Marine Fisheries Commission
NCP	National Contingency Plan
NCWP	Near Coastal Waters Program
NCWQC	North Carolina Water Quality Criteria
NCWQS	North Carolina Water Quality Standards
NCWRC	North Carolina Wildlife Resources Commission
ND	nondetect

LIST OF ACRONYMS AND ABBREVIATIONS (Continued)

NEESA	Naval Energy and Environmental Support Activity
NOAA	National Oceanic Atmosphere Administration
NOAEL	no-observed-adverse-effect-level
NEP	National Estuary Program
NPL	National Priorities List
NPW	net present worth
O&G	oil and grease
O&M	operations and maintenance
OU	operable unit
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyls
PCE	tetrachloroethene
PEF	particulate emissions factor
POLs	petroleum, oil, and lubricants
POTW	publicly owned treatment works
ppb	parts per billion
ppm	parts per million
PRAP	Proposed Remedial Action Plan
PRGs	preliminary remediation goals
PVC	polyvinyl chloride
QA/QC	quality assurance/quality control
QI	quotient index
RA	risk assessment
RAAs	remedial action alternatives
RBCs	region III risk-based concentrations
RCRA	Resource Conservation and Recovery Act
RfD	reference dose
RG	remediation goals
RGO	remediation goal options
RI/FS	Remedial Investigation/Feasibility Study
RL	remediation levels
RME	responsible maximum exposure
ROD	Record of Decision
SAP	Sampling and Analysis Plan
SARA	Superfund Amendments and Reauthorization Act
SDWA	Safe Drinking Water Act
SMCL	secondary maximum contaminant level
SOP	standard operating procedure
SQC	sediment quality criteria
SSV	sediment screening value
STP	sewage treatment plant

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

SVE	soil vapor extraction
SVOCs	semivolatile organic compounds
TAL	target analyte list
TBC	to be considered
TCE	trichloroethene
TCL	target compound list
TCLP	toxicity characteristics leaching procedure
TDS	total dissolved solids
TICs	tentatively identified compounds
TPH	total petroleum hydrocarbons
trans-1,2-DCE	trans-1,2-dichloroethene
TRV	terrestrial residential value
TSCA	Toxic Substances Control Act
TSS	total suspended solids
UBK	uptake biokinetic
UCL	upper confidence level
UF	uncertainty factor
µg/L	micrograms per liter
µg/kg	micrograms per kilogram
USC	United States Code
USCS	Unified Soils Classification System
USDI	United States Department of the Interior
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
UST	underground storage tank
VOCs	volatile organic compounds
WOE	weight-of-evidence
WS	Wilderness Society
WQS	water quality standards
WQSV	water quality screening values

EXECUTIVE SUMMARY

INTRODUCTION

Marine Corps Base (MCB), Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) on October 4, 1989 (54 Federal Register 41015, 1989). The United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR), and the United States Department of the Navy (DoN) then entered into a Federal Facilities Agreement (FFA) for MCB, Camp Lejeune. The primary 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 and the environment (Camp Lejeune FFA, 1989).

The Fiscal Year 1995 Site Management Plan for MCB, Camp Lejeune, a primary document identified in the FFA, identifies 27 sites requiring Remedial Investigation/Feasibility Study (RI/FS) activities. These 27 sites have been divided into 14 operable units to simplify the RI/FS activities. This report focuses on Operable Unit (OU) No. 7 which consists of three sites:

- Site 1, the French Creek Liquids Disposal Area
- Site 28, the Hadnot Point Burn Dump
- Site 30, the Sneads Ferry Road Fuel Tank Sludge Area

This report documents the FS conducted for Sites 1 and 28. Based on the results of the RI conducted for OU No. 7, an FS is not required for Site 30.

Baker Environmental, Inc. (Baker) has prepared this FS for Contract Task Order 0231 under the DoN Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) program. The FS has been conducted in accordance with the requirements delineated in the National Oil and Hazardous Substances Pollution Contingency Plan (NOHSPCP or NCP) for remedial actions [40 Code of Federal Regulations (CFR) 300.430]. These NCP regulations were promulgated under CERCLA, commonly referred to as Superfund, and amended by the Superfund Amendments and Reauthorization Act (SARA) signed into law on October 17, 1986. In addition, the USEPA's document Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988) was used as guidance in preparing this FS.

This FS has been based on data collected during the RI conducted by Baker in 1994. Field investigations for the RI began in late March 1994 and continued through early May 1994. Additional groundwater sampling was also conducted in November 1994. Results of the field investigations are summarized in the RI report under separate cover (Baker, 1995).

SITE DESCRIPTION

Site 1

Site 1, the French Creek Liquids Disposal Area, is located approximately one mile east of the New River and one mile southeast of HPIA on the Mainside portion of MCB, Camp Lejeune. The site is situated on both the north and south sides of Main Service Road near the western edge of the Gun Park Area and Force Troops Complex. The French Creek development area, which includes Site 1, the Gun Park Area, and Force Troops Complex, is a self-supportive campus-like development. Supply, storage, and maintenance facilities, account for over 58 percent of the 583 total acres which constitute the French Creek development area. Troop housing occupies nearly 21 percent of the developed area or approximately 122 acres (LANTDIV, 1988).

The northern portion of Site 1 is surrounded by woods and a motor-cross training area to the north, a vehicle storage area associated with Building FC-100 to the east, Main Service Road to the south, and a treeline and Building FC-115 to the west. The majority of the suspected northern disposal area is within two fenced compounds that are associated with Buildings FC-120 and FC-134. The remaining portion of the northern disposal area is located outside of these fenced compounds, to the west and immediately adjacent to Building FC-134.

Building FC-120 serves as a motor transport maintenance facility for the Second Landing Support Battalion. It is a two story brick structure with offices and several vehicle maintenance bays. Building FC-134, located to the north of Building FC-120, provides offices and communication equipment storage also for the Second Battalion. It is a brick structure with offices and one garage bay.

A number of covered material storage areas (i.e., SFC-118, SFC-124, and SFC-125) are located to the north and west of Building FC-120. These smaller covered structures are used for temporary storage of paint, compressed gasses, vehicle maintenance fluids, spent or contaminated materials, and batteries.

In addition to these covered storage structures, an above ground storage tank (AST) area, located adjacent to the northern side of Building FC-120, is utilized to store spent motor oil and ethylene glycol (i.e., anti-freeze). Also, a gasoline service island is located to the west of Building FC-120. The two pumps at the service island provide fuel for vehicles undergoing maintenance at Building FC-120. An underground storage tank (UST) of unknown capacity is associated with this active service island.

Two equipment wash areas are also located adjacent to the northern disposal area. The first wash area is located to the west of Building FC-120 and the second lies to the east of Building FC-134. Both equipment wash areas are concrete-lined and employ an oil and water separator collection basin. Another oil and water separator is located to the north of Building FC-120, adjacent to Building SFC-118. Discharge from the three oil and water separators flows into a drainage ditch and sediment retention pond to the north of Building FC-134.

The southern portion of Site 1 is surrounded by Main Service Road to the north, Daly Road and a wooded area to the east, H. M. Smith boulevard to the south, and Gonzales Boulevard and a wooded area to the west. A portion of the suspected southern disposal area is surrounded by barbed-wire fences which contain a vehicle and equipment Administrative Deadline Lot (ADL), and a hazardous material storage area. The remaining part of the disposal area is not fenced. Vehicle access to this southern disposal area is via a swing-arm gate located along Main Service Road.

The hazardous material storage area, which is concrete-lined and bermed, is located north of Building FC-816. This area is used for the temporary storage of vehicle maintenance fluids, spent or contaminated materials, fuel, and batteries. In addition, a number of storage lockers are located throughout the southern portion of the site. These lockers are used to store paints and other flammable materials used by maintenance and machine shop personnel.

Several small buildings, including Buildings GP-13, GP-14, GP-11, GP-10, GP-19, and 746, are located adjacent to the suspected southern disposal area. The buildings are constructed of either formed metal, concrete block, or wood frame siding. Typically, the buildings are set on poured concrete slabs and have raised seam metal roofs. These buildings house a number of support offices, recreation facilities, machine shops, light-duty vehicle and equipment maintenance bays, and equipment storage areas. Heat is provided to the majority of these buildings by kerosene-fired stoves. Kerosene fuel is stored in ASTs located beside each building.

Two vehicle maintenance ramps are located on the southern portion of the site. The first ramp is located immediately to the south of Building 739 and the second lies to the north of Building GP-19. Both maintenance ramps are constructed of concrete and are used for the upkeep of vehicles and equipment.

Three oil and water separator collection basins are also located on the southern portion of the site. One separator is located adjacent to the Building 739 vehicle maintenance ramp, one separator is located southeast of Building GP-19, and one separator is located south of Building 816, adjacent to an equipment wash area. Discharge from the separator and wash area located south of building 816 flows into a stormwater sewer and then into the drainage ditch adjacent to H. M. Smith Boulevard.

A drainage ditch, which starts in the southern portion of the site, flows west toward the HPIA Sewage Treatment Plant (i.e., Site 28) and empties into Cogdels Creek. Cogdels Creek eventually discharges into the New River which is located approximately one mile west of Site 1.

<u>Site 28</u>

Site 28, the Hadnot Point Burn Dump, is located along the eastern bank of the New River. The site is within the Hadnot Point development area, approximately one mile south of HPIA on the Mainside portion of MCB, Camp Lejeune. The site is bordered to the north by the Hadnot Point STP, to the east and south by wooded areas, and to the west by the New River. Cogdels Creek flows into the New River at Site 28 and forms a natural divide between the eastern and western portions of the site. Vehicle access to the site is via Julian C. Smith Boulevard near its intersection with O Street, and the eastern and western portions of the site are served by an improved gravel road.

A majority of the estimated 23 acres that constitute the site are used for recreation and physical training exercises. The site is predominantly comprised of two lawn and recreation areas, known collectively as the Orde Pond Recreation Area, that are separated by Cogdels Creek. Picnic pavilions, playground equipment, and a stocked fish pond (Orde Pond) are located within this recreation area and they are regularly used by base personnel and their families. In addition, field exercises and physical training activities frequently take place at the recreation area.

The Hadnot Point Sewage Treatment Plant (STP) is located on and adjacent to Site 28. A portion of the STP facility extends across Cogdels Creek, from west to east. The STP operates a number of clarifying, settling, and aeration ponds that are located on either side of Cogdels Creek. Both operational areas of the STP are fenced with six-foot chain link. The treated water from the STP discharges into the New River via an outfall pipe approximately 400 feet from the shoreline.

SITE HISTORY

Site 1

Site 1 had been used by several different mechanized, armored, and artillery units since the 1940s. Reportedly, liquid wastes generated from vehicle maintenance were routinely poured onto the ground surface. During motor oil changes, vehicles were driven to a disposal point and drained of used oil. In addition, acid from dead batteries was reportedly hand carried from maintenance buildings to disposal points. At times, holes were dug for waste acid disposal and then immediately backfilled. Thus, the disposal areas at Site 1 are suspected to contain primarily petroleum, oil, and lubricants (POL) and battery acid.

The total extent of both the northern and southern disposal areas is estimated to be between seven and eight acres. The quantity of POL waste disposed at the areas is estimated to be between 5,000 and 20,000 gallons; the quantity of battery acid waste is estimated to be between 1,000 and 10,000 gallons.

Site 1 continues to serve as a vehicle and equipment maintenance/staging area (Water and Air Research, 1983). However, past disposal practices are no longer in use.

Site 28

Site 28 operated from 1946 to 1971 as a burn area for a variety of solid wastes generated on base. Reportedly, industrial waste, trash, oil-based paint, and construction debris were burned then covered with soil. In 1971, the burn dump ceased operations, and was graded and seeded with grass. The total volume of fill within the dump is estimated to be between 185,000 and 375,000 cubic yards. This estimate was based upon a surface area of 23 acres and a depth ranging from five to ten feet. (Water and Air Research, 1983).

REMEDIAL INVESTIGATION RESULTS

Site 1

Soil

Volatile organic compounds (VOCs) were not found in surface soils and were detected in only four subsurface soil samples scattered throughout the site. The VOC acetone was detected in one sample from the southern portion of the study area. However, the data suggest that acetone may have been an artifact of decontamination activities. TCE and toluene were detected at very low concentrations in subsurface soil samples collected from the northern central portion of the study area.

Semivolatile organic compounds (SVOCs) were not encountered in surface soils, but were detected in a number of subsurface samples. Most notable among the SVOCs detected, were three polynuclear aromatic hydrocarbon (PAH) compounds and di-n-butylphthalate. The positive detections of these compounds were located near the northern central portion of the site. The dispersion of Bis (2-Ethylhexyl) Phthalate (BEHP) suggests the occurrence of laboratory contamination, although detected in excess of ten times the maximum blank concentration of 120 µg/kg.

The pesticides dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, endrin aldehyde, alpha-chlordane, and gamma-chlordane appear to be the most prevalent contaminants within the soil at Site 1. Each of the seven pesticides were detected, at low concentrations, in at least two of the 124 soil samples. The pesticide 4,4'-DDT was the most prevalent, with 10 positive detections ranging from 1.6 J to 18 J µg/kg. ("J" indicates that the analytical result was estimated.) The highest pesticide concentration was that of 4,4'-DDE at 120 µg/kg. In general, pesticide detections were concentrated in the northern portion of the study area. The positive detections are, for the most part, limited to soil samples collected from less than seven feet bgs.

The polychlorinated biphenyls (PCBs) Aroclor 1254 and Aroclor 1260 were each detected once within the subsurface sample set. Aroclor 1254 was detected in a sample from a monitoring well test boring on the southern portion of the site, at a concentration of 18 J µg/kg. Aroclor 1260 was identified at a concentration of 1,300 µg/kg at a boring located near the center of the northern disposal area.

Based on a comparison of base-specific background levels, positive detections of inorganics at Site 1 do not appear to be the result of past disposal practices. Inorganic levels at the site are similar to inorganic background levels.

Groundwater

Positive detections of VOCs and SVOCs in groundwater were limited to the northern portion of the study area. In general, VOC analytical results from the first and second sampling events correlated. The VOC TCE was detected in samples obtained from three of the shallow monitoring wells. The maximum TCE concentration, 27 µg/L, was detected within the sample from monitoring well 1-GW17, located in the central northern portion of the study area. The volatile compounds 1,2-dichloroethene and 1,1-dichloroethene were observed at maximum concentrations of 21 and 2 J µg/L, respectively. The maximum 1,2-dichloroethene and 1,1-dichloroethene concentrations were detected in a sample obtained from well 1-GW10, located to the west of the suspected northern disposal area. Vinyl chloride was detected at an estimated concentration of 4 J µg/L, also from well 1-GW10. Xylenes were detected in a shallow groundwater sample from well 1-GW12, at a maximum concentration of 19 µg/L. The SVOCs phenol and diethylphthalate were detected during the first sampling round only in a sample from well 1-GW17DW, at concentrations of 6 J and 1 J µg/L, respectively.

Inorganic elements were the most prevalent among potential contaminants in groundwater at Site 1 and were found distributed throughout the site. Concentrations of target analyte list (TAL) total metals were generally higher in shallow groundwater samples than in samples obtained from the deeper aquifer. Iron and manganese were detected at concentrations which exceeded the North Carolina Water Quality Standards (NCWQS) drinking water standards in nine and fifteen samples, respectively, obtained during the second sampling round. Barium, calcium, magnesium, potassium, and sodium were detected in each of the 18 shallow and deep groundwater samples.

Site 28

Soil

Volatile organic compounds were found in one surface soil sample and two subsurface samples at very low concentrations. The VOCs benzene, tetrachloroethene, and 1,1,1-trichloroethane were each detected once within the 72 soil samples collected at Site 28. Based upon their wide dispersion, infrequent detection, and low concentration, the occurrence of volatile compounds in soils at Site 28 does not appear to be the result of past disposal practices.

Semivolatile compounds within soil samples at Site 28 appear to be the most directly linked, among organic compounds, to past disposal practices. Several SVOCs were identified in both surface and subsurface soil samples, primarily from the western disposal area. A majority of SVOCs detected in soil samples were PAH compounds, most probably resulting from combustion of waste material or refuse. Several of the semivolatile compounds were detected at concentrations greater than 1,000 μg/kg.

The pesticides dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, alpha-chlordane, and gamma-chlordane appear to be the most widely scattered contaminants within soils at Site 28. Each of the five pesticides were detected in at least 15 of the 72 soil samples. The pesticide 4,4'-DDE was the most prevalent, with 44 positive detections ranging from 3.1 J to 1,600 μg/kg. The highest pesticide concentration was that of 4,4'-DDT at 7,300 μg/kg. In general, higher concentrations of those pesticides more frequently detected, were limited to the western portion of the study area, and in particular among borings 28-GW01, 28-GW01DW, and 28-W-SB12.

Three PCB contaminants, Aroclor 1242, Aroclor 1254, and Aroclor 1260, were detected in soil samples obtained from borings at Site 28. The maximum PCB concentration was 140 J μg/kg from the pilot test boring 28-GW07.

Inorganic elements were detected in both surface and subsurface soil samples from the western portion of the study area at concentrations greater than one order of magnitude above of base-specific background levels. In general, elevated metal concentrations were limited to soils obtained from the western portion of the study area. The metals copper, lead, manganese, and zinc were observed at maximum concentrations greater than two orders of magnitude above base-specific background levels. The same four metals had several positive detections in excess of the one order of magnitude level.

Groundwater

Positive detections of VOCs in groundwater were limited to the central western portion of the study area. The volatile compounds chloroform, ethylbenzene, and xylenes were detected in a single shallow groundwater sample obtained from temporary well 28-TGWPA.

Semivolatile compounds were detected in five of ten shallow groundwater samples obtained during the first sampling round from the western portion of the study area. The maximum SVOC concentration, 99 μg/L, was detected within the sample from temporary monitoring well 28-TGWPA, located in the central western portion of the study area. Semivolatile analyses of groundwater samples were not performed as part of the second sampling round.

The organic pesticide compounds 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, and gamma-chlordane were each detected at least once within samples obtained from six shallow monitoring wells located on the western portion of Site 28, during the first sampling round. Pesticides 4,4'-DDE and 4,4'-DDD were detected within five and six shallow groundwater samples, respectively. The highest pesticide concentration detected was 9 μg/L of 4,4'-DDD, within the sample obtained from monitoring well 28-GW07. A second round of groundwater samples was obtained from those monitoring wells which presented evidence of pesticide contamination during the first sampling round. However, groundwater samples obtained during the second sampling round did not exhibit pesticides.

Inorganic elements were the most prevalent and widely distributed contaminants in groundwater at Site 28 and were found throughout the site. Concentrations of TAL total metals, in samples obtained during both sampling rounds, were generally higher in shallow groundwater samples than in samples collected from the deeper aquifer. Lead was detected, and confirmed by the second sampling round, within only one (28-GW08) of the shallow and deep groundwater samples at a concentration which exceeded the NCWQS and federal action level. Lead was also detected during the first sampling round in a sample retained from temporary well 28-TGWPA at a concentration which exceeded the NCWQS and federal action level. Iron and manganese were the most prevalent inorganic elements detected during both sampling rounds. Concentrations of iron and manganese were confirmed by the second sampling round to have exceeded either federal or state standards within 7 groundwater samples.

<u>*Surface Water*</u>

Orde Pond

Organic compounds (volatiles, semivolatiles, pesticides, and PCBs) were not detected in the two samples collected at Orde Pond. Fourteen of 23 TAL total metals were positively identified in these samples. The thallium concentration in sample 28-OP-SW02, obtained from the eastern end of Orde Pond, exceeded the NOAA chronic screening value of 4.0 µg/L by only 0.7 µg/L. No other total metal concentrations were in excess of chronic screening values.

Cogdels Creek

Organic compounds (volatiles, semivolatiles, pesticides, and PCBs) were not detected in the seven samples collected at Cogdels Creek. Laboratory analyses of the samples indicate that 14 of 23 possible total metals were positively detected. Lead was the only metal identified at a concentration in excess of the NOAA chronic screening values. Lead was detected within each of the seven surface water samples in excess of the 1.32 µg/L screening value. The maximum concentration of lead, 4.2 µg/L, was observed in a sample collected upstream of the study area. None of the positive lead detections exceeded the maximum base-specific surface water background concentration of 10.4 µg/L. No other total metal concentrations in the seven surface water samples exceeded chronic screening values.

New River

A positive detection of one semivolatile organic compound was observed among the five New River surface water samples. The SVOC phenanthrene was detected at a trace concentration of 1 µg/L in sample 28-NR-SW02, located slightly upstream of the study area. The pesticide organic compounds 4,4'-DDE and 4-4'-DDD were detected in surface water sample 28-NR-SW03, located adjacent to the western disposal area, at estimated concentrations of 0.04 J and 0.05 J µg/L, respectively.

Sixteen of 23 TAL total metals were positively identified in the five surface water samples collected from the New River. Copper, lead, thallium, and zinc were each identified at concentrations in excess of NOAA chronic screening values. Thallium and zinc were detected in excess of surface water screening values in one sample each. Copper and lead each exceeded screening values in a total of three surface water samples. The thallium concentration in sample 28-NR-SW04, located at the mouth of Cogdels Creek, exceeded the NOAA chronic screening value of 4.0 µg/L by 1.6 µg/L. Copper and lead were detected, among the five New River surface water samples, at maximum concentrations of 181 and 23.4 µg/L, respectively. Both maximum detections of copper and lead were observed in sample 28-NR-SW01, located approximately 100 yards upstream of the study area. The sample 28-NR-SW03, collected adjacent to the western disposal area, had copper, lead, and zinc concentrations of 6.6, 3.1, and 363 µg/L, respectively. Each of these three detections were in excess of the established chronic surface water screening values for copper, lead, and zinc (6.5, 1.32, and 58.9 µg/L, respectively). No other total metal concentrations in the seven surface water samples exceeded chronic screening values.

<u>*Sediment*</u>

Orde Pond

Volatile and semivolatile organic compounds were not detected among the samples retained for analysis from Orde Pond. The pesticide 4,4'-DDD was detected at an estimated concentration of 8.3 J µg/kg within sample 28-OP-SD01, located near the western bank of Orde Pond. The positive detection of 4,4'-DDD at this location is in excess of the NOAA Effects Range - Low (ER-L) screening criteria of 2 µg/kg. No total metal concentrations in any of the Orde Pond samples exceeded NOAA screening values.

Cogdels Creek

Carbon disulfide was the only volatile organic compound detected among the 14 Cogdels Creek sediment samples. The maximum detection of carbon disulfide, 13 J µg/kg, was identified within sample 28-CC-SD07, collected upstream of the study area. The other detection of carbon disulfide was from a sample located downstream of the site, near the mouth of Cogdels Creek.

A number of semivolatile organic compounds were identified within Cogdels Creek sediment samples. A total of 12 SVOCs were detected in the 14 Cogdels Creek samples. Nine of the 12 detected SVOCs were identified exclusively in samples 28-CC-SD03 and 28-CC-SD02, located adjacent to and downstream of the disposal area. The maximum semivolatile concentration, 1,700 µg/kg, was that of both BEHP and the PAH benzo(a)pyrene. Benzo(a)pyrene was positively detected within nine of the 14 samples submitted for laboratory analysis. Five of those nine positive benzo(a)pyrene detections exceeded the NOAA screening value of 400 µg/kg, all within samples collected upstream of the study area. The phenanthrene concentration in sample 28-CC-SD03, located adjacent to the study area, exceeded the NOAA screening value of 225 µg/kg by 35 µg/kg.

The organic pesticides 4,4'-DDE and 4,4'-DDD were detected within nine and seven of the 14 Cogdels Creek sediment samples, respectively. Each of the detections found upstream and downstream of the study area were in excess of NOAA screening values. Both 4,4'-DDE and 4,4'-DDD were detected at their respective maximum concentrations at sample station 28-CC-SD01, located at the mouth of Cogdels Creek. The positive 4,4'-DDE and 4,4'-DDD detections of 200 J and 450 J µg/kg, respectively, exceeded the NOAA screening value for both pesticide contaminants of 2 µg/kg. The pesticides 4,4'-DDT, alpha-chlordane, and gamma-chlordane were also detected at concentrations which, in each case, exceeded screening values. The three pesticides were observed in only two samples retained from upstream locations. The estimated maximum concentrations of 4,4'-DDT, alpha-chlordane, and gamma-chlordane were 50 J, 5.9 NJ, and 8.4 J µg/kg, respectively.

Twenty-two of 23 TAL total metals were positively identified in the 14 sediment samples retained from Cogdels Creek (selenium was not detected). Lead, mercury, silver, and zinc were each identified at concentrations in excess of NOAA ER-L screening values. Silver and zinc were detected in excess of sediment screening values within one and two Cogdels Creek sediment samples, respectively. Lead and mercury exceeded screening values in seven and four of the 14 Cogdels Creek sediment samples. The silver concentration of 2 mg/kg in sample 28-CC-SD04, located adjacent to the disposal area, exceeded the NOAA screening value for of 1.0 mg/kg. Lead and mercury were detected, among the 14 Cogdels Creek sediment samples, at maximum concentrations of 202 and 0.41 mg/kg, respectively. The maximum detection of lead was observed in sample 28-CC-SD04, located adjacent to the study area. Mercury was observed at a maximum concentration at sample station 28-CC-SD01, located near the mouth of Cogdels Creek. No other total metal concentrations among the 14 Cogdels Creek sediment samples exceeded screening values.

New River

Carbon disulfide was the only volatile organic compound detected among the ten sediment samples collected from the New River. The only detection of carbon disulfide, 2 J µg/kg, was identified within sample 28-NR-SD02, located slightly upstream of the study area. No other volatile compounds were detected.

A number of semivolatile organic compounds were identified within sediment samples retained from the New River. A total of 17 SVOCs, 13 of which were PAHs, were detected in the ten New River sediment samples. Twelve of the 17 positively detected SVOCs were identified at their respective maximum concentrations in sample 28-NR-SD01, located approximately 100 yards upstream of the study area. The maximum PAH concentration, 2,100 µg/kg, was that of chrysene. Chrysene was positively detected within five of the sediment samples submitted for laboratory analysis from the New River. Three of those five positive chrysene detections exceeded the NOAA screening value of 400 µg/kg. Phenanthrene, anthracene, fluoranthene, pyrene, benzo(a)anthracene, and benzo(a)pyrene were also detected within sediment samples in excess of sediment screening values. In general, concentrations of SVOCs in the two samples obtained adjacent to the western disposal area were lower than those detections observed both upstream and downstream of the study area.

The organic pesticides 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, alpha-chlordane, and gamma-chlordane were each detected in either two or three of the ten New River sediment samples. Each of the detections were in excess of NOAA screening values. Both 4,4'-DDE and 4,4'-DDD were detected at their respective maximum concentrations at sample station 28-NR-SD01, located upstream of the study area. The positive 4,4'-DDE and 4,4'-DDD detections of 8.5 and 15 µg/kg, respectively, exceeded the NOAA screening value for both pesticide contaminants of 2 µg/kg. The pesticides 4,4'-DDT, alpha-chlordane, and gamma-chlordane were also detected at concentrations which, in each case, exceeded screening values. Alpha- and gamma-chlordane were observed in only two samples retained from the New River, located adjacent to and downstream of the site. The maximum concentrations of 4,4'-DDT, alpha-chlordane, and gamma-chlordane were 300, 6.6 J, and 4.6 J µg/kg, respectively.

Nineteen of 23 TAL total metals were positively identified in the ten New River sediment samples (beryllium, cadmium, selenium, and thallium were not detected). Antimony, copper, lead, and silver were each identified at concentrations in excess of NOAA ER-L screening values. Each of the four metal contaminants were detected in excess of sediment screening values within two samples retained from the New River. Antimony, copper, and lead were each detected at their respective maximum concentrations among the ten New River samples at station 28-NR-SD01, located upstream of the study area. The copper concentration of 1,340 mg/kg in sample 28-NR-SD01 exceeded the NOAA screening value of 70 mg/kg. Antimony and lead were detected at maximum concentrations of 263 and 38,800 mg/kg, respectively. The NOAA screening values for antimony and lead are 2 and 35 mg/kg, respectively. Concentrations of silver in samples 28-NR-SD03, 3.4 J mg/kg, and 28-NR-SD05, 3.1 J mg/kg, slightly exceeded the NOAA value of 1 mg/kg. No other total metal concentrations among the ten New River sediment samples exceeded screening values.

<u>*Aquatic Organisms*</u>

Orde Pond

The pesticides 4,4'-DDE and alpha-chlordane were detected among the whole body tissue samples collected in Orde Pond. The maximum pesticide concentration was that of 4,4'-DDE at 38 µg/kg. Positive detections of VOCs and SVOCs in whole body tissue samples were rejected due to laboratory contamination. Total xylenes were detected in the American eel tissue sample at an estimated concentration of 8 J µg/kg.

Sixteen metals were detected in the whole body tissue samples collected from Orde Pond. The metals antimony, arsenic, chromium, copper, mercury, selenium, and zinc were found in Orde Pond biotic samples at maximum concentrations of 0.17 J, 0.10 J, 10.7 J, 1.2 J, 0.18 J, 0.45 J, and 26.3 J µg/kg, respectively.

The majority of volatile and semivolatile contaminant analyses from Orde Pond fillet samples were rejected due to laboratory interference. Therefore, the results of those analyses are inconclusive. There were no pesticides or PCBs detected in the fillet tissue samples, however.
Thirteen metals were detected in the fillet tissue samples collected from Orde Pond. The priority pollutant metals arsenic, chromium, copper, mercury, selenium, and zinc were detected in Orde Pond fillet samples at maximum concentrations of 0.1 J, 0.63 J, 0.22 J, 0.23 J, 0.32 J, and 22.9 µg/kg, respectively. The maximum tissue levels of metals in fillet tissue samples were found in the largemouth bass, blue gill, and redear sunfish.

New River

The pesticides beta BHC, 4,4'-DDE, 4,4'-DDD, endrin aldehyde, and alpha-chlordane were detected among the whole body stripped mullet, summer flounder, and Atlantic menhaden in New River tissue samples. Positive detections of VOCs and SVOCs were considered common laboratory contaminants. Twenty of 23 TAL metals were detected in New River whole body tissue samples that were obtained from stripped mullet, summer flounder, and Atlantic menhaden. The metals antimony, arsenic, beryllium, cadmium, chromium, copper, mercury, selenium, silver, and zinc were detected in New River whole body samples at maximum concentrations of 0.23 J, 1.2 J, 0.007 J, 0.02 J, 5.4 J, 4.6 J, 0.014 J, 0.41 J, 0.10 J, and 1.8 J µg/kg, respectively.

The pesticides detected in the fillet tissue samples were identical to the pesticides found in the whole body samples. The VOCs and SVOCs detected in the whole body samples were considered common laboratory contaminants.

Fillet tissue samples, as with whole body samples, from the stripped mullet, summer flounder, spotted sea trout and black drum contained metals. Similar concentrations of metals were found in both fillet and whole body samples. Although metals were detected in all species, not all species contained the same metals.

MEDIA OF CONCERN

Site 1

Based on the results of the human health and ecological risk assessments, the medium of concern at Site 1 was determined to be groundwater.

Site 28

Based on the results of the human health and ecological risk assessments, the medium of concern at Site 28 was determined to be groundwater.

DEVELOPMENT OF REMEDIATION LEVELS AND COCs

Remediation levels (RLs) were developed based on a comparison of contaminant-specific ARARs and the site-specific risk-based action levels. 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 for the RL.

Contaminants which exceeded at RLs were retained as COCs for the FS. The contaminants that did not exceed RLs will no longer be considered as COCs with respect to this FS.

Site 1

In groundwater at Site 1, the following contaminants exceeded an RL and were retained as COCs (refer to Table ES-1):

- TCE
- Manganese
- Mercury

TCE exceeded its RL at two shallow wells, 1-GW10 and 1-GW17, where it was detected at 8J μg/L and 18 μg/L, respectively; the RL for TCE is 2.8 μg/L. Manganese exceeded its RL at six shallow wells, 1-GW01, 1-GW02, 1-GW10, 1-GW11, 1-GW14, and 1-GW17. At these wells, manganese was detected at concentrations of 449J μg/L, 4,65J μg/L 1,200 μg/L, 1,070J μg/L, 250 μg/L, and 95.1 μg/L, respectively. The RL for manganese is 50 μg/L. Mercury exceeded its RL at one shallow well, 1-GW04, where it was detected at 1.2 μg/L; the RL for mercury is 1.1 μg/L.

Although an RL was not developed for vinyl chloride, this contaminant was detected at concentrations that exceeded state standard and federal standards. At well 1-GW10, vinyl chloride was detected at 4J μg/L which slightly exceeded the NCWQS of 0.015 μg/L and the Federal MCL of 2 μg/L. It appears as though this vinyl chloride could be the result of TCE degradation. As a result, the remedial action objectives must address this vinyl chloride.

Site 28

In groundwater at Site 28, the following contaminants exceeded an RL and were retained as COCs (refer to Table ES-2):

- Lead
- Manganese

Lead and manganese exceeded remediation levels in both the shallow and deep aquifers. Lead exceeded its remediation level in one well, 28GW08. (The detected concentration of lead was 126 µg/L; the remediation level is 15 µg/L.) Manganese exceeded its remediation level at six shallow wells, 28GW01, 28GW02, 28GW04, 28GW7, 28GW08, and 28GW13, and one deep well, 28GW01DW. (The detected manganese concentrations were 225 µg/L, 185 µg/L, 55.6 µg/L, 694 µg/L, 1,450 µg/L, 347 µg/L, and 65.8 µg/L, respectively; the remediation level for manganese is 50 µg/L.) Because it is inappropriate to define a plume of metals, the wells where high metals were detected will be considered small AOCs.

REMEDIAL ACTION OBJECTIVES

Site 1

The following remedial action objectives were developed for groundwater at Site 1:

- Mitigate the potential for direct exposure to contaminated groundwater.
- Mitigate the horizontal and vertical migration of contaminated groundwater.
- Restore the shallow aquifer so that contaminants meet their remediation levels.

These remedial action objectives specifically address the interpreted extent of a VOC plume delineated around wells 1-GW10 and 1-GW17. The extent of the plume was based on monitoring well locations where TCE exceeded its RL and vinyl chloride exceeded its state and federal standards, and the direction of groundwater flow (northwest).

Although manganese and mercury exceeded their RLs, these metals were not addressed by the remedial action objectives for the following reasons:

- Manganese concentrations (i.e., both total and filtered) in groundwater at MCB, Camp Lejeune often exceed the NCWQS and federal secondary MCL of 50 µg/L. Elevated manganese levels, at concentrations above the NCWQS and secondary MCL, were reported in samples collected from a number of Base potable water supply wells (Greenhorne and O'Mara, 1992). Manganese concentrations at several Site 1 wells exceeded the NCWQS, but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. As a result, manganese does not appear to be a site-related contaminant. Instead, manganese appears to naturally occur at concentrations exceeding the RL in groundwater throughout the Base.

- Mercury exceeded its RL at only one well by 0.1 µg/L, which is a relatively minor exceedance. In addition, mercury was not detected in any of the dissolved metals samples. Consequently, it is likely that suspended solids in the total metals samples (i.e., high turbidity yield elevated total metals concentrations). Thus, mercury does not appear to be a site-related contaminant.

- There is no record of any historical use, either industrial or disposal, of manganese or mercury at Site 1. This information further supports the theory that manganese and mercury are not site-related contaminants.

Site 28

The following remedial action objective was developed for groundwater at Site 28:

- Mitigate the potential for direct exposure to the groundwater COCs.

No other remedial action objectives, such as preventing the COC migration or remediating the aquifer, were developed because the risks associated with the groundwater COCs are minimal. Manganese and lead at Site 28 do not pose substantial risks for the following reasons:

- Manganese concentrations (i.e., both total and filtered) in groundwater at MCB, Camp Lejeune often exceed the NCWQS and federal secondary MCL of 50 μg/L (Baker, 1994a). Elevated manganese levels, at concentrations above the NCWQS, were reported in samples collected from a number of base potable water supply wells (Greenhorne and O'Mara, 1992). Manganese concentrations at several Site 28 wells exceeded the NCWQS, and all but one sample fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. As a result, manganese does not appear to be a site related contaminant. Instead, manganese appears to naturally occur at concentrations exceeding the RL in groundwater throughout the Base.

- Lead was detected above its remediation level at only one well, 28-GW08. This well, which is situated in an area of loosely compacted fill material, exhibited high turbidity (above 10 turbidity units) and total suspended solids (111 mg/L). In addition, lead was only detected in the total metals sample, not the dissolved metals sample, taken at this well. All of this information suggests that the high lead concentration detected at 28-GW08 may be the result of suspended solids, and the total metals analysis is indicative of lead in the soil and groundwater, not just the amount of lead that is dissolved in the groundwater. As a result, lead does not appear to be a site related contaminant.

Based on this information, the case can be made that an FS for groundwater at Site 28 is not necessary. It is pointless to remediate or prevent the migration of a metal that naturally exists at high levels throughout the Base and a metal that was not detected in the dissolved phase. However, since the site is used as a public recreation area, an FS will be conducted ensuring an overly conservative approach to the protection of human health and the environment. The FS will be focused with only one remedial action objective that accounts for the minimal risks associated with the groundwater COCs.

REMEDIATION ALTERNATIVE DEVELOPMENT AND EVALUATION

Remedial action technologies and process options chosen were combined to form remedial action alternatives (RAAs) to address groundwater at Sites 1 and 28. More specifically, the following AOCs were evaluated for each site:

Site 1

- A VOC plume in the surficial aquifer located within the northern portion of the site.

Site 28

- Small areas of metals contamination (lead and manganese) in groundwater located sporadically throughout the site.

Based on the AOCs identified above, five groundwater RAAs were developed for Site 1, and two groundwater RAAs were developed for Site 28.

Site 1

The following groundwater RAAs were developed and evaluated for Site 1:

- RAA No. 1: No Action
- RAA No. 2: Institutional Controls
- RAA No. 3: Extraction and On-Site Treatment
- RAA No. 4: In-Well Aeration and Off-Gas Carbon Adsorption
- RAA No. 5: Extraction and Off-Site Treatment

A description of the remedial actions associated with each alternative as well as the estimated cost and time frame to implement the alternative follows:

- RAA No. 1: No Action
  Capital Cost: $0
  Annual Operations and Maintenance (O&M) Costs: $0
  Net Present Worth (NPW): $0
  Years to Implement: None

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

- RAA No. 2: Institutional Controls
  Capital Cost: $0
  Annual O&M Costs: $40,000
  NPW: $600,000
  Years to Implement: Estimated 30

Under RAA No. 2, no remedial actions will be performed to reduce the toxicity, mobility, or volume of groundwater contaminants at Site 1. Instead, the following institutional controls will be implemented: continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

- RAA No. 3: Extraction and On-Site Treatment
  Capital Cost: $990,000
  Annual O&M Costs: $70,000
  NPW: $2,100,000
  Years to Implement: Estimated 30

RAA No. 3 is a source collection and treatment alternative. The technologies/process options associated with RAA No. 3 include: extraction wells, on-site treatment (air stripping, neutralization, precipitation, flocculation, sedimentation, and filtration), off-site discharge, continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

- RAA No. 4: In-Well Aeration and Off-Gas Carbon Adsorption
  Capital Cost: $640,000
  Annual Groundwater Monitoring O&M Costs: $40,000
  Annual System O&M Costs: $20,000
  NPW: $1,300,000
  Years to Implement: Estimated 30 for Monitoring; 3 for System Operation

In-well aeration is a new and innovative technology that utilizes circulating air flow within a groundwater well that, in effect, turns the well into an air stripper. Under RAA No. 4, four in-well aeration wells will be installed. Because the radius of influence of an aeration well is approximately 1.5 to 2 times the saturated aquifer thickness, the radius of influence of each well at Site 1 will be approximately 120 to 160 feet. Thus, the wells will intercept the TCE plume as it travels in the direction of groundwater flow. Volatilized organic contaminants collected by the in-well aeration system will be treated near the opening of each well by a carbon adsorption unit.

- RAA No. 5: Extraction and Off-Site Treatment
  Capital Cost: $480,000
  Annual Groundwater Monitoring O&M Costs: $40,000
  Annual System O&M Costs: $130,000
  NPW: $1,400,000
  Years to Implement: Estimated 30 for Monitoring; 3 for System Operation

RAA No. 5 is a source collection and treatment alternative. The technologies/process options associated with RAA No. 5 include: extraction wells, off-site treatment, continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

A summary of the comparative evaluation of alternatives is provided in Table ES-3.

Site 28

The following groundwater RAAs were developed and evaluated for Site 28:

- RAA No. 1: No Action
- RAA No. 2: Institutional Controls

A description of the remedial actions associated with each alternative as well as the estimated cost and time frame to implement the alternative follows:

- RAA No. 1: No Action
  Capital Cost: $0
  (O&M) Costs: $0
  NPW : $0
  Years to Implement: None

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

- RAA No. 2: Institutional Controls
  Capital Cost: $0
  Annual O&M Costs: $30,000
  NPW: $500,000
  Years to Implement: Estimated 30

Under RAA No. 2, no remedial actions will be performed to reduce the toxicity, mobility, or volume of groundwater contaminants at Site 1. Instead, the following institutional controls will be implemented: continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

A summary of the comparative evaluation of alternatives is provided in Table ES-3.

TABLES

TABLE ES-1

FINAL SET OF COCs AND REMEDIATION LEVELS FOR SITE 1 FEASIBILITY STUDY CTO-231 SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium of Concern	Contaminant of Concern	Remediation Level	Unit	Basis of Level
Groundwater	Trichloroethene	2.8	µg/L	NCWQS
	Manganese	50	µg/L	NCWQS
	Mercury	1.1	µg/L	NCWQS

TABLE ES-2

FINAL SET OF COCs AND REMEDIATION LEVELS FOR SITE 28
FEASIBILITY STUDY CTO-231
SITE 28 - HADNOT POINT BURN DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Medium of Concern	Contaminant of Concern	Remediation Level	Unit	Basis of Level
Groundwater	Lead	15	µg/L	NCWQS
	Manganese	50	µg/L	NCWQS

TABLE ES-3

SUMMARY OF ALTERNATIVE EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
OVERALL PROTECTIVENESS • Human Health	No reduction in potential human health risks, except through natural attenuation of the contaminated groundwater.	Institutional controls and natural attenuation will reduce potential human health risks.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential human health risks.	Institutional controls, natural attenuation, and in-well aeration will reduce potential human health risks.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential human health risks.
• Environmental Protection	No reduction in potential risks to ecological receptors, except through natural attenuation of the contaminated groundwater.	Institutional controls and natural attenuation will reduce potential risks to ecological receptors.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential risks to ecological receptors.	Institutional controls, natural attenuation, and in-well aeration will reduce potential risks to ecological receptors.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential risks to ecological receptors.
COMPLIANCE WITH ARARS • Chemical-Specific ARARs	No active effort made to reduce contaminant levels to below federal or state ARARs. However, contaminants are expected to meet ARARs via natural attenuation processes.	No active effort made to reduce contaminant levels to below federal or state ARARs. However, contaminants are expected to meet ARARs via natural attenuation processes.	Contaminants within the wells' radii of influence are expected to meet chemical-specific ARARs.	Contaminants within the wells' radii of influence are expected to meet chemical-specific ARARs.	Contaminants within the wells' radii of influence are expected to meet chemical-specific ARARs.
• Location-Specific ARARs	Not applicable.	Not applicable.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.
• Action-Specific ARARs	Not applicable.	Not applicable.	Can be designed to meet action-specific ARARs.	Can be designed to meet action-specific ARARs.	Can be designed to meet action-specific ARARs.
LONG-TERM EFFECTIVENESS AND PERMANENCE • Magnitude of Residual Risk	The residual risk from untreated contaminants will be minimal; natural attenuation will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and natural attenuation will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and the extraction/ treatment system will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and in-well aeration will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and the extraction/ treatment system will mitigate any residual risk that may exist.

TABLE ES-3 (Continued)

SUMMARY OF ALTERNATIVE EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
• Adequacy and Reliability of Controls	No controls	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure.	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure until remediation levels are met.	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure until remediation levels are met.	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure until remediation levels are met.
• Need for 5-year Review	Review will be required to ensure adequate protection of human health and the environment.	Review will be required to ensure adequate protection of human health and the environment.	Until remediation levels are met, review will be required to ensure adequate protection of human health and the environment.	Until remediation levels are met, review will be required to ensure adequate protection of human health and the environment.	Until remediation levels are met, review will be required to ensure adequate protection of human health and the environment.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT • Treatment Process Used	No active treatment process applied.	No active treatment process applied.	The treatment process includes air stripping for VOC removal and neutralization, precipitation, flocculation, sedimentation, and filtration as pretreatment for the air stripper.	The treatment process includes in-well air stripping and off-gas carbon adsorption for VOC removal.	The treatment processes, include air stripping and carbon adsorption for VOC removal; also, flocculation and sedimentation for metals removal.
• Amount Destroyed or Treated	Eventually, all of the contaminants will be treated by natural attenuation.	Eventually, the majority of the contaminants are expected to be treated by natural attenuation.	Eventually, the majority of the contaminants are expected to be treated by the extraction/treatment system.	The majority of the contaminants are expected to be treated by the in-well aeration system.	Eventually, the majority of the contaminants are expected to be treated by the extraction/treatment system.
• Reduction of Toxicity, Mobility, or Volume	No COC reduction except by natural attenuation.	No COC reduction except by natural attenuation.	Nearly 100% reduction in toxicity, mobility, and volume is expected.	Nearly 100% reduction in contaminant toxicity, mobility, and volume is expected.	Nearly 100% reduction in contaminant toxicity, mobility, and volume is expected.

TABLE ES-3 (Continued)

SUMMARY OF ALTERNATIVE EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
• Residuals Remaining After Treatment	No active treatment process applied.	No active treatment process applied.	Treatment residuals will include sludge, off-gases from the air stripper, and treated groundwater. The sludge should be non-hazardous, the off-gases will be within acceptable air discharge limits, and the treated groundwater will be within acceptable groundwater discharge limits.	Treatment residuals will include the small amount of liquid left in the knockout tank (most likely less than 5 gallons) and spent carbon. The liquid should be non-hazardous, but the spent carbon will contain adsorbed contaminants.	Treatment residuals will include spent carbon, sludge, off-gases from the air stripper, and treated groundwater. The sludge should be non-hazardous, the off-gases will be within acceptable air discharge limits, and the treated groundwater will be within acceptable groundwater discharge limits.
• Statutory Preference for Treatment	Not satisfied.	Not satisfied.	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.	Potential risks to the community will be increased during system installation and operation.	Potential risks to the community will be increased during system installation and operation.	Potential risks to the community will be increased during system installation and operation.
• Worker Protection	No risks to workers.	No significant risks to workers.	Potential risks to workers will be increased; worker protection is required.	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 if aquifer drawdown does not affect surrounding water bodies.	No additional environmental impacts.	No additional environmental impacts if aquifer drawdown does not affect surrounding water bodies.
• Time Until Action is Complete	Unknown.	Thirty years was used to estimate NPW costs. The exact time for completion of remediation is unknown.	Thirty years was used to estimate NPW costs. The exact time for completion of remediation is unknown.	Three years was used to estimate in-well aeration costs; 30 years was used to estimate monitoring costs. The exact time for completion of remediation is unknown.	Three years was used to estimate trucking costs; 30 years was used to estimate monitoring costs. The exact time for completion of remediation is unknown.

TABLE ES-3 (Continued)

SUMMARY OF ALTERNATIVE EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
IMPLEMENTABILITY • Ability to Construct and Operate	No construction or operation activities.	No construction or operation activities; institutional controls have been easily implemented in the past.	The infrastructure within a developed area like Site 1 poses some minor construction problems. O&M may be difficult because groundwater must be lifted above ground surface for treatment, and metals precipitation could clog well screens.	The technology has been commercially applied, but it is still relatively new. The infrastructure within a developed area like Site 1 poses some minor construction problems. also, metals precipitation could clog well screens.	The infrastructure within a developed area like Site 1 poses some minor construction problems. Also, metals precipitation could clog well screens.
• Ability to Monitor Effectiveness	No proposed monitoring plan; failure to detect contamination could result in potential ingestion of groundwater.	Proposed monitoring plan will detect contaminants before significant exposure can occur.	Proposed monitoring plan will detect contaminants before significant exposure can occur; O&M checks will provide notice of a system failure.	Proposed monitoring plan will detect contaminants before significant exposure can occur; O&M checks will provide notice of a system failure.	Proposed monitoring plan will detect contaminants before significant exposure can occur; O&M checks will provide notice of a system failure.
• Availability of Services and Capacities; Equipment	No services or equipment required.	No special services or equipment required.	Services and equipment are readily available.	The patented technology is exclusively licensed to a single vendor.	Services and equipment are readily available.
• Requirements for Agency Coordination	None required.	Must submit semiannual reports to document sampling.	The substantive requirements of air and water discharge permits must be met.	The substantive requirements of air and water discharge permits must be met.	Air and water discharge permits may be required if existing permits are not adequate for the additional groundwater load.
COST (Net Present Worth)	$0	$600,000	$2,100,000	$1,300,000	$1,400,000

TABLE ES-4

SUMMARY OF ALTERNATIVE EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 28, HADNOT POINT BURN DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls
OVERALL PROTECTIVENESS • Human Health	No reduction in potential human health risks.	Institutional controls reduce potential human health risks.
• Environmental Protection	No reduction in potential risks to ecological receptors.	Institutional controls reduce potential risks to ecological receptors.
COMPLIANCE WITH ARARS • Chemical-Specific ARARs	Manganese is expected to exceed chemical-specific ARARs, but it exceeds ARARs in groundwater throughout MCB, Camp Lejeune. Lead is believed to be the result of suspended solids so it is not expected to exceed ARARs.	Manganese is expected to exceed chemical-specific ARARs, but it exceeds federal and/or state ARARs in groundwater throughout MCB, Camp Lejeune. Lead is believed to be the result of suspended solids so it is not expected to exceed ARARs.
• Location-Specific ARARs	Not applicable.	Not applicable.
• Action-Specific ARARs	Not applicable.	Not applicable.
LONG-TERM EFFECTIVENESS AND PERMANENCE • Magnitude of Residual Risk	The residual risk from untreated lead and manganese will be minimal.	The residual risk from untreated lead and manganese will be minimal; institutional controls will mitigate any residual risk that may exist.
• Adequacy and Reliability of Controls	Not applicable-no controls.	The monitoring plan is adequate and reliable for determining effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure.
• Need for 5-year Review	Review will be required to ensure adequate protection of human health and the environment.	Review will be required to ensure adequate protection of human health and the environment.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT • Treatment Process Used	No treatment process.	No treatment process.
• Amount Destroyed or Treated	None.	None.
• Reduction of Toxicity, Mobility, or Volume	None.	None.
• Residuals Remaining After Treatment	Not applicable-no treatment.	Not applicable-no treatment.
• Statutory Preference for Treatment	Not satisfied.	Not satisfied.
SHORT-TERM EFFECTIVENESS • Community Protection	Potential risks to the community will not be increased.	Potential risks to the community will not be increased.
• Worker Protection	No risks to workers.	No significant risks to workers.

TABLE ES-4 (Continued)

SUMMARY OF ALTERNATIVE EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 28, HADNOT POINT BURN DUMP
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls
• Environmental Impact	No additional environmental impacts; current impacts will continue.	No additional environmental impacts; current impacts will continue.
• Time Until Action is Complete	Not applicable.	Estimated 30 years.
IMPLEMENTABILITY • Ability to Construct and Operate	No construction or operation activities.	No construction or operation activities; institutional controls have been easily implemented in the past.
• Ability to Monitor Effectiveness	No monitoring plan; failure to detect contamination could result in potential ingestion of groundwater.	Proposed monitoring plan will detect contaminants before significant exposure can occur.
• Availability of Services and Capacities; Equipment	No services or equipment required.	No special services or equipment required.
• Requirements for Agency Coordinations	None required.	Must submit semiannual reports to document sampling.
COST (Net Present Worth)	$0	$500,000

1.0 INTRODUCTION TO THE FEASIBILITY STUDY

Marine Corps Base (MCB), Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) on October 4, 1989 (54 Federal Register 41015, 1989). The United States Environmental Protection Agency (USEPA) Region IV, the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR), and the United States Department of the Navy (DoN) then entered into a Federal Facilities Agreement (FFA) for MCB, Camp Lejeune. The primary 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 and the environment (Camp Lejeune FFA, 1989).

The Fiscal Year 1995 Site Management Plan for MCB, Camp Lejeune, a primary document identified in the FFA, identifies 27 sites requiring Remedial Investigation/Feasibility Study (RI/FS) activities. These 27 sites have been divided into 14 operable units to simplify the RI/FS activities. This report focuses on Operable Unit (OU) No. 7 which consists of three sites:

- Site 1, the French Creek Liquids Disposal Area
- Site 28, the Hadnot Point Burn Dump
- Site 30, the Sneads Ferry Road Fuel Tank Sludge Area

This report documents the FS conducted for Sites 1 and 28. Based on the results of the RI conducted for OU No. 7, an FS is not required for Site 30 (see Section 1.4).

Baker Environmental, Inc. (Baker) has prepared this FS for Contract Task Order 0231 under the DoN Atlantic Division Naval Facilities Engineering Command (LANTDIV) Comprehensive Long-Term Environmental Action Navy (CLEAN) program. The FS has been conducted in accordance with the requirements delineated in the National Oil and Hazardous Substances Pollution Contingency Plan (NOHSPCP or NCP) for remedial actions [40 Code of Federal Regulations (CFR) 300.430]. These NCP regulations were promulgated under CERCLA, commonly referred to as Superfund, and amended by the Superfund Amendments and Reauthorization Act (SARA) signed into law on October 17, 1986. In addition, the USEPA's document Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (USEPA, 1988) was used as guidance in preparing this FS.

This FS has been based on data collected during the RI conducted by Baker in 1994. Field investigations for the RI began in late March 1994 and continued through early May 1994. Additional groundwater sampling was also conducted in November 1994. Results of the field investigations are summarized in the RI report under separate cover (Baker, 1995).

1.1 Purpose of the FS

The purpose of the FS for OU No. 7 is to identify remedial action alternatives that are protective of human health and the environment, attain federal and state requirements that are applicable or relevant and appropriate, and are cost-effective. In general, the FS process under CERCLA serves to ensure that appropriate remedial alternatives are developed and evaluated, such that relevant information concerning the remedial action options can be presented and an appropriate remedy selected.

The FS involves two major phases:

- Development and Screening of Remedial Action Alternatives
- Detailed Analysis of Remedial Action Alternatives

The first phase includes the following major activities: (1) developing remedial action objectives and remediation levels, (2) developing general response actions, (3) identifying volumes or areas of affected media, (4) identifying and screening potential technologies and process options, (5) evaluating process options, (6) assembling alternatives, (7) defining alternatives, and (8) screening and evaluating alternatives.

Section 121(b)(1) of CERCLA requires that an assessment of permanent 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 be conducted. 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, to 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 major phase of the FS consists of: (1) evaluating the potential alternatives in detail with respect to nine evaluation criteria to address statutory requirements and preferences of CERCLA; and (2) performing a comparative analysis of the evaluated alternatives.

1.2 Organization of the FS

This FS is divided into two volumes, Volume I and Volume II, which correspond to Sites 1 and 28, respectively. Volume I contains Sections 1.0 through 6.0, and Volume II contains Sections 7.0 through 12.0. Tables and figures are located at the end of each section, and all references for both Volumes I and II are located in Section 12.0. In addition, the appendices corresponding to each site are located at the end of each volume.

1.3 Operable Unit Description

MCB, Camp Lejeune (also referred to as the "Activity") is located in Onslow County, North Carolina. MCB, Camp Lejeune currently covers approximately 234 square miles and is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean (see Figure 1-1). The western border of MCB, Camp Lejeune is defined by U. S. Route 17 and State Route 24. The eastern and southern borders are defined by the Atlantic Ocean shoreline, and the northern border is defined by the City of Jacksonville, North Carolina. More extensive background information on the Base is presented in the RI report (Baker, 1995).

Operable units were formed at MCB, Camp Lejeune as an incremental step toward addressing individual site concerns. The purpose of an operable unit is to simplify the specific problems associated with a site or group of sites. There are currently 27 Installation Restoration Program (IRP) sites at MCB, Camp Lejeune which have been grouped into 14 operable units. Sites 1, 28, and 30 (Sites 1 and 28 are the subjects of this FS) were grouped together as OU No. 7. These sites were grouped together because of the similar nature of wastes that are suspected to have been disposed of at each site, and the relative geographic location of the three sites.

OU No. 7 is located on the eastern portion of the base, situated between the New River and Sneads Ferry Road, south of the Hadnot Point Industrial Area (HPIA). Site 1 is referred to as the French Creek Liquids Disposal Area, Site 28 is the Hadnot Point Burn Dump, and Site 30 is known as the Sneads Ferry Road Fuel Tank Sludge Area. Site 1 is located on both the north and south sides of Main Service Road, approximately one mile southeast of HPIA. Site 28 is located along the eastern shore of the New River, immediately south of the Julian C. Smith Boulevard and O Street intersection. Site 30 is located approximately 4-1/2 miles south of HPIA, along a tank trail that intersects Sneads Ferry Road from the southwest.

1.4 Results of the Site 30 RI

As part of the RI, human health and ecological risk assessments (RAs) were conducted for Site 30. The results of the RAs indicated that, under the current and future land use scenarios at Site 30, the identified risks to human health and the environment were within acceptable ranges. Based on current data, neither soil nor groundwater were adversely impacted from any past disposal activities at the site, and the ecology of the study area appeared to be healthy. Contaminants detected in the surface water and sediment did not appear to be site-related.

Since the site media posed no current or potential adverse impacts to public health or the environment, no remedial response actions were justifiable. Therefore, no FS was conducted for Site 30.

2.0 INTRODUCTION TO SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA

Section 2.0 marks the beginning of the Site 1 portion of the FS. This section presents the organization of the Site 1 report and the following Site 1 background information: a site description, a site history, a summary of previous investigations, the surface water hydrology and drainage features, the geology, the hydrogeology, the extent of contamination, a summary of the human health risk assessment, and a summary of the ecological risk assessment. More extensive Site 1 background information is provided in the RI report (Baker, 1995).

2.1 Report Organization

The Site 1 portion of the FS is organized into five main sections: (1) an introduction to the site, (2) the development of remediation goal options, remediation levels, and remedial action objectives, (3) the identification and preliminary screening of remedial action technologies, (4) the development and screening of remedial action alternatives, and (5) the detailed analysis of remedial action alternatives.

2.2 Site Description

Site 1, the French Creek Liquids Disposal Area, is located approximately one mile east of the New River and one mile southeast of HPIA on the Mainside portion of MCB, Camp Lejeune. The site is situated on both the north and south sides of Main Service Road near the western edge of the Gun Park Area and Force Troops Complex. The French Creek development area, which includes Site 1, the Gun Park Area, and Force Troops Complex, is a self-supportive campus-like development. Supply, storage, and maintenance facilities, account for over 58 percent of the 583 total acres which constitute the French Creek development area. Troop housing occupies nearly 21 percent of the developed area or approximately 122 acres (LANTDIV, 1988).

A site map is presented on Figure 2-1. The site boundaries coincide with the approximate boundaries of the northern and southern disposal areas that are identified on the figure. The following subsections describe the northern and southern portions of the Site 1 and the surrounding areas.

2.2.1 Northern Portion of Site 1

As shown on Figure 2-1, the northern portion of Site 1 is surrounded by woods and a motor-cross training area to the north, a vehicle storage area associated with Building FC-100 to the east, Main Service Road to the south, and a treeline and Building FC-115 to the west. The majority of the suspected northern disposal area is within two fenced compounds that are associated with Buildings FC-120 and FC-134. The remaining portion of the northern disposal area is located outside of these fenced compounds, to the west and immediately adjacent to Building FC-134.

Building FC-120 serves as a motor transport maintenance facility for the Second Landing Support Battalion. It is a two story brick structure with offices and several vehicle maintenance bays. Building FC-134, located to the north of Building FC-120, provides offices and communication equipment storage also for the Second Battalion. It is a brick structure with offices and one garage bay.

A number of covered material storage areas (SFC-118, SFC-124, and SFC-125) are located to the north and west of Building FC-120. These smaller covered structures are used for temporary storage of paint, compressed gases, vehicle maintenance fluids, spent or contaminated materials, and batteries.

In addition to these covered storage structures, an above ground storage tank (AST) area, located adjacent to the northern side of Building FC-120, is utilized to store spent motor oil and ethylene glycol (i.e., anti-freeze). Also, a gasoline service island is located to the west of Building FC-120. The two pumps at the service island provide fuel for vehicles undergoing maintenance at Building FC-120. An underground storage tank (UST) of unknown capacity is associated with this active service island.

Two equipment wash areas are also located near the northern portion of the site. The first wash area is located to the west of Building FC-120 and the second lies to the east of Building FC-134. Both equipment wash areas are concrete-lined and employ an oil and water separator collection basin. Another oil and water separator is located to the north of Building FC-120, adjacent to Building SFC-118. Discharge from the three oil and water separators flows into a drainage ditch and sediment retention pond to the north of Building FC-134.

There are two surface water features, a retention pond and a swampy area, that influence drainage near the northern portion of the site. The retention pond, located behind Building FC-134, receives surface water runoff via a gravel ditch from the parking lot and surrounding areas. Surface water runoff north of Building FC-134 drains into a swampy area toward a topographic low.

2.2.2 Southern Portion of Site 1

As shown in Figure 2-1, the southern portion of Site 1 is surrounded by Main Service Road to the north, Daly Road and a wooded area to the east, H. M. Smith boulevard to the south, and Gonzales Boulevard and a wooded area to the west. A portion of the suspected southern disposal area is surrounded by barbed-wire fences which contain a vehicle and equipment Administrative Deadline Lot (ADL), and a hazardous material storage area. The remaining part of the disposal area is not fenced. Vehicle access to this southern disposal area is via a swing-arm gate located along Main Service Road.

The hazardous material storage area, which is concrete-lined and bermed, is located north of Building 816. This area is used for the temporary storage of vehicle maintenance fluids, spent or contaminated materials, fuel, and batteries. In addition, a number of storage lockers are located throughout the southern portion of the site. These lockers are used to store paints and other flammable materials used by maintenance and machine shop personnel.

Several small buildings, including Buildings GP-10, GP-11, GP-12, GP-13, GP-14, GP-19, and 746, are located adjacent to the suspected southern disposal area. The buildings are constructed of either formed metal, concrete block, or wood frame siding. Typically, the buildings are set on poured concrete slabs and have raised seam metal roofs. These buildings house a number of support offices, recreation facilities, machine shops, light-duty vehicle and equipment maintenance bays, and equipment storage areas. Heat is provided to the majority of these buildings by kerosene-fired stoves. Kerosene fuel is stored in ASTs located beside each building.

Two vehicle maintenance ramps are associated with the southern portion of the site. The first ramp is located immediately to the south of Building 739 and the second lies to the north of Building GP-19. Both maintenance ramps are constructed of concrete and are used for the upkeep of vehicles and equipment.

Three oil and water separator collection basins are also associated with the southern portion of the site. One separator is located adjacent to the Building 739 vehicle maintenance ramp, one separator is located southeast of Building GP-19, and one separator is located south of Building 816, adjacent to an equipment wash area. Discharge from the separator and wash area located south of Building 816 flows into a stormwater sewer and then into the drainage ditch located adjacent to H. M. Smith Boulevard.

The drainage ditch, which starts near the southern portion of the site, flows west toward the HPIA Sewage Treatment Plant (i.e., Site 28) and empties into Cogdels Creek. Cogdels Creek eventually discharges into the New River which is located approximately one mile west of Site 1.

2.3 Site History

Site 1 had been used by several different mechanized, armored, and artillery units since the 1940s. Reportedly, liquid wastes generated from vehicle maintenance were routinely poured onto the ground surface. During motor oil changes, vehicles were driven to a disposal point and drained of used oil. In addition, acid from dead batteries was reportedly hand carried from maintenance buildings to disposal points. At times, holes were dug for waste acid disposal and then immediately backfilled. Thus, the disposal areas at Site 1 are suspected to contain primarily petroleum, oil, and lubricants (POL) and battery acid.

The total extent of both the northern and southern disposal areas is estimated to be between seven and eight acres. The quantity of POL waste disposed at these areas is estimated to be between 5,000 and 20,000 gallons; the quantity of battery acid waste is estimated to be between 1,000 and 10,000 gallons.

Site 1 continues to serve as a vehicle and equipment maintenance/staging area (Water and Air Research, 1983). However, past disposal practices are no longer in use.

2.4 Previous Investigations

This section presents a summary of previous investigations conducted at Site 1. These investigations include an Initial Assessment Study (IAS), a Confirmation Study, additional investigations conducted by Baker, an Aerial Photographic Investigation, and a Remedial Investigation.

2.4.1 Initial Assessment Study

An IAS was conducted by Water and Air Research, Inc. in 1983. The IAS identified a number of sites at MCB, Camp Lejeune, including Site 1, as potential sources of contamination. The IAS reviewed historical records and aerial photographs, performed field inspections, and conducted personnel interviews to evaluate potential hazards at various sites on MCB, Camp Lejeune. The IAS recommended performing confirmation studies at Site 1 to evaluate the necessity of conducting mitigating actions or cleanup operations.

2.4.2 Confirmation Study

From 1984 through 1987, a Confirmation Study was conducted by Environmental Science and Engineering, Inc. The study consisted of two steps: a Verification Step, performed in 1984, and a Confirmation Step, performed in 1986 and 1987. The purpose of the study was to investigate potential contaminant source areas identified in the IAS Report. At Site 1, this Confirmation Study focused on the presence of potential contaminants in groundwater, surface water, and sediment.

Organic and metal contaminants were identified in several groundwater samples collected from the shallow aquifer. During both the 1984 and 1986 investigations, tetrachloroethene (PCE), trichloroethene (TCE), cadmium, chromium, and lead exceeded present regulatory limits in shallow aquifer samples. The same contaminants, however, were not observed in the deeper aquifer. Therefore, it appeared that no vertical migration had occurred up to this point. In addition, groundwater, surface water, and sediment contained detectable concentrations of oil and grease (O&G) which is not unusual considering that POL was disposed of at this site.

Upon completion of the Confirmation Study, a Site Summary Report was written to summarize the results of the study. The report recommended that further characterization of the site be performed to complete the RI/FS process. The report also recommended that following the characterization of potentially impacted environmental media, a risk assessment be conducted to identify unacceptable risks to human health and the environment

2.4.3 Additional Investigations

Due to a lack of soil data, Baker conducted an additional soil assessment in 1991. The purpose of this soil assessment was to identify contaminants prior to initiating a proposed construction project on the southern portion of the site. Baker also conducted an additional round of groundwater sampling in 1993 to support future RI scoping activities.

Analytical results from these additional investigations suggested the presence of inorganic constituents, particularly heavy metals, in both soil and groundwater. Concentrations of cadmium, chromium, lead, and manganese were distributed sporadically throughout sampling stations across the site. In addition, these inorganics were detected in reference groundwater and soil samples obtained from hydraulically upgradient locations. As a result, it appeared that inorganic levels similar to those detected at Site 1 also existed in areas surrounding the site.

2.4.4 Aerial Photographic Investigation

In 1992, an interim aerial photographic investigation report was completed by the USEPA's Environmental Photographic Interpretation Center (EPIC). At Site 1, black-and-white aerial photographs from 1944, 1949, 1952, 1956, 1960, 1964, 1984, 1988, and 1990 were made available for examination of surface conditions. The photographs indicated that over time significant clearing and construction had occurred within the suspected disposal areas. In addition, site operations, including the staging of equipment and vehicles, appeared to increase significantly over time.

2.4.5 Remedial Investigation

Baker conducted an RI at OU No. 7 from late March through early May 1994. As part of the RI, additional groundwater sampling was conducted in November 1994 using a new, low-flow sampling technique. The purpose of the RI was to evaluate the nature and extent of the threat to public health and the environment caused by the release of hazardous substances, pollutants, or contaminants. The purpose was also to support the Feasibility Study documented in this report.

At Site 1, soil and groundwater investigations were conducted. Specific sampling locations are identified on Figure 2-2. Surface water and sediment investigations were also proposed at Site 1 (Final Project Plans, 1993) within a drainage ditch. However, these investigations were not conducted because the ditch was dry throughout the field program.

Field data related to the physical characteristics (e.g., hydrologic, geologic, and hydrogeological conditions) of Site 1 were analyzed and interpreted to assist in determining contaminant movement. Sections 2.5, 2.6, and 2.7 of this FS summarize the RI findings related to the physical characteristics at the site. Data collected from each site was also analyzed and interpreted to evaluate the extent of contamination for each medium investigated. Section 2.8 of this FS summarizes the results of the RI laboratory analyses and describes the extent of contamination at Site 1. As part of the RI, human health and ecological risk assessments were conducted to determine potential site risks. Sections 2.9 and 2.10 summarize the results of these risk assessments.

2.5 Surface Water Hydrology and Drainage Features

Based on findings from the RI, there are several surface water features influencing surface drainage in the immediate vicinity of Site 1. Near the northern portion of Site 1, a retention pond, located behind Building FC-134, receives surface water runoff, via a gravel ditch, from the parking lot and the surrounding areas. Near the southern portion of Site 1, a drainage ditch, located south of Building 816 and traversing east to west, receives surface water runoff from the southern portion of the site and nearby parking lots (see Figure 2-1). During the RI field investigation, however, the ditch was observed to be dry with ponded water in some areas.

2.6 Geology

The soils encountered during the RI at Site 1 were generally uniform in the shallow and deep subsurface. Shallow soils (less than 30 feet bgs) consisted of mostly sand and silty-sand, with lenses of silt and clay. These soils represent the Quaternary age "undifferentiated" Formation, which characterizes the surficial water table aquifer. One to two feet of fill material was also noted underlying the site in many places.

The sands were fine-grained with varied amounts of silt (5 to 15 percent) and clay (less than 5 percent). Results of the standard penetration tests (commonly referred to as "blow counts," ASTM 1568) indicated that the sands have a relative density ranging from loose to very dense. Based on the visual-manual method for soil description (ASTM D-2488), the sands classify as SM according to Unified Soil Classification System (USCS).

Two deep soil borings, advanced to approximately 120 feet bgs, indicated generally uniform deep lithology. A mixture of sandy-clay and limestone fragments was encountered at approximately 25 to 27 feet bgs. Based on a geologic/hydrogeologic report published by the USGS (Harned, et al., 1989) for MCB, Camp Lejeune, the sandy-clay and limestone fragments represent the top of the River Bend Formation (Oligocene age), which includes the Castle Hayne aquifer. Sand, sand-shell mixtures, and limestone fragments within a sandy-clay matrix were encountered at depths below 55 feet bgs.

2.7 Hydrogeology

The hydrogeologic setting was evaluated during the RI by installing a network of shallow and deep monitoring wells throughout the northern and southern portions of the site. The hydrogeologic setting in the vicinity of Site 1 consists of several aquifer systems. For this study, the most upper two aquifer systems were investigated, the surficial and Castle Hayne. The surficial aquifer lies within the "undifferentiated" deposits of sand, silt, and clay. The thickness of the surficial aquifer in the vicinity of Site 1 is approximately 27 feet, based on the occurrence of the sand and limestone mixtures which mark the upper portion of the River Bend Formation. The underlying Castle Hayne aquifer consists of sand, silt, clay, shell hash, and limestone fragments. Based on the lithology encountered during the test borings, there does not appear to be a significant hydraulic separation of the two aquifers since no distinct groundwater retarding unit was encountered.

Two rounds of groundwater level measurements were collected (water table contour maps are provided in the RI Report). The initial round of measurements (March 19, 1994) was collected prior to the investigation and, therefore only include the existing wells. Groundwater elevations measured in the shallow wells on May 9, 1994, varied from 5.36 to 12.00 feet above msl. In the existing monitoring wells where two rounds of measurements were collected (March 19 and May 9, 1994), the water levels declined between 0.69 and 1.80 feet. The decline in the water table appears to be the result of normal daily and/or seasonal fluctuations. Groundwater elevations measured in the deep wells varied from 6.47 to 7.65 feet above msl. Slightly different groundwater elevations between the surficial and deep aquifers were measured. The elevation differentials between the surficial and deep aquifers have created a slight downward vertical gradient which is noteworthy since this may contribute to the vertical migration of contaminants.

Groundwater flow is generally west-northwest across Site 1 in the direction of the New River. Groundwater flow direction evaluated during previous investigations also determined similar results. Although a contour map was not developed for the deep aquifer, flow is also expected to be in a west-northwest direction due to the influence of the New River. An estimate of the horizontal groundwater gradient for the surficial aquifer calculated from the May 9, 1994 elevation data is 0.0027 (to the west-northwest), indicating a relatively flat water table surface.

Based on information obtained from a USGS publication (Harned, et al., 1989) and interviews with Base personnel four supply wells, HP-608, HP-609, HP-638 and HP-655, are located within a one-mile radius of Site 1. Of these four wells, only HP-609 is currently on-line. As shown in Figure 2-2, well HP-638 is located within the boundaries of Site 1. HP-638 was sampled during previous investigations (Water and Air Research, 1983; Greenhorne & O'Mara, 1992) and the analytical results indicated benzene contamination. Consequently, the well was placed out of service by Base personnel. The potential sources of the benzene included the numerous maintenance facilities in the area, Site 1 (past and current activities), and a previously existing aboveground fuel tank (used for an emergency generator) located next to the well house.

2.8 Extent of Contamination

This section addresses the extent of contamination in soil (both surface and subsurface) and groundwater at Site 1. The information presented is based on analytical results from the RI. All sampling locations that are referred to in this section are identified on Figure 2-2. Please note that concentrations denoted with a "J" are estimated analytical results.

2.8.1 Soil

Volatile organic compounds (VOCs), semivolatile organics compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and metals were detected in soil samples from Site 1.

VOCs were not found in surface soils, but they were detected four out of 110 subsurface samples scattered throughout the site. The VOC acetone was detected in one sample from the southern portion of the study area. However, the data suggested that this acetone may have been an artifact of decontamination activities. Three other VOCs, TCE, toluene, and 1,1,2,2-TCA were detected at very low concentrations. TCE and toluene were each detected only once in samples from the northern central portion of the study area. TCE was detected at 3J µg/kg and toluene was detected at 1J µg/kg. 1,1,2,2-TCA was detected once in a sample for the southern central portion of the study area at a concentration of 27 µg/kg.

SVOCs were not encountered in surface soils, but were detected in a number of subsurface soil samples. Most notable among the SVOCs detected were three polyaromatic hydrocarbon (PAH) compounds, di-n-butylphthalate, and bis (2-ethylhexyl) phthalate (BEHP). The positive detections of these compounds were located near the northern central portion of the site. However, the PAHs and di-n-butylphthalate were detected only once out of 110 samples. BEHP was detected in 45 of the 110 samples, but the widespread distribution of these detection locations (i.e., there was no apparent source area) suggested that this SVOC was the result of laboratory contamination. BEHP is a common laboratory contaminant.

The pesticides dieldrin, 4,4'-DDE, 4,4'-DDD, 4,4'-DDT, endrin aldehyde, alpha-chlordane, and gamma-chlordane were detected in the soil at Site 1. Each of these pesticides was detected, at low concentrations, in at least two of the 124 soil samples. The pesticide 4,4'-DDT was the most prevalent, with 10 positive detections, and the highest pesticide concentration was that of 4,4'-DDE at 120 micrograms per kilogram (µg/Kg). This detected concentration does not exceed the USEPA Region III risk-based concentration for 4,4'-DDE, 1.9 mg/Kg. In general, pesticide detections were concentrated in the northern portion of the study area. The positive detections were, for the most part, limited to soil samples collected from depths less than seven feet below ground surface.

The PCBs aroclor 1254 and aroclor 1260 were each detected once within the subsurface soil sample set. Aroclor 1254 was detected in a sample from a monitoring well test boring on the southern portion of the site at a concentration of 18 µg/kg. Aroclor 1260 was detected at a boring near the center of the northern disposal area at a concentration of 1300 µg/kg. These detected concentrations exceed the Toxic Substances Control Act (TSCA) guidance of 1,00 µg/kg for PCBs in residential soil.

Several metals were also detected in the surface and subsurface soil at Site 1. The range of metals levels and the range at which they were detected in Base background samples are presented below.

Detected Levels (mg/kg) of Metals in Surface Soil at Site 1 and Range (mg/kg) for Base Background Samples:

- Antimony: 9.0J - 11.9; 0.3 - 8.0
- Arsenic: 0.57 - 2.0; 0.2 - 1.8
- Beryllium: 0.19 - 0.19; 0.03 - 0.16
- Cadmium: 0.62 - 2.0; 0.18 - 0.58

- Chromium: 1.5 - 6.4; 0.3 - 12.5
- Copper: 1.6 - 4.9; 0.5 - 87.2
- Lead: 1.0 - 23.5; 0.5 - 142.0
- Nickel: 1.6 - 3; 0.6 - 3.6
- Zinc: 3.5 - 26.9; 0.3 - 28.3

Detected Levels (mg/kg) of Metals in Subsurface Soil at Site 1 and Range (mg/kg) for Base Background Samples:

- Antimony: 6.1J - 7.8J; 0.4 - 6.9
- Arsenic: 0.6 - 5.6; 0.03 - 1.50
- Cadmium: 0.62 - 1.1; 0.17 - 1.20
- Chromium: 1.5 - 17.5; 0.7 - 10.5
- Copper: 1.1 - 5; 0.5 - 6.6
- Lead: 1.3 - 60.4J; 0.5 - 11.5
- Mercury: 0.06 - 0.34; 0.01 - 0.68
- Nickel: 1.2 - 4.4; 0.6 - 4.7
- Selenium: 0.81 - 1.5J; 0.12 - 0.55
- Silver: 1J - 1J; 0.18 - 1.00
- Zinc: 0.63J - 78.6J; 0.3 - 11.6

As shown, the detected concentrations of these metals did not significantly differ from base-specific background concentrations. Therefore, the positive detections of metals in soil did not appear to be the result of past disposal practices.

2.8.2 Groundwater

VOCs, SVOCs, and metals were detected in groundwater samples from Site 1.

Positive detections of VOCs in groundwater were limited to the northern portion of the study area. TCE was detected in samples obtained from three of the shallow monitoring wells. The maximum TCE concentration, 27 micrograms per liter (μg/L), was detected within a sample from monitoring well 1-GW17, located in the central northern portion of the study area. This detected concentration exceeds the federal standard for TCE, 2.8 μg/L. Two other VOCs, 1,2-dichloroethene and 1,1-dichloroethene, were observed at maximum concentrations of 21 μg/L and 2 μg/L, respectively. 1,2-dichloroethene did not exceed its federal standard of 1000 μg/kg and 1,1-dichloroethene did not exceed its federal standard of 7 μg/L. The maximum 1,2-dichloroethene and 1,1-dichloroethene concentrations were detected in a sample obtained from well 1-GW10, located to the west of the suspected northern disposal area. Vinyl chloride was also detected at well 1-GW10. The maximum concentration of vinyl chloride, 4 μg/L, exceeds the state standard of 0.015 μg/L. Xylenes were detected in a shallow groundwater sample from well 1-GW12, at a maximum concentration of 19 μg/L.

Like VOCs, the positive detections of SVOCs were limited to the northern portion of the study area. Phenol and diethylphthalate were detected during the first sampling round only in a sample from deep well 1-GW17DW, at concentrations of 6 μg/L and 1 μg/L, respectively. There is no state standard for phenol but diethylphthalate did not exceed its state standard of 5000 μg/L.

Metals were the most prevalent among contaminants detected in the groundwater at Site 1 and were found distributed throughout the site. Each of the 23 total analyte list (TAL) metals was detected at least once within the shallow aquifer, and 13 of the 23 TAL metals were detected at least once within the deep aquifer. The positive detections of metals were distributed sporadically throughout the site and did not appear to be related to the groundwater flow direction. As a result, most of this metals contamination did not appear to be site related. Iron and manganese, in particular, were detected at maximum concentrations of 29200 μg/L and 1200 μg/L which exceeded their state standards of 300 μg/L and 50 μg/L, respectively. However, positive detections of iron and manganese were distributed sporadically throughout the site, indicative of natural site conditions rather than disposal activities. In addition, iron and manganese concentrations in groundwater throughout MCB, Camp Lejeune often exceed state and federal standards. During past studies, manganese concentrations at a nearby potable water supply well and at several Site 1 wells exceeded the standards, but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune.

2.9 Human Health Risk Assessment

As part of the RI, a human health RA was conducted to assess potential risks associated with contamination at Site 1. Under the current scenario, on-site military personnel were assumed to be the potential receptors. Under the future scenario, future residents (both children and adults) and future construction workers were assumed to be the potential receptors. Exposure to soil via ingestion, dermal contact, and inhalation was analyzed for military personnel; exposure to soil via ingestion dermal contact, and inhalation was analyzed for future construction workers; and exposure to soil and groundwater via ingestion, dermal contact, and inhalation were analyzed for future residents.

The human health RA indicated that there were no unacceptable potential risks (neither carcinogenic nor noncarcinogenic) associated with exposure to the surface soil and subsurface soil contaminants of potential concern (COPCs). Therefore, soil was not determined to be a media of concern at Site 1. However, there were some potential future risks associated with ingestion of the groundwater COPCs.

There were potential carcinogenic and noncarcinogenic risks to the future residential child and adult receptors upon exposure to groundwater. The potential noncarcinogenic risks from groundwater were 17.3 and 7.6 for the child and adult receptors, respectively. These values exceeded the acceptable level of "1". The potential carcinogenic risk from groundwater was 1.7×10^{-4} for the adult receptor. This risk exceeded the acceptable range of "1×10^{-4} to 1×10^{-6}". Arsenic and manganese were the primary COPCs contributing to these risks.

Although arsenic and manganese in the groundwater created some potential risk if ingested by future residents, it is important to keep in perspective the way in which this risk was determined. The approach used in the human health RA was highly conservative. At Site 1, it was the future residential scenario that created risk. However, this scenario is unlikely to occur in the foreseeable future because Site 1 is actively being used as a vehicle maintenance and equipment storage area. In addition, ingestion of groundwater by future residents is unlikely to occur because the groundwater at Site 1 is not used as a potable water source. There are four water supply wells located within a one-mile radius of the site. However, there is only one supply well on-line today.

In addition, upon comparison of arsenic and manganese levels in the groundwater to state and federal regulatory standards, only manganese exceeded its standard. Thus, although both arsenic and manganese contributed to the site risks, arsenic did not exceed regulatory standards. This indicates the highly conservative nature of the human health RA.

Another fact to consider is that the levels of arsenic and manganese used to calculate groundwater exposure risks were primarily taken from off-site wells. Also, concentrations at these off-site wells either did not exceed regulatory standards or exceeded the standards infrequently. Consequently, it is reasonable to assume that the risks associated with arsenic and manganese are over-estimations of the risk that actually exists.

2.10 Ecological Risk Assessment

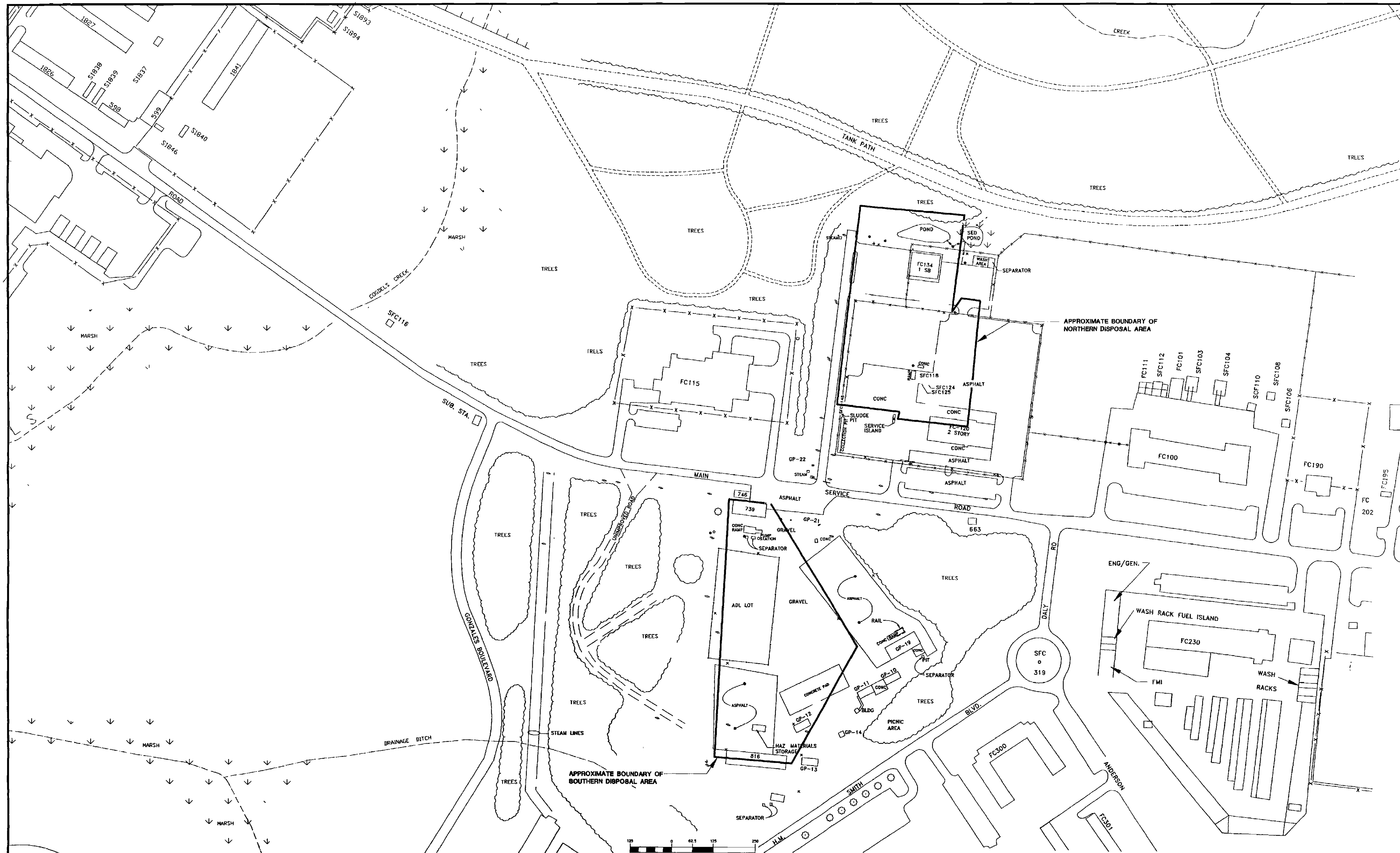
In addition to the human health RA, an ecological RA was conducted during the RI. The purpose of the ecological RA was to determine if COPCs were adversely impacting the ecological integrity of aquatic and terrestrial communities on or adjacent to the site. The ecological RA also evaluated the potential effects of COPCs on sensitive environments including wetlands, protected species, and fish nursery areas. The following paragraphs describe the state of aquatic and terrestrial communities as determined in the ecological RA.

Within the boundaries of Site 1, there were no aquatic communities identified that would be exposed to site related COPCs. The only surface water feature in which aquatic communities could exist is the southern drainage ditch, but this ditch is dry most of the time. As a result, the assessment concluded that there is no ecological risk associated with aquatic communities.

The only site related COPCs that could potentially affect terrestrial communities were metals. In particular, the presence of cadmium and chromium in surface soil indicated a slight potential for affecting terrestrial invertebrates and plants at the site. However, because the concentrations of these metals only slightly exceeded the literature values used to determine risk, cadmium and chromium were not expected to present a significant ecological risk. (Cadmium concentrations ranged from 0.62 to 2.0 mg/Kg which only slightly exceeds the literature value of 0.5 mg/Kg; chromium concentrations ranged from 1.5 to 13.1 mg/Kg which only slightly exceeds the literature value of 10 mg/Kg.)

Based on the terrestrial food chain model, there appeared to be a slight risk for deer, rabbit, fox, and quail receptors. However, this risk was expected to be insignificant because of the low levels by which terrestrial reference values were exceeded. The quotient index (QI) calculated for each COPC was less than "1" with the exception of manganese. The QI for manganese was 1.32 for the rabbit and 1.57 for the quail. However, because these QIs were less than "2", there is most likely only a small potential that the animals at Site 1 are being adversely affected by site conditions.

SECTION 2.0 FIGURES



LEGEND

⊙	VEGETATION	— — —	CREEK/DRAINAGE
—x—	FENCE	↓ ↓	MARSH

SOURCE: LANTDIV, FEBRUARY 1992

DATE	JULY 1995
SCALE	1" = 125'
DRAWN	REL
REVIEWED	TFT
S.O.#	62470-231-0000
CADD#	231132FS

NORTH

FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

SITE MAP
SITE 1 – FRENCH CREEK
LIQUIDS DISPOSAL AREA

SCALE 1" = 125'   DATE JULY 1995

FIGURE No
2-1

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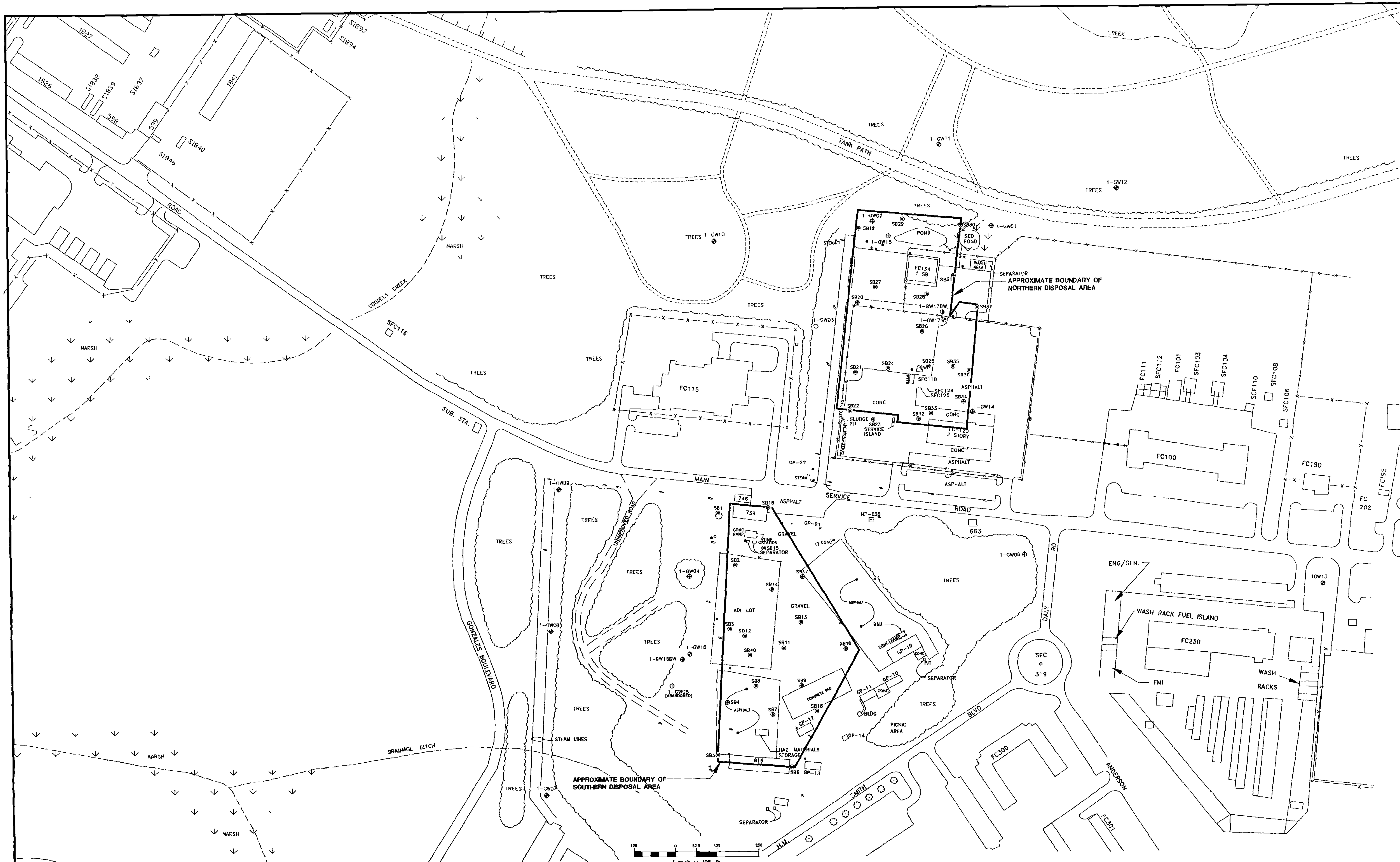


LEGEND	
1-GW01	EXISTING SHALLOW MONITORING WELL
1-GW07	NEWLY INSTALLED SHALLOW MONITORING WELL (BAKER, 1994)
1-GW16DW	NEWLY INSTALLED DEEP MONITORING WELL (BAKER, 1994)
SB1	SOIL BORING LOCATION (BAKER, 1994)
	VEGETATION
	CREEK/DRAINAGE
	FENCE
	MARSH

SOURCE: LANTDIV, FEBRUARY 1992

DATE	JULY 1995
SCALE	1" = 125'
DRAWN	REL
REVIEWED	TFT
S O #	62470-231-0000
CADD#	231101FS

NORTH

FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

REMEDIAL INVESTIGATION
SAMPLING LOCATIONS
SITE 1 - FRENCH CREEK
LIQUIDS DISPOSAL AREA

SCALE 1" = 125' DATE JULY 1995

FIGURE No
2-2

3.0 REMEDIATION GOAL OPTIONS, REMEDIATION LEVELS, AND REMEDIAL ACTION OBJECTIVES - SITE 1

This section presents remediation goal options, remediation levels, and remedial action objectives for Site 1 in Operable Unit No. 7. Section 3.1 identifies the media and contaminants of concern, and Section 3.2 identifies the exposure routes and receptors at Site 1. In Section 3.3, remediation goal options and final remediation levels are developed. Section 3.3 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 3.4.

3.1 Media of Concern/Contaminants of Concern

The only medium of concern at Site 1 is groundwater. Exposure to groundwater generated both carcinogenic and noncarcinogenic human health risks that exceeded acceptable levels. Subsurface soil human health risks were within acceptable risk levels, the subsurface soil was not considered a medium of concern. Surface soil human health risks were also within acceptable levels. However, surface soil ecological risks slightly exceeded acceptable levels. Cadmium and chromium in the surface soil contributed to this ecological risk, but the detected concentrations of these metals only slightly exceeded the literature values used to determine risk. Cadmium concentrations ranged from 0.62 to 2.0 mg/kg, which only slightly exceeds the literature value of 0.5 mg/kg. Chromium concentrations ranged from 1.5 to 13.1 mg/kg, which only slightly exceeds the literature value of 10 mg/kg. As a result, surface soil was not considered a medium of concern.

The set of groundwater COPCs evaluated during the RA is listed in Table 3-1. These COPCs are considered preliminary COCs for the FS. The detected concentrations of the preliminary COCs will be compared to the remediation levels developed in Section 3.3.4 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 consideration in the FS. The final set of COCs will become the basis for a set of remedial action objectives applicable to the site.

3.2 Exposure Routes and Receptors

The results of the human health and the ecological RAs indicate that the exposure route of concern for groundwater is ingestion. Current receptors include military personnel (i.e., surface soil exposure) and wildlife (terrestrial and aquatic). Future receptors include potential adult and child residents (i.e., groundwater exposure).

3.3 Remediation Goal Options and Remediation Levels

Remediation goal options are established based on information such as federal and state criteria and risk-based action levels. Section 3.3.1 presents the definition of applicable or relevant and appropriate federal and state requirements and "to be considered" requirements. Section 3.3.2 identifies and evaluates site specific federal and state criteria for the COCs at Site 1. Section 3.3.3 develops site specific risk-based action levels for the COCs at Site 1. 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.

3.3.1 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. The first type, chemical-specific ARARs, includes requirements which set health or risk-based concentration limits or ranges for specific hazardous substances, pollutants, or contaminants. Maximum Contaminant Levels (MCLs) established under the Safe Drinking Water Act (SDWA) are examples of chemical-specific ARARs.

The second type of ARARs, location-specific, set restrictions on activities based upon the characteristics of the site and/or the nearby suburbs. Examples of this type of ARAR 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 do not need to be obtained for removal or remedial actions implemented on site but their substantive requirements 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, specific site characteristics, and particular remedial actions proposed for the site. Potential ARARs identified for Site 1 are presented in the following section.

The preamble to the proposed rule in 40 CFR Part 300.400(g)(3) states that "advisories, criteria, or guidance to-be-considered (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, 1990a).

3.3.2 Potential ARARs and TBCs Identified for Site 1

A set of chemical-specific, location-specific, and action-specific ARARs were identified and evaluated for Site 1 and are discussed below.

3.3.2.1 <u>Chemical-Specific ARARs and TBCs</u>

Potential chemical-specific ARARs and TBCs identified for the preliminary COCs at Site 1 are listed on Table 3-2. These ARARs/TBCs were based on federal MCLs, North Carolina Water Quality Standards (NCWQS) applicable to ground waters, and federal risk-based health advisories (HAs) for adults and children. A brief description of each 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 in Table 3-2, MCLs have been established for all of the groundwater COCs. The federal MCL will be considered an ARAR for Site 1.

North Carolina Water Quality Standards (Groundwater) - Under the North Carolina Administrative Code (NCAC), Title 15A, Subchapter 2L, Section .0200, (15A NCAC 2L.0200) the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR) has established groundwater standards (NCWQSs) for three classifications of groundwater within the state: GA, GSA, and GC. Class GA waters are those ground waters in the state naturally containing 250 milligram per liter (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 water quality standards for the ground waters 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 1.0×10^{-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 ground waters are the same except for chloride and total dissolved solids concentrations (15A NCAC 2L.0202).

The Class GA groundwater NCWQS for the groundwater COCs for Site 1 are listed on Table 3-2. As shown on the table, the majority of the state standards are the same as or more stringent than the federal MCLs. The NCWQS will be considered an ARAR for Site 1.

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

Long-term HAs for the groundwater COCs are included for both a child (10 kg) and an adult (70 kg) are listed on Table 3-2.

3.3.2.2 Location-Specific ARARs

Potential location-specific ARARs identified for Site 1 are listed on Table 3-3. An evaluation determining the applicability of these location-specific ARARs with respect to Site 1 is also presented and summarized on Table 3-3. Based on this evaluation, specific sections of the following location-specific ARARs may be applicable to Site 1:

- Federal Endangered Species Act
- North Carolina Endangered Species Act
- RCRA Location Requirements

Please note that the citations listed on Table 3-3 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.

3.3.2.3 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 1. A set of potential action-specific ARARs are listed on Table 3-4. These ARARs are based on RCRA, CWA, SDWA, and Department of Transportation (DOT) requirements. Note that the citations listed on Table 3-4 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 after the remedial action alternatives have been identified for Site 1. Additional action-specific ARARs may also be identified and evaluated at that time.

3.3.3 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 1 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, 1989a; USEPA, 1991). For noncarcinogenic effects, concentrations were calculated to correspond to an 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 action levels for remediation. For carcinogenic effects, concentrations were calculated to correspond to $1.0x10^{-4}$ (one in ten thousand), 1.0×10^{-5} (one in one hundred thousand), and 1.0×10^{-6} (one in one million) ICR over a lifetime of exposure to the carcinogen. Exposure was evaluated for all significant exposure pathways for a given medium. A $1.0x10^{-4}$ risk level was used as an end point for determining action levels for remediation. Based on the NCP (40 CFR 300.430) for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an ICR between $1.0x10^{-4}$ and $1.0x10^{-6}$. 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.

3.3.3.1 Risk Evaluation Assessment

Medium-specific risk-based action levels were determined in accordance with USEPA guidance (USEPA, 1989a). Reference doses (RfDs) were used to evaluate noncarcinogenic action levels, while cancer slope factors (CSFs) were used to evaluate carcinogenic action levels.

Potential exposure pathways and receptors used to determine action levels are site-specific. They consider the current and future land use of a site. Ingestion of groundwater was the exposure scenario used to determine risk-based action levels for Site 1.

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 (years) over the course of a potentially exposed individual's lifetime (70 years).

Estimation methods and models used in this section were consistent with current USEPA risk assessment guidance (USEPA, 1989a; 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). Carcinogenic levels for the military personnel in the current scenario were based on 4 years. 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 military personnel scenario, the following input parameters were used to determine the action levels: military personnel were assumed to ingest 2 liters of water per day, 250 days per year, over a 4 year period (USEPA, 1989a). 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, 1989a). Table 3-5 summarizes the input parameters used to estimate the groundwater ingestion action levels.

3.3.3.2 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 military personnel, future adult residents, and future children residents have been calculated for the groundwater ingestion scenario discussed below. In addition, both carcinogenic and noncarcinogenic action levels have been calculated. Calculations are provided in Appendix A of this report.

Groundwater ingestion action levels were estimated for the groundwater within the entire operable unit. Currently, there are no known receptors of the groundwater. Military personnel receive potable water from the base distribution system. Consequently, a hypothetical current and future ingestion action level was estimated for the COCs. In order to estimate conservative action levels for subpopulations (i.e., military personnel, adult residents and child residents), specific input variables were developed for each subpopulation. Tables 3-6 through 3-11 present the risk-based action levels calculated for the carcinogenic and noncarcinogenic COCs in the groundwater.

3.3.3.3 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 human health RA indicate that the cumulative current and future baseline cancer risks associated with groundwater are not within the USEPA's acceptable risk range of 1.0×10^{-4} to 1.0×10^{-6} primarily because of the presence of arsenic and manganese. A comparison between the risk-based action levels and the maximum concentrations of groundwater COCs has been conducted. The risk-based action levels and chemical-specific ARARs were compared to maximum contaminant concentrations as shown in Table 3-12. As shown on the table, the maximum concentrations of TCE, arsenic, manganese, and mercury exceed the risk-based action levels and/or the 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., worst case) conservative estimate, and aids in screening and identifying remedial alternatives. Risk-based action levels are not to be used in making final remedial decisions.

3.3.3.4 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 computation involves 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 form 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.

3.3.4 Summary of Remediation Levels and Final COCs

Remediation levels (RLs) associated with the preliminary COCs at Site 1 are presented on Table 3-13. This list was based on a comparison of chemical-specific ARARs and the site-specific risk-based action levels identified throughout Section 3.3.2 and 3.3.3. 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 in Table 3-13.

In order to determine the final set of COCs, the maximum contaminant concentrations detected in the groundwater were compared to the remediation levels presented on Table 3-9. 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 be considered to be COCs with respect to this FS. Based on this comparison, the following COCs exceeded a remediation level and were retained as COCs for Site 1:

- Trichloroethene (TCE)
- Manganese
- Mercury

The final set of COCs and the associated RLs are presented on Table 3-14.

3.4 Remedial Action Objectives

The following remedial action objectives have been developed for Site 1:

- Mitigate the potential for direct exposure to contaminated groundwater.
- Mitigate the horizontal and vertical migration of contaminated groundwater.
- Restore the shallow aquifer so that contaminants meet their remediation levels.

Figure 3-1 identifies the sampling locations where TCE was positively detected. As shown, TCE exceeded its RL at two shallow wells, 1-GW10 and 1-GW17. As a result, the approximate extent of TCE contamination was delineated around these wells. This extent of contamination is considered to be an area of concern (AOC) at Site 1, and the remedial action objectives specifically apply to this AOC. The approximate size of the AOC is 24,000 square feet and the approximate pore volume is 4,500,000 gallons (based on a saturated aquifer thickness of 84 feet and an effective porosity of 0.3).

Although it was not considered as a preliminary COC for the FS, vinyl chloride was detected at a concentration that exceeded state and federal standards. At well 1-GW10, vinyl chloride was detected at 2 μg/L and 4J μg/L during the first and second rounds of sampling, respectively. These concentrations slightly exceeded the NCWQS of 0.015 μg/l and the Federal MCL of 2 μg/l. Most likely, this vinyl chloride is the result of TCE degradation. As a result, the remedial action objectives will address this vinyl chloride at well 1-GW10 along with the TCE that exceeded RLs.

Also shown on Figure 3-1 are sampling locations where manganese and mercury exceeded RLs. Although these metals exceeded RLs, they are not addressed by the remedial action objectives for the following reasons:

- Manganese concentrations (i.e., both total and filtered) in groundwater at MCB, Camp Lejeune often exceed the NCWQS and federal secondary MCL of 50 μg/L. Elevated manganese levels, at concentrations above the NCWQS and secondary MCL, were reported in samples collected from a number of Base potable water supply wells (Greenhorne and O'Mara, 1992). Manganese concentrations at several Site 1 wells exceeded the NCWQS, but fell within the range of concentrations for samples collected elsewhere at MCB, Camp Lejeune. As a result, manganese does not appear to be a site-related contaminant. Instead, manganese appears to naturally occur at concentrations exceeding the RL in groundwater throughout the Base.

- Mercury exceeded its RL at only one well by 0.1 μg/L, which is a relatively minor exceedance. In addition, mercury was not detected in any of the dissolved metals samples. Consequently, it is likely that suspended solids in the total metals samples (i.e., high turbidity yield elevated total metals concentrations). Thus, mercury does not appear to be a site-related contaminant.

- There is no record of any historical use, either industrial or disposal, of manganese or mercury at Site 1. This information further supports the theory that manganese and mercury are not site-related contaminants.

SECTION 3.0 TABLES

TABLE 3-1

PRELIMINARY CONTAMINANTS OF CONCERN FOR THE FS
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminant of Potential Concern Evaluated in the RA [1]	Preliminary Contaminant of Concern for the FS [2]
Groundwater	Trichloroethene	X
	1,2-Dichloroethene	X
	Arsenic	X
	Barium	X
	Manganese	X
	Mercury	X

[1] This list includes all of the contaminants of potential concern evaluated in the Risk Assessment (Baker, 1995)
[2] The determination of the set of preliminary contaminants of concern for the FS was based on two criteria: (1) the contaminant was found to be a contaminant of concern from the results of the RA, or (2) standards and/or criteria are established for the contaminant.

TABLE 3-2

POTENTIAL CHEMICAL-SPECIFIC ARARs AND TBCs
FEASIBILTIY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant	NCWQS (1)	Federal MCL (2)	Federal Health Advisories(3)	
			Adult	Child
Trichloroethene	2.8	5	NE	NE
1,2-Dichloroethene	NA	100(4)	2,000	6,000
Arsenic	50	50	NE	NE
Barium	2,000	2,000	NE	NE
Manganese	50	NE	NE	NE
Mercury	1.1	2	NE	2

Notes: Concentrations expressed in microgram per liter (ug/L)
(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) Health Advisories - Nonenforceable guidelines, therefore, a TBC
(4) MCL for cis-1,2-dichloroethene
NE = No Criteria Established

TABLE 3-3

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
FEASIBLITY STUDY CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
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 1, therefore, this act will not be considered as 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(c)	No known historical or archeological data is known to be present at the sites, therefore, this act will not be considered as 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 1, therefore, this act will not be considered as 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	There are no creeks, streams or rivers located near and/or within the operable unit boundaries. Therefore, this act will not be considered as 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	Many protected species have been sited near and on MCB Camp Lejeune such as the American alligator, the Bachmans sparrow, the Black skimmer, the Green turtle, the Loggerhead turtle, the piping plover, the Red-cockaded woodpecker, and the rough-leaf loosestrife (LeBlond, 1991),(Fussell, 1991),(Walters, 1991). In addition, the alligator has been sighted on Base. Therefore, this will be considered as 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 rate species, and the State watch list.	GS 113-331 to 113-337	Since the American alligator has been sighted within MCB Camp Lejeune (in Wallace Creek), this will be considered as 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 as an ARAR.

TABLE 3-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
FEASIBLITY STUDY CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
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	Based on a review of Wetland Inventory Maps, there are no wetlands present at Site 1. Therefore, this will not 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. 7 is primarily within a minimal flooding zone (outside the 500-year floodplain). The immediate areas around Site 1 are not within the 100-year floodplain (FEMA, 1987). Therefore, this may not be an ARAR for the operable unit.
Wilderness Act - requires that federally owned wilderness area 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 1, therefore, this act will not be considered as 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 1, therefore, this will not be considered as 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 1, therefore, this act will not be considered as 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	No activities will affect land or water uses in a coastal zone, therefore, this act will not be considered as 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 the operable unit, therefore, this act will not be considered as an ARAR.

TABLE 3-3 (Continued)

EVALUATION OF POTENTIAL LOCATION-SPECIFIC ARARs
FEASIBLITY STUDY CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
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 operable unit includes the on-site storage, treatment, or disposal of RCRA hazardous waste. Therefore, these requirements may be an applicable ARAR for the operable unit.

TABLE 3-4

POTENTIAL ACTION-SPECIFIC ARARs
FEASIBILITY STUDY CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
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, 268
	New Landfill	40 CFR 264
	New Surface Impoundment	40 CFR 264
	Dike Stabilization	40 CFR 264
	Excavation, Groundwater Diversion	40 CFR 264, 268
	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 107

(1) RCRA = Resource Conservation Recovery Act
CWA = Clean Water Act
SDWA = Safe Drinking Water Act
DOT = Department of Transportation

TABLE 3-5

SUMMARY OF EXPOSURE DOSE INPUT PARAMETERS
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Input Parameter	Units	Receptor		
		Future Child	Future Adult	Current Military Personnel
Groundwater (mg/L)				
Ingestion Rate, IR	L/d	1	2	2
Exposure Frequency, EF	d/y	350	350	250
Exposure Duration, ED	y	6	30	4
Exposure Time, ET	h/d	0.25	0.25	0.25
Surface Area, SA	cm^2	2,300	5,800	5,800
Averaging Time, Noncarc., ATnc	d	2,190	10,950	1,460
Averaging Time, Carc., ATcarc	d	25,550	25,550	25,550
Conversion Factor, CF	L/cm^3	0.001	0.001	0.001
Body Weight, BW	kg	15	70	70

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 3-6

GROUNDWATER INGESTION ACTION LEVELS
BASED ON CARCINOGENIC RISK
FUTURE ADULT RESIDENT
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Carcinogenic Risk - Based Action Level - Future Adult Resident		
	Carcinogenic Target Risk Level 1.0 x 10^{-04}	Carcinogenic Target Risk Level 1.0 x 10^{-05}	Carcinogenic Target Risk Level 1.0 x 10^{-06}
Trichloroethene	774	77.4	7.74
Arsenic	5	0.5	0.05

Note: Action level concentrations expressed as ug/L

TABLE 3-7

GROUNDWATER INGESTION ACTION LEVELS
BASED ON CARCINOGENIC RISK
FUTURE CHILD RESIDENT
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Carcinogenic Risk - Based Action Level - Future Child Resident		
	Carcinogenic Target Risk Level 1.0×10^{-04}	Carcinogenic Target Risk Level 1.0×10^{-05}	Carcinogenic Target Risk Level 1.0×10^{-06}
Trichloroethene	1,659	165.9	16.59
Arsenic	10	1.0	0.1

Note: Action level concentrations expressed as ug/L

TABLE 3-8

GROUNDWATER INGESTION ACTION LEVELS
BASED ON CARCINOGENIC RISK
CURRENT MILITARY PERSONNEL
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Carcinogenic Risk - Based Action Level - Current Military Personnel		
	Carcinogenic Target Risk Level 1.0 x 10^{-04}	Carcinogenic Target Risk Level 1.0 x 10^{-05}	Carcinogenic Target Risk Level 1.0 x 10^{-06}
Trichloroethene	8,130	813	81.3
Arsenic	51	5.1	0.51

Note: Action level concentrations expressed as ug/L

TABLE 3-9

GROUNDWATER INGESTION ACTION LEVELS BASED ON
NONCARCINOGENIC RISK
FUTURE ADULT RESIDENT
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Noncarcinogenic Risk - Based Action Level - Future Adult Resident		
	Noncarcinogenic Target Risk Level 1.0	Noncarcinogenic Target Risk Level 0.1	Noncaracinogenic Target Risk Level 0.01
Trichloroethene	219	21.9	2.19
1,2-Dichloroethene	328	32.8	3.28
Arsenic	11	1.1	0.11
Barium	2,555	255.5	25.55
Manganese	183	18.3	1.83
Mercury	11	1.1	0.11

Note: Action level concentrations expressed as μg/L

TABLE 3-10

GROUNDWATER INGESTION ACTION LEVELS BASED ON NONCARCINOGENIC RISK FUTURE CHILD RESIDENT FEASIBILITY STUDY CTO-231 SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA MCB, CAMP LEJEUNE, NORTH CAROLINA

	Noncarcinogenic Risk - Based Action Level - Future Child Resident		
Contaminant of Concern	Noncarcinogenic Target Risk Level 1.0	Noncarcinogenic Target Risk Level 0.1	Noncarcinogenic Target Risk Level 0.01
Trichloroethene	94	9.4	0.94
1,2-Dichloroethene	141	14.1	1.41
Arsenic	5	0.5	0.05
Barium	1,095	109.5	10.95
Manganese	78	7.8	0.78
Mercury	5	0.5	0.05

Note: Action level concentrations expressed as μg/L

TABLE 3-11

GROUNDWATER INGESTION ACTION LEVELS BASED ON NONCARCINOGENIC RISK
CURRENT MILITARY PERSONNEL
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Noncarcinogenic Risk - Based Action Level - Current Military Personnel		
	Noncarcinogenic Target Risk Level 1.0	Noncarcinogenic Target Risk Level 0.1	Noncarcinogenic Target Risk Level 0.01
Trichloroethene	307	30.7	3.07
1,2-Dichloroethene	460	46	4.6
Arsenic	15	1.5	0.15
Barium	3,577	357.7	35.77
Manganese	256	25.6	2.56
Mercury	15	1.5	0.15

Note: Action level concentrations expressed as µg/L

TABLE 3-12

COMPARISON OF GROUNDWATER CONCENTRATIONS TO ARARs AND RISK-BASED ACTION LEVELS FEASIBILITY STUDY CTO-231 SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA MCB, CAMP LEJEUNE, NORTH CAROLINA

Containment of Concern	ARAR		Groundwater Ingestion Risk - Based Action Level		Maximum Detected Concentration
	NCWQS [1]	Federal MCL [2]	Carcinogenic	Noncarcinogenic	
Trichloroethene	2.8	5	NA	94	27
1,2-Dichloroethene	NE	100[3]	NA	141	10
Arsenic	50	50	5	5	15.2
Barium	2,000	2,000	NA	1,095	76.6
Manganese	50	NE	NA	78	1,200
Mercury	1.1	2	NA	5	1.2

Notes: Concentrations expressed in microgram per liter (µg/L)
(1) NCWQS = North Carolina Water Quality Standards for Groundwater
(2) MCL = Safe Drinking Water Act Maximum Contaminant Level
(3) MCL for cis-1,2-dichloroethene
NA = Not Applicable
NE = Not Established

TABLE 3-13

REMEDIATION LEVELS
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media	Contaminant of Concern	Remediation Level	Unit	Basis of Remediation Level
Groundwater	Trichloroethene	2.8	μg/L	NCWQS
	1,2-Dichloroethene	100[1]	μg/L	MCL
	Arsenic	50	μg/L	NCWQS
	Barium	2,000	μg/L	NCWQS
	Manganese	50	μg/L	NCWQS
	Mercury	1.1	μg/L	NCWQS

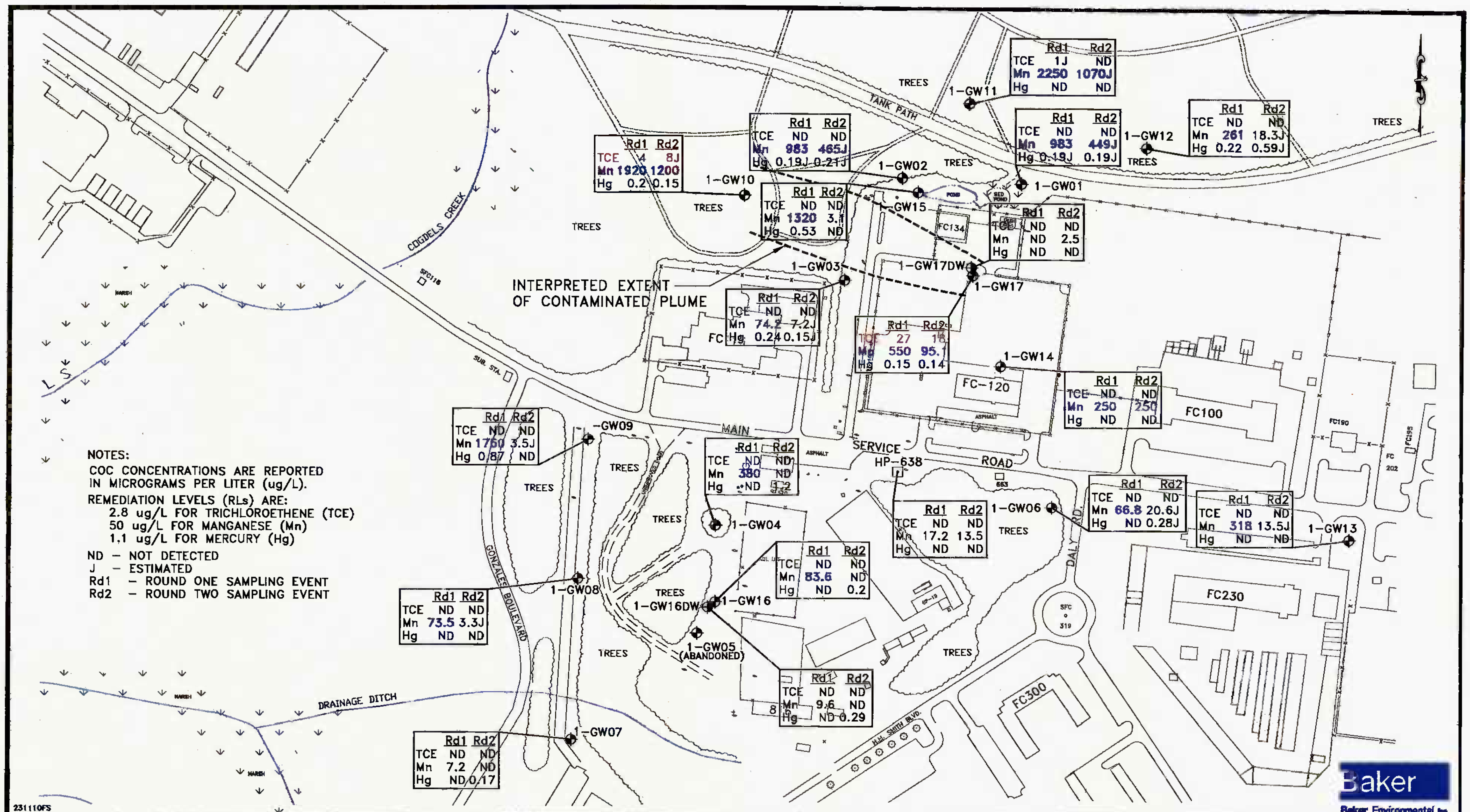
[1] MCL for cis-1,2-dichloroethene

TABLE 3-14

FINAL SET OF COCs
FEASIBILITY STUDY CTO-231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Contaminant of Concern	Remediation Level	Unit	Basis of Remediation Level
Trichloroethene	2.8	μg/L	NCWQS
Manganese	50	μg/L	NCWQS
Mercury	1.1	μg/L	NCWQS

SECTION 3.0 FIGURES



LEGEND

1-GW07 SHALLOW MONITORING WELL
1-GW16DW DEEP MONITORING WELL
HP-638 EXISTING WATER SUPPLY WELL
TCE 8J CONCENTRATION EXCEEDING THE TCE RL
Mn 1200 CONCENTRATION EXCEEDING THE MANGANESE RL
Hg 1.2 CONCENTRATION EXCEEDING THE MERCURY RL

SOURCE: LANTDIV, FEBRUARY 1992 AND W.K. DICKSON & ASSOC., JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE 3-1
GROUNDWATER AREA OF CONCERN
SITE 1 – FRENCH CREEK LIQUIDS DISPOSAL AREA
FEASIBILITY STUDY CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01497DD01Y

4.0 IDENTIFICATION AND PRELIMINARY SCREENING OF REMEDIAL ACTION TECHNOLOGIES - SITE 1

Section 4.0 includes the identification and preliminary screening of remedial action technologies and process options that may be applicable to the remediation of groundwater at Site 1. More specifically, Section 4.1 identifies a set of general response actions, Section 4.2 identifies remedial action technologies and process options for each general response action, and Section 4.3 presents the preliminary screening of remedial action technologies and process options. After this preliminary screening, the remaining technologies/process options undergo a process option evaluation in Section 4.4. A brief description of the technologies/process options that passed the process option evaluation is presented in Section 4.5.

4.1 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. Table 4-1 lists the general response actions that will satisfy the remedial action objectives identified for Site 1. As shown on Table 4-1, four general response actions have been identified for the groundwater objectives: no action, institutional controls, containment/collection actions, and treatment/discharge actions. A brief description of these general response actions follows.

4.1.1 No Action

The NCP requires the evaluation of the no action response action as part of the FS process. A no action response provides a baseline assessment for comparisons involving other remedial alternatives that have 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 itself.

4.1.2 Institutional Controls

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

4.1.3 Containment/Collection Actions

This general response action combines containment actions 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 without disturbing or removing the waste from the site. Collection actions can include technologies that collect contaminants via withdrawal techniques such as pumping or interceptor trenches.

4.1.4 Treatment/Discharge Actions

Treatment actions for contaminated groundwater include chemical, biological, and thermal treatment, physical removal systems, and in situ treatment systems. Discharge actions include on-site and off-site discharge.

4.2 Identification of Remedial Action Technologies and Process Options

In this step, an extensive set of potentially applicable technologies and process options will be identified for each of the general response actions. The term "technology type" will refer to general categories of technologies such as physical/chemical treatment, thermal treatment, biological treatment, and in situ treatment. The term "process option" will refer 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 known 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.

Remedial action technology types that are potentially applicable at Site 1 are listed on Table 4-2 with respect to their corresponding general response action. (These technology types are listed in the column titled "Remedial Action Technology".) Also identified on the table are applicable process options associated with each of the listed technology types.

4.3 Preliminary Screening of Remedial Action Technologies and Process Options

In this step, the set of remedial action technologies and process options identified in the previous section will be screened (or reduced) by evaluating the technologies with respect to technical implementability and site-specific factors. This screening step will be accomplished by using readily available information from the RI (with respect to contaminant types, contaminant concentrations, and on-site characteristics) to screen out technologies and process options that cannot be effectively implemented at the site (USEPA, 1988). In general, all technologies and process options which appear to be applicable to the site contaminants and to the site conditions will be retained for further evaluation. This preliminary screening is presented on Table 4-3. Following the preliminary screening, each process option remaining will be evaluated in Section 4.4.

As shown on Table 4-3, several technologies and/or process options were eliminated from further evaluation because they were determined to be inappropriate for the site and/or the contaminants present at the site. The specific reasons for retaining or eliminating process options are provided in the column titled "Site-Specific Applicability". The technologies/process options that were eliminated include:

- Fencing
- Capping
- Vertical Barriers
- Horizontal Barriers
- Extraction/Injection Wells
- Hydrofracturing
- Aerobic Biological Treatment
- Chemical Dechlorination
- Chemical Reduction
- Ion Exchange
- Electrodialysis
- Electrochemical Ion Generation
- Distillation
- Oil/Water Separation
- Thermal Treatment
- Engineered Wetland Treatment
- POTW Treatment
- RCRA Facility Treatment

- Reverse Osmosis
- Discharge by Reinjection

The technologies and process options that passed this preliminary screening are listed on Table 4-4.

4.4 Process Option Evaluation

The objective of the process option evaluation is to select only one process option for each applicable remedial technology type 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.

The process options listed on Table 4-4 were evaluated based on three criteria: effectiveness, implementability, and relative cost. The effectiveness evaluation focused on: the potential effectiveness of process options 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 implementability evaluation 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 cost evaluation 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 options evaluation is presented on Table 4-5. It is important to note that the elimination of a process option does not mean that the process option/technology 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 potential alternatives.

4.5 Final Set of Remedial Action Technologies/Process Options

Table 4-6 identifies the final set of feasible technologies/process options that will be used to develop remedial action alternatives in Section 5.0. A brief description of each technology/process option is presented below.

4.5.1 No Action

The no action response provides a baseline for comparison with other response actions. Under the no action response, groundwater at Site 1 will be left in place, and passive remediation can occur. Passive remediation involves natural attenuation processes, such as biodegradation, volatilization, photolysis, leaching, adsorption, and chemical reactions between subsurface materials that over time destroy contaminants of concern. Factors that influence these natural processes include: water content in soil, soil porosity/permeability, clay content, adsorption site density, pH, oxidation/reduction potential, temperature, wind, evaporation, precipitation, microbial community, chemical composition and concentration, depth of incorporation, irrigation management, soil management, and availability of nutrients.

4.5.2 Groundwater Monitoring

A long-term groundwater monitoring program could be implemented at Site 1 as an institutional control. This program would continue to provide information regarding the effectiveness of any remedial activities conducted at the site.

4.5.3 Aquifer-Use Restrictions

An ordinance restricting the use of the deep aquifer (i.e., the Castle Hayne Aquifer) at Site 1 as a drinking water source could be implemented as an institutional control. This restriction would help reduce the risk to both human and ecological populations from ingestion and direct contact with the contaminants that could possibly migrate into the Castle Hayne.

4.5.4 Deed Restrictions

Deed restrictions limiting future placement of wells at the site may be used as an institutional control measure. Deed restrictions help reduce the risk to human populations from ingestion of and direct contact with contaminated groundwater.

4.5.5 Extraction Wells

The extent and migration of a contaminated groundwater plume may be contained or controlled via pumping techniques. Existing wells or additional extraction wells, strategically located according to the hydrogeologic and chemical characteristics of an aquifer and contaminants of concern, are typically used. The extraction wells are pumped at specific rates such that the cone of influence from the well system intercepts the contaminant plume. Groundwater pumping may be combined with treatment technologies to allow for discharge.

Pumping techniques utilizing extraction wells are reliable and proven techniques for the management of groundwater contamination and aquifer restoration. Installation is relatively easy and quick (Wagner, 1986).

4.5.6 Air Stripping

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

4.5.7 Carbon Adsorption

Carbon adsorption is a physical 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 either replaced or regenerated. The time to reach breakthrough is the most critical operating parameter of this type of treatment system (Rich, 1987).

4.5.8 Neutralization

Neutralization is the interaction of an acid with a base or vice versa to yield a final pH of approximately 7.0. This technology 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 and oils and grease. The major limitation of neutralization is that it is subject to the influence of temperature (USEPA, 1990a).

4.5.9 Precipitation/Flocculation

Precipitation is a process in which materials in solution are transferred into a solid phase for removal. Flocculation is a process in which chemical coagulants cause colloidal particles to agglomerate into larger particles. Removal of heavy metals is the most common precipitation/flocculation application in wastewater treatment.

Generally, lime or sodium sulfide is added to the wastewater in a rapid mixing tank along with flocculating agents such as alum, ferric chloride, and ferric sulfate. The wastewater then flows to a flocculation chamber where additional mixing is conducted and retention time is provided resulting in the agglomeration of precipitate particles (Rich, 1987). The insoluble precipitate is then removed for recovery or disposal using solids separation technologies such as sedimentation or filtration.

4.5.10 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 include sand, coal, garnet, and diatomaceous earth. Filtration is generally preceded by chemical precipitation and neutralization.

4.5.11 Sedimentation

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

4.5.12 In-Well Aeration

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.

The process of in-well aeration involves injecting into a well air that is not intended to enter the aquifer, although it may enter in a dissolved form. After being injected into the bottom of the well, the air moves up through the well resulting in an in-well air lift pump effect. This 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. Groundwater, however, is never lifted above ground surface. Any groundwater that rises within the well moves out of the well before it reaches the ground surface and recirculates through the aquifer. Thus, under an in-well aeration system, groundwater is treated without being lifted above the ground surface. In addition to treating contaminants via volatilization, in-well aeration may provide enhanced bioremediation within the aquifer and vadose zone.

4.5.13 Off-Site Discharge - Pipeline to Stream

Treated groundwater from Site 1 can be discharged off-site to the New River or Cogdels Creek which eventually flows into the New River. However, the capacity of Cogdels Creek must be considered if it is to be used as a discharge point.

4.5.14 Off-Site Treatment - HPIA Treatment System

Groundwater can be discharged to one of two groundwater treatment systems that are located within the HPIA Operable Unit (Sites 78, 21, 22, and 24) at MCB, Camp Lejeune. These treatment systems are currently treating contaminated groundwater from the HPIA Operable Unit and consist of oil/water separation, flocculation, surge/settling, air stripping, and carbon adsorption units. Both treatment systems have the capacity to accept contaminated groundwater from other sites at the Base.

SECTION 4.0 TABLES

TABLE 4-1

GENERAL RESPONSE ACTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Media of Concern	Remedial Action Objective	General Response Action
Groundwater	• Mitigate the potential for direct exposure to contaminated groundwater. • Mitigate the horizontal and vertical migration of contaminated groundwater. • Restore the shallow aquifer so that contaminants meet their remediation levels.	• No Action • Institutional Controls • Containment/Collection Actions • Treatment/Discharge Actions

TABLE 4-2

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB CAMP LEJEUNE, NORTH CAROLINA

Media of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Ordinances	Aquifer-Use Restrictions
		Access Restrictions	Deed Restrictions
			Fencing
	Containment/Collection Actions	Capping	Clay/Soil Cap
			Asphalt/Concrete Cap
			Soil Cover
			Multi-layered 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/Discharge Actions	Biological Treatment	Aerobic • Aerated Lagoon • Activated Sludge • Powered Activated Carbon Treatment • Trickling filter • Rotating Biological Contractor
			Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Steam Striping
			Carbon Adsorption
			Chemical Dechlorination
			Ultraviolet (UV) Oxidation
			Chemical Oxidation • Hydrogen Peroxide • Chlorine • Potassium Permanganate • Ozonation
			Chemical Reduction
			Reverse Osmosis
			Ion Exchange
			Electrodialysis

TABLE 4-2 (Continued)

POTENTIAL SET OF REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS FEASIBILITY STUDY CTO-0231 SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA MCB CAMP LEJEUNE, NORTH CAROLINA

Media of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater (Continued)	Treatment/Discharge Actions (Continued)	Physical/Chemical Treatment (Continued)	Electrochemical Ion Generation
			Distillation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
			Oil/Water Separation
		Thermal Treatment	Incineration ● Liquid Injection ● Rotary Kiln ● Fluidized Bed ● Multiple Hearth
			Molten Salt
			Plasma Arc Torch
			Pyrolysis
			Wet Air Oxidation
		Engineered Wetland Treatment	Constructed Wetlands
		Off-Site Treatment	POTW
			RCRA Facility
			Sewage Treatment Plant
			HPIA Treatment System
		In-Situ Treatment	Biodegradation
			Air Sparging
			In-Well Aeration
			Dual Phase Extraction
			Passive Treatment Wall
		On-Site Discharge	Surface Water
			Reinjection ● Injection Wells ● Infiltration Galleries
		Off-Site Discharge	POTW
			Pipeline to Stream
			Sewage Treatment Plant
			Deep Well Injection

TABLE 4-3

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
No Action	No Action	Not Applicable	No action - contaminated groundwater remains as is.	Potentially applicable to any site; required by the NCP.	Retained
Institutional Controls	Monitoring	Groundwater Monitoring	Ongoing monitoring of existing wells.	Potentially applicable.	Retained
	Ordinances	Aquifer-Use Restrictions	Prohibit use of the contaminated aquifer as a potable water source.	Potentially applicable.	Retained
	Access Restrictions	Deed Restrictions	Limit the future use of land including placement of wells.	Potentially applicable.	Retained
		Fencing	Limit access by installing a fence around contaminated area.	A fence alone will not prevent contaminant migration.	Eliminated
Containment/Collection Actions	Capping	Clay/Soil Cap Asphalt/Concrete Cap Soil Cover Multilayered Cap	Capping material placed over areas of contamination.	Typically used in conjunction with vertical barriers which are not technically feasible at Site 1. A cap alone will not prevent contaminant migration.	Eliminated
	Vertical Barriers	Grout Curtain	Pressure injection of grout in a regular pattern of drilled holes to contain contamination.	No continuous confining layer under the site for the wall to adjoin to.	Eliminated
		Slurry Wall	Trench around areas of contamination. The trench is filled with a soil bentonite slurry to limit migration of contaminants.	No continuous confining layer under the site for the wall to adjoin to.	Eliminated
		Sheet Piling	Interlocking sheet pilings installed via drop hammer around areas of contamination.	No continuous confining layer under the site for the wall to adjoin to.	Eliminated
		Rock Grouting	Specialty operation for sealing fractures, fissures, solution cavities, or other voids in rock to control flow of groundwater.	No bedrock underlies the site.	Eliminated

TABLE 4-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	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.	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.	Potentially applicable.	Retained
		Extraction/Injection Wells	Injection wells inject uncontaminated groundwater to enhance collection of contaminated groundwater via extraction wells. Injection wells can also inject material into an aquifer to remediate groundwater.	Based on the low permeability of soils at the site, injected liquid may mound in the subsurface formations rather than flowing through.	Eliminated
		Hydrofracturing	Pressurized water is injected to create fractures in the formation, thus improving permeability; used to enhance pump and treat systems.	The fractures may open new passageways through which contaminants can spread; pilot scale technology.	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/Discharge 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.	Eliminated
		Anaerobic	Degradation of organics using microorganisms in an anaerobic environment.	Potentially applicable to halogenated VOCs.	Retained

TABLE 4-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment/Discharge Actions (Continued)	Physical/Chemical Treatment	Air Stripping	Mixing large volumes of air with water in a packed volume to promote transfer of VOCs to air.	Potentially applicable to VOCs.	Retained
		Steam Stripping	Mixing large volumes of steam with water in a packed column to promote transfer of VOCs to air.	Potentially applicable to VOCs.	Retained
		Carbon Adsorption	Adsorption of contaminants onto activated carbon by passing water through carbon column.	Potentially applicable to VOCs.	Retained
		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 application of this technology.	Eliminated
		Ultraviolet (UV) Oxidation	Ultraviolet radiation is used to destroy organic contaminants as water flows into a treatment tank; an ozone destruction unit treats off-gases from the treatment tank.	Potentially applicable to VOCs.	Retained
		Chemical Oxidation • Hydrogen Peroxide • Chlorine • Potassium Permanganate • Ozonation	Addition of an oxidizing agent to raise the oxidation state of a substance. Effective for organics and some metals, primarily iron and manganese.	Potentially applicable to VOCs.	Retained
		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 the groundwater contaminants.	Eliminated
		Reverse Osmosis	Using high pressure to force water through an RO membrane leaving contaminants behind. Effective for dissolved solids (organic and inorganic).	Not applicable to the groundwater contaminants.	Eliminated

TABLE 4-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment/Discharge Actions (Continued)	Physical/Chemical Treatment (Continued)	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 the groundwater contaminants	Eliminated
		Electrodialysis	Metal ions are removed when an electric current drives contaminated water through ion exchangers in membrane form.	Not applicable to the groundwater contaminants.	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 the groundwater contaminants.	Eliminated
		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 inappropriate for treating groundwater with 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. Applicable to particulates 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. Applicable to suspended solids.	Potentially applicable.	Retained
		Flocculation	Small, unsettleable particles suspended in a liquid medium are made to agglomerate into large particles by the addition of flocculating agents. Applicable to particulates and inorganics.	Potentially applicable as pretreatment for a VOC removal technology.	Retained

TABLE 4-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment/Discharge Actions (Continued)	Physical/Chemical Treatment (Continued)	Sedimentation	Removal of suspended solids in an aqueous waste stream via gravity separation. Applicable to suspended solids.	Potentially applicable as pretreatment for a VOC removal technology.	Retained
		Oil/Water Separation	Materials in solution are transferred into a separate phase for removal. Effective for petroleum hydrocarbons.	Not applicable to the groundwater contaminants.	Eliminated
	Thermal Treatment	Incineration ● Liquid Injection ● Rotary Kiln ● Fluidized Bed ● Multiple Hearth	Combustion of waste at high temperatures. Different incinerator types can be applicable to pumpable organic wastes, combustible liquids, soils, slurries, or sludges.	Incineration is relatively expensive when there are low contaminant concentration in groundwater; extensive dewatering may be required.	Eliminated
		Molten Salt	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 concentration in groundwater; extensive dewatering may be required.	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 concentration in groundwater; extensive dewatering may be required.	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 concentration in groundwater; extensive dewatering may be required.	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 concentration in groundwater; extensive dewatering may be required.	Eliminated

TABLE 4-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment/Discharge 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.	Implementation of this technology will restrict the current use of land at Site 1.	Eliminated
	Off-Site Treatment	POTW	Extracted groundwater discharged to Jacksonville POTW for treatment.	Not applicable since this POTW will not accept contaminated groundwater.	Eliminated
		RCRA Facility	Extracted groundwater transported to licensed RCRA facility for treatment and/or disposal.	Distance to nearest RCRA Facility, and the volume of groundwater that must be transported, make this option impractical.	Eliminated
		Sewage Treatment Plant	Extracted groundwater discharged to Base STP for treatment.	Potentially applicable for low VOC concentrations.	Retained
		HPIA Treatment System	Extracted groundwater discharged to HPIA shallow aquifer treatment system.	Potentially applicable.	Retained
	In Situ Treatment	Biodegradation	System of introducing nutrients and oxygen to waste for the stimulation or augmentation of microbial activity to degrade contamination. Applicable to a wide range of organic compounds.	Potentially applicable to VOCs.	Retained
		Air Sparging	"In situ air stripping"; air is injected into the aquifer creating an underground air stripper; used in conjunction with soil vapor extraction.	Potentially applicable to VOCs.	Retained
		In-Well Aeration	"In-well air stripping". Process of inducing air into a well by applying a vacuum. The result is an in-well air lift pump effect that serves to strip volatiles from groundwater inside the well.	Potentially applicable to VOCs.	Retained
		Dual Phase Extraction	A high vacuum placed in a well removes liquid and gas; applicable to VOCs in low permeability or heterogeneous formations.	Potentially applicable to VOCs.	Retained

TABLE 4-3 (Continued)

PRELIMINARY SCREENING OF GROUNDWATER TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response	Remedial Action Technology	Process Option	Description	Site-Specific Applicability	Screening Results
Treatment/Discharge Actions (Continued)	In Situ Treatment (Continued)	Passive Treatment Wall	A permeable reaction wall is installed across the flow path of a contaminant plume, allowing the plume to passively move through the wall; applicable to VOCs and inorganics.	Potentially applicable to halogenated VOCs.	Retained
	On-Site Discharge	Surface Water	Treated water discharged to stream on the site (i.e., drainage ditch near the southern disposal area).	Potentially applicable.	Retained
		Reinjection • Injection Wells • Infiltration Galleries	Treated water reinjected into the site aquifer via use of shallow infiltration galleries (trenches) or via deep injection wells.	Based on the low permeability of soils at the site, injected liquid may mound in the subsurface formations rather than flowing through.	Eliminated
	Off-Site Discharge	POTW	Treated water discharged to Jacksonville POTW.	Potentially applicable.	Retained
		Pipeline to Stream	Treated water discharged to river off site (i.e., New River, Cogdels Creek).	Potentially applicable.	Retained
		Sewage Treatment Plant	Treated water discharged to Hadnot Point STP.	Potentially applicable.	Retained
		Deep Well Injection	Treated water is reinjected into the brine aquifer located under the Castle Hayne aquifer.	Potentially applicable.	Retained

TABLE 4-4

SET OF POTENTIAL TECHNOLOGIES/PROCESS OPTIONS THAT PASSED THE PRELIMINARY SCREENING SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA FEASIBILITY STUDY CTO-0231 MCB CAMP LEJEUNE, NORTH CAROLINA

Media of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Ordinances	Aquifer-Use Restrictions
		Access Restrictions	Deed Restrictions
	Containment/Collection Actions	Extraction	Extraction Wells
		Subsurface Drains	Interceptor Trenches
	Treatment/Discharge Actions	Biological Treatment	Anaerobic
		Physical/Chemical Treatment	Air Stripping
			Steam Stripping
			Carbon Adsorption
			UV Oxidation
			Chemical Oxidation
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		Off-Site Treatment	Sewage Treatment Plant
			HPIA Treatment System
		In Situ Treatment	Biodegradation
			Air Sparging
			In-Well Aeration
			Dual Phase Extraction
			Passive Treatment Wall
		On-Site Discharge	Surface Water
		Off-Site Discharge	POTW
			Pipeline to Stream
			Sewage Treatment Plant
			Deep Well Injection

TABLE 4-5

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	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/or the effects of natural attenuation	• Easily implemented	• No cost	Retained as per the requirements of the NCP
Institutional Controls	Monitoring	Groundwater Monitoring	• Will effectively detect contaminant increases so that exposure can be avoided	• Easily implemented	• Low capital • Low O&M	Retained because of its effectiveness and low cost
	Ordinances	Aquifer-Use Restrictions	• Effective at preventing future exposure to groundwater • Effectiveness dependent on continued future implementation	• Easily implemented	• Negligible cost	Retained because of its effectiveness and negligible cost
	Access Restrictions	Deed Restrictions	• Effective at preventing future exposure to groundwater • Effectiveness dependent on continued future implementation	• Easily implemented • Legal requirements	• Negligible cost	Retained because of its effectiveness and negligible cost
Containment/ Collection Actions	Extraction	Extraction Wells	• Inorganics may precipitate and clog well screens; this necessitates frequent maintenance and equipment replacement • Effective for collecting and/or containing a contaminated groundwater plume • Potential exposures during implementation • Conventional, widely demonstrated technology	• Easily implemented • Equipment readily available	• Moderate capital • Low O&M	Retained because it is a conventional technology and more easily implemented than an interceptor trench

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Containment/ Collection Actions (Continued)	Subsurface Drains	Interceptor Trenches	• Effective for collecting and/or containing a contaminated groundwater plume • More effective for shallow groundwater plumes • 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 trenches require more surface area and are less cost effective than extraction wells
Treatment/ Discharge 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 of • Low contaminant concentrations may make operation difficult	• Moderate capital • Moderate O&M	Eliminated because it has not been widely demonstrated and contaminant concentrations at Site 1 are low
	Physical/ Chemical Treatment	Air Stripping	• Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling • More effective for low concentrations of waste that are highly volatile and have low water solubility, like TCE • Commercially proven and widely used technology • Contaminant transfer rather than destruction technology	• Equipment and vendors readily available • Mobile units available • May require bench-scale testing • Off-gas and/or tower scale treatment may be required • May require air emissions permit	• Low to 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 and performance record, and its relatively low cost

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	Physical/ Chemical Treatment (Continued)	Steam Stripping	• Pretreatment and frequent column cleaning may be required to avoid inorganic and biological fouling • More effective for contaminants that are more water soluble and relatively less volatile • Commercially proven • Contaminant transfer rather than destruction technology • Lower efficiency in cold weather	• Readily available, but not as common as air stripping • Off-gas and/or tower scale treatment may be required • May require air emissions permit	• Moderate capital • Moderate to high O&M	Eliminated because it is less effective than air stripping for contaminants that are highly volatile with low water solubility (i.e., TCE)
		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	• Readily available, conventional technology • Spent carbon must be properly regenerated or disposed of • Pretreatment may be required to reduce or remove suspended solids, oil and grease, and unstable chemical compounds	• 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 • VOCs may be volatilized rather than destroyed and 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 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	Physical/ Chemical Treatment (Continued)	Chemical Oxidation	• If oxidation reactions are not complete, residual hazardous compounds may remain in the waste stream • Reliable and proven on industrial wastewaters for metals (manganese, iron) treatment • Can be used alone or in conjunction with precipitation	• Well-demonstrated • Readily available, conventional equipment	• Low to moderate capital • Moderate O&M • Ozonation has a higher capital cost because it requires ozone generation and destruction units	Eliminated because metals are not a primary treatment concern
		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 pretreatment for air stripping and/or carbon absorption
		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	• Widely used and well demonstrated • Equipment is basic and easily designed • Compact, single units that are deliverable to the site	• Low capital • Moderate O&M	Retained because it may be necessary as pretreatment for air stripping and/or carbon absorption
		Filtration	• Conventional, proven method of removing suspended solids from wastewater • Does not remove contaminants other than suspended solids • Pretreatment for oil and grease required • 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 pretreatment for air stripping and/or carbon absorption

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	Physical/ Chemical Treatment (Continued)	Flocculation	• Conventional, proven technology • Applicable to any 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 pretreatment for air stripping and/or carbon absorption
		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 reinjection 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 pretreatment for air stripping and/or carbon absorption
	Off-Site Treatment	Sewage Treatment Plant	• Effectiveness and reliability require pilot test to determine	• Readily implementable if STP will accept waste • May be difficult to gain STP acceptance of waste • Modifications to permits may be required	• Moderate capital • Low O&M	Eliminated because of the dificulties associated with gaining STP acceptance of the waste

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	Off-Site Treatment (Continued)	HPIA Treatment System	• Effective and reliable for VOC removal	• System has the capacity to accept the groundwater • Transportation via pipeline may not be feasible due to the distance to the system and utilities that are in the way • Transportation via trucking is feasible	• Moderate capital • Low O&M	Retained because the HPIA treatment system can easily accept the waste and it can effectively treat the COC
	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 it has not been widely demonstrated and there is no soil contamination associated with groundwater contamination at Site 1
		Air Sparging	• Commercially proven technology • Groundwater does not need to be lifted above ground surface in order to be treated • Contaminant transfer rather than destruction technology • Does not provide a closed loop system for air circulation; volatiles may escape to the atmosphere between air injection wells and vapor extraction wells • Contamination of the vadose zone may occur as contaminated groundwater passes through it • Fouling of the system may occur by oxidized constituents in the groundwater	• Secondary treatment of off-gas may be required • May require air emissions permit	• Moderate to high capital • Low to moderate O&M	Eliminated because volatiles may escape between injection and extraction wells, and contamination of the vadose zone may occur

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	In Situ Treatment (Continued)	In-Well Aeration	• Limited commercial track record • Groundwater does not need to be lifted above ground surface in order to be treated • Contaminant transfer rather than destruction technology • Provides a closed loop system for air circulation; volatiles are less likely to escape because they will be collected within the aeration wells • Compared to air sparging with soil vapor extraction, contamination of soil within vadose zone is less likely to occur • Fouling of the system may occur by oxidized constituents in the groundwater	• Secondary treatment of off-gas may be required • May require air emissions permit	• Moderate to high capital • Low to moderate O&M	Retained because compared to air sparging, escape of volatiles and contamination of the vadose zone are less likely to occur
		Dual-Phase Extraction	• The maximum suction lift is approximately 30' bgs • Requires both water and vapor treatment • Groundwater must be lifted above ground surface in order to be treated	• Emerging technology • Equipment and materials should be readily available	• Low to moderate capital • Low to moderate O&M	Eliminated because unlike in-well aeration, treatment of both water and vapor is required

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	In Situ Treatment (Continued)	Passive Treatment Wall	• Not widely demonstrated; only one full-scale application to date • Contaminant destruction rather than transfer technology • Inorganics precipitation may occur resulting in a reduction of permeability through the wall. • Iron grinding should not become exhausted before treatment is complete	• 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 because it has not been widely demonstrated
	On-Site Discharge	Surface Water	• Effective and reliable discharge method	• Based on the low pumping rates expected, the drainage ditch located near the southern disposal area (which ultimately flows into Cogdels Creek) should have the capacity to handle discharge from a pump and treat system • Compared to direct discharge to Cogdels Creek, the on-site drainage ditch is located farther from the AOC	• Moderate to high capital • Low to moderate O&M	Eliminated because Cogdels Creek (off-site) is located closer to the AOC
	Off-Site Discharge	POTW	• Effective and reliable discharge method	• Discharge permits required • Acceptance by a local POTW may be difficult to obtain	• High capital • Moderate O&M	Eliminated because of the high cost and difficulty in gaining acceptance of the waste

TABLE 4-5 (Continued)

SUMMARY OF GROUNDWATER PROCESS OPTION EVALUATION
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

General Response Action	Remedial Action Technology	Process Option	Evaluation			Evaluation Results
			Effectiveness	Implementability	Relative Cost	
Treatment/ Discharge Actions (Continued)	Off-Site Discharge (Continued)	Pipeline to Stream	• Effective and reliable discharge method	• Discharge permits required • Distance to New River from site may make this option difficult to implement • Cogdels Creek is located relatively close to the AOC • Based on the low pumping rates, Cogdels Creek should have the capacity to handle discharge from a pump and treat system	• Moderate to high capital • Low O&M	Retained because Cogdels Creek is located relatively close to the AOC
		Sewage Treatment Plant	• Effective and reliable discharge method	• Discharge permit may need to be modified • Capacity of the STP may not be able to accept the flow • Distance to STP may make this option difficult to implement	• Low capital • Low O&M	Eliminated because of the distance to the nearest STP
		Deep Well Injection	• Injection wells effectiveness is highly dependent on site geology/ hydrogeology • Wells may clog due to inorganics precipitation over time	• Discharge permit required • Injection wells must be installed	• Moderate capital • Moderate O&M	Eliminated because injection wells may clog over time

TABLE 4-6

FINAL SET OF POTENTIAL REMEDIAL ACTION TECHNOLOGIES AND PROCESS OPTIONS
FEASIBILITY STUDY CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB CAMP LEJEUNE, NORTH CAROLINA

Media of Concern	General Response Action	Remedial Action Technology	Process Option
Groundwater	No Action	No Action	Not Applicable
	Institutional Controls	Monitoring	Groundwater Monitoring
		Ordinances	Aquifer-Use Restrictions
		Access Restrictions	Deed Restrictions
	Containment/Collection Actions	Extraction	Extraction Wells
	Treatment/Discharge Actions	Physical/Chemical Treatment	Air Stripping
			Carbon Adsorption
			Neutralization
			Precipitation
			Filtration
			Flocculation
			Sedimentation
		In Situ Treatment	In-Well Aeration
		Off-Site Discharge	Pipeline to Stream
		Off-Site Treatment	HPIA Treatment System

5.0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES - SITE 1

In this section, remedial action technologies and process options chosen for Site 1 will be combined to form remedial action alternatives (RAAs). Following the development of these RAAs (Section 5.1), each RAA may be evaluated against the short-term and long-term aspects of three criteria: effectiveness, implementability, and cost (Section 5.2). The RAAs with the most favorable evaluation are then retained for further consideration during the detailed analysis (Section 6.0). Note that the screening evaluation at this step of the FS is optional. It will only be conducted if too many RAAs are initially developed.

5.1 Development of Remedial Action Alternatives

RAAs were developed by combining the general response actions, remedial action technologies, and process options that are listed on Table 4-6. Five RAAs were developed for groundwater at Site 1: no action, institutional controls, extraction and on-site treatment, in-well aeration and off-gas carbon adsorption, and extraction and off-site treatment. A description of these Groundwater RAAs is presented in the following subsections.

5.1.1 RAA No. 1: No Action

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

Although this RAA does not involve active remediation, passive remediation of the groundwater will occur via natural attenuation processes. These processes include naturally occurring biodegradation, volatilization, dilution, photolysis, leaching, adsorption, and chemical reactions between subsurface materials.

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.

5.1.2 RAA No. 2: Institutional Controls

Under RAA No. 2, no remedial actions will be performed to reduce the toxicity, mobility, or volume of contaminated groundwater at Site 1. Instead, the following institutional controls will be implemented: continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

The purpose of the groundwater monitoring plan is to track the contaminated plume's migration over time. Figure 5-1 identifies the well locations where groundwater will be semiannually monitored. Samples will be collected from wells 1-GW01, 1-GW02, 1-GW03, 1-GW10, 1-GW11, 1-GW12, 1-GW17, and 1-GW17DW (deep well) and analyzed for VOCs. Additional wells may be added to this monitoring plan, if necessary.

In addition to groundwater monitoring, the Base Master Plan will be modified to include aquifer-use restrictions which will prohibit future use of the aquifer as a potable water source. Also, deed restrictions will be implemented to limit the future use of land at the site, including placement of wells.

Although this RAA does not involve active remediation, passive remediation of the groundwater will occur via natural attenuation processes. These processes include biodegradation, volatilization, dilution, photolysis, leaching, adsorption, and chemical reactions between subsurface materials.

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.

5.1.3 RAA No. 3: Extraction and On-Site Treatment

RAA No. 3 is a source collection and treatment alternative. The technologies/process options associated with RAA No. 3 include: extraction wells, on-site treatment consisting of air stripping, neutralization, precipitation, flocculation, sedimentation, and filtration, off-site discharge, continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

Under RAA No. 3, three extraction wells will be installed as shown on Figure 5-2 to collect groundwater from the surficial aquifer. The radius of influence for each well will be approximately 400 feet. (Radius of influence calculations are included in Appendix B of Volume I.) The pumping rates of the wells will allow their combined radii of influence to intercept the contaminated plume.

After being extracted, the groundwater will be transported by pipeline to the on-site treatment plant identified on Figure 5-2. At the treatment plant, the groundwater will receive VOC treatment via a low profile air stripper and pretreatment via chemical addition, precipitation, flocculation, sedimentation, and filtration. A typical process flow diagram is presented on Figure 5-3. Although carbon adsorption is typically used as a polishing step after air stripping, it is not included in the Site 1 treatment train because of the low VOC concentrations that will be treated. VOCs discharged to the atmosphere are expected to be within acceptable limits. Periodic air sampling associated with treatment plant operation and maintenance will ensure that discharges to the atmosphere remain within acceptable limits. After receiving treatment, groundwater will be discharged off-site to Cogdels Creek.

In addition to extraction, treatment, and discharge, RAA No. 3 incorporates a long-term groundwater monitoring plan to measure the effects of this remedial action alternative. Wells to be monitored semiannually under this program are identified on Figure 5-2. As shown, samples will be collected from wells 1-GW01, 1-GW02, 1-GW03, 1-GW10, 1-GW11, 1-GW12, 1-GW17, and 1-GW17DW (deep well) and analyzed for VOCs. Additional wells may be added to this monitoring plan if necessary. In addition, aquifer-use and deed restrictions will be implemented under this RAA. Aquifer-use restrictions will prohibit use of the aquifer as a potable water source, and deed restrictions will limit future use of the land at Site 1, including placement of wells.

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.

5.1.4 RAA No. 4: In-Well Aeration and Off-Gas Carbon Adsorption

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 carbon adsorption unit.

Under RAA No. 4, four in-well aeration wells will be installed as shown in Figure 5-4. Because the radius of influence of an aeration well is approximately 1.5 to 2 times the saturated aquifer thickness (Buermann, W., 1944), the radius of influence of each well at Site 1 will be approximately 120 to 160 feet. Thus, the wells will intercept the contaminated plume as it travels in the direction of groundwater flow.

A typical in-well aeration well and the associated treatment processes are depicted in Figure 5-5. A separate vacuum pump, knockout tank, and carbon adsorption unit will be located near the opening of each well. The knockout tank will remove any liquids that have traveled up the well and the carbon adsorption unit will treat off-gases that were stripped within the well. Treated vapors from the carbon adsorption unit will be discharged to the atmosphere.

Because in-well aeration is a relatively new and innovative technology, a field pilot test is recommended prior to initiating the system design. The pilot test will determine the loss of efficiency over time as a result of inorganics precipitation and oxidation on the well screen, the radius of influence of the aeration wells under various heads of injection air pressure, the rate of off-gas organic contaminant removal via carbon adsorption, and carbon breakthrough times.

In addition to the in-well aeration system, RAA No. 4 incorporates a long-term groundwater monitoring plan to measure the effects of this remedial action alternative. Wells to be monitored semiannually under this program are identified on Figure 5-4. As shown, samples will be collected from wells 1-GW01, 1-GW02, 1-GW03, 1-GW10, 1-GW11, 1-GW12, 1-GW17, and 1-GW17DW (deep well) and analyzed for VOCs. Additional wells may be added to this monitoring plan if necessary. In addition, aquifer-use and deed restrictions will be implemented under this RAA. Aquifer-use restrictions will prohibit use of the aquifer as a potable water source, and deed restrictions will limit future use of the land at Site 1, including placement of wells.

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.

5.1.5 RAA No. 5: Extraction and Off-Site Treatment

RAA No. 5 is a source collection and treatment alternative. The technologies/process options associated with RAA No. 5 include: extraction wells, off-site treatment, continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

Under RAA No. 5, three extraction wells will be installed to collect groundwater from the surficial aquifer. The location of these wells will be identical to the location of the extraction wells associated with RAA No. 3 (see Figure 5-2). The radius of influence for each well will be approximately 400 feet. (Radius of influence calculations are included in Appendix B of Volume I.) The pumping rates of the wells will allow their combined radii of influence to intercept the contaminated plume.

Once groundwater is extracted, it will be transported to the HPIA Treatment System by tanker trucks. The HPIA treatment system, located within the HPIA Operable Unit (Sites 78, 21, 22, and 24) at MCB, Camp Lejeune, consists of oil/water separation, flocculation, surge/settling, air stripping, and carbon adsorption units. Thus, the system will provide VOC treatment and metals pretreatment for contaminated groundwater from Site 1. The system is currently treating contaminated groundwater from the HPIA Operable Unit, but it has the capacity to accept additional groundwater from other sites.

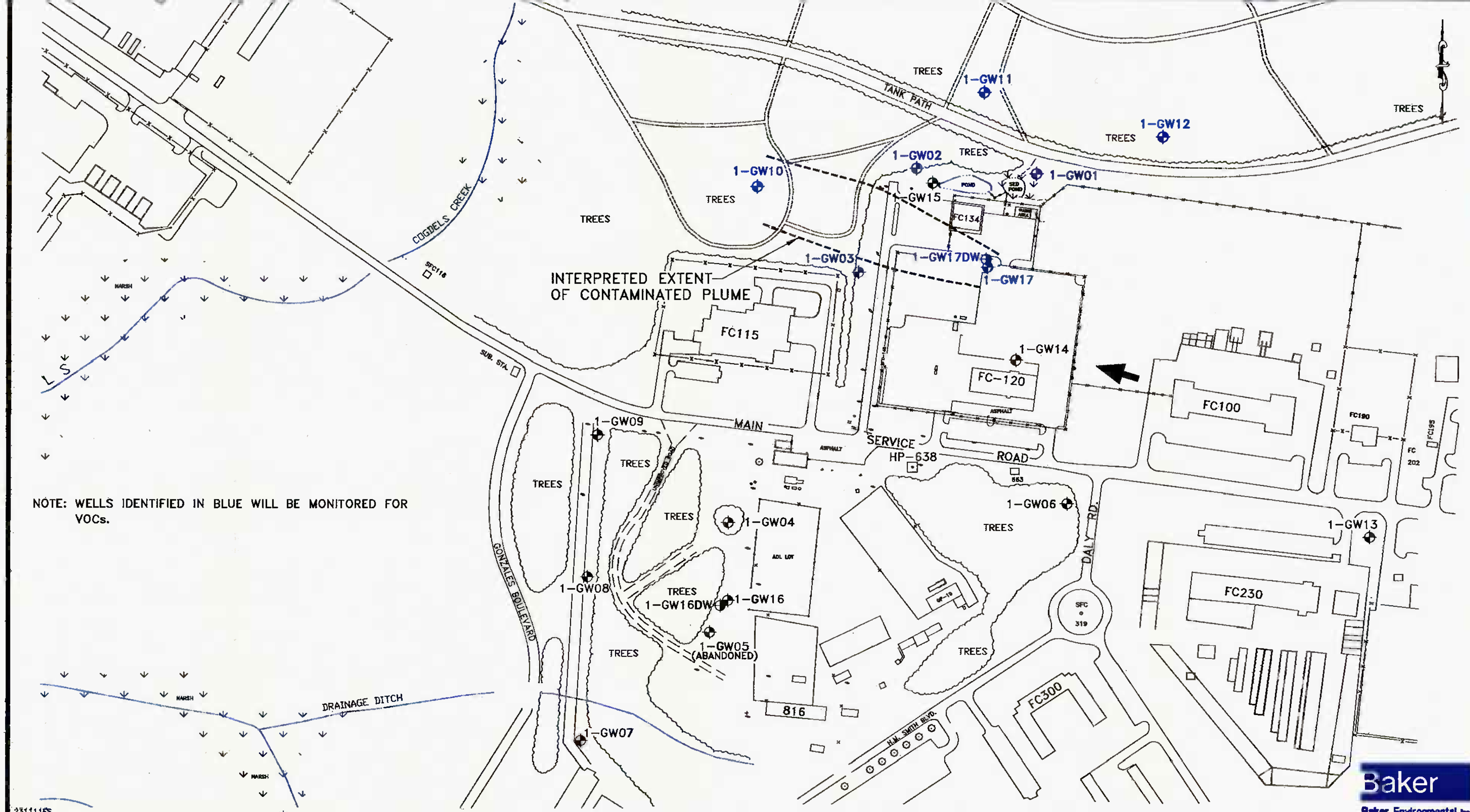
In addition to groundwater extraction and off-site treatment, RAA No. 5 incorporates a long-term groundwater monitoring plan to measure the effects of this remedial action alternative. Wells to be monitored semiannually under this program are identified in Figure 5-1. (The monitoring plan associated with RAA No. 5 will be identical to the monitoring plan associated with RAA No. 2.) As shown, samples will be collected from wells 1-GW01, 1-GW02, 1-GW03, 1-GW10, 1-GW11, 1-GW12, 1-GW17, and 1-GW17DW (deep well) and analyzed for VOCs. Additional wells may be added to this monitoring plan if necessary. In addition, aquifer-use and deed restrictions will be implemented under this RAA. Aquifer-use restrictions will prohibit use of the aquifer as a potable water source, and deed restrictions will limit future use of the land at Site 1, including placement of wells.

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.

5.2 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 1, the decision was made not to conduct this preliminary RAA screening step. Therefore, all of the developed RAAs will undergo the detailed evaluation presented in Section 6.0.

SECTION 5.0 FIGURES



LEGEND

- 1-GW07 SHALLOW MONITORING WELL
- 1-GW16DW DEEP MONITORING WELL
- HP-638 WATER SUPPLY WELL THAT IS NOT IN SERVICE
- APPROXIMATE GROUNDWATER FLOW DIRECTION

SOURCE: LANTDIV, FEBRUARY 1992 AND W.K. DICKSON & ASSOC., JUNE 1994

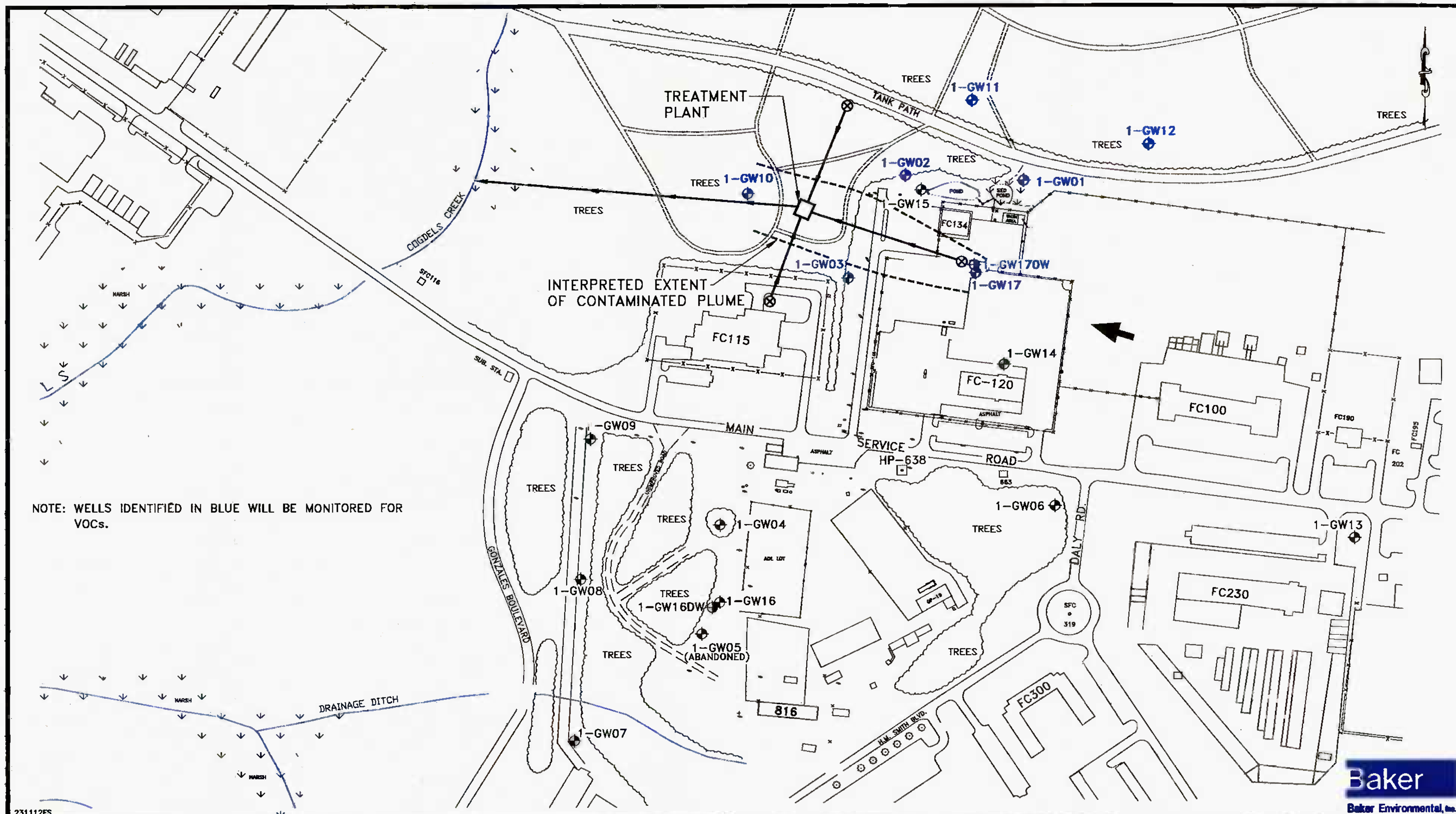
300 0 150 300 600

1 inch = 300 ft.

FIGURE 5-1
RAA NO. 2: INSTITUTIONAL CONTROLS-MONITORING PLAN
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
FEASIBILITY STUDY CTO-0231

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01497DDB2Y



LEGEND

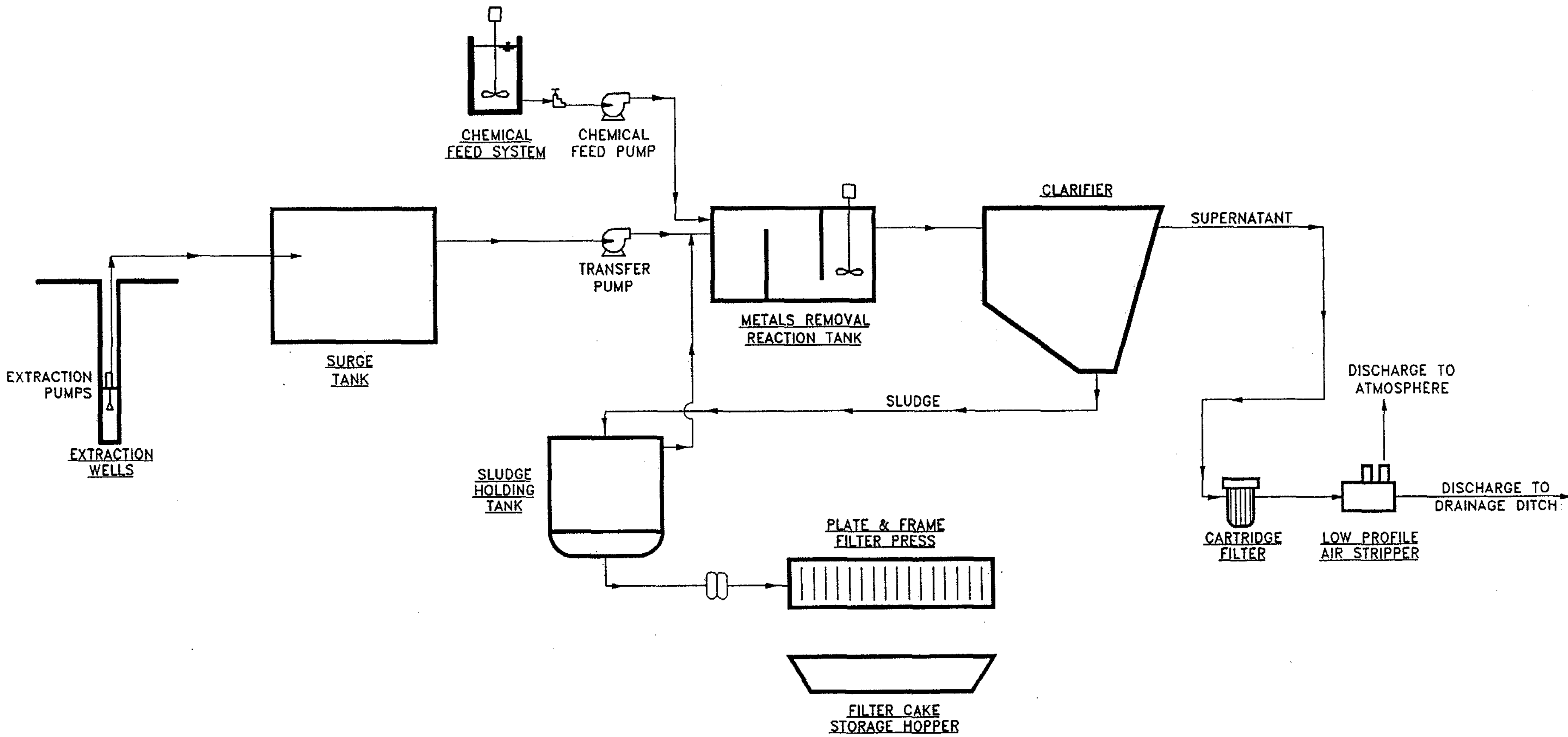
1-GW07 SHALLOW MONITORING WELL
1-GW16DW DEEP MONITORING WELL
HP-638 WATER SUPPLY WELL THAT IS NOT IN SERVICE
APPROXIMATE GROUNDWATER FLOW DIRECTION
EXTRACTION WELL
GROUNDWATER CONVEYANCE LINE

SOURCE: LANTDIV, FEBRUARY 1992 AND W.K. DICKSON & ASSOC., JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE 5-2
RAA No. 3:
EXTRACTION AND ON-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



Baker
Baker Environmental, Inc.

FIGURE 5-3
RAA No. 3:
EXTRACTION AND ON-SITE TREATMENT -
PROCESS FLOW DIAGRAM
SITE 1 - FRENCH CREEK
LIQUIDS DISPOSAL AREA
FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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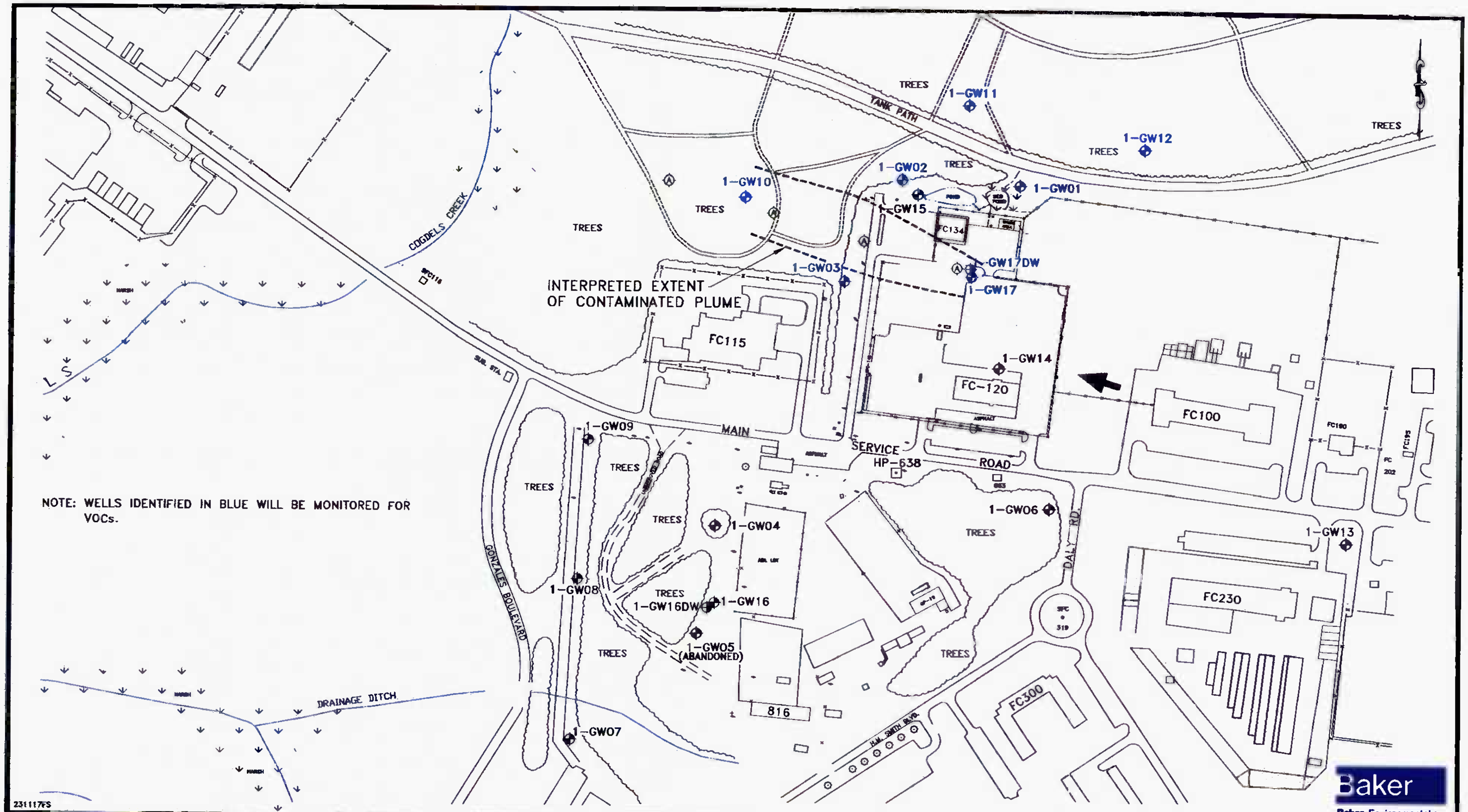

LEGEND

1-GW07 SHALLOW MONITORING WELL

1-GW16DW DEEP MONITORING WELL

HP-638 WATER SUPPLY WELL THAT IS NOT IN SERVICE

APPROXIMATE GROUNDWATER FLOW DIRECTION

IN-WELL AERATION WELL

SOURCE: LANTDIV, FEBRUARY 1992 AND W.K. DICKSON & ASSOC., JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE 5-4
RAA No. 4: IN-WELL
AERATION AND OFF-GAS CARBON ADSORPTION
SITE 1 – FRENCH CREEK LIQUIDS DISPOSAL AREA

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01497DD02Y

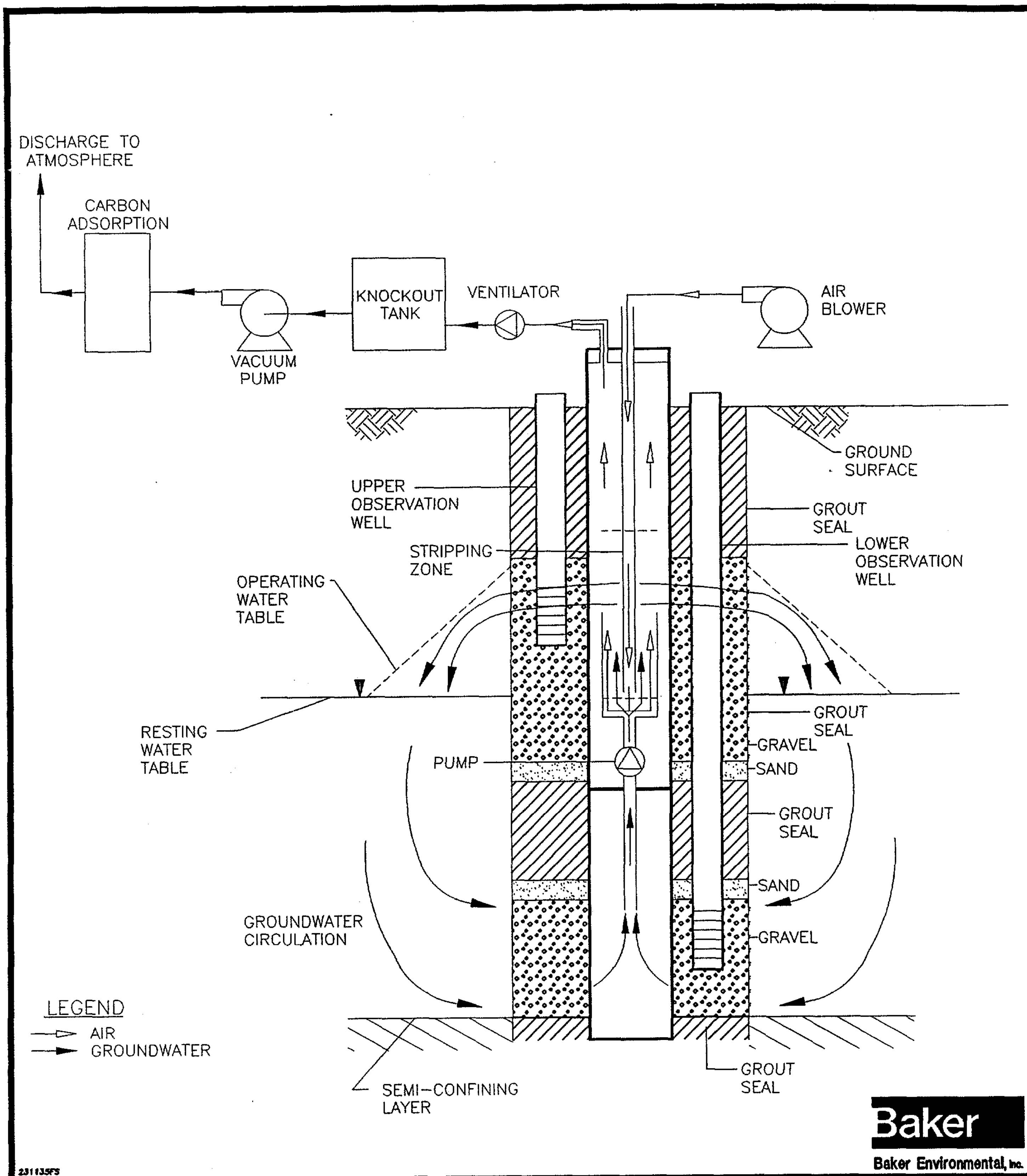

FIGURE 5-5
RAA No. 4: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION –
TYPICAL WELL DETAIL AND PROCESS FLOW DIAGRAM
SITE 1 – FRENCH CREEK LIQUIDS DISPOSAL AREA
FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

6.0 DETAILED ANALYSIS OF REMEDIAL ACTION ALTERNATIVES - SITE 1

This section contains a detailed analysis of the Site 1 RAAs that were developed in Section 5.0. Section 6.1 presents an overview of evaluation criteria that will be used in the detailed analysis. Sections 6.2 and 6.3 present the two parts of the detailed analysis: the individual analyses of remedial action alternatives, and a 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 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 alternatives for Site 1.)

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 DEHNR, USEPA Region IV, and the public.

6.1 Overview of Evaluation Criteria

The following paragraphs describe the nine 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 criterion 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 unrestricted use and 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 (ARARs): 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 of the respective ARARs or that there is a sound rationale for waiving an ARAR. During the detailed analysis, information on federal and state chemical-specific ARARs will be assembled along with previously identified action-specific and location-specific ARARs. Alternatives will be refined to ensure compliance with these requirements.

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 in 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 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, and/or the surrounding environment. This includes potential threats to human health and the environment associated with the excavation, treatment, and transportation of hazardous substances, potential cross-media impacts of the remedy, and the estimated duration of time 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 (e.g., treatment, storage, or disposal capacity) associated with the alternative. Implementability considerations often affect the timing of various remedial alternatives (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. Cost estimates developed for the Site 1 RAAs are presented in Appendix C of Volume I.

As per the USEPA guidance (USEPA, 1988) the accuracy of the cost estimates will be in a range of -30 to +50 percent. The exact accuracy of each cost estimate depends upon the assumptions made and the availability of costing information. The present worth costs were calculated assuming a five percent discount factor and a zero percent inflation rate. All costs presented in the following sections are 1994 dollar values. In addition, it has been assumed that groundwater monitoring will be conducted semiannually 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 final FS, PRAP, and ROD reports, as appropriate.

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, only preliminary assessment of community acceptance can be conducted during the development of the FS, since formal public comment will not be received until after the public comment period for the PRAP is held.

6.2 Individual Analysis of Alternatives

The following subsections present the detailed analysis of groundwater 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 the evaluation criteria. Table 6-1 summarizes the individual, detailed analysis.

6.2.1 RAA No. 1: No Action

Description

Under the no action alternative, groundwater at Site 1 will remain as is. No active remedial actions will be implemented. Passive remediation, however, will occur over time via natural attenuation processes.

Assessment

Overall Protection of Human Health and the Environment: Under RAA No. 1, no remedial actions will be implemented. As a result, there will be no reduction in potential human health or environmental risks except through natural attenuation of the groundwater contaminants.

Compliance With ARARs: Under the no action alternative, no active effort is made to reduce contaminant levels to below the federal and/or state chemical-specific ARARs. Over time, however, natural attenuation is expected to reduce contaminants to below chemical-specific ARARs. No action-specific or location-specific ARARs apply to this no action alternative.

Long-Term Effectiveness and Permanence: Residual risk from untreated contaminants will remain at the site under the no action alternative because humans could potentially come in contact with the contaminated groundwater. However, it is highly unlikely that this scenario will occur because: (1) the surficial aquifer is not used as a potable water source (Harned, et. al., 1989), and (2) the two potable water supply wells located within one mile of Site 1 are no longer in service. Thus, the residual risk associated with leaving contaminants untreated at the site will be minimal. Natural attenuation will mitigate any residual risk, no matter how insignificant, that may exist.

The results of running the Solute Plume 2D-H Model, an analytical model for solute transport in groundwater (see Appendix D of Volume I), indicate that the contaminants detected at Site 1 do not currently impact the nearest receptor, former water supply well HP-638. Also, the contaminants will not impact this receptor in the future because their concentrations will naturally attenuate and decrease over time. Thus, leaving the contaminants untreated at the site will be effective in the long run.

The no action alternative does not include any controls for managing the untreated contaminants that will remain on site. However, because contaminants will remain indefinitely at the site, RAA No. 1 will require 5-year reviews to ensure that adequate protection of human health and the environment is maintained. However, 5-year reviews alone may not be sufficient for monitoring the effectiveness of this no action alternative.

Reduction of Toxicity, Mobility, or Volume Through Treatment: The no action alternative does not provide an active means for toxicity, mobility, or volume reduction of the groundwater contaminants. However, the majority of the contaminants are expected to be treated by natural attenuation and nearly 100 percent reduction in toxicity, mobility, and volume of contaminants is expected. The natural attenuation processes are expected to have irreversible effects provided no further contaminant spills occur at the site.

Since no active treatment is associated with RAA No. 1, the alternative does not satisfy the statutory preference for treatment. Also, there will be no treatment residuals.

Short-Term Effectiveness: There are no remedial action activities associated with RAA No. 1. Therefore, implementation of this RAA will not increase risks to the community. Implementation also will not pose any risks to workers, nor will it create 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 technically implementable since it does not involve construction or operation activities. This alternative also does not include a monitoring plan so there is no way of determining the alternative's effectiveness. If increases in contaminant levels are not detected, ingestion of contaminated groundwater could possibly occur in the future.

In terms of administrative feasibility, RAA No. 1 should not require additional coordination with other agencies. In addition, the availability of services, materials, and/or technologies is not applicable to this alternative.

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

6.2.2 RAA No. 2: Institutional Controls

<u>Description</u>

RAA No. 2 differs from the no action alternative by including the following institutional controls: continued groundwater monitoring, aquifer-use restrictions, and deed restrictions. Under the proposed monitoring plan, eight wells will be analyzed for VOCs (see Figure 5-2). Additional wells may be added to this monitoring plan, if necessary. Although RAA No. 2 does not provide for active remediation, the groundwater may experience passive remediation via natural attenuation processes.

<u>Assessment</u>

Overall Protection of Human Health and the Environment: Under RAA No. 2, institutional controls and natural attenuation will reduce potential human health and environmental risks associated with exposure to groundwater.

Compliance With ARARs: Under RAA No. 2, no active effort is made to reduce contaminant levels to below the federal and/or state chemical-specific ARARs. Over time, however, natural attenuation is expected to reduce contaminants to below chemical-specific ARARs. No action-specific or location-specific ARARs apply to this alternative.

Long-Term Effectiveness and Permanence: The magnitude of residual risk associated with untreated contaminants left at the site will be minimal because the surficial aquifer is not used as a potable water source and the two supply wells located near the site are not in use. Nevertheless, RAA No. 2 will further reduce residual risk for the following reasons: (1) the aquifer-use restrictions will restrict groundwater from being used as a potable water source in the future, (2) the deed restrictions will limit future use of land at Site 1 (including placement of wells), (3) the monitoring plan will detect any improvement or deterioration in groundwater quality, and (4) natural attenuation processes will reduce contaminant levels.

The results of running the Solute Plume 2D-H Model, an analytical model for solute transport in groundwater (see Appendix D of Volume I), indicate that the contaminants detected at Site 1 do not currently impact the nearest receptor, former water supply well HP-638. Also, the contaminants will not impact this receptor in the future because their concentrations will naturally attenuate and decrease over time. Thus, leaving contaminants untreated in the groundwater will be effective in the long run.

RAA No. 2 is based on adequate and reliable institutional controls that will help to manage the untreated contaminants remaining in the aquifer. For example, the proposed monitoring plan will be an adequate and reliable control for assessing the effectiveness of the remedial action alternative. Similarly, aquifer-use and deed restrictions will be adequate and reliable controls for preventing human exposure to the groundwater.

Because RAA No. 2 is not designed to be a complete removal action, it 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 No. 2 does not provide an active treatment process for toxicity, mobility, or volume reduction of the groundwater contaminants. However, the majority of the contaminants are expected to be treated by natural attenuation and nearly 100 percent reduction in contaminant toxicity, mobility, and volume is expected. The natural attenuation processes are expected to have irreversible effects provided that no further contaminant spills occur at the site.

Since no active treatment is associated with RAA No. 1, the alternative does not satisfy the statutory preference for treatment. Also, there will be no treatment residuals.

Short-Term Effectiveness: Implementation of the institutional controls associated with RAA No. 2 will not increase risk to the community. In addition, implementation will not pose any significant risk to workers other than the risks associated with groundwater sampling. Implementation also will not create any significant environmental impacts. The amount of time for the action to be complete (i.e., the time required for natural attenuation to remediate the aquifer) is unknown. For costing purposes, 30 years of continued groundwater monitoring has been assumed.

Implementability: RAA No. 2 is technically implementable since groundwater sampling and ordinance procurement have been easily implemented in the past. In addition, the effectiveness of this RAA can be adequately monitored since the RAA includes a monitoring plan. If the groundwater quality appears to be deteriorating, additional remedial actions could easily be implemented along with RAA No. 2.

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. In addition, all required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA No. 2 is $0. O&M costs of approximately $40,000 annually are projected for sampling semiannually for 30 years. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $600,000.

6.2.3 RAA No. 3: Extraction and On-Site Treatment

<u>Description</u>

RAA No. 3 includes the installation of three extraction wells that will intercept the contaminated plume. Once the groundwater is extracted, it will undergo VOC treatment at an on-site treatment plant. Finally, treated groundwater will be discharged to Cogdels Creek which eventually flows into the New River. RAA No. 3 also includes the same institutional controls that are associated with RAA No. 2: continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

<u>Assessment</u>

Overall Protection of Human Health and the Environment: Because RAA No. 3 provides institutional controls and active groundwater remediation, this RAA will reduce potential risks to human health and the environment.

Compliance With ARARs: Under RAA No. 3, the groundwater quality in the aquifer will be improved at the initiation of the extraction/treatment system. Over time, the contaminated plume is expected to meet federal and/or state chemical-specific ARARs. In addition, RAA No. 3 can be designed to meet all of the location-specific and action-specific ARARs that are defined in Section 3.0.

Long-Term Effectiveness and Permanence: Although the magnitude of residual risk is minimal, RAA No. 3 will further reduce risk for the following reasons: (1) the aquifer-use restrictions will restrict groundwater from being used as a potable water source, (2) the deed restrictions will limit future use of land at Site 1, (3) the monitoring plan will detect any improvement or deterioration in groundwater quality, and (4) the extraction/treatment system will restore the aquifer so that contaminants meet their RLs.

Groundwater extraction/treatment systems are both adequate and reliable controls to some extent. The system will restore the groundwater constituents to acceptable limits, but it may take a long time (possibly up to 30 years). Also, the extraction/treatment system may not be able to collect contaminants that escape into subsurface pore spaces and fissures or sorb to solid materials. In addition, the impact that inorganics may have on the overall operation of the treatment system cannot accurately be predicted at this time. There is a potential for equipment replacement and repair.

The proposed monitoring plan and periodic O&M system checks will be adequate and reliable controls for determining the effectiveness of RAA No. 3. Aquifer-use and deed restrictions will be adequate and reliable controls for preventing future human exposure to the groundwater.

Until remediation levels are met, RAA No. 3 will require 5-year reviews.

Reduction of Toxicity, Mobility, or Volume Through Treatment: Since RAA No. 3 involves active remediation, the alternative will result in toxicity, mobility, and volume reduction of contaminants. The groundwater will be treated via a low profile air stripper. Thus, RAA No. 3 satisfies the statutory preference for treatment.

Eventually, the majority of the contaminants are expected to be treated by the extraction/treatment system. Also, the treatment process should be irreversible provided no further contaminant spills occur at the site.

Treatment residuals will include sludge, off-gases from the air stripper, and treated groundwater. The sludge should be non-hazardous, the off-gases will be within acceptable air discharge limits, and the treated groundwater will be within acceptable groundwater discharge limits.

Short-Term Effectiveness: Dust production during the underground piping and extraction well installation may cause some risk to the community and workers. In addition, workers will be required to wear protection during the installation and operation of the extraction/treatment system. Continued groundwater sampling will also cause some minor risks to workers. In terms of environmental impacts, RAA No. 3 may cause aquifer drawdown during groundwater extraction, but no other environmental impacts are anticipated.

With respect to the time required to complete the remedial action, the groundwater extraction/treatment system will be operated for many years prior to achieving complete groundwater restoration. The exact amount of time is unknown. For costing purposes, 30 years of system operation have been assumed based on past experience with pump and treat systems and case studies.

Implementability: RAA No. 3 is a technically implementable alternative. Similar pump and treat systems have proven to be implementable at other MCB, Camp Lejeune sites, and all technologies/process options are conventional and well-demonstrated to be reliable. However, the infrastructure within a developed area like Site 1 does pose some minor construction challenges.

Also, high dissolved metals may precipitate out of solution and clog the well screens. This would require frequent maintenance and equipment replacement making system O&M more difficult.

Under RAA No. 3, the groundwater monitoring plan and periodic O&M system checks will monitor the effectiveness of the alternative. The monitoring plan will indicate if the groundwater quality is significantly improving or deteriorating. If it is deteriorating, additional remedial actions could easily be implemented along with the extraction/treatment system.

In terms of administrative feasibility, RAA No. 3 requires extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of air and water discharge permits must be met. However, all required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA No. 3 is approximately $990,000. O&M costs of approximately $70,000 are projected for treatment plant O&M and groundwater monitoring for 30 years. Assuming an annual percentage rate of 5 percent the NPW of this alternative is $2,100,000.

6.2.4 RAA No.4: In-Well Aeration and Off-Gas Carbon Adsorption

Description

RAA No. 4 involves the installation of four in-well aeration wells along the lengthwise extent of the contaminated plume. VOCs collected by the in-well aeration system will be treated by carbon adsorption near the top of each well and subsequently discharged to the atmosphere. A field pilot test is recommended to determine the loss of efficiency over time as a result of inorganics precipitation and oxidation, the radius of influence of the wells under various heads of injection air pressure, and the rate of off-gas organic contaminant removal via carbon adsorption and carbon breakthrough. RAA No. 4 also includes the same institutional controls as RAA Nos. 2 and 3 (continued groundwater monitoring, aquifer-use restrictions, and deed restrictions).

Assessment

Overall Protection of Human Health and the Environment: Because RAA No. 4 provides active groundwater remediation, continued groundwater monitoring, and restrictions on future aquifer and land use, this RAA will reduce potential risks to human health and the environment.

Compliance With ARARs: Under RAA No. 4, the groundwater quality will be improved at the initiation of the in-well aeration system. Over time, the plume is expected to meet federal and/or state chemical-specific ARARs. In addition, RAA No. 4 can be designed to meet all of the location-specific and action-specific ARARs that are defined in section 3.0.

Long-Term Effectiveness and Permanence: RAA No. 4 will reduce the magnitude of residual risks for the following reasons: (1) the aquifer-use restrictions will restrict groundwater from being used as a potable water source, (2) the deed restrictions will limit future use of land at Site 1, (3) the monitoring plan will detect any improvement or deterioration in groundwater quality, and (4) the in-well aeration system will restore the aquifer to acceptable levels.

In-well aeration will be an adequate and reliable control because it can restore the aquifer within an acceptable amount of time, usually less than one year. Equipment repair or replacement may be necessary, but it is less likely given the short duration of system operation.

Under RAA No. 4, the proposed monitoring plan and periodic O&M system checks will be adequate and reliable controls for determining the effectiveness of the alternative. Aquifer-use and deed restrictions will be adequate and reliable controls for preventing future human exposure to the groundwater.

Until remediation levels are met, RAA No. 4 will require 5-year reviews.

***Reduction of Toxicity, Mobility, or Volume Through Treatment*:** Since RAA No. 4 involves active remediation, the alternative is expected to result in nearly 100 percent toxicity, mobility, and volume reduction of the site contaminants. The groundwater will be treated via in-well air stripping and off-gas carbon adsorption. Thus, RAA No. 4 satisfies the statutory preference for treatment. The in-well aeration system is expected to treat the majority of the groundwater contamination. However, none of the contaminants will be destroyed. The treatment process should be irreversible provided no further contaminant spills occur at the site.

Treatment residuals will include the small amount of liquid left in the knockout tank (most likely less than 5 gallons) and spent carbon. The liquid be non-hazardous, but the spent carbon will contain adsorbed contaminants.

***Short-Term Effectiveness*:** Dust production during the aeration well installation may cause some risk to the community and workers. In addition, workers will be required to wear protection during the installation and operation of the system and groundwater sampling. However, the system will create no additional environmental impacts.

The exact time for the in-well aeration system to meet the remedial action objectives is unknown. For costing purposes, 3 years of operation have been assumed (based on case studies) with 30 years of groundwater monitoring.

***Implementability*:** Although in-well aeration has been applied full-scale, it is still a relatively new technology. As such, a field pilot-scale study is required to identify critical design parameters. Regardless, RAA No. 4 appears to be technically implementable at Site 1. An important advantage of this system is 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. In addition, the infrastructure within a developed area like Site 1 may pose some construction difficulties.

Under RAA No. 4, the groundwater monitoring plan and periodic O&M system checks will monitor the effectiveness of the alternative. The monitoring plan will indicate if the groundwater quality is significantly improving or deteriorating. If it is deteriorating, additional remedial actions could easily be implemented along with the in-well aeration system.

In terms of administrative feasibility, RAA No. 4 will require extensive coordination with the Base Public Works/Planning Department. Also, the substantive requirements of air and water discharge permits must be met. Although the patented technology is exclusively licensed to a single vendor, the required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA No. 4 is approximately $640,000. Annual O&M costs of approximately $40,000 are projected for 30 years of groundwater monitoring. Annual O&M costs of approximately $20,000 are projected for 3 years of system operation. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $1,300,000.

6.2.5 RAA No. 5: Extraction and Off-Site Treatment

Description

RAA No. 5 includes the installation of three extraction wells that will intercept the contaminated plume. Once the groundwater is extracted, it will be transported by tanker truck for off-site treatment to the HPIA Treatment System located within the HPIA Operable Unit at MCB, Camp Lejeune. Thus, there is no on-site treatment associated with this RAA. RAA No. 5 also includes the same institutional controls that are associated with RAA Nos. 2, 3, and 4: continued groundwater monitoring, aquifer-use restrictions, and deed restrictions.

Assessment

Overall Protection of Human Health and the Environment: Because RAA No. 5 provides institutional controls and active groundwater remediation, this RAA will reduce potential risks to human health and the environment.

Compliance With ARARs: Under RAA No. 5, the groundwater quality in the aquifer will be improved at the initiation of the extraction/off-site treatment system. Over time, the plume is expected to meet federal and/or state chemical-specific ARARs. In addition, RAA No. 5 can be designed to meet all of the location-specific and action-specific ARARs that are defined in section 3.0.

Long-Term Effectiveness and Permanence: Although the magnitude of residual risk is minimal, RAA No. 5 will further reduce risk for the following reasons: (1) the aquifer-use restrictions will restrict groundwater from being used as a potable water source, (2) the deed restrictions will limit future use of land at Site 1, (3) the monitoring plan will detect any improvement or deterioration in groundwater quality, and (4) the extraction/treatment system will restore the aquifer so that RLs are met.

Groundwater extraction/treatment systems are both adequate and reliable controls to some extent. The system will restore the groundwater constituents to acceptable limits, but it may take a long time (possibly up to 30 years). Also, extraction/treatment systems may not be able to collect contaminants that escape into subsurface pore spaces and fissures or sorb to solid materials. In addition, the impact that inorganics may have on the overall operation of the treatment system cannot accurately be predicted at this time. There is a potential for equipment replacement and/or repairs.

The monitoring plan and periodic O&M system checks will be adequate and reliable controls for determining the effectiveness of RAA No. 5. Aquifer-use and deed restrictions will be adequate and reliable controls for preventing future human exposure to the groundwater.

Until remediation levels are met, RAA No. 5 will require the USEPA's 5-year review.

Reduction of Toxicity, Mobility, or Volume Through Treatment: Since RAA No. 5 involves active remediation, the alternative is expected to result in nearly 100 percent toxicity, mobility, and volume reduction. The groundwater will be treated via air stripping and carbon adsorption at the HPIA treatment system. Thus, RAA No. 5 satisfies the statutory preference for treatment.

Eventually, the majority of the contamination is expected to be treated by extraction and off-site treatment. However, none of the contaminants will be destroyed. The treatment process is expected to have irreversible effects provided no further contaminant spills occur at the site.

Treatment residuals will include sludge, off-gases from the air stripper, spent carbon, and treated groundwater. The sludge should be non-hazardous, the off-gases will be within acceptable air discharge limits, and the treated groundwater will be within acceptable groundwater discharge limits.

Short-Term Effectiveness: Dust production during the underground piping and extraction well installation may cause some risk to the community and workers. In addition, workers will be required to wear protection during the installation and operation of the extraction/off-site treatment system and during groundwater sampling. In terms of environmental impacts, RAA No. 5 may cause aquifer drawdown during groundwater extraction.

With respect to the time required to complete the remedial action, the groundwater extraction/off-site treatment system will be operated for many years prior to achieving complete groundwater restoration. The exact amount of time is unknown. For costing purposes, it was assumed that the plume would be remediated after five pore volumes are removed. At 15 gpm, this would take three years. Thus, trucking of the groundwater was assumed to last 3 years, and continued groundwater monitoring was assumed to last 30 years.

Implementability: RAA No. 5 is a technically implementable alternative. Similar extraction/treatment systems have proven to be implementable at other MCB, Camp Lejeune sites, and all technologies/process options are conventional and well-demonstrated to be reliable. However, the infrastructure within a developed area like Site 1 does pose some minor construction challenges. Also, high dissolved metals may precipitate out of solution and clog well screens. This would require frequent maintenance and equipment replacement. In addition, transporting the groundwater by tanker truck may become impractical if the system operates for more than three years.

Under RAA No. 5, the groundwater monitoring plan and periodic O&M system checks will monitor the effectiveness of the alternative. The monitoring plan will indicate if the groundwater quality is significantly improving or deteriorating. If it is deteriorating, additional remedial actions could easily be implemented along with the extraction/off-site treatment system.

In terms of administrative feasibility, RAA No. 5 requires extensive coordination with the Base public works/planning department. Also, there are substantive requirements of air and water discharge permits that must be met. However, all required services, materials, and/or technologies should be readily available.

Cost: The estimated capital cost associated with RAA No. 5 is approximately $480,000. Annual O&M costs of $40,000 are projected for 30 years of groundwater monitoring, and annual O&M costs of $130,000 are project for 3 years of groundwater transport and treatment. Assuming an annual percentage rate of 5 percent, the NPW of this alternative is $1,400,000.

6.3 Comparative Analysis

This section presents a comparative analysis of the groundwater RAAs. The purpose of the comparative analysis is to identify the relative advantages and disadvantages of each RAA with respect to the evaluation criteria.

6.3.1 Overall Protection of Human Health and the Environment

RAA No. 1, the no action alternative, does not reduce potential risks to human health and the environment except through natural attenuation of the groundwater. On the other hand, RAA Nos. 2, 3, 4, and 5 all provide some means, other than natural attenuation, for reducing potential risks. RAA Nos. 2, 3, 4, and 5 involve institutional controls which will reduce risks. In addition, RAA Nos. 3, 4, and 5 involve active remediation systems (groundwater extraction/on-site treatment, in-well aeration, and groundwater extraction/off-site treatment) which provide additional protection to human health and the environment. However, the additional protection that RAA Nos. 3, 4, and 5 provide through active remediation systems may not be necessary considering the minimal risks associated with the groundwater contaminants.

If the contaminated plume is left alone to passively remediate, the residual risk that remains will be minimal for the following reasons:

- As a COC, TCE was detected at low concentrations, 8 µg/L at well 1-GW10 and 27 µg/L at well 1-GW17, that only slightly exceed the RL of 5 µg/L. These low groundwater concentrations, in addition to non-detectable levels in the soil, indicate that there is no significant source of TCE at the site. Instead, the TCE is most likely the result of random, isolated spills.

- Based on the analytical model for solute transport in groundwater (Appendix D), TCE at Site 1 does not currently impact the nearest receptor, the former water supply well HP-638.

- Vinyl chloride was detected at a low concentration, 4J µg/L at well 1-GW10, which only slightly exceeds the NCWQS of 0.015 µg/L and the Federal MCL of 2 µg/L. Based on this low concentration, and the fact that vinyl chloride was detected at only one well, it does not appear that there is a significant source of vinyl chloride at the site.

Considering the minimal risks associated with the contaminated groundwater, institutional controls (RAA No. 2) will be adequate for protecting human health and the environment. Groundwater extraction and treatment (RAA Nos. 3 and 5) and in-well aeration (RAA No. 4) will be unnecessary to provide adequate protection. No action, however, provides no protection. Therefore RAA No. 1 may be inferior to the other four alternatives, and RAA Nos. 3, 4, and 5 may overcompensate for the minor risks that exist at the site.

6.3.2 Compliance with ARARs

Under all five RAAs, groundwater contaminants are expected to eventually meet federal and state chemical-specific ARARs. Under RAA Nos. 1 and 2, contaminants will meet ARARs via passive remediation (or natural attenuation). Under RAA Nos. 3, 4, and 5, contaminants will meet ARARs via active remediation (extraction/treatment or in-well aeration).

RAA Nos. 3, 4, and 5 can be designed to meet all of the location- and action-specific ARARs that apply to them. No location- or action-specific ARARs apply to RAA Nos. 1 and 2.

6.3.3 Long-Term Effectiveness and Permanence

Because all five RAAs involve some form of remediation, whether it is active or passive, they will all be effective at decreasing contaminant levels in the long run. In addition, the results of all RAAs will be permanent.

Although residual risks associated with untreated contaminants will be minimal (see Section 6.3.1), RAA No. 1 is the only alternative that will allow residual risk to remain uncontrolled at the site. RAA Nos. 2, 3, 4, and 5 involve continued groundwater monitoring, aquifer-use restrictions, and deed restrictions, which are all adequate and reliable controls; RAA No. 1 involves no controls. As a result, RAA Nos. 2, 3, 4, and 5 can mitigate the potential for human health exposure through the use of institutional controls, but RAA No. 1 cannot. Also, the effectiveness of RAA Nos. 2, 3, 4, and 5 can be determined more often than the effectiveness of RAA No. 1 can be determined.

Under all five RAAs, untreated contaminants will remain at the site indefinitely. As a result, all five RAAs require 5-year reviews to ensure that adequate protection of human health and the environment is maintained. Under RAA Nos. 3, 4, and 5, however, this review will not be necessary once the remediation levels are achieved.

6.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

RAA Nos. 1 and 2 do not involve active treatment processes so these alternatives will only reduce toxicity, mobility, or volume of the contaminants via passive remediation. RAA Nos. 3, 4, and 5, however, involve extraction/treatment and in-well aeration so they will reduce the toxicity, mobility, and volume of contaminants via active remediation. (RAA Nos. 3, 4, and 5 satisfy the statutory preference for treatment.) Under all five RAAs, however, the majority of the groundwater contaminants are expected to eventually be treated.

There are no treatment residuals associated with RAA Nos. 1 and 2. Under RAA Nos. 3, 4, and 5, however, active treatment processes will create residuals like metals sludge, spent carbon, and contaminated condensed vapor. These additional residuals will require proper disposal.

6.3.5 Short-Term Effectiveness

All five RAAs will reduce contaminant levels. However, RAA Nos. 3, 4, and 5 will create the most risk during implementation. Risks to the community and workers will be increased during extraction well, aeration well, piping, and treatment plant installation and operation. RAA No. 2 creates some minor risks associated with groundwater sampling, but these are insignificant compared to the risks associated with RAA Nos. 3, 4, and 5. Implementation of RAA No. 1 will create no risks.

The time in which RAA Nos. 3 and 5 will achieve the remedial action objectives (approximately 30 years) is relatively large compared to RAA No. 4 (approximately 3 years). However, all RAAs, with the exception of the no action alternative, involve continued groundwater monitoring for 30 years. The amount of time required for natural attenuation to restore the aquifer (i.e., RAA Nos. 1 and 2) is unknown.

6.3.6 Implementability

RAA No. 1 is the most implementable, if not the most effective, alternative. RAA Nos. 2, 3, and 5 use conventional, well-demonstrated, and commercially available technologies so these RAAs are proven to be implementable and reliable. RAA No. 4 (in-well aeration), however, involves an emerging technology that does not have an extensive commercial track record. A field pilot test is necessary to determine this alternative's implementability. Regardless, RAA Nos. 3, 4, and 5 create more risk than RAA No. 2 during implementation.

Despite its high level of implementability, RAA No. 1 does not include adequate monitoring to determine its effectiveness. As a result, failure to detect increases in contaminant levels could result in potential ingestion of groundwater. RAA Nos. 2, 3, 4, and 5 do involve monitoring plans so there will be notice of contaminant increases before significant exposure occurs.

6.3.7 Cost

In terms of NPW, the No Action Alternative (RAA No. 1) would be the least expensive RAA to implement, followed by RAA No. 2, RAA No. 4, RAA No. 5, and then RAA No. 3. The estimated NPW values in increasing order are $0 (RAA No. 1), $600,000 (RAA No. 2), $1,300,000 (RAA No. 4), $1,400,000 (RAA No. 5), and $2,100,000 (RAA No. 3).

SECTION 6.0 TABLES

TABLE 6-1

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
OVERALL PROTECTIVENESS • Human Health	No reduction in potential human health risks, except through natural attenuation of the contaminated groundwater.	Institutional controls and natural attenuation will reduce potential human health risks.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential human health risks.	Institutional controls, natural attenuation, and in-well aeration will reduce potential human health risks.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential human health risks.
• Environmental Protection	No reduction in potential risks to ecological receptors, except through natural attenuation of the contaminated groundwater.	Institutional controls and natural attenuation will reduce potential risks to ecological receptors.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential risks to ecological receptors.	Institutional controls, natural attenuation, and in-well aeration will reduce potential risks to ecological receptors.	Institutional controls, natural attenuation, and the groundwater extraction/ treatment system will reduce potential risks to ecological receptors.
COMPLIANCE WITH ARARS • Chemical-Specific ARARs	No active effort made to reduce contaminant levels to below federal or state ARARs. However, contaminants are expected to meet ARARs via natural attenuation processes.	No active effort made to reduce contaminant levels to below federal or state ARARs. However, contaminants are expected to meet ARARs via natural attenuation processes.	Contaminants within the wells' radii of influence are expected to meet chemical-specific ARARs.	Contaminants within the wells' radii of influence are expected to meet chemical-specific ARARs.	Contaminants within the wells' radii of influence are expected to meet chemical-specific ARARs.
• Location-Specific ARARs	Not applicable.	Not applicable.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.	Can be designed to meet location-specific ARARs.
• Action-Specific ARARs	Not applicable.	Not applicable.	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 6-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
LONG-TERM EFFECTIVENESS AND PERMANENCE • Magnitude of Residual Risk	The residual risk from untreated contaminants will be minimal; natural attenuation will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and natural attenuation will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and the extraction/ treatment system will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and in-well aeration will mitigate any residual risk that may exist.	The residual risk from untreated contaminants will be minimal; institutional controls and the extraction/ treatment system will mitigate any residual risk that may exist.
• Adequacy and Reliability of Controls	No controls	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure.	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure until remediation levels are met.	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure until remediation levels are met.	The proposed monitoring plan is adequate and reliable for determining the alternative's effectiveness; aquifer-use and deed restrictions are adequate and reliable for preventing human health exposure until remediation levels are met.
• Need for 5-year Review	Review will be required to ensure adequate protection of human health and the environment.	Review will be required to ensure adequate protection of human health and the environment.	Until remediation levels are met, review will be required to ensure adequate protection of human health and the environment.	Until remediation levels are met, review will be required to ensure adequate protection of human health and the environment.	Until remediation levels are met, review will be required to ensure adequate protection of human health and the environment.
REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT • Treatment Process Used	No active treatment process applied.	No active treatment process applied.	The treatment process includes air stripping for VOC removal and neutralization, precipitation, flocculation, sedimentation, and filtration as pretreatment for the air stripper.	The treatment process includes in-well air stripping and off-gas carbon adsorption for VOC removal.	The treatment processes, include air stripping and carbon adsorption for VOC removal; also, flocculation and sedimentation for metals removal.

TABLE 6-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
• Amount Destroyed or Treated	Eventually, the majority of the contaminants are expected to be treated by natural attenuation.	Eventually, the majority of the contaminants are expected to be treated by natural attenuation.	Eventually, the majority of the contaminants are expected to be treated by the extraction/treatment system.	The majority of the contaminants are expected to be treated by the in-well aeration system.	Eventually, the majority of the contaminants are expected to be treated by the extraction/treatment system.
• Reduction of Toxicity, Mobility, or Volume Through Treatment	No COC reduction except by natural attenuation.	No COC reduction except by natural attenuation.	Nearly 100% reduction in toxicity, mobility, and volume is expected.	Nearly 100% reduction in contaminant toxicity, mobility, and volume is expected.	Nearly 100% reduction in contaminant toxicity, mobility, and volume is expected.
• Residuals Remaining After Treatment	No active treatment process applied.	No active treatment process applied.	Treatment residuals will include sludge, off-gases from the air stripper, and treated groundwater. The sludge should be non-hazardous, the off-gases will be within acceptable air discharge limits, and the treated groundwater will be within acceptable groundwater discharge limits.	Treatment residuals will include the small amount of liquid left in the knockout tank (most likely less than 5 gallons) and spent carbon. The liquid should be non-hazardous, but the spent carbon will contain adsorbed contaminants.	Treatment residuals will include spent carbon, sludge, off-gases from the air stripper, and treated groundwater. The sludge should be non-hazardous, the off-gases will be within acceptable air discharge limits, and the treated groundwater will be within acceptable groundwater discharge limits.
• Statutory Preference for Treatment	Not satisfied.	Not satisfied.	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.	Potential risks to the community will be increased during system installation and operation.	Potential risks to the community will be increased during system installation and operation.	Potential risks to the community will be increased during system installation and operation.
• Worker Protection	No risks to workers.	No significant risks to workers.	Potential risks to workers will be increased; worker protection is required.	Potential risks to workers will be increased; worker protection is required.	Potential risks to workers will be increased; worker protection is required.

TABLE 6-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
• Environmental Impact	No additional environmental impacts.	No additional environmental impacts.	No additional environmental impacts if aquifer drawdown does not affect surrounding water bodies.	No additional environmental impacts.	No additional environmental impacts if aquifer drawdown does not affect surrounding water bodies.
• Time Until Action is Complete	Unknown.	Thirty years was used to estimate NPW costs. The exact time for completion of remediation is unknown.	Thirty years was used to estimate NPW costs. The exact time for completion of remediation is unknown.	Three years was used to estimate in-well aeration costs; 30 years was used to estimate monitoring costs. The exact time for completion of remediation is unknown.	Three years was used to estimate trucking costs; 30 years was used to estimate monitoring costs. The exact time for completion of remediation is unknown.
IMPLEMENTABILITY • Ability to Construct and Operate	No construction or operation activities.	No construction or operation activities; institutional controls have been easily implemented in the past.	The infrastructure within a developed area like Site 1 poses some minor construction problems. O&M may be difficult because groundwater must be lifted above ground surface for treatment, and metals precipitation could clog well screens.	The technology has been commercially applied, but it is still relatively new. The infrastructure within a developed area like Site 1 poses some minor construction problems. also, metals precipitation could clog well screens.	The infrastructure within a developed area like Site 1 poses some minor construction problems. Also, metals precipitation could clog well screens.
• Ability to Monitor Effectiveness	No proposed monitoring plan; failure to detect contamination could result in potential ingestion of groundwater.	Proposed monitoring plan will detect contaminants before significant exposure can occur.	Proposed monitoring plan will detect contaminants before significant exposure can occur; O&M checks will provide notice of a system failure.	Proposed monitoring plan will detect contaminants before significant exposure can occur; O&M checks will provide notice of a system failure.	Proposed monitoring plan will detect contaminants before significant exposure can occur; O&M checks will provide notice of a system failure.
• Availability of Services and Capacities; Equipment	No services or equipment required.	No special services or equipment required.	Services and equipment are readily available.	The patented technology is exclusively licensed to a single vendor.	Services and equipment are readily available.

TABLE 6-1 (Continued)

SUMMARY OF DETAILED ANALYSIS
FEASIBILITY STUDY, CTO-0231
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NORTH CAROLINA

Evaluation Criteria	RAA No. 1 No Action	RAA No. 2 Institutional Controls	RAA No. 3 Extraction and On-Site Treatment	RAA No. 4 In-Well Aeration and Off-Gas Carbon Adsorption	RAA No. 5 Extraction and Off-Site Treatment
• Requirements for Agency Coordination	None required.	Must submit semiannual reports to document sampling.	The substantive requirements of air and water discharge permits must be met.	The substantive requirements of air and water discharge permits must be met.	Air and water discharge permits may be required if existing permits are not adequate for the additional groundwater load.
COST (Net Present Worth)	$0	$600,000	$2,100,000	$1,300,000	$1,400,000

APPENDIX A - RISK-BASED ACTION LEVEL CALCULATIONS - SITE 1

INGESTION OF GROUNDWATER ACTION LEVEL, revised 5/31/95
FEASABILITY STUDY
CTO-0231, SITE 1
MCB CAMP LEJEUNE
FUTURE ADULT RESIDENT

C = TR or THI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD

Where:	INPUTS
C = contaminant concentration in water ((ug/L)	
TR = total lifetime risk	1E-04
THI = total hazard index	1
CSF = carcinogenic slope factor	specific
RfD = reference dose	specific
IRw = daily water ingestion rate (L/Day)	2
EF = exposure frequency (days/yr)	350
ED = exposure duration (yr)	30
BW = 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

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/l)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/yr)	Slope Factor (mg/kg-day)-1	Target Excess Risk
Trichloroethene	774	2	350	30	70	70	365	1.10E-02	1.0E-04
1,2-Dichloroethene	0	2	350	30	70	70	365		1.0E-04
Arsenic	5	2	350	30	70	70	365	1.75E+00	1.0E-04
Barium	0	2	350	30	70	70	365		1.0E-04
Manganese	0	2	350	30	70	70	365		1.0E-04
Mercury	0	2	350	30	70	70	365		1.0E-04

Contaminant	Concentration Noncarcinogen (ug/L)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/yr)	Reference Dose (mg/kg-day)	Target Hazard Index
Trichloroethene	219	2	350	30	70	30	365	6.00E-03	1
1,2-Dichloroethene	328	2	350	30	70	30	365	9.00E-03	1
Arsenic	11	2	350	30	70	30	365	3.00E-04	1
Barium	2555	2	350	30	70	30	365	7.00E-02	1
Manganese	183	2	350	30	70	30	365	5.00E-03	1
Mercury	11	2	350	30	70	30	365	3.00E-04	1

File Name: 1GWIAR.WQ1

INGESTION OF GROUNDWATER ACTION LEVEL, revised 5/31/95
FEASABILITY STUDY
CTO-0231, Site 1
MCB CAMP LEJEUNE
FUTURE CHILD RESIDENT

C = TR or THI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD

Where:	INPUTS
C = contaminant concentration in water ((ug/L)	
TR = total lifetime risk	1E-04
THI = total hazard index	1
CSF = carcinogenic slope factor	specific
RfD = reference dose	specific
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

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/l)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/yr)	Slope Factor (mg/kg-day)-1	Target Excess Risk
Trichloroethene	1659	1	350	6	15	70	365	1.10E-02	1.0E-04
1,2-Dichloroethene	0	1	350	6	15	70	365		1.0E-04
Arsenic	10	1	350	6	15	70	365	1.75E+00	1.0E-04
Barium	0	1	350	6	15	70	365		1.0E-04
Manganese	0	1	350	6	15	70	365		1.0E-04
Mercury	0	1	350	6	15	70	365		1.0E-04

Contaminant	Concentration Noncarcinogen (ug/L)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/yr)	Reference Dose (mg/kg-day)	Target Hazard Index
Trichloroethene	94	1	350	6	15	6	365	6.00E-03	1
1,2-Dichloroethene (total)	141	1	350	6	15	6	365	9.00E-03	1
Arsenic	5	1	350	6	15	6	365	3.00E-04	1
Barium	1095	1	350	6	15	6	365	7.00E-02	1
Manganese	78	1	350	6	15	6	365	5.00E-03	1
Mercury	5	1	350	6	15	6	365	3.00E-04	1

INGESTION OF GROUNDWATER ACTION LEVEL, revised 5/31/95
FEASABILITY STUDY
CTO-0231, SITE 1
MCB CAMP LEJEUNE
MILITARY PESONNEL

C = TR or THI * BW * ATc or ATnc * DY / IRw * EF * ED * CSF or 1/RfD

Where:	INPUTS
C = contaminant concentration in water ((ug/L)	
TR = total lifetime risk	1E-04
THI = total hazard index	1
CSF = carcinogenic slope factor	specific
RfD = reference dose	specific
IRw = daily water ingestion rate (L/Day)	2
EF = exposure frequency (days/yr)	250
ED = exposure duration (yr)	4
BW = body weight (kg)	70
ATc = averaging time for carcinogen (yr)	70
ATnc = averaging time for noncarcinogen (yr)	4
DY = days per year (day/year)	365

Note: Inputs are scenario and site specific

Contaminant	Concentration Carcinogen (ug/l)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Carc Time (years)	Days per year (day/yr)	Slope Factor (mg/kg-day)-1	Target Excess Risk
Trichloroethene	8130	2	250	4	70	70	365	1.10E-02	1.0E-04
1,2-Dichloroethene	0	2	250	4	70	70	365		1.0E-04
Arsenic	51	2	250	4	70	70	365	1.75E+00	1.0E-04
Barium	0	2	250	4	70	70	365		1.0E-04
Manganese	0	2	250	4	70	70	365		1.0E-04
Mercury	0	2	250	4	70	70	365		1.0E-04

Contaminant	Concentration Noncarcinogen (ug/L)	Ingestion Rate (L/day)	Exposure Frequency (day/year)	Exposure Duration (year)	Body Weight (kg)	Average Noncarc Time (years)	Days per year (day/yr)	Reference Dose (mg/kg-day)	Target Hazard Index
Trichloroethene	307	2	250	4	70	4	365	6.00E-03	1
1,2-Dichloroethene	460	2	250	4	70	4	365	9.00E-03	1
Arsenic	15	2	250	4	70	4	365	3.00E-04	1
Barium	3577	2	250	4	70	4	365	7.00E-02	1
Manganese	256	2	250	4	70	4	365	5.00E-03	1
Mercury	15	2	250	4	70	4	365	3.00E-04	1

File Name: 1GWIAR.WQ1

APPENDIX B - RADIUS OF INFLUENCE CALCULATIONS - SITE 1

S.O. No. 62470-231-0000-05700

Subject: CTO 231 OU#7, SITE #1

NCB CAMP LEJEUNE

EXT. WELL RADII OF INFLUENCE - KEELY

Sheet No. 1 of 3

Drawing No.

Computed by KMC Checked By TLB 3-8-95 Date 3/7/95

Baker

CTO 231
OU#7 - Site #1

NO PUMP TEST WAS PERFORMED AT SITE 1 SO DATA FROM THE HPIA PUMP TEST WILL BE ASSUMED TO APPLY TO SITE 1. (HPIA IS LOCATED APPROXIMATELY 1 MILE FROM SITE 1.) BASED ON THE HPIA PUMP TEST, A PUMPING RATE OF 5 GPM WILL BE ASSUMED FOR EACH EXTRACTION WELL AT SITE 1. THE FOLLOWING DATA WILL ALSO BE ASSUMED TO APPLY TO SITE 1:

TRANSMISSIVITY = 4.5×10^2 GPD/FT (BAKER, 1993) } AVERAGE FOR RW-1, P-1 & 24-1 FROM FINAL BASIS OF DESIGN
STORATIVITY (AVG.) = 5.067×10^{-2} (BAKER, 1993)
HYDRAULIC GRADIENT = 0.0027 FT/FT (BAKER, 1995)
POROSITY (%) = 30% (BAKER, 1995)
GW FLOW VELOCITY ≈ 2.9×10^{-2} FT/DAY (BAKER, 1995)
SATURATED AQUIFER THICKNESS = 80 FT. (APPROXIMATE)
ESTIMATED MAX. DEPTH OF CONTAMINATION = 100 FT. (APPROXIMATE)

REFERENCE:

KEELY, JOSEPH F. AND CHIN FU TSANG (1983). VELOCITY PLOTS AND CAPTURE ZONES OF PUMPING CENTERS FOR GROUNDWATER INVESTIGATIONS.

ASSUMPTIONS:

- STEADY & UNIFORM FLOW IN POROUS, CONFINED AQUIFER
- AQUIFER IS HOMOGENEOUS, ISOTROPIC, INFINITE IN AREAL EXTENT
- CONSTANT IN THICKNESS
- AQUIFER CAN SUSTAIN AVERAGE PUMPING RATE OF: Q = 15 GPM = 21,600 GPD FOR EXTENDED PERIOD OF TIME.

S.O. No. 62470-231-0000-05700

Subject: CTO 231 OU#7 SITE #1

MCB CAMP LEJEUNE

EXT. WELL RADII OF INFLUENCE-KEELY

Sheet No. 2 of 3

Drawing No.

Computed by KMC Checked By TLB 3-8-95 Date 3/7/95

Baker

EXTRACTION SYSTEM OBJECTIVES:

1. EXTRACT TCE CONTAMINATED GROUNDWATER
2. CREATE HYDRAULIC BARRIER AND CAPTURE ZONE TO RETARD CONTAMINANT MIGRATION.

SPACING OF EXTRACTION WELLS (KEELY, 1983)

$$r = \frac{Q}{2\pi h n V_n}$$

; WHERE r = DISTANCE TO DOWNGRADIENT STAGNATION POINT (FT)

Q = PUMPING RATE (GPD) = 21,600 GPD

h = EFFECTIVE SATURATED THICKNESS YIELDING WATER TO WELL (FT)

n = POROSITY = 0.30

Vn = AVERAGE LINEAR VELOCITY

S.O. No. 62470-231-0000-05700

Subject: CTO 231 OU#7 SITE #1

MCB CAMP LEJEUNE

EXT. WELL RADII OF INFLUENCE-KEELY

Sheet No. 3 of 3

Drawing No.

Computed by VMC   Checked By TLB 3.8.95   Date 3/7/95

Baker

$$V_n = \frac{Q}{An} = \frac{KI}{n}$$; WHERE I = HYDRAULIC GRADIENT = 0.0027 FT/FT

$K = T/b = 4.5 \times 10^2 / 80 = 5.6$ GPD

b = SATURATION THICKNESS

SUBSTITUTING:

$$V_n = \frac{TI}{bn} \quad \text{AND} \quad r = \frac{Q}{2\pi h n \left(\frac{TI}{bn}\right)}$$

OR ~ $$r = \frac{Qb\cancel{n}}{2\pi h \cancel{n} TI}$$

ASSUMING $h = b$ (ACTUALLY $h \leq b$ ∴ THIS WILL CALCULATE LARGER STAGNATION DISTANCE; SO ASSUMPTION $h = b$ IS CONSERVATIVE.)

$$r = \frac{Q}{2\pi TI} = \frac{21{,}600 \text{ GPD}}{2\pi(4.5\times10^2)(0.0027)}$$

r = 2,829.42 FEET DOWNGRADIENT

KNOWING:

$2\pi r$ = INFLOW ZONE

πr = INFLOW ZONE ON ONE SIDE OF WELL OR RADIUS OF INFLUENCE

$\pi r = \pi(2829.42) = 8{,}889$ FEET = RADIUS OF INFLUENCE

CONCLUSIONS:

BASED ON THE KNOWLEDGE OF THE SITE, THE CONTAMINATION AND PAST EXPERIENCE OF 5 GPM EXTRACTION WELLS; A RADIAL DISTANCE OF 8,889 FEET IS UNREALALISTIC. THEREFORE THE THEIS EQ. WILL BE USED.

S.O. No. 62470-231-0000-05700

Subject: CTO 231 O.U. #7 SITE #1

NCB CAMP LEJEUNE

EXTR. WELL RADII OF INFLUENCE

Sheet No. 1 of 5

Drawing No.

Computed by MDS Checked By KHC Date 3-6-95

Baker

USING PUMP TEST DATA FROM HPIA PUMP TEST AND ASSUMPTIONS FROM FINAL BASIS OF DESIGN REPORT FOR THE HADNOT POINT INDUSTRIAL AREA SHALLOW ACQUIFER GROUNDWATER TREATMENT SYSTEM (BAKER, 1993), THE FOLLOWING RADIUS OF INFLUENCE WAS COMPUTED:

ASSUMPTIONS:

TRANSMISSIVITY (gpd/ft.): $T_{AVG.} = 4.5 \times 10^2$ gpd/ft.

STORATIVITY (AVG.) = 5.067×10^{-2}

AVG. FOR RW-1, P-1 & 24- FROM FINAL BASIS OF DESIGN (BAKER, 199

USING THE THEIS EQUATION:

$$s = \frac{114.6\ Q\ (W(u))}{T}$$

WHERE: s = DRAWDOWN IN FEET

Q = PUMPING RATE IN GPM

T_{AVG} = TRANSMISSIVITY IN GPD/FT.

SOLVING FOR $W(u) = \dfrac{sT}{114.6\ Q}$

KNOW:

s = 0.25 FT. (BOUNDARY CONDITION) (BAKER, 1993)

$T = 4.5 \times 10^2$ GPD/FT.

Q = 3.0 GPM

$$W(u) = \frac{(0.25)(450)}{114.6\ (3.0)}$$

$W(u) = 0.327$

FROM APPENDIX 9.E - GROUNDWATER AND WELLS; 2ND EDITION; DRISCOLL (DRISCOLL, 1989), (SEE ATTACHED).

$$u = 7.72 \times 10^{-1}$$

S.O. No. 62470-231-0000-05700

Subject: CTO 231 O.U. #7 SITE #1

MCB CAMP LEJEUNE

EXTR. WELL RADII OF INFLUENCE

Sheet No. 2 of 5

Drawing No.

Computed by MDS Checked By KMC Date 3/6/95

Baker

IN THE W(u) WELL FUNCTION, $u = \dfrac{1.87\, r^2 S}{T t}$;

WHERE r = RADIUS IN FEET FROM CENTER OF PUMPED WELL TO A POINT WHERE DRAWDOWN IS MEASURED

S = STORATIVITY = 5.067×10^{-2} (BAKER, 1993)

T = TRANSMISSIVITY = 4.5×10^{2} GPD/FT. (BAKER, 1993)

t = TIME SINCE PUMPING STARTED, IN DAYS = 30 DAYS

AND: $r = \sqrt{\dfrac{u\, T t}{1.87\, S}}$

$$r = \sqrt{\frac{(7.72 \times 10^{-1})(450)(30)}{1.87(5.067 \times 10^{-2})}}$$

r = 332 FEET

VARIOUS PUMPING DURATIONS WERE COMPUTED FOR THE EXISTING SITE 1 CONDITIONS. DURATION TIMES FOR 30, 60 AND 90 DAYS WERE COMPUTED AND ARE NOTED ON SHEET No. 3 OF 5. ADDITIONALLY, VARIOUS PUMPING FLOW RATES WERE IDENTIFIED. THESE FLOW RATES ARE ALSO NOTED ON SHEET 3 OF 5.

BASED ON EXISTING SITE 1 CONDITIONS, THE SELECTED RADIUS OF INFLUENCE FOR AN EXTRACTION WELL WILL BE ASSUMED TO BE 390 FEET AT A PUMPING RATE OF 5 GPM.

S.O. No. 62470-231-0000-05700

Subject: CTO 231 O.U. #7 SITE #1

MCB CAMP LEJEUNE

EXTR. WELL RADII OF INFLUENCE

Sheet No. 3 of 5

Drawing No.

Computed by LMC Checked By TJB 3-8-95 Date 3/7/95

Q (GPM)	W(u)	u *'	t (days)	r (FEET)
5	0.196	1.07	30	390
4	0.245	9.3×10^{-1} ✓	30	364
3	0.327	7.72×10^{-1}	30	332
2	0.491	5.62×10^{-1}	30	283
1.5	0.654	4.3×10^{-1} ✓	30	248
1	0.982	2.71×10^{-1}	30	196
4	0.245	9.30×10^{-1}	60	515
3	0.327	7.72×10^{-1}	60	469
2	0.491	5.62×10^{-1}	60	400
4	0.245	9.30×10^{-1}	90	630
3	0.327	7.72×10^{-1}	90	574
2	0.491	5.62×10^{-1}	90	490

*' VALUES NOTE ARE INTERPOLATED VALUES FOR u.

Baker

S.O. No. 62470-231-0000-05700
Subject: CTO 231 OU #7 SITE #1
NCBC CAMP LEJEUNE
EXTR. WELL RADII OF INFLUENCE
Sheet No. 4 of 5
Drawing No.
Computed by NCS Checked By KMC Date 3-6-95

APPENDIX 9.E.

Values of *W(u)* Corresponding to Values of *u* for Theis Nonequilibrium Equation

N \ u	N×10⁻¹⁵	N×10⁻¹⁴	N×10⁻¹³	N×10⁻¹²	N×10⁻¹¹	N×10⁻¹⁰	N×10⁻⁹	N − 10⁻⁸	N×10⁻⁷	N×10⁻⁶	N×10⁻⁵	N×10⁻⁴	N×10⁻³	N×10⁻²	N×10⁻¹	N
1.0	33.9616	31.6590	29.3564	27.0538	24.7512	22.4486	20.1460	17.8435	15.5409	13.2383	10.9357	8.6332	6.3315	4.0379	1.8229	0.2194
1.1	33.8662	31.5637	29.2611	26.9585	24.6559	22.3533	20.0507	17.7482	15.4456	13.1430	10.8404	8.5379	6.2363	3.9436	1.7371	.1860
1.2	33.7792	31.4767	29.1741	26.8715	24.5689	22.2663	19.9637	17.6611	15.3586	13.0560	10.7534	8.4509	6.1494	3.8576	1.6595	.1584
1.3	33.6992	31.3966	29.0940	26.7914	24.4889	22.1863	19.8837	17.5811	15.2785	12.9759	10.6734	8.3709	6.0695	3.7785	1.5889	.1355
1.4	33.6251	31.3225	29.0199	26.7173	24.4147	22.1122	19.8096	17.5070	15.2044	12.9018	10.5993	8.2968	5.9955	3.7054	1.5241	.1162
1.5	33.5561	31.2535	28.9509	26.6483	24.3458	22.0432	19.7406	17.4380	15.1354	12.8328	10.5303	8.2278	5.9266	3.6374	1.4645	.1000
1.6	33.4916	31.1890	28.8864	26.5838	24.2812	21.9786	19.6760	17.3735	15.0709	12.7683	10.4657	8.1634	5.8621	3.5739	1.4092	.08631
1.7	33.4309	31.1283	28.8258	26.5232	24.2206	21.9180	19.6154	17.3128	15.0103	12.7077	10.4051	8.1027	5.8016	3.5143	1.3578	.07465
1.8	33.3738	31.0712	28.7686	26.4660	24.1634	21.8608	19.5583	17.2557	14.9531	12.6505	10.3479	8.0455	5.7446	3.4581	1.3098	.06471
1.9	33.3197	31.0171	28.7145	26.4119	24.1094	21.8068	19.5042	17.2016	14.8990	12.5964	10.2939	7.9915	5.6906	3.4050	1.2649	.05620
2.0	33.2684	30.9658	28.6632	26.3607	24.0581	21.7555	19.4529	17.1503	14.8477	12.5451	10.2426	7.9402	5.6394	3.3547	1.2227	.04890
2.1	33.2196	30.9170	28.6145	26.3119	24.0093	21.7067	19.4041	17.1015	14.7989	12.4964	10.1938	7.8914	5.5907	3.3069	1.1829	.04261
2.2	33.1731	30.8705	28.5679	26.2653	23.9628	21.6602	19.3576	17.0550	14.7524	12.4498	10.1473	7.8449	5.5443	3.2614	1.1454	.03719
2.3	33.1286	30.8261	28.5235	26.2209	23.9183	21.6157	19.3131	17.0106	14.7080	12.4054	10.1028	7.8004	5.4999	3.2179	1.1099	.03250
2.4	33.0861	30.7835	28.4809	26.1783	23.8758	21.5732	19.2706	16.9680	14.6654	12.3628	10.0603	7.7579	5.4575	3.1763	1.0762	.02844
2.5	33.0453	30.7427	28.4401	26.1375	23.8349	21.5323	19.2298	16.9272	14.6246	12.3220	10.0194	7.7172	5.4167	3.1365	1.0443	.02491
2.6	33.0060	30.7035	28.4009	26.0983	23.7957	21.4931	19.1905	16.8880	14.5854	12.2828	9.9802	7.6779	5.3776	3.0983	1.0139	.02185
2.7	32.9683	30.6657	28.3631	26.0606	23.7580	21.4554	19.1528	16.8502	14.5476	12.2450	9.9425	7.6401	5.3400	3.0615	.9849	.01918
2.8	32.9319	30.6294	28.3268	26.0242	23.7216	21.4190	19.1164	16.8138	14.5113	12.2087	9.9061	7.6038	5.3037	3.0261	.9573	.01686
2.9	32.8968	30.5943	28.2917	25.9891	23.6865	21.3839	19.0813	16.7788	14.4762	12.1736	9.8710	7.5687	5.2687	2.9920	.9309	.01482
3.0	32.8629	30.5604	28.2578	25.9552	23.6526	21.3500	19.0474	16.7449	14.4423	12.1397	9.8371	7.5348	5.2349	2.9591	.9057	.01305
3.1	32.8302	30.5276	28.2250	25.9224	23.6198	21.3172	19.0146	16.7121	14.4095	12.1069	9.8043	7.5020	5.2022	2.9273	.8815	.01149
3.2	32.7984	30.4958	28.1932	25.8907	23.5881	21.2855	18.9829	16.6803	14.3777	12.0751	9.7726	7.4703	5.1706	2.8965	.8583	.01013
3.3	32.7676	30.4651	28.1625	25.8599	23.5573	21.2547	18.9521	16.6495	14.3470	12.0444	9.7418	7.4395	5.1399	2.8668	.8361	.008939
3.4	32.7378	30.4352	28.1326	25.8300	23.5274	21.2249	18.9223	16.6197	14.3171	12.0145	9.7120	7.4097	5.1102	2.8379	.8147	.007891
3.5	32.7088	30.4062	28.1036	25.8010	23.4985	21.1959	18.8933	16.5907	14.2881	11.9855	9.6830	7.3807	5.0813	2.8099	.7942	.006970
3.6	32.6806	30.3780	28.0755	25.7729	23.4703	21.1677	18.8651	16.5625	14.2599	11.9574	9.6548	7.3526	5.0532	2.7827	.7745	.006160
3.7	32.6532	30.3506	28.0481	25.7455	23.4429	21.1403	18.8377	16.5351	14.2325	11.9300	9.6274	7.3252	5.0259	2.7563	.7554	.005448
3.8	32.6266	30.3240	28.0214	25.7188	23.4162	21.1136	18.8110	16.5085	14.2059	11.9033	9.6007	7.2985	4.9993	2.7306	.7371	.004820
3.9	32.6006	30.2980	27.9954	25.6928	23.3902	21.0877	18.7851	16.4825	14.1799	11.8773	9.5748	7.2725	4.9735	2.7056	.7194	.004267
4.0	32.5753	30.2727	27.9701	25.6675	23.3649	21.0623	18.7598	16.4572	14.1546	11.8520	9.5495	7.2472	4.9482	2.6813	.7024	.003779
4.1	32.5506	30.2480	27.9454	25.6428	23.3402	21.0376	18.7351	16.4325	14.1299	11.8273	9.5248	7.2225	4.9236	2.6576	.6859	.003349
4.2	32.5265	30.2239	27.9213	25.6187	23.3161	21.0136	18.7110	16.4084	14.1058	11.8032	9.5007	7.1985	4.8997	2.6344	.6700	.002969
4.3	32.5029	30.2004	27.8978	25.5952	23.2926	20.9900	18.6874	16.3848	14.0823	11.7797	9.4771	7.1749	4.8762	2.6119	.6546	.002633
4.4	32.4800	30.1774	27.8748	25.5722	23.2696	20.9670	18.6644	16.3619	14.0593	11.7567	9.4541	7.1520	4.8533	2.5899	.6397	.002336
4.5	32.4575	30.1549	27.8523	25.5497	23.2471	20.9446	18.6420	16.3394	14.0368	11.7342	9.4317	7.1295	4.8310	2.5684	.6253	.002073
4.6	32.4355	30.1329	27.8303	25.5277	23.2252	20.9226	18.6200	16.3174	14.0148	11.7122	9.4097	7.1075	4.8091	2.5474	.6114	.001841
4.7	32.4140	30.1114	27.8088	25.5062	23.2037	20.9011	18.5985	16.2959	13.9933	11.6907	9.3882	7.0860	4.7877	2.5268	.5979	.001635
4.8	32.3929	30.0904	27.7878	25.4852	23.1826	20.8800	18.5774	16.2748	13.9723	11.6697	9.3671	7.0650	4.7667	2.5068	.5848	.001453
4.9	32.3723	30.0697	27.7672	25.4646	23.1620	20.8594	18.5568	16.2542	13.9516	11.6491	9.3465	7.0444	4.7462	2.4871	.5721	.001291
5.0	32.3521	30.0495	27.7470	25.4444	23.1418	20.8392	18.5366	16.2340	13.9314	11.6289	9.3263	7.0242	4.7261	2.4679	.5598	.001148
5.1	32.3323	30.0297	27.7271	25.4246	23.1220	20.8194	18.5168	16.2142	13.9116	11.6091	9.3065	7.0044	4.7064	2.4491	.5478	.001021

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S.O. No. 62470-231-0000-05700

Subject: CTO 231 OU #7 SITE #1

MCB CAMP LEJEUNE

EXTR. WELL RADII OF INFLUENCE

Sheet No. 5 of 5

Drawing No.

Computed by MDS Checked By [signature] Date 3/6/95

Appendix 9.E. Continued

N \ u	N×10⁻¹⁵	N×10⁻¹⁴	N×10⁻¹³	N×10⁻¹²	N×10⁻¹¹	N×10⁻¹⁰	N×10⁻⁹	N×10⁻⁸	N×10⁻⁷	N×10⁻⁶	N×10⁻⁵	N×10⁻⁴	N×10⁻³	N×10⁻²	N×10⁻¹	N
5.2	32.3129	30.0103	27.7077	25.4051	23.1026	20.8000	18.4974	16.1948	13.8922	11.5896	9.2871	6.9850	4.6871	2.4306	.5362	.0009086
5.3	32.2939	29.9913	27.6887	25.3861	23.0835	20.7809	18.4783	16.1758	13.8732	11.5706	9.2681	6.9659	4.6681	2.4126	.5250	.0008086
5.4	32.2752	29.9726	27.6700	25.3674	23.0648	20.7622	18.4596	16.1571	13.8545	11.5519	9.2494	6.9473	4.6495	2.3948	.5140	.0007198
5.5	32.2568	29.9542	27.6516	25.3491	23.0465	20.7439	18.4413	16.1387	13.8361	11.5336	9.2310	6.9289	4.6313	2.3775	.5034	.0006409
5.6	32.2388	29.9362	27.6336	25.3310	23.0285	20.7259	18.4233	16.1207	13.8181	11.5155	9.2130	6.9109	4.6134	2.3604	.4930	.0005708
5.7	32.2211	29.9185	27.6159	25.3133	23.0108	20.7082	18.4056	16.1030	13.8004	11.4978	9.1953	6.8932	4.5958	2.3437	.4830	.0005085
5.8	32.2037	29.9011	27.5985	25.2959	22.9934	20.6908	18.3882	16.0856	13.7830	11.4804	9.1779	6.8758	4.5785	2.3273	.4732	.0004532
5.9	32.1866	29.8840	27.5814	25.2789	22.9763	20.6737	18.3711	16.0685	13.7659	11.4633	9.1608	6.8588	4.5615	2.3111	.4637	.0004039
6.0	32.1698	29.8672	27.5646	25.2620	22.9595	20.6569	18.3543	16.0517	13.7491	11.4465	9.1440	6.8420	4.5448	2.2953	.4544	.0003601
6.1	32.1533	29.8507	27.5481	25.2455	22.9429	20.6403	18.3378	16.0352	13.7326	11.4300	9.1275	6.8254	4.5283	2.2797	.4454	.0003211
6.2	32.1370	29.8344	27.5318	25.2293	22.9267	20.6241	18.3215	16.0189	13.7163	11.4138	9.1112	6.8092	4.5122	2.2645	.4366	.0002864
6.3	32.1210	29.8184	27.5158	25.2133	22.9107	20.6081	18.3055	16.0029	13.7003	11.3978	9.0952	6.7932	4.4963	2.2494	.4280	.0002555
6.4	32.1053	29.8027	27.5001	25.1975	22.8949	20.5923	18.2898	15.9872	13.6846	11.3820	9.0795	6.7775	4.4806	2.2346	.4197	.0002279
6.5	32.0898	29.7872	27.4846	25.1820	22.8794	20.5768	18.2742	15.9717	13.6691	11.3665	9.0640	6.7620	4.4652	2.2201	.4115	.0002034
6.6	32.0745	29.7719	27.4693	25.1667	22.8641	20.5616	18.2590	15.9564	13.6538	11.3512	9.0487	6.7467	4.4501	2.2058	.4036	.0001816
6.7	32.0595	29.7569	27.4543	25.1517	22.8491	20.5465	18.2439	15.9414	13.6388	11.3362	9.0337	6.7317	4.4351	2.1917	.3959	.0001621
6.8	32.0446	29.7421	27.4395	25.1369	22.8343	20.5317	18.2291	15.9265	13.6240	11.3214	9.0189	6.7169	4.4204	2.1779	.3883	.0001448
6.9	32.0300	29.7275	27.4249	25.1223	22.8197	20.5171	18.2145	15.9119	13.6094	11.3068	9.0043	6.7023	4.4059	2.1643	.3810	.0001293
7.0	32.0156	29.7131	27.4105	25.1079	22.8053	20.5027	18.2001	15.8976	13.5950	11.2924	8.9899	6.6879	4.3916	2.1508	.3738	.0001155
7.1	32.0015	29.6989	27.3963	25.0937	22.7911	20.4885	18.1860	15.8834	13.5808	11.2782	8.9757	6.6737	4.3775	2.1376	.3668	.0001032
7.2	31.9875	29.6849	27.3823	25.0797	22.7771	20.4746	18.1720	15.8694	13.5668	11.2642	8.9617	6.6598	4.3636	2.1246	.3599	.00009219
7.3	31.9737	29.6711	27.3685	25.0659	22.7633	20.4608	18.1582	15.8556	13.5530	11.2504	8.9479	6.6460	4.3500	2.1118	.3532	.00008239
7.4	31.9601	29.6575	27.3549	25.0523	22.7497	20.4472	18.1446	15.8420	13.5394	11.2368	8.9343	6.6324	4.3364	2.0991	.3467	.00007364
7.5	31.9467	29.6441	27.3415	25.0389	22.7363	20.4337	18.1311	15.8286	13.5260	11.2234	8.9209	6.6190	4.3231	2.0867	.3403	.00006583
7.6	31.9334	29.6308	27.3282	25.0257	22.7231	20.4205	18.1179	15.8153	13.5127	11.2102	8.9076	6.6057	4.3100	2.0744	.3341	.00005886
7.7	31.9203	29.6178	27.3152	25.0126	22.7100	20.4074	18.1048	15.8022	13.4997	11.1971	8.8946	6.5927	4.2970	2.0623	.3280	.00005263
7.8	31.9074	29.6048	27.3023	24.9997	22.6971	20.3945	18.0919	15.7893	13.4868	11.1842	8.8817	6.5798	4.2842	2.0503	.3221	.00004707
7.9	31.8947	29.5921	27.2895	24.9869	22.6844	20.3818	18.0792	15.7766	13.4740	11.1714	8.8689	6.5671	4.2716	2.0386	.3163	.00004210
8.0	31.8821	29.5795	27.2769	24.9744	22.6718	20.3692	18.0666	15.7640	13.4614	11.1589	8.8563	6.5545	4.2591	2.0269	.3106	.00003767
8.1	31.8697	29.5671	27.2645	24.9619	22.6594	20.3568	18.0542	15.7516	13.4490	11.1464	8.8439	6.5421	4.2468	2.0155	.3050	.00003370
8.2	31.8574	29.5548	27.2523	24.9497	22.6471	20.3445	18.0419	15.7393	13.4367	11.1342	8.8317	6.5298	4.2346	2.0042	.2996	.00003015
8.3	31.8453	29.5427	27.2401	24.9375	22.6350	20.3324	18.0298	15.7272	13.4246	11.1220	8.8195	6.5177	4.2226	1.9930	.2943	.00002699
8.4	31.8333	29.5307	27.2282	24.9256	22.6230	20.3204	18.0178	15.7152	13.4126	11.1101	8.8076	6.5057	4.2107	1.9820	.2891	.00002415
8.5	31.8215	29.5189	27.2163	24.9137	22.6112	20.3086	18.0060	15.7034	13.4008	11.0982	8.7957	6.4939	4.1990	1.9711	.2840	.00002162
8.6	31.8098	29.5072	27.2046	24.9020	22.5995	20.2969	17.9943	15.6917	13.3891	11.0865	8.7840	6.4822	4.1874	1.9604	.2790	.00001936
8.7	31.7982	29.4957	27.1931	24.8905	22.5879	20.2853	17.9827	15.6801	13.3776	11.0750	8.7725	6.4707	4.1759	1.9498	.2742	.00001733
8.8	31.7868	29.4842	27.1816	24.8790	22.5765	20.2739	17.9713	15.6687	13.3661	11.0635	8.7610	6.4592	4.1646	1.9393	.2694	.00001552
8.9	31.7755	29.4729	27.1703	24.8678	22.5652	20.2626	17.9600	15.6574	13.3548	11.0523	8.7497	6.4480	4.1534	1.9290	.2647	.00001390
9.0	31.7643	29.4618	27.1592	24.8566	22.5540	20.2514	17.9488	15.6462	13.3437	11.0411	8.7386	6.4368	4.1423	1.9187	.2602	.00001245
9.1	31.7533	29.4507	27.1481	24.8455	22.5429	20.2404	17.9378	15.6352	13.3326	11.0300	8.7275	6.4258	4.1313	1.9087	.2557	.00001115
9.2	31.7424	29.4398	27.1372	24.8346	22.5320	20.2294	17.9268	15.6243	13.3217	11.0191	8.7166	6.4148	4.1205	1.8987	.2513	.000009988
9.3	31.7315	29.4290	27.1264	24.8238	22.5212	20.2186	17.9160	15.6135	13.3109	11.0083	8.7058	6.4040	4.1098	1.8888	.2470	.000008948
9.4	31.7208	29.4183	27.1157	24.8131	22.5105	20.2079	17.9053	15.6028	13.3002	10.9976	8.6951	6.3934	4.0992	1.8791	.2429	.000008018
9.5	31.7103	29.4077	27.1051	24.8025	22.4999	20.1973	17.8948	15.5922	13.2896	10.9870	8.6845	6.3828	4.0887	1.8695	.2387	.000007185
9.6	31.6998	29.3972	27.0946	24.7920	22.4895	20.1869	17.8843	15.5817	13.2791	10.9765	8.6740	6.3723	4.0784	1.8599	.2347	.000006439

AS COPIED FROM APPENDIX 9.E GROUNDWATER AND WELLS, 2ND ED. (DRISCOLL, 1989)

APPENDIX C - COST ESTIMATES - SITE 1

ESTIMATED COSTS FOR RAA NO. 2 - SITE 1

TABLE C-1
ESTIMATED COSTS FOR RAA No. 2

RAA No. 2: INSTITUTIONAL CONTROLS
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

MONITORING 8 EXISTING WELLS

ANNUAL O&M COSTS

Jun-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	240	$40	$9,600		2 sampling events/yr, 5 days/event, 12 hrs/day/person, 2 people	Engineering Estimate - Previous Projects
Travel	Sample Event	2	$1,450	$2,900		Includes car rental and airfare for 2 people	Engineering Estimate - Previous Projects
Per Diem	Sample Event	2	$660	$1,320		Includes lodging and meals for 2 people	Engineering Estimate - Previous Projects
Laboratory Analysis & Data Validation							
VOCs	Sample	42	$173	$7,266		Cost includes both laboratory analysis and data validation	Basic Ordering Agreement
Equipment	Sample Event	2	$1,300	$2,600		Ice, DI water, expendables, etc.	Engineering Estimate - Previous Projects
Sample Shipping	Sample Event	2	$1,830	$3,660		2 coolers per day for 5 days; $183/cooler	Engineering Estimate - Previous Projects
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate - Previous Projects
Well Replacement	Year	1	$5,300	$5,300		Equal annual cost of replacing 6 wells every 5 years for 30 years	Engineering Estimate - Previous Projects
Total Groundwater Monitoring O&M Costs					$39,000		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$0	
TOTAL ANNUAL O&M COSTS	$39,000	Assuming 30 Years of Monitoring
PRESENT WORTH VALUE	$600,000	Based on a 5% Discount Rate

S.O. No. 62470-231

Subject: Cost Estimate Assumptions for Groundwater Monitoring O&M - Site 1

Sheet No. 1 of 4

Drawing No.

Computed by TLB Checked By MDS Date 5.5.95

Baker

GROUNDWATER MONITORING O&M

GENERAL ASSUMPTIONS:

- Groundwater will be sampled semiannually for 30 years.
- The discount rate is 5%.
- 8 wells will be sampled for VOCs and 1 well will be sampled for VOCs and TAL inorganics (as shown on Figure 5-1 of the FS report).

LABOR:

2 people × 12 hrs/day × 5 days/sampling event × 2 events/yr.
= 240 hrs/yr.

TRAVEL:

Car rental: 5 days @ $65/day = $325
Air fare: $556/round trip × 2 people = $1112
Total = $1437/event

PER DIEM:

Lodging - 5 nights @ $40/night × 2 people = $400
Meals - 5.5 days @ $26/day × 2 people = $286
$686/event

S.O. No. 62470-231

Subject: Cost Estimate Assumptions for Groundwater Monitoring O&M - Site 1

Sheet No. 2 of 4

Drawing No.

Computed by TLB Checked By MDS Date 5.5.95

Baker

GROUNDWATER MONITORING O&M

LABORATORY ANALYSES & DATA VALIDATION (QUANTITY CALCULATIONS):

① VOCs →
8 samples (1 at each well targeted for VOCs)
5 rinsates (1/day)
1 duplicates (1 for every 10 samples collected)
1 trip 1 ms/msd (1 for every 20 samples collected)
5 trip blanks (1/day)
1 field blank (1/sampling event)
21 VOC analyses/6 mos. → 42/yr.

EQUIPMENT:

Per event... (Costs are estimates based on previous projects)

Assume \$50/day for meters, HNu, bailers, etc:
5 days × \$50/day = \$250/event

Assume \$25/day/person for health & safety equipment
5 days × \$25/day/person × 2 people = \$250/event

Assume \$225/event for sampling expendables

Assume \$275/event for decon expendables

Assume \$300/event for ice, DI water

Total = \$1300/event

S.O. No. 62470-231

Subject: COST ESTIMATE ASSUMPTIONS FOR GW MONITORING O&M - Site 1 REPLACEMENT

Sheet No. 3 of 4

Drawing No.

Computed by MDS Checked By TLB Date 7-3-95

Baker

Well Replacement

Assumptions:

Replace 7 shallow wells every 5 years for 30 years.

Replace 1 Deep well every 5 years for 30 years.

$n = 30$, $i = 5\%$, Deep well = 120', Shallow well = 20'

Find

Equal annual cost

Solution:

Cost for single episode

ITEM	UNIT COST	UNITS	NUMBER OF UNITS	
Mobilization	$1500	Event	1	$1500
Wells, deep	$ 60	LF	120	$ 7200
Wells, shallow	$ 48	LF	100	$1480
Covers	$ 400	EACH	8	$ 3,200
Development	$ 200	EACH	8	$ 1,600
Per diem drill crew	$ 180	CREW-DAY	10	$ 1,800
Standby	$ 140	HR	10	$ 1,400
Drums	$ 42	EACH	20	$ 840
IDW management	$ 140	HR	20	$ 2,800
Abandonment	$ 10	LF	160	$ 1,600
Geologist	$ 40	HR	120	$ 4,800
Per diem geologist	$ 70	DAY	10	$ 700

TOTAL $28,920

SAY $ 29,000

S.O. No. 62470-231

Subject: COST ESTIMATE ASSUMPTIONS FOR GW MONITORING O&M - Site 1 Replacement

Sheet No. 4 of 4

Drawing No.

Computed by MD Checked By TLB Date 7-3-95

Baker

CONTINUED FROM PAGE 1

PW CALC

* {(P/F, 5%, 5) + (P/F, 5%, 10) + (P/F, 5%, 15) + (P/F, 5%, 20) + (P/F, 5%, 25) + (P/F, 5%, 30)} x $29,000

* {.7835 + .6139 + .4810 + .3769 + .2953 + .2314} x $29,000 = 2.782 x $29,000 = $80,678 Present Worth

Equal Annual Cost Calc

(A/P, 5%, 30) x $80,678 =

.0651 x $80,678 = $5,251/year EQUAL Annual Cost

USE $5,300

ESTIMATED COSTS FOR RAA NO. 3 - SITE 1

TABLE C-2
ESTIMATED COSTS FOR RAA No. 3

RAA No. 3: EXTRACTION AND ON-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
MONITORING 8 EXISTING WELLS
15 GPM TREATMENT FACILITY

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST 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
Total General Costs					$57,000		
SITE WORK							
Site Work During System Installation:							
Clearing	Acre	0.8	$8,000	$6,400		Clear and grub, chip stumps	Means Site 1994, 021-104
Saw Cutting Through Asphalt	LF	660	$5	$3,300		Assuming asphalt is 4" thick	Means Site 1994, 020-728
Removing Portion of Existing Fence	LF	60	$14	$840			Means Site 1994, 020-550
Piping Trench for the Collection Line	LF	1150	$4	$4,600		Includes excavation, removal, backfill, and tamping	Means Site 1994, A12.73-110 & -310
Piping Trench for the Discharge Line	LF	975	$4	$3,900		Includes excavation, removal, backfill, and tamping	Means Site 1994, A12.73-110
Excavation for Treatment Plant Slab	CY	50	$12	$600		Roughly 25' x 25' x 2'excavation	Means Site 1994, 022-200
Backfill Around Treatment Plant Slab	CY	30	$5	$150		Roughly 5' x 2' x 80' around plant	Means Site 1994, 022-226 & -208
Cut and Fill for Driveway to Treatment Plant	CY	350	$5	$1,750		Includes excavation, water wagon, backfill, and tamping	Means Site 1994, A12.1-214
Construction of Asphalt Driveway	LF	300	$27	$8,100		Assuming asphalt is 4" thick	Means Site 1994, A12.5-111
Water Connection at Treatment Plant	LF	400	$8	$3,200		Includes trenching & laying a 1" copper line	Means Site 1994, 026-662 & 022-258
Overhead Electrical to Treatment Plant	LF	400	$25	$10,000		Includes overhead routing and poles	Means Site 1994, 167-1900 & Estimate
Erosion Protection at Discharge Point	CY	5	$62	$310		For rip rap around headwall	Engineering Estimate- Previous Projects
Site Restoration:							
Replace Removed Fence With a Gate	EA	1	$1,475	$1,475		8' high, 12' opening, 1 gate	Means Site 1994, 028-300
Replace Removed Fence	LF	30	$10	$300		Replacement fence	Engineering Estimate -Previous Projects
Topsoil Spreading in Cleared Areas	SY	4000	$3	$12,000		*Topsoil for 0.8 acres that were cleared*	Means Site 1994, 022-286
Top Dressing Around Treatment Plant	CY	8	$40	$320		Around 20' x 20' treatment plant slab, 6" thick	Means Site 1994, 022-286
Fine Grading and Seeding for Revegetation	SY	4000	$2	$8,000		*Revegetation for 0.8 acres that were cleared*	Means Site 1994, 022-286
Pavement Replacement Over Trench	SY	180	$46	$8,280		Assuming asphalt pavement 8" thick	Means Site 1994, 025-104 & Estimate
Total Site Work Costs					$74,000		

TABLE C-2 (CONTINUED)
ESTIMATED COSTS FOR RAA No. 3

RAA No. 3: EXTRACTION AND ON-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
CONCRETE/STRUCTURAL							
Pre-fabricated Building for Treatment Plant	EA	1	$30,000	$30,000		20' x 20' building	Engineering Estimate- Previous Projects
Installation of Building	EA	1	$7,500	$7,500			Engineering Estimate- Previous Projects
Foundation for Building	EA	1	$3,848	$3,848		20' x 20' 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 1994, A12.3-750 & Estimate
Total Concrete/Structural Costs					$43,000		
EXTRACTION WELLS							
Shallow Extraction Well Installation	LF	300	$450	$135,000		6" stainless steel; each well approximately 100 ft. deep	Engineering Estimate- Previous Projects
Well Development	EA	3	$375	$1,125			Engineering Estimate- Previous Projects
Extraction Well Pumps	EA	3	$2,550	$7,650		Includes well pump, level tracking device, and regulator	Vendor Quote
Appurtenances	EA	3	$1,000	$3,000			Vendor Quote
Installation of Pumps and Appurtenances	LS	1	$110,081	$110,081		Assuming 75% of equipment cost	Engineering Estimate- Previous Projects
Manholes (Materials and installation)	EA	3	$1,754	$5,262		Includes materials, excavation, backfill, trim, and compaction	Means Site 1994, A12.3-710
Total Extraction Well Costs					$262,000		
PIPING SYSTEM							
2" PVC Line for Recovery	LF	1450	$5	$7,250		Includes materials and installation (also includes down-hole line)	Means Site 1994, 026-678
2" PVC Line for Discharge to Creek	LF	975	$5	$4,875		Includes materials and installation	Means Site 1994, 026-678
1/2" Polyethylene Air Supply Line	LF	1450	$2	$2,900		Includes materials and installation (also includes down-hole line)	Means Site 1994, 026-854
3" PVC Containment Line for Recovery	LF	1450	$6	$8,700		Includes materials and installation	Means Site 1994, 026-678
Fittings	LS	1	$1,523	$1,523		Assume 15% of Total Piping Cost	Engineering Estimate- Previous Projects
Total Piping System Costs					$25,000		
TREATMENT EQUIPMENT							
Package VOC and Metals Removal System	EA	1	$70,600	$70,600		Includes air stripper, surge tank, mix vessel, floc and clarifier vessel, filter press, sludge hopper, and associated pumps and mixers	Vendor Quote
Blower/Compressor	EA	3	$2,500	$7,500			Vendor Quote
Flowmeter	EA	1	$1,500	$1,500			Vendor Quote
Piping and Fittings	LS	1	$19,900	$19,900		Assume 25% of equipment cost	Engineering Estimate- Previous Projects
Instrumentation	LS	1	$7,960	$7,960		Assume 10% of equipment cost	Engineering Estimate- Previous Projects
Installation of Equipment	LS	1	$59,700	$59,700		Assume 75% of equipment cost	Engineering Estimate- Previous Projects
Total Treatment Plant Equipment Costs					$167,000		
TOTAL DIRECT CAPITAL COSTS					$628,000		

TABLE C-2 (CONTINUED)
ESTIMATED COSTS FOR RAA No. 3

RAA No. 3: EXTRACTION AND ON-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jun-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$75,360	$75,360		12% of Total Direct Cost	Engineering Estimate
Design and Construction Administration	LS	1	$94,200	$94,200		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$94,200	$94,200		15% of Total Direct Cost	Engineering Estimate
Start-up Costs	LS	1	$94,200	$94,200		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$358,000		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	240	$40	$9,600		2 sampling events/yr, 5 days/event, 12 hrs/day/person, 2 people	Engineering Estimate - Previous Projects
Travel	Sample Event	2	$1,450	$2,900		Includes car rental and airfare for 2 people	Engineering Estimate - Previous Projects
Per Diem	Sample Event	2	$660	$1,320		Includes lodging and meals for 2 people	Engineering Estimate - Previous Projects
Laboratory Analysis & Data Validation							
VOCs	Sample	42	$173	$7,266		Cost includes both laboratory analysis and data validation	Basic Ordering Agreement
Equipment	Sample Event	2	$1,300	$2,600		Ice, DI water, expendables, etc.	Engineering Estimate - Previous Projects
Sample Shipping	Sample Event	2	$1,830	$3,660		2 coolers per day for 5 days; $183/cooler	Engineering Estimate - Previous Projects
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate - Previous Projects
Well Replacement	Year	1	$5,300	$5,300		Equal annual cost of replacing 6 wells every 5 years for 30 years	Engineering Estimate - Previous Projects
Total Groundwater Monitoring O&M Costs					$39,000		

TABLE C-2 (CONTINUED)
ESTIMATED COSTS FOR RAA No. 3

RAA No. 3: EXTRACTION AND ON-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
15 GPM TREATMENT FACILITY
MONITORING 8 EXISTING WELLS

ANNUAL O&M COSTS

Jun-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST 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 - Previous Projects
Labor for Sampling	Month	12	$240	$2,880		8 hr/month, 12 months/yr, at $30/hr	Engineering Estimate - Previous Projects
Air Sampling - Analysis	Sample	24	$200	$4,800		Assume 2 samples/month	Engineering Estimate - Previous Projects
Effluent Sampling - Analysis	Sample	24	$300	$7,200		Assume 2 samples/month	Engineering Estimate - Previous Projects
Sludge Disposal	Month	12	$300	$3,600		2 drums/month at $150/drum disposal costs	Engineering Estimate - Previous Projects
Electricity	*Month*	12	$150	$1,800		24 hr/day, 365 days/year operation	Means Site 1994, 010-034 & Estimate
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate - Previous Projects
Total Treatment System O&M Costs					$32,000		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	**$986,000**	
TOTAL ANNUAL O&M COSTS	**$71,000**	Assuming 30 Years of Monitoring and System Operation
PRESENT WORTH VALUE	**$2,100,000**	Based on a 5% Discount Rate

COST ESTIMATE ASSUMPTIONS
FOR RAA NO.3: EXTRACTION AND ON-SITE TREATMENT
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

GENERAL ASSUMPTIONS

Based on the radius of influence calculations provided in Appendix B of Volume I, each pump will operate at 5 GPM and the radius of influence of each well will be approximately 400 feet. Total peak flow will be 15 GPM.

Based on case studies and past experience, the life of the pump and treat system is assumed to be 30 years.

The discount rate used to calculate present worth is 5%.

It is assumed that Cogdels Creek can accommodate the 15 GPM flow generated by the remediation system with no negative impact.

Groundwater flow is generally along a flow path approximated by a line extending from 1-GW17 to 1-GW10.

SITE WORK

The asphalt driveway that will service the treatment plant is assumed to run from the asphalt driveway on the north side of Building FC-115 to the treatment plant area. This is approximately 300 LF.

The area to be cleared is approximately 2000 LF in length and 15-20 feet wide. This figure is based on the length of groundwater collection and discharge lines.

The slab for the treatment building is 20 feet by 20 feet and the excavation is 25 feet by 25 feet. This should provide adequate space for constructing forms.

A total of two asphalt saw cuts will be needed. The first is in the back of Building FC-115 across an existing driveway (20 feet across and 5 feet wide, total of 50 feet). The second is south of Building FC-134 across an existing asphalt lot (300 feet long and 5 feet wide, total of 610 feet).

Approximately 30 feet of fencing will have to be removed and replaced with a gate at each of 2 locations. Thirty feet of fencing will have to be removed from an area on the north side of Building FC-115 and the west side of Building FC-134.

The asphalt driveway is assumed to be 300 feet long and 20 feet wide, and constructed out of 4 inches of asphalt paving and 5 inches of gravel base. The Means Site cost is noted as being $69.50 per linear foot. This cost includes curbing which will not be necessary at this site. So, $38.74 (for curbing) was subtracted from $69.50. It is assumed that the subbase of the driveway will have an elevation of 18 inches above grade. Cut and fill was estimated as follows: 300 feet (length) x 20 feet (width) x 1.5 feet fill. This is 333 cubic yards (rounded to 350 for the estimate).

Underground collection and discharge lines are shown on Figure 5-2.

It is assumed water and electric connections will occur at Building FC-115.

SITE RESTORATION

Gates will be placed at locations where fencing was removed.

Pavement replacement will mirror what was saw cut. Approximately 320 feet x 5 feet = 1,600 square feet or 60 square yards.

EXTRACTION WELLS

Extraction wells will be approximately 100 feet deep which coincides with the depth to the confining layer.

Extraction wells will be equipped with pneumatic pumps.

The $450/LF cost for well installation includes mobilization, mud rotary drilling, crew per diem, stand by time, bentonite, sand, stainless steel screen and riser, well installation, IDW management, and a geologist.

A manhole is needed at each location to house the pumps' controller and piping and provide enough space to work in.

Appurtenances include items such as elbows, fittings, and valves. The vendor recommended $1,000 per well ($3,000 total).

PIPING SYSTEM

Discharge and airlines run from the treatment plant to each well. Assume the following for piping lengths for 1/2 inch air lines and 2 inch discharge lines:

	Plant to well	Down hole
North well	350 linear feet	100 linear feet
South well	300 linear feet	100 linear feet
East well	500 linear feet	100 linear feet
Total	1150 linear feet	300 linear feet

Three inch discharge line runs from the treatment plant to Cogdels Creek.

TREATMENT PLANT

The treatment plant was sized for 15 GPM.

Metals treatment is needed so the air stripper is not fouled.

GROUNDWATER MONITORING O&M

See "Cost Estimate Assumptions for Groundwater Monitoring O&M", Appendix C, Volume I.

ESTIMATED COSTS FOR RAA NO. 4 - SITE 1

TABLE C-3
ESTIMATED COSTS FOR RAA No. 4

RAA No. 4: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

4 AERATION WELLS
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST 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	LS	1	$200,000	$200,000			Vendor Quote & Engineering Estimate
Total General Costs					$257,000		
SITE WORK							
Site Work During System Installation:							
Clearing	Acre	0.25	$8,000	$2,000		Clear and grub, and chip stumps	Means Site 1994, 021-104
Electrical Work	LF	1300	$20	$26,000		Cost for installation	Means Site 1994, 167-1900 & Estimate
Site Restoration:							
Topsoil Spreading in Cleared Areas	SY	6200	$3	$18,600			Means Site 1994, 022-286
Fine Grading and Seeding for Revegetation	SY	4800	$2	$9,600			Means Site 1994, 022-286
Total Site Work Costs					$56,000		

TABLE C-3 (CONTINUED)
ESTIMATED COSTS FOR RAA No. 4

RAA No. 4: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

4 AERATION WELLS
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
AERATION SYSTEM							
Well Installation	LF	120	$105	$12,600		Borings, casings, sandpack, bentonite pellets, and bentonite grout	Vendor Quote
Well Development	EA	4	$375	$1,500			Engineering Estimate- Previous Projects
Installation of UVB-200 Air Lift System	EA	4	$7,282	$29,128			Vendor Quote
Air Blower	EA	4	$2,200	$8,800			Vendor Quote
Knockout Tank	EA	4	$2,000	$8,000			Vendor Quote
Installation of Equipment	LS	1	$12,600	$12,600		Assume 75% of total equipment costs	Engineering Estimate- Previous Projects
Vapor Phase Activated Carbon Unit	EA	4	$2,000	$8,000			Vendor Quote
Install Carbon Unit	LS	1	$6,000	$6,000		Assume 75% of total equipment costs	Vendor Quote
Electricity	LS	1	$6,200	$6,200		Assume 25% of total equipment costs	
Total Aeration System Costs					$93,000		
TOTAL DIRECT CAPITAL COSTS					$406,000		

TABLE C-3 (CONTINUED)
ESTIMATED COSTS FOR RAA No. 4

RAA No. 4: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

4 AERATION WELLS
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$48,720	$48,720		12% of Total Direct Cost	Engineering Estimate
Design and Construction Administration	LS	1	$60,900	$60,900		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$60,900	$60,900		15% of Total Direct Cost	Engineering Estimate
Start-up Costs	LS	1	$60,900	$60,900		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$231,000		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	240	$40	$9,600		2 sampling events/yr, 5 days/event, 12 hrs/day/person, 2 people	Engineering Estimate - Previous Projects
Travel	Sample Event	2	$1,450	$2,900		Includes car rental and airfare for 2 people	Engineering Estimate - Previous Projects
Per Diem	Sample Event	2	$660	$1,320		Includes lodging & meals for 2 people	Engineering Estimate - Previous Projects
Laboratory Analysis - VOCs	Sample	42	$173	$7,266		Cost includes both laboratory analysis and data validation	Basic Ordering Agreement
Equipment	Sample Event	2	$1,300	$2,600		Ice, DI water, expendable, etc.	Engineering Estimate - Previous Projects
Sample Shipping	Sample Event	2	$1,830	$3,660		2 coolers per day for 5 days; $183/cooler	Engineering Estimate - Previous Projects
Reporting	Sample Event	2	$3,000	$6,000		Laboratory reports, administration, etc.	Engineering Estimate - Previous Projects
Well Replacement	Year	1	$5,300	$5,300		Equal annual cost of replacing 6 wells every 5 years for 30 years	Engineering Estimate - Previous Projects
TOTAL GROUNDWATER MONITORING O&M COSTS					$39,000		

TABLE C-3 (CONTINUED)
ESTIMATED COSTS FOR RAA No. 4

RAA No. 4: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

4 AERATION WELLS
MONITORING 8 EXISTING WELLS

ANNUAL O&M COSTS

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
TREATMENT SYSTEM O&M (Based on 30 years of system operation)							
Aeration Equipment O&M by Subcontractor	Per Quarter	4	$2,150	$8,600		2 days of O&M per quarter, includes labor & travel costs	Vendor Quote and Engineering Estimate
Carbon Replacement	Unit	4	$350	$1,400		350#/GAC unit at $1.00/#=$350/unit; approx. 4-year carbon "life"	Engineering Estimate
Disposal of Water	Month	2	$300	$600		2 drums/year at $150/drum disposal costs	Engineering Estimate
Air Sampling	Per Event	6	$600	$3,600		Includes materials and labor	Engineering Estimate
Administration & Reports	HR	100	$50	$5,000		25 hrs/quarter at $50/hr	Engineering Estimate
TOTAL TREATMENT SYSTEM O&M COSTS					$19,000		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	$637,000	
TOTAL ANNUAL GROUNDWATER MONITORING O&M COSTS	$39,000	Assuming 30 Years of Monitoring
TOTAL ANNUAL SYSTEM O&M COSTS	$19,000	Assuming 3 Years of System Operation
PRESENT WORTH VALUE	$1,300,000	

COST ESTIMATE ASSUMPTIONS
FOR RAA NO. 4: IN-WELL AERATION AND OFF-GAS CARBON ADSORPTION
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

GENERAL ASSUMPTIONS

The radius of influence for each aeration well will be approximately 1.5 to 2 times the saturated aquifer thickness, or 120 to 160 feet.

Based on case studies, the in-well aeration treatment will be complete in approximately 3 years. Groundwater monitoring will continue for 30 years.

The discount rate used to calculate present worth is 5%.

Groundwater flow is generally along a flow path approximated by a line extending from 1-GW17 to 1-GW10.

SITE WORK

The area to be cleared will be approximately 600 LF in length and 15-20 feet wide. It will extend from the treeline to the downgradient aeration well. Thus, approximately 0.25 acres will be cleared.

It is assumed that electric connections will occur at Building FC-115.

AERATION SYSTEM

A separate UVB-200 Air Lift System (which includes the vacuum pump and down-hole components of the aeration well), knockout tank, and vapor phase activated carbon unit will be located near the opening of each aeration well.

GROUNDWATER MONITORING O&M

See "Cost Estimate Assumptions for Groundwater Monitoring O&M", Appendix C, Volume I.

ESTIMATED COSTS FOR RAA NO. 5 - SITE 1

TABLE C-4
ESTIMATED COSTS FOR RAA No. 5

RAA No. 5: EXTRACTION AND OFF-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
TRUCKING TO THE HPIA TREATMENT SYSTEM
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST 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	$14,000	$14,000		Includes mobilization for all subcontractors except tanker truck operator	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 Studies	LS	1	$20,000	$20,000		Assume 15 % of Capital Costs	Engineering Estimate- Previous Projects
Total General Costs					$79,000		
SITE WORK							
Site Work During System Installation:							
Clearing	Acre	0.3	$8,000	$2,400		Clear and grub, and chip stumps	Means Site 1994, 021-104
Saw Cutting Through Asphalt	LF	660	$5	$3,300		Assuming asphalt is 8" thick	Means Site 1994, 020-728
Removing Portion of Existing Fence	LF	60	$14	$840			Means Site 1994, 020-550
Trenching for Pipelines	LF	1150	$4	$4,600		Includes excavation, removal, backfill, and tamping	Means Site 1994, A12.73-110 & -310
Excavation for Equipment Building	CY	22	$12	$264		15' x 20' x 2'excavation	Means Site 1994, 022-200
Backfill Around Equipment Building	CY	18	$5	$90		Roughly 5' x 2' x 48' around plant	Means Site 1994, 022-226 & -208
Cut and Fill for Driveway to Treatment Plant	CY	350	$5	$1,750		Includes excavation, water wagon, backfill, and tamping	Means Site 1994, A12.1-214
Construction of Asphalt Driveway	LF	300	$27	$8,100		Assuming asphalt is 8" thick	Means Site 1994, A12.5-111
Water Connection at Equipment Building	LF	400	$8	$3,200		Includes trenching & laying a 1" copper line	Means Site 1994, 026-662 & 022-258
Overhead Electrical to Equipment Building	LF	400	$25	$10,000		Includes overhead routing and poles	Means Site 1994, 167-1900 & Estimate
Site Restoration:							
Replace Removed Fence With a Gate	EA	1	$1,475	$1,475		8' high, 12' opening	Means Site 1994, 028-300
Replace Fence	LF	30	$10	$300		Replacement fence.	Engineering Estimate- Previous Project
Topsoil Spreading in Cleared Areas	SY	1500	$3	$4,500			Means Site 1994, 022-286
Top Dressing Around Treatment Plant	CY	50	$40	$2,000			Means Site 1994, 022-286
Fine Grading and Seeding for Revegetation	SY	1500	$2	$3,000			Means Site 1994, 022-286
Pavement Replacement Over Trench	SY	180	$46	$8,280		Assuming pavement is 8" thick	Means Site 1994, 025-104 & Estimate
Total Site Work Costs					$54,000		

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

RAA No. 5: EXTRACTION AND OFF-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
TRUCKING TO THE HPIA TREATMENT SYSTEM
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
DIRECT CAPITAL COSTS (CONTINUED):							
CONCRETE/STRUCTURAL							
Pre-fabricated Equipment Building	EA	1	$5,000	$5,000		8' x 16' building	Engineering Estimate- Previous Projects
Installation of Building	EA	1	$7,000	$7,000			Engineering Estimate- Previous Projects
Foundation for Building	EA	1	$3,000	$3,000		8' x 16' on-grade slab	Engineering Estimate- Previous Projects
Total Concrete/Structural Costs					$15,000		
EXTRACTION SYSTEM							
Shallow Extraction Well Installation	LF	90	$450	$40,500		6" stainless steel	Engineering Estimate- Previous Projects
Well Development	EA	3	$375	$1,125			Engineering Estimate- Previous Projects
Extraction Well Pumps	EA	3	$2,550	$7,650		Includes well pump, level tracking device, and regulator	Vendor Quote
Appurtenances	EA	3	$1,000	$3,000			
Installation of Pumps and Appurtenances	LS	1	$39,206	$39,206		Assuming 75% of equipment cost	Engineering Estimate- Previous Projects
Manholes	EA	3	$1,754	$5,262		Includes materials, excavation, backfill, trim, and compaction	Means Site 1994, A12.3-210
Air Blower/Compressor	EA	3	$2,500	$7,500			Vendor Quote
Installation of Air Blower/Compressor	LS	1	$5,625	$5,625		Assume 75% of equipment cost	Vendor Quote
2" PVC Pipe: Groundwater Recovery Line	LF	1450	$5	$7,250		Includes materials and installation (also includes down-hole line)	Means Site 1994, 026-678
1/2" Polyethylene Air Supply Line	LF	1450	$2	$2,900		Includes materials and installation (also includes down-hole line)	Means Site 1994, 026-854
3" PVC Pipe: Containment of Recovery & Air Lines	LF	1450	$6	$8,700		Includes materials and installation (also includes down-hole line)	Means Site 1994, 026-678
Fittings for Pipelines	LS	1	$1,015	$1,015		Assume 10% of Total Piping Cost	Engineering Estimate- Previous Projects
Surge Tank	EA	2	$5,000	$10,000		Includes materials and installation	Engineering Estimate
Secondary Containment at Holding Tank	EA	2	$5,000	$10,000			
Instrumentation	LS	1	$2,815	$2,815		Assume 10% of equipment cost	Engineering Estimate- Previous Projects
Total Extraction System Costs					$140,000		
DISCHARGE SYSTEM							
Connections to Treatment System	LS	1	$20,000	$20,000		Includes materials and installation (also includes down-hole line)	Means Site 1994, 026-678
Total Discharge System Costs					$20,000		
TOTAL DIRECT CAPITAL COSTS					$308,000		

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

RAA No. 5: EXTRACTION AND OFF-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

3 EXTRACTION WELLS
TRUCKING TO THE HPIA TREATMENT SYSTEM
MONITORING 8 EXISTING WELLS

CAPITAL COSTS (DIRECT AND INDIRECT)

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
INDIRECT CAPITAL COSTS:							
Engineering and Design	LS	1	$36,960	$36,960		12% of Total Direct Cost	Engineering Estimate
Design and Construction Administration	LS	1	$46,200	$46,200		15% of Total Direct Cost	Engineering Estimate
Contingency Allowance	LS	1	$46,200	$46,200		15% of Total Direct Cost	Engineering Estimate
Start-up Costs	LS	1	$46,200	$46,200		15% of Total Direct Cost	Engineering Estimate
TOTAL INDIRECT CAPITAL COSTS					$176,000		

ANNUAL O&M COSTS

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
GROUNDWATER MONITORING O&M (Based on semiannual sampling for 30 years)							
Labor	Hours	240	$40	$9,600		*2 sampling events/yr, 5 days/event, 12 hrs/day/person, 2 people*	Engineering Estimate - Previous Projects
Travel	Sample Event	2	$1,450	$2,900		Includes car rental and airfare for 2 people	Engineering Estimate - Previous Projects
Per Diem	Sample Event	2	$660	$1,320		Includes lodging and meals for 2 people	Engineering Estimate - Previous Projects
Laboratory Analysis - VOCs	Sample	42	$173	$7,266		Cost includes both laboratory analysis and data validation	Basic Ordering Agreement
Equipment	Sample Event	2	$1,300	$2,600		Ice, DI water, expendable, etc.	Engineering Estimate - Previous Projects
Sample Shipping	Sample Event	2	$1,830	$3,660		2 coolers per day for 5 days; $183/cooler	Engineering Estimate - Previous Projects
Reporting	*Sample Event*	2	$3,000	$6,000		*Laboratory reports, administration, etc.*	Engineering Estimate - Previous Projects
Well Replacement	Year	1	$5,300	$5,300		Equal annual cost of replacing 6 wells every 5 years for 30 years	Engineering Estimate - Previous Projects
Total Groundwater Monitoring O&M Costs					$39,000		
SYSTEM O&M (Based on 3 years of system operation)							
Operating Labor	Hours	120	$30	$3,600		Approximately 10 hrs/month at $30/hr for one year	Engineering Estimate
Maintenance Labor	Hours	96	$30	$2,880		Approximately 8 hrs/month for one year	Engineering Estimate
Electricity	*Per Year*	1	$6,000	$6,000		*For air compressors and pumping equipment*	*Engineering Estimate*
Administration	Hours	144	$35	$5,040		Approximately 12 hrs/month for one year	Engineering Estimate
Effluent Sampling Labor	Hours	96	$35	$3,360		Approximately 8 hrs/month for one year	Engineering Estimate
Effluent Sampling Analysis	Sample	24	$300	$7,200			Engineering Estimate
Reporting	Each	4	$2,000	$8,000		Lab reports, etc. (1 report per quarter)	Engineering Estimate
Total System O&M Costs					$36,000		

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

RAA No. 5: EXTRACTION AND OFF-SITE TREATMENT
SITE 1 - FRENCH CREEK LIQUID DISPOSAL AREA
MCB CAMP LEJEUNE, NC

3 EXTRACTION WELLS
TRUCKING TO THE HPIA TREATMENT SYSTEM
MONITORING 8 EXISTING WELLS

ANNUAL O&M COSTS

Jul-95

COST COMPONENT	UNIT	QUANTITY	UNIT COST	SUBTOTAL COST	TOTAL COST	ASSUMPTIONS/COMMENTS	UNIT COST SOURCE
TRUCKING O&M (Based on 3 years of groundwater extraction and trucking)							
21,000 Gallon Holding Tank Rental	Month	12	$2,460	$29,520		2 holding tanks rented at $1230/tank/month	Vendor Quote
7,000 Gallon Tanker Truck Rental	Day	104	$100	$10,400		1 tanker truck needed for 2 days every 3 wks	Vendor Quote
Mobilization/Demobilization	Each	34	$1,200	$40,800			Vendor Quote
Truck Cleaning	Semiannual Event	2	$350	$700			Vendor Quote
Truck Operator	Hours	832	$27	$7,344		Operator will work 34 days per year, 8 hrs/day	Vendor Quote
Total Trucking O&M Costs					$89,000		

SUMMARY OF TOTAL CAPITAL AND O&M COSTS

TOTAL DIRECT AND INDIRECT CAPITAL COSTS	**$484,000**	
TOTAL ANNUAL GROUNDWATER MONITORING O&M COSTS	**$39,000**	Assuming 30 Years of Monitoring
TOTAL ANNUAL SYSTEM AND TRUCKING O&M COSTS	**$125,000**	Assuming 3 Years of System Operation and Trucking
PRESENT WORTH VALUE	**$1,400,000**	Based On a 5% Discount Rate

COST ESTIMATE ASSUMPTIONS
FOR RAA NO. 5: EXTRACTION AND OFF-SITE TREATMENT
SITE 1, FRENCH CREEK LIQUIDS DISPOSAL AREA
MCB, CAMP LEJEUNE, NC

GENERAL ASSUMPTIONS

Based on the radius of influence calculations provided in Appendix B of Volume I, each pump will operate at 5 GPM and the radius of influence of each well will be 400 feet. Total peak flow will be 15 GPM.

Groundwater extraction and trucking to the HPIA treatment system will continue for 3 years. Groundwater monitoring will continue for 30 years.

The discount rate used to calculate present worth is 5%.

Groundwater flow is generally along a flow path approximated by a line extending from 1-GW17 to 1-GW10.

SITE WORK

The asphalt driveway that will service the treatment plant is assumed to run from the asphalt driveway on the north side of Building FC-115 to the treatment plant area. This is approximately 300 LF.

The area to be cleared is approximately 1000 LF in length and 15-20 feet wide. This figure is based on the length of groundwater collection line.

The slab for the treatment building is 20 feet by 20 feet and the excavation is 25 feet by 25 feet. This should provide adequate space for constructing forms.

A total of two asphalt saw cuts will be needed. The first is in the back of Building FC-115 across an existing driveway (20 feet across and 5 feet wide, total of 50 feet). The second is south of Building FC-134 across an existing asphalt lot (300 feet long and 5 feet wide, total of 610 feet).

Approximately 30 feet of fencing will have to be removed at each of 2 locations. Thirty feet of fencing will have to be removed from an area on the north side of Building FC-115 and the west side of Building FC-134.

The asphalt driveway is assumed to be 300 feet long and 20 feet wide, and constructed out of 4 inches of asphalt paving and 5 inches of gravel base. The Means Site cost is noted as being $69.50 per linear foot. This cost includes curbing which will not be necessary at this site. So, $38.74 (for curbing) was subtracted from $69.50. It is assumed that the subbase of the driveway will have an elevation of 18 inches above grade. Cut and fill was estimated as follows: 300 feet (length) x 20 feet (width) x 1.5 feet fill. This is 333 cubic yards (350 will be used).

Underground collection lines are shown on Figure 5-2.

It is assumed water and electric connections will occur at Building FC-115.

SITE RESTORATION

Fence north of Building FC-115 will be replaced with a gate; the fence will be replaced at the other location.

Pavement replacement will mirror what was saw cut. Approximately 320 feet x 5 feet = 1,600 square feet or 60 square yards.

EXTRACTION WELLS

Extraction wells will be approximately 100 feet deep which coincides with the depth to the confining layer.

Extraction wells will be equipped with pneumatic pumps.

The $450/LF cost for well installation includes mobilization, mud rotary drilling, crew per diem, stand by time, bentonite, sand, stainless steel screen and riser, well installation, IDW management, and a geologist.

A manhole is needed at each location to house the pumps' controller and piping and provide enough space to work in.

Appurtenances include items such as elbows, fittings, and valves. The vendor recommended $1,000 per well ($3,000 total).

PIPING SYSTEM

Recovery lines, airlines and conduit run from the treatment plant to each well. Assume the following for piping lengths for 1/2 inch air lines, 2 inch recovery and 3 inch containment lines:

	Plant to well	Down hole
North well	350 linear feet	100 linear feet
South well	300 linear feet	100 linear feet
East well	500 linear feet	100 linear feet
Total	1150 linear feet	300 linear feet

No discharge line is needed.

TREATMENT PLANT

Carbon replacement is not needed at HPIA treatment facility due to the treatment of groundwater at this site. Carbon polishing is a back-up treatment at this facility and not used unless needed. As a result, a cost for carbon filter replacement is not included.

GROUNDWATER MONITORING O&M

See "Cost Estimate Assumptions for Groundwater Monitoring O&M", Appendix C, Volume I.

APPENDIX D - SOLUTE PLUME2D-H MODEL

SOLUTE PLUME2D-H MODEL

Introduction

The PLUME2D-H (Version 3.01) analytical model for solute transport in groundwater was used to evaluate the migration of contamination in the vicinity of Operable Unit No. 7, Site 1, MCB Camp Lejeune, North Carolina. This model is part of the Solute program package developed by Milovan S. Beljin for the International Groundwater Modeling Center, Golden, Colorado. This model was used to compute the two-dimensional, horizontal distribution of trichloroethene (TCE) in the shallow water-bearing zone through time.

The Solute model package includes eleven analytical models, providing a variety of initial conditions (i.e., source areal extent, type of release, and areal extent of the aquifer) and site-specific aquifer conditions (i.e., groundwater velocity, porosity, and dispersivity). Some of these models also take into account solute-specific geochemical behavior such as adsorption and decay. PLUME2D-H was selected based on its similarity in source and sink geometry, boundary conditions, and initial solute conditions.

The PLUME2D-H simulation of the fate and transport problem is based on the generalized advection-dispersion equation by Wilson and Miller (1978), as outlined in Beljin (1993).

The assumptions of the model include:

- Steady and uniform flow in a porous, confined aquifer.
- The aquifer is homogeneous, isotropic, infinite in areal extent, and constant in thickness.
- The source is a fully penetrating solute injection well with continuous and constant injection.
- The solute is distributed instantaneously into the entire aquifer thickness beneath the source.
- Sorption is in a state of linear isothermal equilibrium.
- No expansion or compression of the fluid media.

These assumptions simplify present site conditions, and as a result, several site- and solute-specific parameters required estimation. This model provides an order-of-magnitude estimate of the variation of solute concentrations with time and distance.

The purpose of this model is to compute the solute tranport of the TCE contamination noted at sampling location 1-GK117, with respect to the existing, currently non-producing, groundwater supply well, HP-638. Both Model Parameters and Model Results are presented, herein, to aid model and site specific description and overall understanding.

Model Parameters

Input parameters required by the PLUME2D-H model include geometry of the aquifer/water-bearing system and the source area, type and rate of release, site-specific aquifer characteristics, and solute-specific characteristics. Specific input data for the PLUME2D-H model include groundwater flow velocity, aquifer thickness, porosity, longitudinal and lateral dispersivity, retardation factor, solute half-life, source configuration, and source strength.

A grid was overlain on the site, normal to groundwater flow direction (see Figure D-1 of this Appendix). The grid was developed with one hundred foot cell spacing (both directions). As noted on Figure D-1, two cells were identified as the approximate source location. The grid cells (0, 600) and (100, 600) are the source's cell locations, while grid cell (0, 0) is the receptor's cell location.

The water-bearing zone thickness for Operable Unit No. 7 is estimated to be 100 feet, based on data obtained during the site investigation. It is noted that both the depth and thickness of the water-bearing zone are simplified in this model. An additional simplification is the assumption that the entire water-bearing zone consists of a fine sand. Actual Operable Unit No. 7 site conditions identified interbedded silty sand and clayey sand. Therefore, the water-bearing zone parameters used for this model are considered a worst case scenario.

The model assumes a constant source with a continuous release into the saturated zone (worst case scenario). The model was used to calculate the concentrations of TCE at a specific distance from the source for time periods of 10, 50 and 100 years.

Table 1 provides a summary of the input parameters used in this TCE model. Porosity and velocity values were based on results of the RI (Baker, 1995). Dispersivity values were based on published data (USEPA, 1985).

TABLE 1
SOLUTE PLUME2D-H INPUT PARAMETERS

Input Parameters	Parameter Value
Porosity (Ne,0)	30%
Velocity (V)	0.029 ft/day
Longitudinal Dispersivity	500 ft
Lateral Dispersivity	167 ft

The remaining parameters are contaminant-specific, and are discussed in the following sections.

<u>Trichloroethene Model Parameters</u>

Table 2 lists the additional input parameters for the TCE model. The half-life was based on published data (Howard et al, 1991). The source concentration and retardation factor were calculated based on contaminant parameters and site conditions. A description of these calculations follows.

TABLE 2
SOLUTE PLUME2D-H INPUT PARAMETERS
FOR TRICHLOROETHENE MODEL

Input Parameters	Parameter Value
Half-Life	300 days
Source Concentration	6.113×10^{-4} lbs/day
Retardation	27.1

Source Concentration (lbs/day): The source concentration was estimated based on the maximum trichloroethene concentration detected in groundwater at the site (27 μg/L). The source concentration was calculated using the following equation:

$$Q_c = C * Vu \tag{1}$$

Where: Q_c = source concentration (lbs/day)
C = concentration of trichloroethene (μg/L)
Vu = unit flow through the source area (L/day)

This formula includes the unit groundwater flow through the source area. The unit groundwater flow was calculated with the equation:

$$Vu = V * W * b \tag{2}$$

Where: Vu = unit flow through the source area (ft^3/day)
V = groundwater flow velocity (ft/day)
W = width of the source area (feet)
b = aquifer thickness (feet)

The data used in this equation was based on information obtained during the site assessment (V = 0.029 ft/day, W = 125 feet and b = 100 feet).

The unit flow rate was calculated at 362.5 ft^3/day (or 10,269.12 L/day). This unit flow rate and the maximum TCE concentration detected at the site (27 μg/L) were used in equation 1 to estimate the source concentration at 6.113×10^{-4} lbs/day.

Retardation: Partitioning of the contaminants to the soils by adsorption has the effect of slowing (retarding) the migration of the contaminant. Retardation is primarily due to adsorption of the compound and the organic carbon in the soil; although soil characteristics, such as soil particle surface area, affect migration. Retardation may be expressed as:

$$R_d = 1 + (\beta K_d) / \Theta \tag{3}$$

Where: R_d = retardation factor (unitless)
β = bulk density (estimated at 1.5 g/cm^3)

Kd	=	distribution coefficient
Θ	=	total porosity (30%)

K_d is estimated based on the following equation:

$$K_d = K_{oc} \times F_{oc} \tag{4}$$

Where:

K_d	=	distribution coefficient (ml/g)
K_{oc}	=	organic carbon partition coefficient (940; USEPA, 1982)
F_{oc}	=	fraction of organic carbon in soil (0.555%, based on regional analytical results)

The distribution coefficient is calculated as 5.22 ml/g. Therefore, the retardation factor can be estimated as: $R_d = 27.1$.

Model Results

The following summary represents the model's results for the given site conditions.

TABLE 3

SOLUTE PLUME2D-H SITE SPECIFIC RESULTS FOR TRICHLOROETHENE MODEL 10, 50 AND 100 YEARS

Description of Solute Model Run	Qc (#/day)	Dispersivity Long. (feet)	Dispersivity Lateral (feet)	Calc. Conc. C (mg/L)	Distance/ Direction from Source (feet)	Distance/ Direction from Receptor (feet)
10 years	6.11E-04	500	167	2.80E-08	100/ Southwest	500/ Northeast
50 years	6.11E-04	500	167	3.12E-08	100/ Southwest	500/ Northeast
100 years	6.11E-04	500	167	3.12E-08	100/ Southwest	500/ Northeast

Under the existing site conditions, the results from the models indicate that TCE will not migrate off-site, and will not reach the potable supply well, HP-638.

Additional model runs were conducted to determine the approximate level of TCE (at sampling location 1-GW17), required to notice the North Carolina Water Quality Standard of 2.8 µg/L at the potable supply well, HP-638. The following table represents the values computed.

TABLE 4

SOLUTE PLUME2D-H ELEVATED SOURCE CONCENTRATION RESULTS FOR TRICHLOROETHENE MODEL
100 YEARS

Description of Solute Model Run	Qc (#/day)	Dispersivity Long. (feet)	Dispersivity Lateral (feet)	Calc. Conc. C (mg/L)	Distance/ Direction from Source (feet)	Distance/ Direction from Receptor (feet)
100 years - elevated Qc	1.00E+12	500	167	5.59E-08	400/ Southwest	200/ Northeast
100 years - elevated Qc	1.00E+15	500	167	5.99E-10	500/ Southwest	100/ Northeast

Upon conclusion of the 100 year elevated Qc run, in which Qc equals 1×10^{15} lbs/day, the model results indicate that a concentration of 5.99×10^{-10} mg/L would be experienced approximately one hundred feet away from the potable supply well, HP-638. This noted input Qc value calculates to a source contamination level of 4.42×10^{19} µg/L. This source contamination is much higher than the actual, experienced 27 µg/L; thus the conclusion holds that under the existing site conditions trichloroethene will not migrate off-site nor reach the potable supply well, HP-638.

SOLUTE MODEL FOR SITE 1 - MCB CAMP LEJEUNE, N.C.

1. First Run of Solute:

Years to Review - 10 years (3,650 days)
- 50 years (18,250 days)
- 100 years (36,500 days)

Site Based Input Data:

GW (seepage velocity = 0.029 ft/day
Aquifer thickness (b) = 100 ft.
Porosity = 30% or 0.3
Longitudinal dispersivity = 500 ft.
Lateral dispersivity = 1/3 Dl = 167 ft.
Retardation factor = 27.1
Half-life (TCE) = 300 days
Number of point sources = 2 (see grid)

Source Strength:

Vu = V * kl 8 b; where kl = width of source = 125 ft.
Vu = (2.9 x 10^{-2} ft/day) (125') (100')
Vu = 362.5 ft^3/day (28.329 l/ft^3) = 10.269.12 l/day

Qc = C Vu, where c = 27 μg/l (max GW17 for TCE - Round 1)
Qc = (27 x 10^{-6} g/l) (10.269.12 l/day) (1#/453.59 g)
Qc = 6.113 x 10^{-4} #/day

10-YEAR MODEL

10 Years

```
*****************************************************
*                                                   *
*   INTERNATIONAL GROUND WATER MODELING CENTER      *
*                                                   *
*         S O L U T E   version 3.01                *
*                                                   *
*    ANALYTICAL MODELS FOR SOLUTE TRANSPORT         *
*                                                   *
*****************************************************
```

Model: PLUME2D-H

PROJECT......... = CTO231OU7S1
USER NAME....... = CHAVARA
DATE............ = 03-02-1995
DATA FILE....... = U:\SOLUTE\CTO231\10YR S1.DAT

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .029 [ft/d]
AQUIFER THICKNESS................. = 100 [ft]
POROSITY.......................... = .3
LONGITUDINAL DISPERSIVITY......... = 500 [ft]
LATERAL DISPERSIVITY.............. = 167 [ft]
RETARDATION FACTOR................ = 27.1
HALF-LIFE......................... = 300 [d]
NUMBER OF POINT SOURCES........... = 2

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = .0006113 [lb/d]
ELAPSED TIME................... = 3650 [d]

SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 100 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = .0006113 [lb/d]

ELAPSED TIME................... = 3650 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN....... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN....... = 0 [ft]
DISTANCE INCREMENT DELX........... = 100 [ft]
DISTANCE INCREMENT DELY........... = 100 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 2
NUMBER OF NODES IN Y-DIRECTION.... = 7

CONCENTRATION C [mg/l]

ROW\COLUMN		1	2
	[ft]	0.00	100.00
1	0.00 [ft]	0.0000D+00	0.0000D+00
2	100.00 [ft]	0.0000D+00	0.0000D+00
3	200.00 [ft]	0.0000D+00	0.0000D+00
4	300.00 [ft]	0.0000D+00	0.0000D+00
5	400.00 [ft]	0.0000D+00	0.0000D+00
6	500.00 [ft]	2.4135D-08	2.7967D-08
7	600.00 [ft]	-1.0000D+00	-1.0000D+00

50-YEAR MODEL

50 Years

```
*****************************************************
*                                                   *
*   INTERNATIONAL GROUND WATER MODELING CENTER      *
*                                                   *
*        S O L U T E   version 3.01                 *
*                                                   *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT          *
*                                                   *
*****************************************************
```

Model: PLUME2D-H

PROJECT......... = CTO231OU7S1
USER NAME....... = CHAVARA
DATE............ = 03-02-1995
DATA FILE....... = U:\SOLUTE\CTO231\50YR S1.DAT

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .029 [ft/d]
AQUIFER THICKNESS................. = 100 [ft]
POROSITY.......................... = .3
LONGITUDINAL DISPERSIVITY......... = 500 [ft]
LATERAL DISPERSIVITY.............. = 167 [ft]
RETARDATION FACTOR................ = 27.1
HALF-LIFE......................... = 300 [d]
NUMBER OF POINT SOURCES........... = 2

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = .0006113 [lb/d]
ELAPSED TIME................... = 18250 [d]

SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 100 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = .0006113 [lb/d]

ELAPSED TIME.................. = 18250 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN....... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN....... = 0 [ft]
DISTANCE INCREMENT DELX........... = 100 [ft]
DISTANCE INCREMENT DELY........... = 100 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 2
NUMBER OF NODES IN Y-DIRECTION.... = 7

CONCENTRATION C [mg/l]

ROW\COLUMN		1	2
	[ft]	0.00	100.00
1	0.00 [ft]	0.0000D+00	0.0000D+00
2	100.00 [ft]	0.0000D+00	0.0000D+00
3	200.00 [ft]	0.0000D+00	0.0000D+00
4	300.00 [ft]	0.0000D+00	0.0000D+00
5	400.00 [ft]	0.0000D+00	0.0000D+00
6	500.00 [ft]	2.6531D-08	3.1214D-08
7	600.00 [ft]	-1.0000D+00	-1.0000D+00

100 YEAR MODEL

100 Years

```
*****************************************************
*                              *
*   INTERNATIONAL GROUND WATER MODELING CENTER    *
*                              *
*        S O L U T E   version 3.01        *
*                              *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT      *
*                              *
*****************************************************
```

Model: PLUME2D-H

PROJECT......... = CTO231OU7S1
USER NAME....... = CHAVARA
DATE............ = 03-02-1995
DATA FILE....... = U:\SOLUTE\CTO231\100YRS1.DAT

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .029 [ft/d]
AQUIFER THICKNESS................. = 100 [ft]
POROSITY.......................... = .3
LONGITUDINAL DISPERSIVITY......... = 500 [ft]
LATERAL DISPERSIVITY.............. = 167 [ft]
RETARDATION FACTOR................ = 27.1
HALF-LIFE......................... = 300 [d]
NUMBER OF POINT SOURCES........... = 2

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = .0006113 [lb/d]
ELAPSED TIME................... = 36500 [d]

SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 100 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = .0006113 [lb/d]

ELAPSED TIME.................. = 36500 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN....... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN....... = 0 [ft]
DISTANCE INCREMENT DELX........... = 100 [ft]
DISTANCE INCREMENT DELY........... = 100 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 2
NUMBER OF NODES IN Y-DIRECTION.... = 7

CONCENTRATION C [mg/l]

ROW\COLUMN		1	2
	[ft]	0.00	100.00
1	0.00 [ft]	0.0000D+00	0.0000D+00
2	100.00 [ft]	0.0000D+00	0.0000D+00
3	200.00 [ft]	0.0000D+00	0.0000D+00
4	300.00 [ft]	0.0000D+00	0.0000D+00
5	400.00 [ft]	0.0000D+00	0.0000D+00
6	500.00 [ft]	2.6531D-08	3.1214D-08
7	600.00 [ft]	-1.0000D+00	-1.0000D+00

ELEVATED Q, 100-YEAR MODEL

$\Delta c = 1 \times 10^{12}$ #/day

```
****************************************************
*                          *
*   INTERNATIONAL GROUND WATER MODELING CENTER    *
*                          *
*       S O L U T E   version 3.01        *
*                          *
*   ANALYTICAL MODELS FOR SOLUTE TRANSPORT      *
*                          *
****************************************************
```

Model: PLUME2D-H

PROJECT......... = CTO231OU7S1
USER NAME....... = CHAVARA
DATE............ = 03-02-1995
DATA FILE....... = u:\solute\cto231\x100yrs1.dat

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .029 [ft/d]
AQUIFER THICKNESS................. = 100 [ft]
POROSITY.......................... = .3
LONGITUDINAL DISPERSIVITY......... = 500 [ft]
LATERAL DISPERSIVITY.............. = 167 [ft]
RETARDATION FACTOR................ = 27.1
HALF-LIFE......................... = 300 [d]
NUMBER OF POINT SOURCES........... = 2

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = 1000000000000 [lb/d]
ELAPSED TIME................... = 36500 [d]

SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 100 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = 1,000,000,000,000 [lb/d]

ELAPSED TIME................... = 36500 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN....... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN....... = 0 [ft]
DISTANCE INCREMENT DELX........... = 100 [ft]
DISTANCE INCREMENT DELY........... = 100 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 2
NUMBER OF NODES IN Y-DIRECTION.... = 7

CONCENTRATION C [mg/l]

ROW\COLUMN		1	2
	[ft]	0.00	100.00
1	0.00 [ft]	0.0000D+00	0.0000D+00
2	100.00 [ft]	0.0000D+00	0.0000D+00
3	200.00 [ft]	3.3138D-08	5.5857D-08
4	300.00 [ft]	3.3228D-03	5.2663D-03
5	400.00 [ft]	3.5340D+02	5.0437D+02
6	500.00 [ft]	4.3401D+07	5.1061D+07
7	600.00 [ft]	-1.0000D+00	-1.0000D+00

$\Delta c = 9.99 \times 10^{14}$ #/day

```
******************************************************
*                                                    *
*  INTERNATIONAL GROUND WATER MODELING CENTER        *
*                                                    *
*          S O L U T E   version 3.01                *
*                                                    *
*  ANALYTICAL MODELS FOR SOLUTE TRANSPORT            *
*                                                    *
******************************************************
```

Model: PLUME2D-H

PROJECT......... = CTO231OU7S1
USER NAME....... = CHAVARA
DATE............ = 03-02-1995
DATA FILE....... = u:\solute\cto231\z100yrs1.dat

INPUT DATA:

GROUNDWATER (SEEPAGE) VELOCITY.... = .029 [ft/d]
AQUIFER THICKNESS................. = 100 [ft]
POROSITY.......................... = .3
LONGITUDINAL DISPERSIVITY......... = 500 [ft]
LATERAL DISPERSIVITY.............. = 167 [ft]
RETARDATION FACTOR................ = 27.1
HALF-LIFE......................... = 300 [d]
NUMBER OF POINT SOURCES........... = 2

SOURCE NO. 1

X-COORDINATE OF THE SOURCE..... = 0 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = 999,999,999,999,999 [lb/d]
ELAPSED TIME................... = 36500 [d]

SOURCE NO. 2

X-COORDINATE OF THE SOURCE..... = 100 [ft]
Y-COORDINATE OF THE SOURCE..... = 600 [ft]
SOURCE STRENGTH................ = 999999999999999 [lb/d]

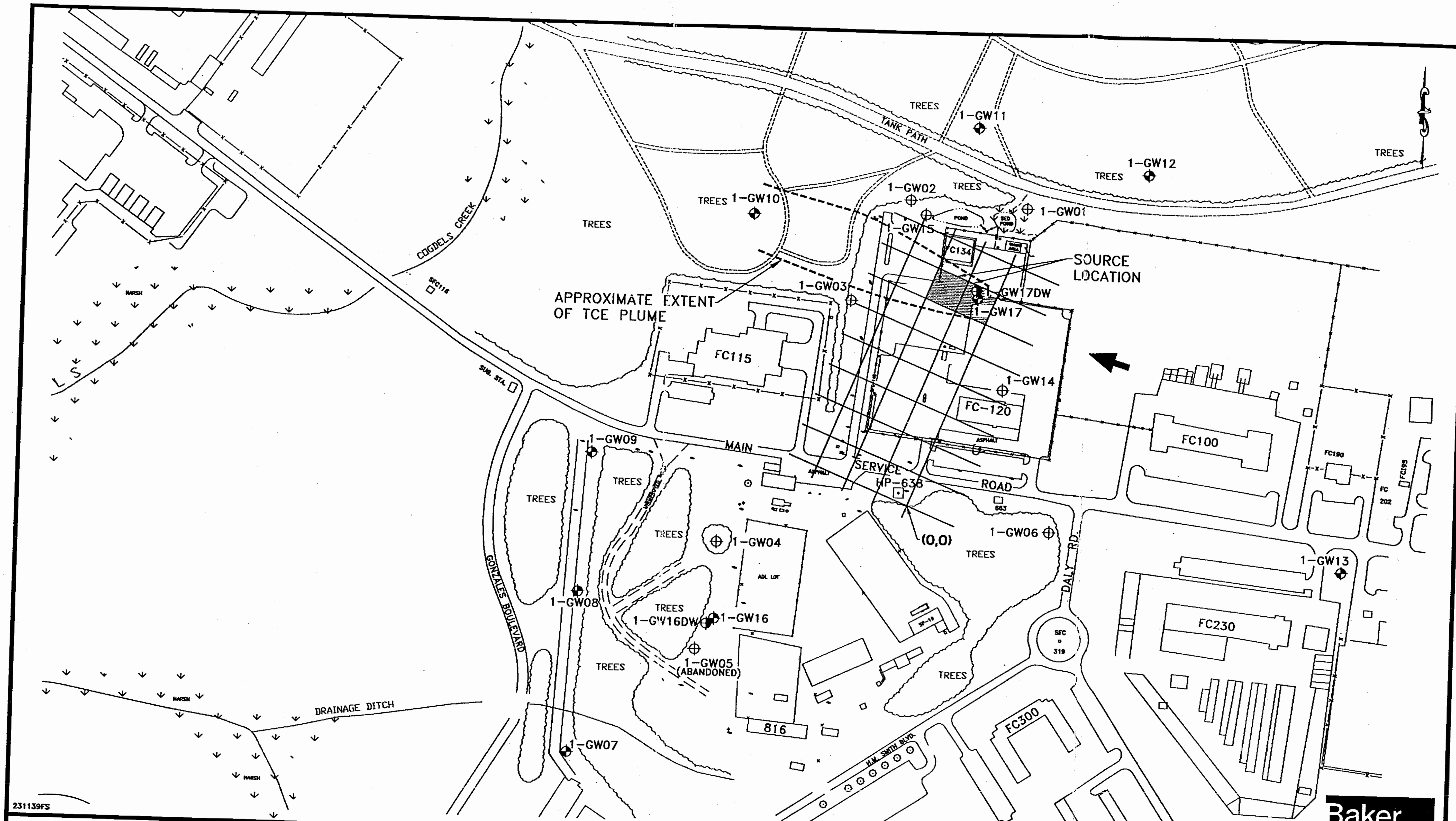
ELAPSED TIME.................. = 36500 [d]

GRID DATA:

X-COORDINATE OF GRID ORIGIN....... = 0 [ft]
Y-COORDINATE OF GRID ORIGIN....... = 0 [ft]
DISTANCE INCREMENT DELX........... = 100 [ft]
DISTANCE INCREMENT DELY........... = 100 [ft]
NUMBER OF NODES IN X-DIRECTION.... = 2
NUMBER OF NODES IN Y-DIRECTION.... = 7

CONCENTRATION C [mg/l]

ROW\COLUMN		1	2
	[ft]	0.00	100.00
1	0.00 [ft]	0.0000D+00	0.0000D+00
2	100.00 [ft]	3.4131D-10	5.9879D-10
3	200.00 [ft]	3.3138D-05	5.5857D-05
4	300.00 [ft]	3.3228D+00	5.2663D+00
5	400.00 [ft]	3.5340D+05	5.0437D+05
6	500.00 [ft]	4.3401D+10	5.1061D+10
7	600.00 [ft]	-1.0000D+00	-1.0000D+00



LEGEND

- 1-GW017 SHALLOW MONITORING WELL
- 1-GW17DW DEEP MONITORING WELL
- HP-638 WATER SUPPLY WELL THAT IS NOT IN SERVICE
- APPROXIMATE GROUNDWATER FLOW DIRECTION
- EXTRACTION WELL
- (0,0) GRID ORIGIN

SOURCE: LANTDIV, FEBRUARY 1992 AND W.K. DICKSON & ASSOC., JUNE 1994

300 0 150 300 600

1 inch = 300 ft.

FIGURE D-1
APPENDIX D, VOLUME 1
SOLUTE MODEL GRID
SITE 1 – FRENCH CREEK LIQUIDS DISPOSAL AREA
FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

01497DD03Z

LEGEND

VEGETATION — FENCE — CREEK/DRAINAGE — MARSH

SOURCE LANTDIV, FEBRUARY 1992

DATE	JULY 1995
SCALE	1" = 125'
DRAWN	REL
REVIEWED	TFT
SO#	62470-231-0000
CADD#	231132FS

NORTH

FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvar

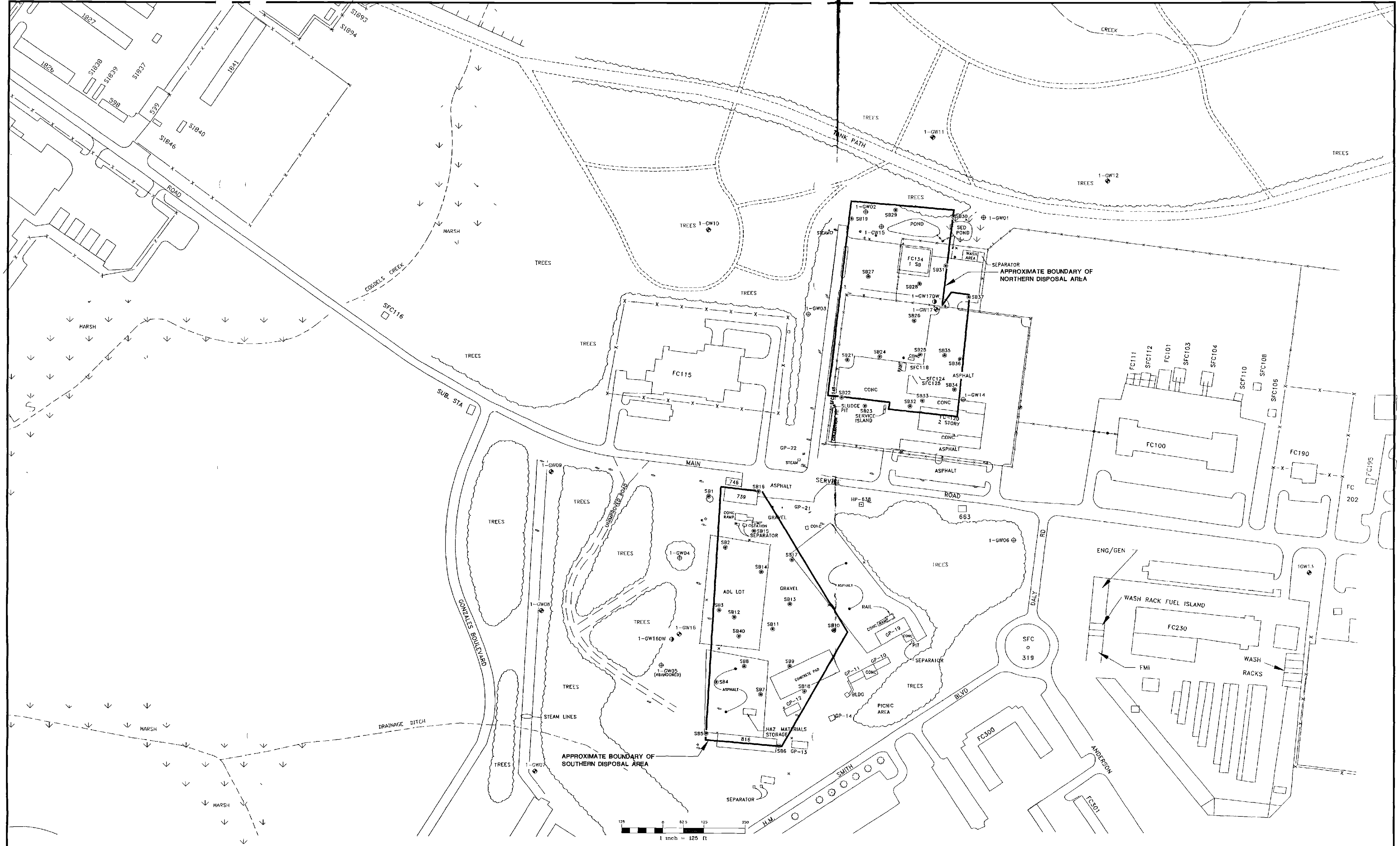
Baker
Baker Environmental, Inc

SITE MAP
SITE 1 - FRENCH CREEK
LIQUIDS DISPOSAL AREA

SCALE 1" = 125'   DATE JULY 1995

FIGURE No
2-1

01497DDB3X



LEGEND

1-GW01	EXISTING SHALLOW MONITORING WELL
1-GW07	NEWLY INSTALLED SHALLOW MONITORING WELL (BAKER, 1994)
1-GW16DW	NEWLY INSTALLED DEEP MONITORING WELL (BAKER, 1994)
SB1	SOIL BORING LOCATION (BAKER, 1994)
	VEGETATION
—x—	FENCE
— — —	CREEK/DRAINAGE
↓ ↓	MARSH

SOURCE: LANTDIV, FEBRUARY 1992

DATE	JULY 1995
SCALE	1" = 125'
DRAWN	REL
REVIEWED	TFT
S O #	62470-231-0000
CADD #	231101FS

NORTH

FEASIBILITY STUDY CTO-0231
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

REMEDIAL INVESTIGATION
SAMPLING LOCATIONS
SITE 1 - FRENCH CREEK
LIQUIDS DISPOSAL AREA

SCALE 1" = 125'
DATE JULY 1995

FIGURE No.
2-2