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FINAL

REMEDIAL INVESTIGATION REPORT FOR OPERABLE UNIT NO. 2 (Sites 6, 9 and 82)

MARINE CORPS BASE, CAMP LEJEUNE NORTH CAROLINA

CONTRACT TASK ORDER 0133

VOLUME 1 OF 2; TEXT

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LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Area of Concern
ARARs	Applicable or Relevant and Appropriate Requirements
AWQC	Federal Ambient Water Quality Criteria
Baker	Baker Environmental, Inc.
bgs	below ground surface
BOD	biological oxygen demand
CDI	Chronic Daily Intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CH	high plasticity clay
CL	low plasticity clay
CLEAN	Comprehensive Long-Term Environmental Action Navy
CLP	Contract Laboratory Program
COC	Contaminant of Concern
COD	chemical oxygen demand
CSF	Cancer Slope Factor
DoN	Department of the Navy
Eh	Oxidation Reduction Potential
EPIC	Environmental Photographic Interpretation Center
ERA	Ecological Risk Assessment
ER-M	Effects Range-Median
ESE	Environmental Science and Engineering, Inc.
ETC	Electromagnetic terrain conductivity
FFA	Federal Facilities Agreement
FID	flame ionization detector
FWSV	Freshwater Water Quality Screening Values
gpm	gallons per minute
GPR	ground penetrating radar
HA	Health Advisory
HEAST	Health Effects Assessment Summary Tables
HHI	Hardin and Huber, Inc.
HI	hazard index
Hoggard-Eure	Hoggard-Eure Associates
HQ	hazard quotient
IAS	Initial Assessment Study
ICR	Incremental Cancer Risk
ID	inside diameter
IDW	Investigative Derived Wastes
IRIS	Integrated Risk Information System
IRP	Installation Restoration Program

k	hydraulic conductivity
K_{oc}	Organic Carbon Partition Coefficient
K_{ow}	Octanol-Water Partition Coefficient
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
LANTNAVFAC-ENGCOM	Atlantic Division, Naval Facilities Engineering Command
LEL	lower explosive limit
LOAEL	Lowest Observed Adverse Effect Level
MCAS	Marine Corps Air Station
MCB	Marine Corps Base
MCL	Maximum Contaminant Level
mg/kg	milligram per kilogram
MF	Modifying Factor
MH	plastic silt
MI	Mobility Index
ML	low plasticity silt
msl	mean sea level
NACIP	Navy Assessment and Control of Installation Pollutants Program
NBC	nuclear, biological, and chemical
N.C. DEHNR	North Carolina Department of Environment, Health and Natural Resources
NCSPCS	North Carolina State Plane Coordinate System
NCWQS	North Carolina Water Quality Standards
NEESA	Naval Energy and Environmental Support Activity
NOAA	National Oceanic and Atmospheric Administration
NOAEL	No Observed Adverse Effect Level
NPL	National Priorities List
PAH	polynuclear aromatic hydrocarbon
PCBs	polychlorinated biphenyls
PHA	Public Health Assessment
PID	photoionization detector
ppb	parts per billion
ppm	parts per million
PVC	polyvinyl chloride
QA/QC	Quality Assurance/Quality Control
RA	Risk Assessment
RCRA	Resource Conservation and Recovery Act
RfD	Reference Dose
RI/FS	Remedial Investigation/Feasibility Study
S, S	storativity, solubility
SA	Site Assessment
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service
SM	silty sand
SMCL	Secondary Drinking Water Regulations
SQC	Sediment Quality Criteria
SOPs	Standard Operating Procedures

SSV	Sediment Screening Values
SVOCs	semivolatile organic compounds
SWQSVs	Surface Water Quality Screening Values
T	transmissivity
TAL	Target Analyte List
TBC	to be considered
TCL	Target Compound List
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TEF	Toxicity Equivalency Factor
TSS	total suspended solids
TVS	total volatile solids
TOC	total organic carbon
TRC	Technical Review Committee
UCL	Upper Confidence Limit
UF	Uncertainty Factor
µg/l	micrograms per liter
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VOCs	volatile organic compounds
VP	Vapor Pressure
WAR	Water and Air Research, Inc.
Weston	Weston Geophysical Corporation
WOE	Weight of Evidence

EXECUTIVE SUMMARY

INTRODUCTION

Marine Corps Base (MCB), Camp Lejeune, North Carolina was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) that became effective on October 4, 1989 (54 Federal Register 41015, October 4, 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 was to ensure that environmental impacts associated with past and present activities at the MCB were thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives were developed and implemented as necessary to protect public health and the environment.

This report describes the RI conducted at Operable Unit (OU) No. 2, which is comprised of Sites 6, 9, and 82.

SITE DESCRIPTION

Operable Unit No. 2 is located approximately 1.75 miles east of the New River and 2 miles south of State Route 24 on the mainside portion of MCB Camp Lejeune. The unit is bordered by Holcomb Boulevard to the west, Sneads Ferry Road to the south, Piney Green Road to the east, and by Wallace Creek, which makes up the north boundary. Camp Lejeune Railroad operates rail lines parallel to Holcomb Boulevard bordering Operable Unit No. 2. OU No. 2 covers an area of approximately 210 acres. OU No. 2 consists of three sites: Sites 6, 9, and 82.

There are distinctive areas of concern within each site of OU No. 2. The following section describes the background of each site.

Site 9

Site 9 is referred to in this report as the "Fire Training Area" (the formal name, as provided in the FFA, is "Fire Fighting Training Pit at Piney Green Road"). The site covers an area of approximately 2.6 acres. Site 9 is bounded by Holcomb Boulevard to the west, Bear Head

Creek approximately 500 feet to the north, Piney Green Road to the east and Sneads Ferry Road to the south. Site 6 also borders Site 9 to the north. Locally, the site is bounded by unnamed streets leading to various storage buildings in the vicinity.

Site 9 consists of an asphalt-lined fire training pit, an oil/water separator, four aboveground storage tanks (ASTs), and a fire tower (smoke house). The fire training pit, located in the southern area of the site, is used to conduct training exercises for extinguishing fires. The oil/water separator is located next to the fire training pit to collect water used in the training exercises and storm water that falls into the pit. The recovered product collected in the oil/water separator is disposed of off site. Two of the ASTs at Site 9 are 2500-gallon steel tanks labeled "DO NOT USE". These tanks are currently not in use. Two additional storage tanks are located in a bermed area. These tanks are constructed of steel and contain approximately 500 gallons each of jet fuel.

Site 6

Site 6 is located north of and adjacent to Site 9. Site 6 is bounded on the north by Site 82, by Piney Green Road to the east, by Site 9 to the south, and by Holcomb Boulevard to the west. Site 6 covers an area of approximately 177 acres that incorporates Storage Lots 201 and 203, the wooded area between the storage lots, and a ravine, which begins at Site 6 and bisects Site 82. Three surface water bodies are associated with Site 6 for the purpose of this RI: Wallace Creek, Bear Head Creek, and a ravine located in the wooded area north of Lot 203 that drains to Wallace Creek. The ravine is intermittent and it receives surface runoff and groundwater discharge during various periods.

Open Storage Lot 201 (Lot 201) is a fenced lot located in the south-central portion of Site 6. It is a flat area with sparse vegetation around the fence lines. The lot is approximately 25 acres in size. It is currently being used for the storage of military vehicles and equipment, lumber, hydraulic oils and lubricants, non-PCB transformers, and other supplies (ESE, 1991).

Open Storage Lot 203 (Lot 203) is a fenced lot located in the northern portion of Site 6 covering approximately 46 acres. Lot 203 is a relatively flat area with elevation differences of approximately five feet. The ground surface is comprised of both naturally existing soil and fill material. Lot 203 is bordered by Site 82 to the north, Piney Green Road to the east, woods to the south, and by Holcomb Boulevard to the west. Lot 203 is currently inactive.

Approximately 40 55-gallon drums are present at Lot 203. The majority of the drums, if labeled, were identified as containing lubricants, petroleum products, or corrosives. Empty storage tanks were also found on Lot 203. They were labeled as containing diesel fuel, gasoline, and kerosene (Baker, 1992).

A ravine is located in the northwest section of Site 6. The steepest area of the ravine is located "inside" of Storage Lot 203. The banks of the ravine gradually decline as the ravine bisects Site 82. The elevation ranges from 25 feet above msl at the north boundary of Lot 203 to 5 feet above msl where the ravine meets Wallace Creek. The surface of the ravine area is littered with various debris including batteries, fencing, tires, empty unlabeled drums, wire cables, commercial ovens, commodes, and respirator cartridges. An empty drum labeled "DDT" was also found in the ravine area, as were small canisters labeled to contain "DDT". The canisters were dated "1958."

Woods and open fields surround both Storage Lots 201 and 203 and make up the remaining area of Site 6. The topography of the wooded areas is relatively flat, but localized trenching and mounding is visible just north of Lot 203 and west of Piney Green Road. The wooded areas are randomly littered with debris including spent ammunition casings, and empty or rusted drums. Markings were observed on a few drums located north of Lot 203 (most drums did not contain markings due to their condition and age). These drums were marked as "lubrication oils". Many of the drums observed were only rusted shells or fragments of drums. (Baker, 1992)

Site 82

Site 82 is situated at the northern end of OU No. 2. It is bordered to the north by Wallace Creek, to the east by Piney Green Road, to the west by Holcomb Boulevard, and to the south by Site 6. Site 82 encompasses approximately 30 acres and is predominantly covered by woodlands. The site is randomly littered with debris including communication wire, spent ammunition casings, and empty or rusted drums. Markings were observed on a few drums, however, most of the drums did not contain markings due to their condition and age. Some of the drums were marked as "lubrication oil" and "anti-freeze".

The topography within Site 82 is relatively flat near the southern portion of the site, but becomes very steep near the bank of Wallace Creek. Localized trenching and mounding is

visible near the southern portion of the site. The ravine bisects the site, as shown on Figure 1-3.

SITE HISTORY

Site 9

Site 9 has been used as a fire fighting training area from the early 1960s to the present. Fire extinguishing activities took place in an unlined pit. In 1981 the pit was lined with asphalt. The training fires in the pit were started with used oil, solvents, and contaminated fuels (unleaded). Approximately 30,000 to 40,000 gallons of JP-4 and JP-5 fuel were also burned in the fire training pit (Baker, 1992).

Site 6

Site 6 has a long history of various uses including the disposal and storage of wastes and supplies. This discussion on the history of Site 6 has been broken down into Storage Lot 201, Storage Lot 203, and the wooded areas and ravine to simplify the historical descriptions of these areas.

Currently, Lot 201 is used to store military equipment, vehicles, hydraulic oils, and other "non-hazardous" supplies. Pesticides were reportedly stored in the northeast and southeast corners of the lot. Transformers containing PCBs were reportedly stored in the southwest corner of the lot (Water and Air Research, 1983).

Lot 203 has been used as a disposal area since the 1940s. There is little documentation on the disposal activities at this lot. Lot 203 in not currently active as a storage or disposal area, but the ground surface is littered with various debris. Lot 203 was also used for the storage and disposal of radio and communication parts, shredded tires, lubricants, petroleum products, corrosives, expended demolition kit training materials, ordnance, sheet metal debris, wire cables, and wooded pallets. Empty and full 55-gallon drums were found at various locations throughout Lot 203.

Lot 203 is currently fenced. From historical photographs, it appears that the fenced boundaries have changed since the lot was in operation. Former employees at Lot 203 have

reported disposal of various chemicals including PCBs, cleaning solvents, electrolytes from used batteries, and waste oils.

The wooded areas around Lots 201 and 203 are randomly littered with debris including drums, metal storage containers, and spent ammunition cartridges. No organized disposal operations are documented for the wooded areas. A ravine is located on the northern boundary of Lot 203. As previously stated, this area is currently littered with various debris. From the deposition of the debris in the ravine, it appears that trucks may have dumped their contents into the ravine from above.

Site 82

Site 82 was identified as a result of the 1986 site assessment conducted at Site 6, and from the 1992 Site Inspection. Surface water samples collected from Wallace Creek exhibited levels of volatile organic compounds (VOCs) at several locations. The source of the VOC contamination in Wallace Creek at that time was unknown. It appeared unlikely that the source of the contamination originated from Site 6 (Lot 203), and, therefore, was attributed to another source near the creek. The area located north of Lot 203 and west of Piney Green Road was established as Site 82 - The Piney Green Road VOC Site.

No previous records indicated that Site 82 was used for disposal or waste handling activities. The area is, however, littered with debris such as trash, communication wire, and drums of various sizes (e.g., 55- gallon and 5- gallon containers).

PREVIOUS INVESTIGATIONS

During the period 1983 through 1991, various studies were conducted at Sites 6, 9, and 82 by the Department of the Navy. These studies included an Initial Assessment Study and a Confirmation Study under the DoN's Installation Restoration Program. The studies included soil investigations at Site 6 (Lots 201 and 203), groundwater investigations at Sites 6, 9, and 82 and surface water/sediment investigations at Wallace Creek and Bear Head Creek.

Soil samples collected from shallow borings at Lot 201 and 203 were analyzed for pesticides. Low levels of pesticides ranging in concentration from 1.3 µg/kg to 770 µg/kg were detected in almost all of the soil samples. Groundwater samples collected from eight shallow monitoring wells at Site 6 revealed low levels of volatile organic compounds such as carbon disulfide and

chloromethane in well 6GW6, which is located to the east of Lot 201. In addition, low levels of benzene and 1,1,2,2-tetrachloroethane were detected in well 6GW1, which is located just north of Lot 203. Further investigation of nearby water supply wells revealed elevated levels of trichloroethene (TCE), vinyl chloride, 1,2-dichloroethene, and tetrachloroethene (PCE) in supply wells HP-651 and HP-653. These wells are located east of Piney Green Road near Lot 203. The supply wells are screened to a depth of approximately 200 feet. The wells are no longer in operation due to elevated levels of volatile organic compounds (VOCs).

Three shallow monitoring wells were installed at Site 9. Groundwater samples were collected in 1984, 1986, and 1987. In addition, one sample was collected in 1984 from a nearby supply well. No contamination was detected in the supply well. Low levels of phenol were detected in all three shallow monitoring wells. In addition, low levels of lead and chromium were detected in all three wells.

Upstream and downstream surface water samples were collected from Wallace Creek and Bear Head Creek. Surface water samples collected from Wallace Creek revealed elevated levels of VOCs such as TCE, vinyl chloride, and 1,2-dichloroethene. No organic contamination was detected in Bear Head Creek. Sediment samples collected from Bear Head Creek revealed low levels of pesticides (13 to 75 µg/kg) both upstream and downstream from Site 6. No pesticides were detected in either sample collected from Wallace Creek. However, PAHs (1,990 µg/kg total) were detected in the downstream sediment sample collected near Holcomb Boulevard.

Site 82

A Site Inspection (SI) was conducted at Site 82 in June, 1991 by Halliburton NUS Environmental Corporation (NUS). The investigation was initiated based on results from an Environmental Science and Engineering (ES&E) field investigation in 1986 (the investigation was conducted as part of a study for Site 6). During this investigation, surface water samples collected from Wallace Creek contained VOCs. It was determined that the source of the VOCs in Wallace Creek most likely did not originate from Site 6 (Lot 203). Subsequently a new site, Site 82, was created to investigate the source of the VOCs (NUS, 1992).

The investigation conducted by NUS consisted of installing six shallow soil borings and three shallow monitoring wells, soil and groundwater sampling, and surface water and sediment sampling (Wallace Creek). Results from the investigation indicated positive detections of

organic contamination in all of the media sampled. Pesticides (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, endosulfan II, and dieldrin) were detected in soil (33 to 110 µg/kg) and sediment (12 to 69 µg/kg) samples with lower levels in surface water and groundwater. PCB (PCB-1260 and PCB-1242) contamination was also present in soil (150 to 1,900 µg/kg), groundwater (15 µg/l), surface water (80 µg/l), and sediments (220 to 700 µg/kg). Further, levels of TCE (3 to 74 µg/l), 1,2-dichloroethene (6 to 64 µg/l), and vinyl chloride (11 µg/l) were detected in surface water samples. No VOCs were detected in any of the wells sampled.

REMEDIAL INVESTIGATION ACTIVITIES

A Remedial Investigation (RI) was conducted at Operable Unit No. 2 beginning in August 1992 (Final Project Plans were submitted in May 1992). The RI focused on various areas of concern within Operable Unit No. 2 including: Lot 201, Lot 203, the wooded areas surrounding both storage lots, the ravine north of Lot 203, Site 9, Site 82, Wallace Creek, and Bear Head Creek. Moreover, the investigation was conducted in two phases of work: Phase I (August through November 1992) and Phase II (February through May 1993). The Phase II study primarily focused on Site 82, where deep groundwater contamination was identified during the Phase I Study.

The soil investigation focused the reported disposal areas within Lot 201 and Lot 203. Sampling grids were established at the following areas:

- Two reported pesticide storage areas within Lot 201
- A reported PCB storage area within Lot 201
- A reported pesticide disposal area within Lot 203
- A reported PCB disposal area within Lot 203

In addition, the soil investigation focused on other portions of Operable Unit No. 2 that were determined to be environmental concerns based on site reconnaissances and review of historical photographs. Sampling grids were established at the following areas:

- The wooded areas to the north, east, and south of Lot 201
- Site 82
- The fenced-in portion of Lot 203
- The ravine north of Lot 203

Two sampling grids were also established at Site 9 to evaluate potential soil contamination. The grids were established at:

- The fire training pit and oil/water separator
- Aboveground storage tanks

The grid points were surveyed by a licensed surveyor prior to initiating the soil investigation. Shallow borings were augered at each grid point and soil samples were collected at 2-foot continuous intervals until the water table was encountered. The majority of the samples were analyzed for full Target Compound List (TCL) organics and Target Analyte List (TAL) inorganics. In areas where a certain contaminant was expected based on existing information (e.g., pesticide disposal area at Lot 203), the majority of samples were analyzed for that particular contaminant of concern (e.g.,TCL pesticides); however, at least ten percent of samples collected from these areas were analyzed for full TCL organics and TAL inorganics.

The groundwater investigation focused on evaluating surficial and deep groundwater quality at Operable Unit No. 2. Shallow wells were installed in the wooded areas, Site 82 Lot 201, Lot 203, and Site 9. Deep groundwater wells were installed at Site 9, Lot 201, Lot 203, and Site 82. Groundwater samples were analyzed for full TCL organics and TAL inorganics (total and dissolved metals analysis). Furthermore, two rounds of samples were collected from the Phase I and existing wells, and one round of samples were collected from the Phase II wells. The groundwater investigation also included three to four rounds of water level measurements. These measurements included staff gauges that were installed in Bear Head Creek and Wallace Creek.

Placement of monitoring wells was based on reported storage/disposal areas, results of a geophysical investigation conducted at Lot 203, and review of historical aerial photographs produced by the U.S. Environmental Protection Agency (EPA) Environmental Photographic Interpretation Center (EPIC). Additionally, the placement of the Phase II shallow wells were based on the results of a soil gas survey and placement of the Phase II deep wells were based on the results of the Phase I analytical results.

Surface water and sediment investigations were conducted in Bear Head Creek, Wallace Creek, and the ravine. Surface and subsurface sediment samples were collected from the middle portion of the stream as well as from the stream bank. Deep surface water samples

were collected when the depth of water exceeded five feet. All samples were analyzed for full TCL organics and TAL inorganics.

An aquatic survey was also conducted at Wallace Creek and Bear Head Creek. Fish population studies, fish tissue analysis, and benthic population studies were conducted in both streams. Representative fish tissue samples were submitted for full TCL organics and TAL inorganics analysis.

In addition to these studies, an ordnance survey was required at Lot 203 and the wooded areas surrounding Lot 203 due to the presence of surface and subsurface unexploded ordnance (UXO). On two occasions, the MCB Camp Lejeune ordnance specialists were contacted to examine UXO. In both cases, the devices were not determined to present a hazard.

PHYSICAL CHARACTERISTICS OF OPERABLE UNIT NO. 2

Surface Water Hydrology

OU No. 2 is located approximately 1.75 miles east of the New River and 12.5 miles north of the New River's outlet into the Atlantic Ocean. Two drainages exist within and adjacent to Sites 6 and 82. Wallace Creek forms the northern border of Site 82 and flows in a southwesterly direction toward the New River. An estimated flow rate of 14.4 cubic feet per second (CFS) or 6,463 gallons per minute (gpm) was calculated based on Manning's equation. Wallace Creek is surrounded by marsh that exhibits extensive surface ponding. Based on staff gauge measurements, it was determined that Wallace Creek is a gaining stream (i.e., receives groundwater discharge). Moreover, the portion of Wallace Creek adjacent to OU No. 2 appears to be slightly effected by tidal changes on the New River based on visual observations. Bear Head Creek lies within the southern portion of Site 6 and empties into Wallace Creek approximately 0.75 miles downstream from the site.

The NC DEHNR classifies bodies of water within the state according to their designated use. Wallace Creek from its source to the New River and Bear Head Creek from its source to Wallace Creek are designated as Class SB NSW (Nutrient Sensitive Waters) surface waters. The Class SB NSW designation denotes tidal saltwaters protected for primary recreation, fishing and for the propagation and survival of aquatic life.

Geology

MCB Camp Lejeune is located in the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast. Regionally, they comprise 10 aquifers and nine confining units which overlie igneous and metamorphic basement rocks of pre-Cretaceous age. These sediments were deposited in marine or near-marine (i.e., coastal plain) environments and range in age from early Cretaceous to Quaternary time.

Surficial soil conditions are generally uniform throughout OU No. 2. In general, surficial soils consist of unconsolidated deposits of silty and clayey sand, silt, and clay. These soils represent the Quaternary "undifferentiated" formation which characterizes the surficial aquifer.

Several areas investigated within OU No. 2 contain large amounts of fill or reworked material. These materials were encountered throughout Lot 201, Lot 203, and portions of Site 9. Historical aerial photographs revealed that soils within and adjacent to the Lot 203 have been excavated and reworked extensively over the years. Soil boring data indicates that fill material exists in these areas to depths greater than five feet bgs in some cases.

Soils were classified during the drilling program to a maximum depth of 236 feet bgs. Additional information on deep subsurface soil conditions to 310 feet bgs was also obtained from boring logs of supply wells in the area. Deeper subsurface soils (below 35 feet) are also generally consistent throughout the site. In general, the deeper subsurface soils consist of fine to medium-grained silty sand, silt, silty-sandy clay, and sandy-marly limestone fragments (gravel size). The appearance and classification of the deeper sands are similar to that described for the surficial sands. Below a depth of 50 to 60 feet, however, the sands become very dense to hard (blow counts above 50). Large amounts of shell fragments were noted frequently in the sands. Thin lenses of clay are interbedded within the sands.

The upper silty sand unit, which is encountered from the ground surface, ranges in thickness from approximately 40 to 140 feet. This silty sand unit is thickest in the northern portion of the site and decreases toward the southern portion of the site. Within the upper silty sand unit, thin discontinuous layers of clay (borings HP-653 and 6GW2D) and limestone (boring HP-635) are present. The clay varies in thickness from approximately 2 to 10 feet while the limestone varies in thickness from approximately 3 to 5 feet.

Underlying the upper silty sand is a limestone unit. The limestone unit varies in thickness from approximately 5 feet near the southern portion of the site to 80 feet near the northern portion of the site. Silty sands (lower unit) underlie the limestone unit to a depth of 310 feet bgs (estimated depth). At boring location HP-651, discontinuous layers of clay (approximately 10 feet thick) and limestone (approximately 10 feet) are present at 230 feet and 250 feet deep, respectively. This clay layer also encountered as soil boring/well 6GW1DA at approximately 230 feet.

Hydrogeology

The surficial aquifer is a series of sediments, primarily sand and clay, which commonly extend to depths of 50 to 100 feet. This unit is not used for water supply at MCB Camp Lejeune.

The principal water supply aquifer for the Base is the series of sand and limestone beds that occur between 50 and 300 feet below land surface. This series of sediments generally is known as the Castle Hayne aquifer. The Castle Hayne aquifer is about 150 to 350 feet thick in the area and is the most productive aquifer in North Carolina.

Onslow County and Camp Lejeune lie in an area where the Castle Hayne aquifer contains freshwater, although the proximity of saltwater in deeper layers just below the aquifer and in the New River estuary is of concern in managing water withdrawals from the aquifer.

Surficial groundwater flow patterns in the vicinity of OU No. 2 were evaluated by a network of existing and newly installed shallow monitoring wells (less than 33 feet), and staff gauges installed in Bear Head Creek and Wallace Creek. Groundwater was encountered during the drilling program at varying depths throughout OU No. 2. This variation in groundwater depths is attributed to topographic (i.e., land surface elevations) changes. A high water table (i.e., less than 2 feet bgs) was typically encountered near the banks of Wallace Creek and Bear Head Creek while a lower water table (i.e., greater than 15 feet bgs) was encountered in the vicinity of Site 82 (e.g., vicinities of well clusters 6GW1S/D and 6GW28S/D). An average depth of groundwater across OU No. 2 is approximately 8 feet. A groundwater divide occurs near the north central portion of OU No. 2. Groundwater on the north side of the divide is flowing northwest toward Wallace Creek while groundwater on the south side of the divide is flowing southwest toward Bear Head Creek.

Groundwater elevations (measured from top of PVC casing reference points) ranged from 1.03 feet [well 82MW2 (10/26/92) located near Wallace Creek] to 29.39 [well 6GW2S (4/1/93) located east of Lot 203 across Piney Green Road] feet above msl. Water levels fluctuated between 0.7 and 5.59 feet over a seven month period. In general, the highest water levels were noted on April 1, 1993 and the lowest water levels were noted on November 7, 1993.

The data suggest that the groundwater in the area is most likely not affected by tidal changes on Wallace Creek which were observed to be minimal adjacent to OU No. 2. Water level data was collected over a 24-hour period from monitoring well 6GW28S. Water levels were fairly constant over a 24-hour period as a change of only 0.06-feet was observed. This very small change in water level is most likely the result of normal daily fluctuations, which can be attributed to barometric effects (i.e., atmospheric pressure).

Site-specific surficial and deep aquifer hydraulic characteristics [i.e., hydraulic conductivity (K), transmissivity (T), and storativity (S)] were not evaluated during this investigation. A recent hydrogeologic investigation conducted by Baker (February, 1993) at Hadnot Point (less than 1/2 miles from OU No. 2) provided estimates of T, S, and K within the surficial water-bearing zones. Aquifer pump and recovery test results indicate an average T of 561 gallons/day/feet (75 feet^2/day), an average K of 21 gallons/day/feet (2.8 feet/day or 8.0 x 10^{-4} cm/sec), and an average S of 0.015 for the surficial silty-sands (10 to 25 feet bgs). A very low flow rate of less than 2 gpm was maintained during this test. Slightly higher flow rates of 2 to 4 gpm were observed from shallow well development during the field investigation at OU No. 2.

Deeper groundwater flow patterns in the vicinity of OU No. 2 were evaluated by a network of deep monitoring wells (maximum depth of 230 feet bgs). The deep monitoring well network extends from north of Wallace Creek to Site 9, and east of Piney Green Road to Holcomb Boulevard. Additionally, aquifer hydraulic characteristic data from the deeper water-bearing zones were obtained from well production tests (i.e., also commonly referred to as "well acceptance tests") performed on water supply wells HP-651 and HP-636, which are located along Piney Green Road.

Three rounds of groundwater level measurements were obtained from the deep monitoring wells. Groundwater elevations (measured from top of casing reference points) ranged from 9.06 feet [well 6GW37D (4/1/93) located near the western boundary of Site 82] to 19.13 [well

6GW2D (4/1/93)] located east of Piney Green Road) feet above msl. Water levels fluctuated between 2.20 and 5.17 feet over a six month period.

Water level data was also collected over a 24-hour period from deep monitoring well 6GW28D. The water level was also fairly constant over a 24-hour period as a change of only 0.05-feet was observed. This very small change in water level is most likely the result of normal daily fluctuations. Further, the data suggests that groundwater in the vicinity of OU No. 2 is most likely not affected by tidal changes on Wallace Creek which were observed to be minimal.

Deep groundwater is flowing toward the west with local penetrations toward the general directions of Wallace Creek and Bear Head Creek. The estimated groundwater gradients calculated are within the same magnitude across OU No. 2. The average groundwater gradients in the vicinity of Wallace Creek and the north-central portion of the site are 0.003 and 0.0042, respectively.

Overall, the deep and surficial groundwater flow patterns at OU No. 2 exhibit a similar trend. Subsequently, this trend may suggest that the surficial and deeper water-bearing zones are at a minimum partly hydraulically interconnected. Although some clay layers underlie the site (i.e., boring 6GW2D from 25 to 27 feet bgs) which may impede vertical groundwater movement, these clay layers are discontinuous and are characterized as leaky semi-confining. Accordingly groundwater recharging the surficial water-bearing zones will, over time, migrate vertically into the deeper soils.

NATURE AND EXTENT OF CONTAMINATION

Site 6, Lot 201

Pesticides (4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) were detected in more than half of the surface soil samples collected at the three sampling grids and in approximately one-third of the subsurface soil samples. The majority of the pesticide concentrations were below 100 µg/kg. Some of the pesticides were detected in areas where pesticides were not reportedly stored or handled (i.e., the PCB storage area at grid C).

At only two sampling locations, soil boring SB16 and SB17, did the pesticide levels exceed one part per million (1,000 µg/kg). Soil borings SB16 and SB17 are located in the northeast corner

of sampling grid A, which was reported to be one of two former pesticide storage areas within Lot 201 (the other area is where grid B was established).

Pesticide contamination at soil borings SB16 and SB17 is significant, indicating that this area may have been used to dispose of unused pesticides. It is also possible that this area was impacted via incidental spills from the containers/drums which contained the pesticides. Pesticide levels in surface soils were as high as 1,200,000 µg/kg for 4,4-DDT (soil boring SB17). Pesticides have migrated to subsurface soils as evidenced by elevated levels of pesticides (460,000 µg/kg of 4,4'-DDT) in subsurface soil samples collected from soil boring SB17. However, no pesticides were detected in groundwater at Lot 201.

Subsurface soil samples collected from SB17 also exhibited elevated levels of total xylene (54,000 µg/kg), ethylbenzene (2,800 µg/kg), naphthalene (38,000 µg/kg), and 2-methylnaphthalene (97,000 µg/kg). These constituents were only detected at one location within Lot 201 (i.e., soil boring SB17). Because these constituents are petroleum based, they may be associated with the pesticides since petroleum-based pesticides were used at MCB Camp Lejeune. None of these constituents were detected in nearby monitoring wells.

Polychlorinated biphenyls (PCBs) were detected in only 3 of 87 samples analyzed at Lot 201. The soil sample collected from soil borings SB13 and SB24 within grid A, and from soil boring SB24 within grid B, exhibited PCB contamination. The only elevated PCB level was detected at a concentration of 1,800 µg/kg in the surface soil at boring SB24 within grid A. No PCBs were detected at grid C, which was established over the area where transformers were reportedly stored. The extent of PCB contamination is limited to a few random areas within Lot 201. In addition, no PCBs were detected in groundwater.

With respect to inorganic contaminants in soil, contaminant levels were comparable to other areas within OU No. 2 (i.e., the wooded area, Lot 203, Site 9). Samples (located west of Lot 201) collected from Lot 201 background borings SB38 and SB39 indicated inorganic concentrations within the range of background levels at Camp Lejeune. Therefore, it does not appear that inorganic concentrations in soil are elevated as a result of former waste handling activities at Lot 201.

Groundwater at Lot 201 does not appear to be impacted via former pesticide or transformer storage practices. However, monitoring well 6GW22, which is located within grid A of Lot 201 (i.e., the former pesticide storage area), exhibited TCE at 1.2 µg/l. The source of TCE is

unknown. Soil samples collected from borings within grid A as well as from the monitoring well borehole did not detect TCE or PCE. The extent of TCE in groundwater is believed to be local since no other well downgradient of this area exhibited TCE contamination.

Site 6, Lot 203

The pesticides 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT were detected throughout Lot 203. Only one out of approximately 58 surface soil sampling locations within Lot 203 did the level of pesticides exceed 1,000 µg/kg (soil boring SB30 exhibited 4,4'-DDE and 4,4'-DDT at 2,100 µg/kg and 1,500 µg/kg, respectively). Samples collected from the "DDT" grid, which was established over an area where pesticides were reportedly disposed of, only revealed maximum concentrations of 540 µg/kg, 180 µg/kg, and 770 µg/kg for 4,4'-DDE, 4,4'-DDD, and 4,4'-DDT, respectively. All three maximum values were detected at soil boring SB18 within the "DDT" grid.

As with Lot 201 and the wooded areas surrounding these lots, the majority of the pesticide levels were below 100 µg/kg. The widespread distribution and low levels present on Lot 203 are indicative of former pesticide control practices rather than pesticide disposal. Only at soil boring SB30 (and possibly at SB18 within the "DDT" grid) did the results indicate that pesticides may have been disposed of in that area of Lot 203. Subsurface soil samples collected from this boring, however, exhibited pesticide levels below 500 µg/kg. Pesticides were not present in any groundwater samples (throughout Lot 203 and OU No. 2), indicating that pesticides are relatively immobile in the environment.

Polychlorinated biphenyls (PCBs) were detected at 12 out of 40 sampling locations within Lot 203. The most frequently detected PCB was PCB-1260, which was detected at all 12 locations ranging in concentration from 17 to 42,000 µg/kg. However, only at soil borings SB24, SB26, and SB38 did the PCB levels exceed 1,000 µg/kg. The most elevated concentration, 42,000 µg/kg of PCB-1260, was detected in the surface soil at soil boring SB24. Soil boring SB24 is located along the former railroad spur where historical photographs revealed significant anomalies that may be associated with waste handling and disposal. Subsurface soil samples at this location revealed 72 µg/kg of PCB-1260. Monitoring well 6GW11, which is located within 10 feet of soil boring SB24, did not exhibit organic contamination. Soil samples collected from monitoring well borehole 6GW11 did not exhibit PCB contamination.

Subsurface soil samples collected throughout Lot 203 exhibited PCBs in only three samples. The most elevated concentration of PCB-1260 was detected at soil boring SB22 at a level of 29,000 µg/kg. The surface soil sample collected from this boring did not exhibit any organic contamination. This boring is located in the north central portion of Lot 203 near monitoring well 6GW15S. Soil samples collected from monitoring well borehole 6GW15S did not exhibit PCB contamination. Additionally, groundwater samples collected from this well did not exhibit any PCB constituents; however, low levels of TCE (1.9J µg/l) were present in this well.

Soil samples collected from the northeast corner of Lot 203, which was reported to be an area where PCBs were disposed of, did not exhibit elevated levels of PCBs. Only 4 surface soil samples and one subsurface soil sample exhibited PCB-1260 (19J µg/kg to 53 µg/kg). The sampling locations which exhibited PCBs included soil borings SB3, SB6, SB10, and SB13.

The majority of semivolatile organic compounds (SVOCs) detected at Lot 203 were PAHs. PAHs were primarily detected at nine surface soil sampling locations throughout Lot 203 (i.e., these sampling stations exhibited several PAH constituents as opposed to only one or two PAH constituents). Only one of these locations, soil boring SB38, exhibited contaminant levels above 1,000 µg/kg (at this location, approximately 16,000 µg/kg total PAHs were detected in surface soil). This location also exhibited elevated levels of PCB-1254 (2,100 µg/kg) in surface soil as discussed previously. Subsurface soil samples collected from soil boring SB38 did not exhibit PAH contamination.

Elevated levels of PAH constituents in the subsurface soil at Lot 203 were detected only at soil boring SB22 and soil boring SB41. Approximately 36,000 µg/kg total PAHs were detected at SB22 and approximately 11,000 total PAHs were detected at SB41. Soil boring SB22 also exhibited elevated levels of PCB-1260 (29,000 µg/kg) in the subsurface soil. Soil boring SB22 is located in the north central portion of Lot 203 (near well 6GW15) and soil boring SB41 is located just south of the former railroad spur. Based on the analytical results, it appears that these areas may be associated with waste disposal activities at Lot 203.

The more mobile SVOCs including 1,2-dichlorobenzene, and naphthalene were detected in elevated levels at surface soil samples collected from soil boring SB39, which is located along the former railroad spur. In addition, the PAH constituent acenaphthene was detected at this location at a concentration of 9,500 µg/kg. These SVOCs were detected at a total concentration of approximately 16,000 µg/kg (total SVOC). Subsurface soil samples collected from this boring did not reveal any organic contamination.

Inorganic constituents in soil at Lot 203 were comparable to inorganic levels detected throughout OU No. 2. However, most of the inorganic constituents were detected above background levels.

Groundwater quality at Lot 203 has not been significantly impacted from previous disposal and storage practices. As mentioned above, well 6GW15S, which is located in the north central portion of Lot 203 exhibited low levels of TCE (1.9J µg/l) and total chromium (103 µg/l). Dissolved chromium levels were not detected. Well 6GW11, located near the former railroad spur, was not contaminated. Well 6GW3, located near the ravine, and well 6GW23, located in the southern portion of Lot 203, exhibited levels (i.e., less than 1 µg/l) of PCE and TCE, and total chromium (201 µg/l). The source of the elevated levels of total chromium (above the NCWQS of 50 µg/l) detected in wells 6GW15S and 6GW3 is unknown based on the absence of elevated chromium levels in soil analyses.

Wooded Areas, the Ravine, and Site 82

The wooded areas of Lot 203 can be described as those areas which surround Lot 201 to the north, east, and south, and the area between Lot 203 and Wallace Creek. The area between Lot 203 and Wallace Creek is Site 82. The ravine begins in the northern portion of Lot 203 bisects Site 82 and extends to Wallace Creek. These areas will be discussed separately below.

Wooded Area East of Lot 201

The wooded area east of Lot 201 is primarily contaminated with low levels of pesticides in surface soil (11 locations with a maximum detection of 240 µg/kg of 4,4'-DDT at soil boring SB12), low levels of PAHs in surface soil [5 locations with a maximum detection of approximately 2,000 µg/kg total PAHs (principal constituent was pyrene at 410 µg/kg) at soil boring SB16], and elevated levels of PCB-1260 (26,000 µg/kg) at soil boring SB15. Two other sampling locations, soil borings SB18 and SB21, exhibited low levels of PCB-1260 (less than 300 µg/kg). A subsurface soil sample collected from soil boring SB18 also exhibited low levels of PCB-1260 (83J µg/kg). The three sampling locations where PCB-1260 was detected are all located adjacent to each other along Piney Green Road. According to the EPIC report, this area once served as a training area as noted by the presence of tents and roadways in one of the historical photographs. There is no known or documented waste storage or disposal areas in this section of OU No. 2.

Three other locations in the woods east of Lot 201 exhibited PCB contamination in subsurface soils (no PCBs were detected in surface soil samples from these locations). Low levels of PCB-1260 (46J µg/kg to 100 µg/kg) were detected in subsurface soil samples collected from soil borings SB1, SB17, and SB5. Soil boring SB17 is located approximately 200 feet west of SB18. Soil borings SB1 and SB5 are located over a thousand feet north of the area where PCBs were detected in surface soil near Piney Green Road.

Inorganic levels in soil are comparable to other portions of OU No. 2. No elevated levels were detected at this section of OU No. 2.

Four monitoring wells are located in this section of OU No. 2 (wells 6GW6, 6GW14, 6GW17, and 6GW18). Groundwater quality in the wooded area east of Lot 201 does not appear to have been impacted by either organic or inorganic contamination. No organic or inorganic constituents above Federal or State standards were detected in these four wells.

Wooded Area North of Lot 201

The wooded area north of Lot 201 is bordered to the south by Lot 201, to the north by Lot 203, to the east by Piney Green Road, and to the west by the railroad tracks. Site reconnaissances conducted in this area, as well as test pit excavations, have revealed empty drums on the surface, buried ordnance (only casings and not unexploded ordnance), numerous 5-gallon canisters possibly containing liquid wastes, and debris (e.g., communication wire, bivouac wastes, etc.).

Low levels of pesticides (2.2J µg/kg to 500 µg/kg) were detected in eight of the ten surface soil samples collected during the drilling of test borings. With the exception of the one occurrence of 4,4'-DDE at soil boring SB1, no pesticide contaminant level exceeded 100 µg/kg. Subsurface soil samples collected from this area revealed low levels (i.e., less than 10 µg/kg) of 4,4'-DDT and 4,4'-DDE at two soil borings (SB4 and SB12).

In addition to the low levels of pesticides in a few subsurface soil samples, low levels of benzene (1.0 J µg/kg) and toluene (1.0 J µg/kg) were detected at soil boring SB10.

PCB-1260 was detected at low levels (800 µg/kg) in surface soil at boring SB1. Subsurface soil samples collected from this area did not exhibit PCB contamination.

Low levels of PAHs [approximately 1,700 µg/kg total PAH (principal constituent was butyl benzyl phthalate at 390J µg/kg)] were detected in only one surface soil sample collected at soil boring SB1. PAHs were not detected in any subsurface samples from this area.

Soil boring SB1 exhibited the most contamination in the wooded area north of Lot 201. This boring is located in the northwest section of the woods near Lot 203.

Inorganic concentrations in soil were comparable to other portions of OU No. 2. There were no occurrences of inorganic levels that were an order of magnitude higher than either background levels of other areas (e.g., Lot 201, Lot 203, etc.).

Groundwater quality in this portion of OU No. 2 has been impacted. Two of the six wells in this area (wells 6GW16 and 6GW25) exhibited low levels of organic contamination. Chlorobenzene (maximum of 8,500 µg/l), chloroform (maximum of 20 µg/l), 1,1,2,2-tetrachloroethane (maximum of 60 µg/l), phenol (1.0 µg/l), and 2-chlorophenol (5.0 J µg/l) were detected in well 6GW16. This well was installed near a test pit which revealed numerous 5-gallon canisters containing liquids. Well 6GW25, which is located approximately 1,000 feet upgradient of well 6GW16, exhibited levels of phenol (2.0 J µg/l), chlorobenzene (110 µg/l), and chloroform (1.6 µg/l).

Wooded Area to the South of Lot 201

The wooded area to the south of Lot 201 encompasses the area on both sides of Bear Head Creek and separates Lot 201 from Site 9. Various dirt roads are present throughout these woods. General debris including empty 55-gallon drums, construction debris, and garbage were noted throughout this area.

Pesticides were detected in all surface soil samples collected from this area. Only one location, soil boring SB8, exhibited elevated levels of 4,4'-DDE (4,200 µg/kg), 4,4'-DDT (6,400 µg/kg), and 4,4'-DDD (12,000 µg/kg). The other surface soil samples exhibited pesticides levels well below 200 µg/kg. Soil boring SB8 is located near Piney Green Road approximately 100 feet south of Bear Head Creek. The pesticide 4,4'-DDE was detected in subsurface soil at soil borings SB1 (5.0 µg/kg) and SB6 (3.9J µg/kg).

The only other contamination detected in surface soils were low levels of PAHs (less than 240 µg/kg total PAH) in three samples (soil borings SB11, SB5, and SB8). No PAHs were detected in subsurface soils.

Inorganic compounds were detected in soil at levels that were comparable to other portions of OU No. 2.

Groundwater quality in the wooded area south of Lot 201 does not appear to have been impacted by either organic or inorganic contamination. Five shallow monitoring wells were constructed to monitor groundwater quality in this area. No organics or inorganics were detected above Federal or State standards.

Site 82

Site 82 encompasses the area south of Wallace Creek, west of Piney Green Road, and east of Holcomb Boulevard. The ravine area bisects this portion of OU No. 2. The ravine will be discussed separately.

Low levels of pesticides were detected in the majority of surface soil samples collected from this area. With the exception of surface soil samples collected from soil boring SB1 (1,150 µg/kg total pesticides) and soil boring SB7 (350 µg/kg total pesticides), pesticide levels were below 100 µg/kg for total pesticide concentrations. Subsurface soil samples collected from this area revealed low levels of pesticides (53 µg/kg maximum) in only four samples.

PAHs were detected in only three surface soil samples from this area of OU No. 2. Surface soil samples collected from soil borings SB1 (710 µg/kg total PAH), SB16 (2,420 µg/kg total PAH), and SB7 (380 µg/kg total PAH) revealed low to moderate levels of PAHs. Subsurface soil samples collected from this area revealed PAHs in only one sample collected from soil boring SB7 (587 µg/kg total PAH). Soil boring SB7, which exhibited PAHs at the surface and subsurface, is located near the bottom section of the ravine area. The contamination in this area may be due to surface runoff from the ravine. The ravine exhibited elevated levels of PAHs throughout.

PCB-1260 was detected in only one sample in this portion of OU No. 2. The surface soil sample collected from boring SB17 revealed a concentration of only 3.9 µg/kg. This boring is located just north of Lot 203 near Piney Green Road. The section of Lot 203 to the south of soil boring

SB17 is reportedly where PCBs were disposed of. As discussed previously in Section 4.3.2, no significant levels of PCBs were detected in this portion of Lot 203.

Elevated levels of volatile organic compounds (VOCs) were detected in surface soil samples collected from soil borings SB12 and SB6. Total VOC concentrations in these surface soil samples were approximately 78,000 µg/kg at SB6 and approximately 8,400 µg/kg at SB12. Subsurface soil was contaminated with VOCs at SB12 (approximately 17,000 µg/kg total VOC). Both of these borings are located approximately 300 feet west of Piney Green Road. The borings are approximately 300 feet apart. Based on these results, solvents may have been disposed of within this portion of OU No. 2.

Inorganic levels in soil did not appear to be significantly higher than other portions of OU No. 2.

Surficial groundwater quality has been adversely impacted with volatile organic contamination, primarily TCE, PCE, 1,2-dichloroethene, and 1,1,2,2-tetrachloroethane. Surficial groundwater contamination was evidenced in wells 6GW1S, 82MW1, 82MW2, 6GW28S, 6GW32, and 6GW34. The most significant levels of VOCs were detected in wells 6GW32 (2,200 µg/l of total 1,2-dichloroethene, 74 µg/l of PCE, and 1,500 µg/l of TCE) and 6GW34 (410 µg/l of total 1,2-dichloroethene, 9,600 µg/l of PCE, and 610 µg/l of TCE). Well 6GW34 is located approximately 100 feet west of soil borings SB6 and SB12, which exhibited elevated levels of VOCs in soil samples. Lower levels of VOCs were detected upgradient of well 6GW34 in samples collected from wells 6GW1S and 6GW15 (well 6GW15S is located in the northeast section of Lot 203). Additionally, two of the three temporary wells, which were located downgradient of well 6GW32, exhibited elevated concentrations of volatiles. Several surface water samples, collected from Wallace Creek also exhibited VOCs indicating that the source of VOC contamination in Wallace Creek is most likely groundwater discharge. Monitoring wells 82MW1 and 82MW2, which are located west and northeast of well 6GW32, only exhibited low levels of 1,1,1-trichloroethane (0.5J µg/l) and vinyl chloride (1.6 µg/l), respectively.

Deep groundwater quality is severely impacted with VOC contamination. Monitoring wells 6GW1D, 6GW1DA, 6GW28D, 6GW27D, and 6GW37D exhibited elevated levels of TCE (60 to 58,000 µg/l), PCE (60 to 58,000 µg/l), and total 1,2-dichloroethane (120 to 2,600 µg/l). The highest levels were detected in well 6GW1D.

Surficial groundwater contamination at 6GW1S, which is located next to 6GW1D, did not exhibit levels that would correlate with the significant VOC contamination in the deep groundwater. Supply well HP-651, which is located just east of Piney Green Road approximately 500 feet east of well 6GW1D, also exhibited VOC contamination. This well is approximately 199 feet deep (screened from varying depths between 125 and 194 feet) and is no longer in operation.

The horizontal and vertical extent of deep groundwater contamination has been evaluated. The horizontal extent of off-site contamination west of Site 82 (beyond well 6GW37D), however, has not been fully defined. Moreover, the vertical extent has been evaluated to a depth of 230 feet at only one location. It is unknown at this time whether contamination extends below 230 feet. A clay layer is present as approximately 230 feet deep which may impede the vertical migration of contamination.

Ravine Area

The ravine area begins at the northern fenceline of Lot 203. In the upper portion of the ravine, the banks are steep and covered with debris including empty and partially full 55-gallon drums and other smaller containers. Some of these containers indicated that they contained "DDT" and were dated back to the 1950s. Going northward towards Wallace Creek, the ravine gradually becomes less steep.

Samples collected from the banks of the ravine were identified as soil samples. Samples collected from the middle of the ravine were identified as sediment samples. Specific groundwater quality was not evaluated in the ravine area, however, several surface water samples were collected. The ravine is intermittent in nature. During the wet season, groundwater discharges into the ravine (along with surface runoff). During the dryer seasons, the ravine only receives runoff during rain showers.

The majority of surface soil samples collected from the ravine exhibited low levels of 4,4-DDE (7.5 to 220 µg/kg), 4,4'-DDD (14 to 19 µg/kg), and 4,4'-DDT (25 to 510 µg/kg). These levels are comparable to many of the other pesticide levels in surface soil throughout Operable Unit No. 2. Subsurface soil samples collected from the ravine exhibited lower levels than in the surface soil.

PCB-1260 was detected in one surface soil sample at a concentration of 180 µg/kg (soil boring SB10). None of the subsurface soil samples exhibited PCB contamination.

PAHs were detected at elevated levels in several surface soil samples. Elevated levels of PAHs were detected in surface soil samples collected from soil borings SB11 (15,931 µg/kg), SB14 (9,301 µg/kg), and SB6 (6,020 µg/kg). These soil borings are located in an area where a substantial amount of debris has been disposed of into the ravine. Based on these results, wastes disposed of into the ravine have impacted soil quality. PAHs were also detected in two subsurface soil samples collected from soil boring SB13 (271 µg/kg) and SB14 (344 µg/kg). Soil boring SB13 also exhibited elevated levels of the semi-volatiles isophorone (7,700 µg/kg), naphthalene (9,600 µg/kg), 2-methylnaphthalene (11,000 µg/kg), and VOCs including 4-methyl-2-pentanone (2,000J µg/kg) and total xylenes (950 µg/kg). Soil borings SB13 and SB14 are also located in the southern portion of the ravine (near Lot 203) where debris is present along the banks of the ravine.

Inorganic constituents exhibited similar levels in both surface and subsurface soil and were comparable to other portions of OU No. 2.

Sediment samples were collected at eight sampling stations from the ravine along with surface water samples. As mentioned previously, the ravine is intermittent in nature. Two of the proposed eight sampling stations did not contain water and therefore, no surface water sample could be collected. With the exception of sampling station RV8, all of the surface and subsurface sediment samples exhibited low levels of 4,4'-DDD (4.1 to 45 µg/kg), 4,4'-DDE (23 to 120 µg/kg), and 4,4'-DDT (14 to 210 µg/kg). These levels are comparable to pesticide levels detected in soil throughout OU No. 2. Elevated levels of PAHs were detected at sampling station RV2 (12,573 µg/kg total PAHs), which is located in the southern portion of the ravine where debris is present. Lower levels of PAHs were detected in sediment samples collected from sampling stations RV1, RV3, and RV8.

Six of the eight sediment sampling stations exhibited low levels of PCBs. PCB-1260 was detected in the range of 19 µg/kg to 360 µg/kg.

None of the surface water samples collected from the ravine exhibited organic contamination.

Site 9

Surface and subsurface samples collected from Site 9 revealed low levels of pesticides, VOCs, and SVOCs. Inorganic levels were comparable to other portions of OU No. 2 and therefore do not appear to be present due to fire-fighting training at Site 9.

Pesticides (4,4'-DDE and 4,4'-DDT) were detected in five surface soil samples and eight subsurface soil samples. The most contaminated sample was collected from soil boring SB1, which exhibited 650 µg/kg of 4,4'-DDE and 570 µg/kg of 4,4'-DDT. The remaining samples (surface and subsurface soil) exhibited levels of pesticides in the range of 4 µg/kg to 62 µg/kg. Overall, pesticide levels in surface and subsurface soils were comparable to other areas of OU No. 2.

Soil boring SB1 was the only location where PAH constituents were detected in surface soil. Pyrene and benzo(b)fluoranthene were detected at 59 µg/kg and 46 µg/kg, respectively. Elevated levels of PAHs [8,013 µg/kg total PAHs (principal constituents were pyrene and fluoranthene at 1,800 and 1,700 µg/kg, respectively)] were detected in a subsurface soil sample collected from monitoring well borehole 9GW4. This boring/monitoring well is located approximately 800 feet southeast of Site 9 for purposes of monitoring upgradient groundwater quality. The source of the PAHs in this boring is unknown. Groundwater quality in well 9GW4 is good (no organic constituents were detected).

Low levels of PCE (21 µg/kg) and 1,1,1-trichloroethane (1 µg/kg) were present in the surface soil sample collected from soil boring SB3, which is located approximately 100 feet north of the aboveground storage tanks. Toluene was detected at a level of 2 µg/kg in a surface soil sample collected from soil boring SB35 (SB35 is located adjacent to the oil/water separator).

Groundwater quality at Site 9 does not appear to be significantly impacted by the fire-fighting training activities. Shallow monitoring wells 9GW6 and 9GW8 exhibited low levels of total xylenes (0.9 µg/l) and 2-chloroethylvinyl ether (1 µg/l), respectively. These wells are located approximately 100 feet to the west and east of the training pit, respectively. Total lead and chromium were detected above Federal and State drinking water standards in monitoring wells 9GW1, 9GW2, and 9GW3. Dissolved lead and chromium were not detected above any Federal or State standard.

Wallace Creek

Wallace Creek exhibited elevated levels of VOCs at nine of the eleven sampling stations. The source of contamination is believed to be groundwater discharge from Site 82.

Sampling stations WC7, WC8, and WC9 exhibited TCE (16 to 98 µg/l), 1,2-dichloroethene (9 µg/l to 85 µg/l), PCE (1 µg/l to 4 µg/l), and vinyl chloride (6 µg/l). The sample collected at Station WC7 exhibited a TCE concentration (98µg/l) which exceeds the North Carolina Surface Water Standard of 92.4 µg/l. These sampling stations are located just above that portion of Wallace Creek where the ravine discharges into Wallace Creek (i.e., Station WC7) downstream past the Holcomb Boulevard bridge. Station WC7 exhibited the highest level of contamination. Up gradient sample stations (WC1, WC2, and WC3) only exhibited low levels of 1,2-dichloroethene (4J µg/l) at station WC4, which is approximately 100 feet upstream from the Piney Green Road bridge.

Inorganic constituents including cadmium, copper, mercury, nickel, and zinc were detected above State or Federal standards for surface water. Stations WC3 and WC5 exhibited the highest levels of inorganics. Station WC3 is located approximately one-half mile upstream of the site. The presence of inorganic constituents in Wallace Creek may not be associated with surface water runoff from the ravine.

Pesticides were detected in approximately one-half of the sediment samples collected from Wallace Creek. The concentrations exceeded the EPA Region IV sediment quality screening values (SQSV) for both the lower 10 percentile (ER-L) and median percentile (ER-M). The highest levels of pesticides were detected at stations WC7 and WC8, which are located downstream from the area where the ravine discharges into Wallace Creek. Pesticides were also present, however, in upstream sample station WC1 above the ER-L. It should be noted that the tides may transport contaminants upstream from the point of entry into tidally influenced areas of Wallace Creek. The source of pesticides is likely a combination of historical pest control spraying along with runoff from the ravine.

PCB-1260 was detected at all of the sampling stations with the exception of upstream stations WC1 through WC3. The concentrations ranged from 31 µg/kg to 2,100 µg/kg with the highest levels detected at stations WC6, WC7, and WC8. These stations are located adjacent to Site 82. The source of the PCBs may be due to runoff from the ravine. However, soil samples

collected approximately 300 feet south of Wallace Creek at Site 82 did not exhibit PCB contamination.

PAH constituents were detected at several sampling stations including station WC1, which is located approximately one-mile upstream of the site. Elevated total PAH concentrations were present in samples collected from stations WC5 (1,600 µg/kg), WC6 (1,220 µg/kg), WC8 (2,720 µg/kg), and WC9 (1,149 µg/kg). These stations are located adjacent and downstream of Site 82.

Inorganic constituents in sediment that exceeded SQSVs include copper, lead, silver, and zinc. Station WC3, which is located approximately one-half mile upstream of the site, exhibited the most elevated levels of these constituents.

Tissue analysis of fish and crab specimens collected from Wallace Creek indicated the presence of pesticides, TCE, and PCB that may be attributable to surface water and sediment quality within Wallace Creek. 4,4'-DDE (15 µg/kg to 180 µg/kg) and 4,4'-DDD (8.1 µg/kg to 8.8 µg/kg) were detected in all six tissue samples from Wallace Creek. PCBs were detected in tissue samples ranging in concentration from 51 µg/kg to 1000 µg/kg. Five of the six samples exhibited the presence of PCB-1260. Trichloroethene was detected in two samples at a concentration of 5.0 µg/kg.

Bear Head Creek

Surface water samples collected from Bear Head Creek exhibited aluminum, copper, iron, lead, mercury, nickel, and silver above surface water quality standards. Samples collected both upstream and downstream of the Operable Unit exhibited these inorganics.

Low levels of pesticides (maximum value of 311 µg/kg total pesticides) were detected in sediment samples collected throughout Bear Head Creek. Sample stations BH4, BH5, and BH6 exhibited the highest levels. These stations are located adjacent to Site 6.

VOCs (TCE, PCE, and total xylenes) were detected in sediment samples collected from station BH3 and BH7. Station BH7 is located about one-half mile downstream of OU No. 2. The presence of VOCs in sediment at Bear Head Creek is unusual and unexplainable from the standpoint that neither soil or groundwater in that area of OU No. 2 exhibited VOC contamination. In addition, surface water did not exhibit VOC contamination.

PCB (PCB-1260) was detected at sampling stations BH3, BH4, BH5, and BH6 ranging in concentration from 51 µg/kg to 370 µg/kg.

Lead was the only inorganic constituent which was detected at a level which exceeded the ER-L EPA Region IV SQSV. Elevated levels of lead were detected at stations BH3, BH6, and BH7. These stations are upstream and downstream of the site. Sampling stations adjacent to Site 6 did not exhibit elevated levels of lead.

CONCLUSIONS

Based on the results of the various environmental investigations conducted at Operable Unit No. 2, conclusions for each area of concern and media were developed and are presented below.

Site 6, Lot 201

- The northeast corner of Lot 201 (i.e., grid area A) at the former pesticide storage area is contaminated with elevated levels of pesticides and volatiles that may be associated with former waste storage/handling activities. The extent of soil contamination is limited in area since only two sampling locations (SB16 and SB17) exhibited elevated contaminant levels.

- Former waste storage/handling activities at Lot 201 have not adversely impacted groundwater quality in this portion of Operable Unit No. 2.

- The presence of low levels of pesticides throughout Lot 201 is indicative of former pest control practices and is probably not associated with the former storage of pesticides. Low levels of pesticides were detected at similar concentrations throughout the 210-acre Operable Unit.

- Reported storage of PCB transformers at Lot 201 has not resulted in significant impacts to soil or groundwater, based on the limited number of occurrences and low contaminant levels.

- Low levels of TCE are present in groundwater but at concentrations below the NCWQS.

- Overall, the current health risk to base personnel working at Lot 201 is within the target range of $1x10^{-4}$ and $1x10^{-6}$.

Site 6, Lot 203

- Pesticide levels detected in soil at Lot 203 are not indicative of pesticide disposal. Pesticide levels at Lot 203 are comparable to other portions of Operable Unit No. 2. The southeast corner of Lot 203 did not reveal elevated pesticide levels given that pesticides were reported to be disposed of in this area.

- The area of Lot 203 near the former railroad spur may be associated with previous disposal activities. A limited number of surface and subsurface soil samples collected near the former railroad spur have revealed elevated levels of PCB-1260 and PAHs. Historical aerial photographs indicate significant activity (i.e., surficial anomalies) in this area of Lot 203.

- Disposal activities may have occurred in the north central portion of Lot 203 (near wells 6GW15S/D) where elevated levels of PCBs were detected in subsurface soil samples. In addition to PCBs, elevated levels of PAHs were also detected in this area.

- The reported PCB disposal area in the northeast corner of Lot 203 did not reveal elevated levels of PCBs. The reported area may have been inaccurately identified in Marine Corps memorandums.

- Military training operations at Lot 203 resulted in a substantial amount of buried debris including communication wire, shell casings, battery packs, small 5-gallon containers, and bivouac wastes. No 55-gallon drums were uncovered in any of the test pit excavations within Lot 203. Trenches identified in historical photographs were probably excavated as a means to dispose of military-type wastes and not for purposes of disposing hazardous wastes.

- Numerous drums on the surface of Lot 203 present a potential impact to human health and the environment. Samples collected from these drums indicate that some of the drum contents are characteristically hazardous. None of the drums were noted to be leaking.

- Groundwater quality at Lot 203 has not been significantly impacted by former disposal and storage practices. Trace levels of TCE were detected in well 6GW15, which is located in the north central portion of Lot 203 where disposal activities may have occurred. Trace levels of TCE and PCE were detected in well 6GW23 at concentrations below the NCWQS. Well 6GW23 is located in the south central portion of Lot 203. The source of VOC contamination in well 6GW23 is unknown. Soil samples collected from this borehole as well as other nearby soil borings did not indicated a source. The source of contamination may have been from a previous spill, which has since migrated from the soil to groundwater.

- Total chromium levels detected in wells 6GW3 and 6GW15S were above the NCWQS of 50 µg/l.

- Currently, Lot 203 is inactive and access is restricted. If the storage lot resumed operations, the potential human health risk (i.e., incremental carcinogenic risk) would be within the target range of $1x10^{-4}$ to $1x10^{-6}$.

Site 6 - Wooded Areas

- PCBs were detected in surface and subsurface soil near Piney Green Road east of Lot 201. Disposal activities may have occurred in this area, which once served as a training area.

- Disposal activities may have occurred in the wooded area between Lot 201 and 203. One location (soil boring SB1) exhibited moderate levels of PCBs, PAHs, and pesticides in surface soil. The extent of this contamination is limited in area.

- A former disposal area was identified during the test pit investigation in the wooded area between Lot 201 and Lot 203. Numerous 5-gallon containers, bivouac wastes, and battery packs were encountered. All of the containers were rusted and destroyed to the point where their contents could not be identified; however, solvent-like odors were observed by the sampling team. A sample of the sludge material near the containers revealed that the material is characteristically hazardous due to elevated levels of lead. Chloroform was also detected, but was below TCLP regulatory levels.

- Groundwater quality in the wooded area south of Lot 203 (near the above-mentioned disposal area) has been impacted by former disposal practices. Elevated levels of VOCs (chloroform, chlorobenzene, phenol) were encountered in wells 6GW16 and 6GW25. The concentration of chloroform detected exceeds the NCWQS.

- Potential human exposure to soil within the wooded portions of Operable Unit No. 2 would not result in significant health risks. Incremental carcinogenic risk values are within the acceptable risk range of $1x10^{-4}$ and $1x10^{-6}$. The area is frequented by hunters and military personnel.

Site 82

- The wooded area north of Lot 203 (Site 82) exhibited elevated VOC contaminant levels in soil at two locations near the eastern portion of the site. This area is a potential source of VOC contamination in groundwater.

- A large quantity of drums and debris were observed on the surface and subsurface just north of Lot 203 in the wooded area (Site 82) near monitoring wells 6GW1S and 6GW1D. Samples collected of the waste material analyzed the waste as No. 6 fuel oil, which is typically used for heating. Other drums uncovered could not be identified. This area may also be a source of groundwater contamination at Site 82.

- Shallow and deep groundwater north of Lot 203 (Site 82) exhibited elevated levels of VOC contaminants which exceed both the Federal MCLs and NCWQS. Deep groundwater quality was found to be significantly more contaminated than shallow groundwater quality.

- The horizontal extent of shallow groundwater contamination is defined. The plume apparently originates just north of Lot 203 (in the southern portion of Site 82) and discharges into Wallace Creek. Contaminants have migrated into the deeper portion of the aquifer as evidenced by elevated VOC levels in deep groundwater monitoring wells.

- The horizontal and vertical extent of the deep groundwater contamination has been evaluated. The horizontal extent of offsite contamination west of Site 82 (beyond well 6GW37D), however, has not been fully defined. Moreover, the vertical extent has been

evaluated to a depth of 230 feet. It is unknown at this time whether contamination extends below 230 feet. As mentioned previously, a clay layer is present at approximately 230 feet which may impede the vertical migration of contamination. For purposes of conducting the baseline human health and ecological risk assessment, the deep groundwater database is adequate. For purposes of performing a feasibility study on the deep aquifer, the current database is also adequate to select feasible remedial alternatives. However, additional data points west of Holcomb Boulevard are required to support the design of an alternative which may employ containment/extraction wells. In addition, further studies are required to better assess the presence or absence of contamination on top and below the clay formation.

Ravine

- None of the TCL organics detected in the ravine exceeded applicable water quality criteria values. Surface water concentrations of aluminum, cadmium, copper, iron, lead, silver, and zinc exceed the WQS and/or WQSV in some of the samples. The exceedance of those TAL inorganics occurred in upstream and/or downstream samples or were infrequent in occurrence.

- The presence of elevated levels of PAHs in soil and low levels of PCBs in sediment in the upper portion of the ravine (i.e., near Lot 203) is most likely due to former disposal practices. This portion of the ravine is filled with debris, including empty and partially-filled 55-gallon drums and other containers. In addition, canisters with "DDT" markings were found in the middle section of the ravine (between Lot 203 and Wallace Creek). However, no elevated levels of pesticides were detected in the ravine sediments.

- Soil contamination detected in the ravine has likely migrated to Wallace Creek via surface runoff. Wallace Creek sediments revealed the same constituents detected in ravine soils and sediments.

- Because of the amount of debris and difficulty in accessing the ravine, it is unlikely that human exposure would occur. Incremental carcinogenic risk estimates for the wooded areas and ravine area have indicated that potential human health risks are within the target range of $1x10^{-4}$ and $1x10^{-6}$.

Site 9

- Ongoing fire training exercises at Site 9 have not significantly impacted groundwater quality. Surface soil revealed TPH contamination in a few areas.

- Low levels of pesticides present at Site 9 are likely the result of former pest control practices and not associated with waste disposal.

- Total lead and chromium concentrations were detected in well 9GW3 at concentrations which exceed both the Federal MCLs and NCWQS.

- Potential human health risks to military personnel training at Site 9 are within the incremental carcinogenic risk range of $1x10^{-4}$ and $1x10^{-6}$.

Wallace Creek

- The presence of TCE, PCE, and other VOC contaminants in Wallace Creek is due to shallow and possibly deep groundwater discharge.

- Surface runoff from the ravine and portions of Site 82 (the wooded area north of Lot 203) have impacted sediment quality. Levels of PAHs, PCBs, and pesticides are present in Wallace Creek. These contaminants were also detected in the ravine.

- Pesticides detected in sediment samples have exceeded EPA Region IV sediment screening values. The source of contamination may be due to either runoff from the ravine and/or historical pest control spraying practices. The highest levels of pesticides were detected in two sampling stations that were located just downstream of where the ravine discharges into Wallace Creek. One upstream sampling location exhibited pesticide levels above the sediment screening values. It should be noted that the tides may transport contaminants upstream from the point of entry into tidally influenced areas of Wallace Creek.

- A surface water sample collected from Station WC7 exhibited a TCE concentration which exceeded the North Carolina Surface Water Standard.

- Inorganic levels for aluminum, cadmium, copper, iron, lead, mercury, nickel, silver, and zinc exceeded North Carolina Water Quality Standards (NCWQS) and/or EPA Region IV acute or chronic Water Quality Screening Values (WQSVs). Upstream sampling locations also exhibited inorganic levels which exceeded these standards. The presence of inorganic constituents in Wallace Creek may not be associated with Operable Unit No. 2 since no source of inorganic contamination is apparent.

- The fish community in Wallace Creek appears to be healthy, based on population statistics. No anomalies were observed on any of the fish collected during the aquatic survey.

- The fish population and diversity in Wallace Creek exhibited tissue concentrations of PCBs, pesticides, and TCE, which may be attributable to Site 6 and the ravine area. Ingestion of fish taken from Wallace Creek could result in human health risks (incremental carcinogenic risks) above the target point of $1x10^{-4}$.

Bear Head Creek

- Sediment quality in Bear Head Creek may be impacted via surface runoff from the wooded areas. Low levels PAHs, pesticides, and PCBs were detected in sampling stations which border Site 6. VOC contaminants were also detected in sediment samples; however, the source of the VOC contamination is unknown given that adjacent soil and groundwater did not exhibit VOC contamination. Pesticides in sediment are not likely associated with disposal practices.

- Inorganic constituents detected in sediment are not likely the result of disposal practices at Sites 6 and 9. Upstream sampling locations also exhibited inorganic constituents above EPA Region IV sediment screening values.

- The fish community at Bear Head Creek appears to be healthy, based on population statistics and observations. None of the fish collected at Bear Head Creek exhibited lesions or other anomalies that would represent adverse conditions.

- The fish community in Bear Head Creek had elevated levels of pesticides, PCBs, and zinc in tissue. The presence of these contaminants in fish tissue may be the result of

contaminated sediment. Ingestion of fish taken from Bear Head Creek could result in incremental carcinogenic risks above the $1x10^{-4}$ departure point.

- None of the TCL organic detected in Bear Head Creek exceeded applicable water quality criteria values. Dissolved oxygen concentrations and pH values were below WQS and WQSV at some of the stations, but probably were associated with natural conditions.

- Surface water concentrations of aluminum, copper, iron, lead, mercury, nickel, and silver exceeded the WQS and/or WQSV in some of the samples. The exceedances of these TAL inorganics occurred in upstream and/or downstream samples or were infrequent in occurrence.

RECOMMENDATIONS

1. Further groundwater investigations are required to better define the extent of deep groundwater contamination detected west of Holcomb Boulevard, and on top of and below the clay formation. These studies would be required to support the remedial design of alternatives employing containment/extraction wells.

2. Operating supply wells in the vicinity of Lot 203 should be monitored for VOC contamination. If elevated levels of VOCs are detected, the wells should be closed.

3. As a time critical removal action, a fence should be constructed around the wooded area north of Lot 203 (i.e., Site 82), including the ravine to prevent access. Surficial VOC contamination was encountered in this area.

4. Surficial drums at Lot 203 and in the wooded areas and ravine should be removed, overpacked, and properly disposed of as non-time critical removal action. The drums present a potential source of groundwater contamination and human/ecological health hazard.

5. Additional studies should be conducted in Wallace Creek to determine whether the presence of contaminants such as PCBs and pesticides in fish are due to the site. The limited database is not sufficient to conclude whether bioaccumulation is occurring due to site-related contamination.

6. Based on the results of the Human Health Risk Assessment and on a comparison of groundwater contaminant levels to standards, remedial action of the surficial and deep aquifers under Site 82 is recommended in order to restore the aquifers for future use.

7. Based on the soil data results, remedial action is recommended for "hot spot" areas of soil with elevated levels of VOCs, PCBs, PAHs, and pesticides. These areas may be potential sources of groundwater contamination.

1.0 INTRODUCTION

Marine Corps Base (MCB) Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) National Priorities List (NPL) that became effective on October 4, 1989 (54 Federal Register 41015, October 4, 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 was to ensure that environmental impacts associated with past and present activities at the MCB were thoroughly investigated and appropriate CERCLA response/Resource Conservation and Recovery Act (RCRA) corrective action alternatives were developed and implemented as necessary to protect public health and the environment.

The Fiscal Year 1994 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 13 operable units to simplify proceeding with RI/FS activities. This report describes the RI conducted at Operable Unit (OU) No. 2, which is comprised of Sites 6, 9, and 82.

The purpose of this RI is to fully determine the nature and extent of the threat to public health and the environment caused by the release or threatened release of hazardous substances, pollutants, or contaminants. The RI serves as the basis for the risk assessment (RA) and provides information in support of the FS and record of decision for final remedial action.

This was accomplished by sampling all media (soil, groundwater, sediment, and surface water) at Sites 6, 9 and 82, evaluating the analytical data, and performing a human health and ecological RA. This RI report contains the results of all field investigations and the human health RA. An ecological RA has been prepared under separate cover.

Site 6 is commonly referred to as "Open Storage Lots 201 and 203". Site 9 is entitled the "Fire Training Pit at Piney Green Road". Moreover, Site 82 is known as the "Piney Green Road VOC Site". These sites are located in the north eastern section of MCB Camp Lejeune, north of the Hadnot Point Industrial Area. The sites are bordered by Holcomb Boulevard on the west, Piney Green Road to the east, Wallace Creek to the north, and Sneads Ferry Road to the south. Bear Head Creek separates Site 6 from Site 9. A location map is shown on Figure 1-1

[note that all figures are presented in separate volumes from this RI Report (Volumes I and II).]

This RI Report is to be submitted to the USEPA Region IV, the NC DEHNR, and to members of the Technical Review Committee (TRC) for their review by the DoN, Naval Facilities Engineering Command, Atlantic Division (LANTDIV).

1.1 Operable Unit Description

Operable units (OU) are formed as an incremental step toward addressing individual site problems. There are currently 23 Installation Restoration Program (IRP) sites on MCB Camp Lejeune which have been grouped into twelve operable units to simplify the specific problems associated with a site or a group of sites. Figure 1-2 shows the breakdown of operable units on MCB Camp Lejeune. OU No. 2 includes Sites 6, 9, and 82. Because the three sites border each other, they have been grouped into one operable unit.

OU No. 2 is located approximately two miles east of the New River and two miles south of State Route 24 on the main section of MCB Camp Lejeune. The unit is bordered by Holcomb Boulevard on the west, Sneads Ferry Road on the south, Piney Green Road on the east, and by Wallace Creek on the north boundary. Camp Lejeune Railroad operates rail lines parallel to Holcomb Boulevard bordering OU No. 2. OU No. 2 covers an area of approximately 210 acres. OU No. 2 consists of three sites: Site 6, Site 9, and Site 82. Note that Site 82 was originally referred to as "the wooded area north of Lot 203" in the Final RI/FS Work Plan. This area was renamed during the RI investigation because a previous investigation was conducted at this site which referred to the area as "Site 82."

Site 9, the fire training area, has two aboveground storage tank areas, a fire training pit where flammable liquids are burned as part of training exercises, and an oil/water separator. Site 6 is comprised of Lots 201 and 203, the wooded areas around both storage lots and the ravine area. Site 82 encompasses the wooded area between Lot 203 and Wallace Creek. Lot 201 is active and is used to store military vehicles and supplies. Lot 203 is inactive but was used for storage of military equipment, pesticides, and transformers containing PCBs. Disposal of hazardous substances such as pesticides, paints, and solvents has been reported at Lot 203. In addition, cleaning solvents were reportedly disposed of at Site 82, which is just north of Lot 203. The wooded areas to the south, east and west of the storage lots have no documented disposal activities, but site investigations revealed random disposal of debris

including batteries and 55-gallon drums. Large quantities of debris were also noted in the ravine. Detailed site background and site history descriptions follow in Section 1.2 of this RI report.

1.2 Site Description and History

This section provides a description of the physical setting of the areas of concern within OU No. 2. A detailed history of these areas is also included in this section.

1.2.1 Site Description

There are distinctive areas of concern, as shown on Figure 1-3, within each site of OU No. 2. The following section describes the background of each site.

1.2.1.1 Site 9 Description

Site 9 is referred to in this report as the "Fire Training Area" (the formal name, as provided in the FFA, is "Fire Fighting Training Pit at Piney Green Road"). The site covers an area of approximately 2.6 acres. Site 9 is bounded by Holcomb Boulevard on the west, Site 6 to the north, Piney Green Road on the east, and Sneads Ferry Road on the south. Locally, the site is bounded by unnamed streets leading to various storage buildings in the vicinity. Site 9 consists of an asphalt-lined fire training pit, an oil/water separator, four aboveground storage tanks (ASTs), and a fire tower (smoke house). The fire training pit, located in the southern area of the site, is used to conduct training exercises for extinguishing fires caused by flammable liquids. The oil/water separator is located next to the fire training pit to collect water used in the training exercises and storm water that falls into the pit. The recovered product collected in the oil/water separator is disposed of offsite. Two of the ASTs at Site 9 are 2500-gallon steel tanks labeled "DO NOT USE". These tanks are not currently in use. Two additional storage tanks are located in a bermed area. These tanks are constructed of steel and contain approximately 500 gallons each. Two pressurized containment tanks were also located at Site 9. Their contents are unknown. The smoke house, located in the northern part of Site 9, is also used for training exercises. No fuel products are used in this area.

1.2.1.2 Site 6 Description

Site 6 is located north of and adjacent to Site 9. Site 6 is bounded on the north by Site 82, by Piney Green Road on the east, by Site 9 on the south, and by Holcomb Boulevard on the west. Site 6 covers an area of approximately 177 acres that incorporates Storage Lots 201 and 203, the wooded area behind the storage lots, and a ravine, which begins at Site 6 and bisects Site 82. Three surface water bodies are associated with Site 6 for the purpose of this RI: Wallace Creek, Bear Head Creek, and a ravine (intermittent surface water body) located in the wooded area north of Lot 203 that drains to Wallace Creek. Specific details of the individual areas that make up Site 6 are described below.

Open Storage Lot 201

Open Storage Lot 201 (Lot 201) is a fenced lot located in the south-central portion of Site 6. It is a flat area with sparse vegetation around the fence lines. The ground surface is densely compacted soil. Lot 201 is bordered by woods with Bear Head Creek to the south, Holcomb Boulevard to the west, and Piney Green Road to the east. The lot is approximately 25 acres in size. It is currently being used for the storage of military vehicles and equipment, lumber, hydraulic oils and lubricants, non-PCB transformers, and other supplies (ESE, 1991).

Open Storage Lot 203

Open Storage Lot 203 (Lot 203) is a fenced lot located in the northern portion of Site 6. The fenced area of the lot encompasses approximately 46 acres. Lot 203 is a relatively flat area with elevation differences of approximately five feet. The ground surface is comprised of both naturally existing soil and fill material. Lot 203 varies in vegetation from a hard compact surface with no vegetation to areas with loose sandy soil and dense vegetation. Lot 203 is bordered by woods to the north (Site 82) and south, Piney Green Road to the east, and by Holcomb Boulevard to the west. Lot 203 is currently inactive, but it still contains randomly stored scrap materials from former activities such as rubber rafts, shredded tires, radio/ communications parts, empty ammunition boxes, spent ammunition casings, fiberglass-like material, barbed wire fencing, used demolition kit training materials, a non-PCB transformer, wooden pallets, shredded tires, metal debris, and 55-gallon drums. Figure 1-4 shows the location of the debris in Lot 203.

The 55-gallon drums found on Lot 203 were observed in small groupings throughout the lot. The majority of the drums, if labeled, were identified as containing lubricants, petroleum products, or corrosives. Drum sampling was conducted as part of this RI. The results of the drum sampling are provided in Section 4.0 of this report. The drums will be removed as part of a non-time critical removal action.

Empty storage tanks were also found on Lot 203. They were labeled as containing diesel fuel, gasoline, and kerosene (Baker, 1992). These tanks will also be removed during the non-time critical removal action.

Ravine Area

A ravine is located in the northwest section of Site 6. The ravine begins "inside" of Storage Lot 203 and bisects Site 82. The elevation ranges from 25 feet above msl at the north boundary of Lot 203 to 5 feet above msl where the ravine drains into Wallace Creek. The surface of the ravine area is littered with various debris including batteries, fencing, tires, empty unlabeled drums, wire cables, commercial ovens, commodes, and respirator cartridges. An empty drum labeled "DDT" was also found in the ravine area, as were small canisters labeled to contain "DDT". The date on the canisters was marked November, 1957.

Wooded Areas

Woods and open fields surround both Storage Lots 201 and 203 and make up the remaining area of Site 6. The topography of the wooded areas is relatively flat, but localized trenching and mounding is visible west of Piney Green Road. The wooded areas are randomly littered with debris including spent ammunition casings, and empty or rusted drums. Many of the drums observed were only shells or fragments of drums. (Baker, 1992)

1.2.1.3 Site 82 Description

Site 82 is situated at the northern end of OU No. 2. It is bordered to the north by Wallace Creek, to the east by Piney Green Road, to the west by Holcomb Boulevard, and to the south by Site 6. Site 82 encompasses approximately 30 acres and is predominantly covered by woodlands. The site is randomly littered with debris including communication wire, spent ammunition casings, and empty or rusted drums. Markings were observed on a few drums,

however, most of the drums did not contain markings due to their condition and age. Some of the drums were marked as "lubrication oil" and "anti-freeze".

The topography within Site 82 is relatively flat near the southern portion of the site, but becomes very steep near the bank of Wallace Creek. Localized trenching and mounding is visible near the southern portion of the site. The ravine bisects the site, as shown on Figure 1-3.

1.2.2 Site History

The following paragraphs describe the documented history of OU No. 2. Waste storage and disposal activities at the individual sites are described below.

1.2.2.1 Site 9

Site 9 has been used as a fire fighting training area from the early 1960s to the present. Fire extinguishing activities took place in an unlined pit. In 1981 the pit was lined with asphalt. The training fires in the pit were started with used oil, solvents, and contaminated fuels (unleaded). Approximately 30,000 to 40,000 gallons of JP-4 and JP-5 fuel were also burned in the fire training pit. Chemical retardants containing Diethylene Glycol Monobutyl Ether, proprietary mixtures of hydrocarbons, fluorosurfactants and inorganic salts were occasionally used to extinguish the training fires. (Baker, 1992).

1.2.2.2 Site 6

Site 6 has a long history of various uses including the disposal and storage of wastes and supplies. This section on the history of Site 6 has been broken down into Storage Lot 201, Storage Lot 203, and the wooded and the ravine areas to simplify the historical descriptions of these areas.

Storage Lot 201

Currently, Lot 201 is used to store military equipment, vehicles, hydraulic oils, and other "non-hazardous" supplies. Pesticides were reportedly stored at one time in the northeast and southeast corners of the lot. Transformers containing PCBs were reportedly stored in the southwest corner of the lot (Water and Air Research, 1983). No storage or disposal activities

have supporting documentation other than what is reported in the Initial Assessment Study, prepared in 1983 by Water and air Research.

Storage Lot 203

Storage Lot 203 has been used as a disposal area since the 1940s. There is little documentation on the disposal activities at this lot. Lot 203 in not currently active as a storage or disposal area, but the ground surface is littered with various debris. Pesticides were reported to have been stored in a trailer on Lot 203 as well as in the southeast portion of the lot (Memo: Past Disposal Practices at DRMO Lot 203, 17 January 1989). Drums of DDT were found in the southwestern portion of the lot in 1989 (Memo: Unearthed 55-gallon drums of DDT and 55-gallon drums of unknown substance at Camp Lejeune DRMO Lot 203. 12 January 1989). Five 55-gallon drums and surrounding soil were containerized and disposed of (Memo: 12 January 1989).

Lot 203 was also used for the storage and disposal of radio and communication parts, shredded tires, lubricants, petroleum products, corrosives, expended demolition kit training materials, ordnance, sheet metal debris, wire cables, and wooded pallets. Empty and full 55-gallon drums were found at various locations on Lot 203. A drum survey was conducted as part of this RI and the results are located in Section 4.0 of this report.

Lot 203 is currently fenced. From historical photographs, it appears that the fenced boundaries have changed since the lot was in operation. Former employees at Lot 203 have reported disposal of various chemicals including PCBs, cleaning solvents, electrolytes from used batteries, and waste oils.

Wooded and Ravine Areas

The surface of the wooded areas around Lots 201 and 203 is randomly littered with debris including drums, metal storage containers, and rocket cartridges. No organized disposal operations are documented for the wooded areas. The ravine begins at the northern boundary of Lot 203. As previously stated, the ravine is also currently littered with various debris. From the deposition of the debris in the ravine, it appears that trucks may have dumped their contents into the ravine from Lot 203.

1.2.2.3 Site 82

As described in Section 1.2.1.3, Site 82 is also randomly littered with debris. No organized disposal operations are documented for the site. From the deposition of the debris at Site 82, it appears that the area was used for disposal of miscellaneous debris from Lot 203. Although the name of the site refers to VOCs (the site is named "Piney Green Road VOC Area), there are no documents or memorandums which indicate any disposal of VOCs or solvents.

1.3 Previous Investigations

In response to the passage of the Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA), the DoN initiated the Navy Assessment and Control of Installation Pollutants (NACIP) program to identify, investigate, and clean up past hazardous waste disposal sites at Navy installations. The NACIP investigations conducted by the DoN consisted of Initial Assessment Studies (IAS), similar to the EPA's Preliminary Assessments/Site Investigations (PA/SI) and Confirmation Studies, similar to the EPA's RI/FS. When the Superfund Amendment and Reauthorization Act (SARA) was passed in 1986, the DoN aborted the NACIP program in favor of the Installation Restoration Program (IRP), which adopted the EPA Superfund procedures.

The following sections summarize the previous investigations performed at OU No. 2.

1.3.1 Initial Assessment Study

An IAS was conducted Water and Air Research, Inc., in 1983. The IAS identified a number of sites at MCB Camp Lejeune as potential sources of contamination, including the sites discussed in this RI. The IAS reviewed historical records and aerial photographs, as well as performing field inspections and personnel interviews to evaluate potential hazards at various sites on MCB Camp Lejeune. The IAS recommended performing confirmation studies at Sites 6 and 9 to evaluate the necessity of conducting mitigating actions or clean-up operations.

1.3.2 Confirmation Study

A confirmation study was conducted by Environmental Science and Engineering, Inc. (ESE) in 1984 through 1987. The purpose of this investigation was to investigate the potential source areas identified in the IAS. Sites 6 and 9 were identified in the IAS. The Confirmation Study

was divided into two separate reports: a Verification Step done in 1984 and a Confirmation Step done in 1986 through 1987. The work that was performed at OU No. 2 is summarized by site and media below.

1.3.2.1 Site 6

Soil Investigations

In August 1984, as part of the Verification Step, ESE drilled and sampled ten soil borings at Lot 201. The sampling locations are unknown. Each of the 10 samples was composited from the 0-to-3 foot depth range. The samples were only analyzed for the o,p- and p,p-isomers of DDD, DDE, and DDT (ESE, 1991). It is not known why only these pesticides were analyzed except that pesticides were reportedly stored at Lot 201. The analytical results indicate that DDT,pp was detected in all ten samples. DDD,op; DDT,op; DDD,pp; and DDE,pp were detected in 8 of the 10 samples. DDE,op was detected in 6 of the 10 samples. The maximum detected concentrations for each of the isomers were: DDD,op (0.03640 µg/g); DDE,op (0.0320 µg/g); DDT,op (0.3240 µg/g); DDD,pp (0.1600 µg/g); DDE,pp (0.7700 µg/g); and DDT,pp (0.1400 µg/g). No information is available to assess the analytical methods employed or the Quality Assurance /Quality Control (QA/QC) protocols used in the field or laboratory.

In August, 1984, as part of the Verification Step, ESE drilled and sampled 10 soil borings at Lot 203. The sampling locations are unknown. Each of the 10 samples was composited from the 0-to-3 foot depth range. Two duplicate samples were also collected. The samples were only analyzed for the o,p- and p,p-isomers of DDD, DDE, and DDT (ESE, 1991). The p,p-isomer of DDD,DDE, and DDT were predominant in these samples. DDE,pp was detected in 10 of the 12 samples; DDD,pp was detected in 7 of the 12 samples; and DDT,pp was detected in 6 of the 12 samples. DDE,op was not detected in any of the samples. The maximum detected concentrations for each of the other five isomers were: DDD,op (0.00137 µg/g); DDT,op (0.01580 µg/g); DDD,pp (0.0048 µg/g); DDE,pp (0.0016 µg/g); and DDT,pp (0.0490 µg/g).

Groundwater Sampling

In November 1986, as part of the Characterization Step, four shallow monitoring wells (wells 6GW4, 6GW5, 6GW6, and 6GW7) were installed and sampled in the vicinity of Lot 201 (see Figure 2-8). Table 1-1 provides a summary of well construction details for existing site wells.

TABLE 1-1

SUMMARY OF EXISTING WELL CONSTRUCTION DETAILS
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (1) (feet, above msl)	Boring Depth (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)	Stick-Up (feet, above ground surface)
6GW1S(2)	10/21/86	35.18	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.4
6GW2S(2)	10/21/86	38.37	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.1
6GW3(2)	10/24/86	31.32	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.2
6GW4(2)	10/22/86	27.99	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.4
6GW5(2)	10/22/86	25.67	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.3
6GW6(2)	10/23/86	26.74	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.3
6GW7(2)	10/24/86	17.83	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	2.2
6GW8(2)	10/23/88	22.35	25.5	25.0	5.0 - 25.0	3.0 - 25.0	2.0 - 3.0	1.1
82MW1(3)	06/17/91	8.58	14.02	14.0	4.0 - 14.0	3.0 - 14.0	1.0 - 2.0	2.7
82MW2(3)	06/17/91	6.03	13.02	13.0	3.0 - 13.2	2.0 - 13.0	1.0 - 2.0	3.6
82MW3(3)	06/18/91	24.31	21.05	21.0	11.0 - 21.0	9.0 - 21.0	7.0 - 9.0	3.3
82MW30(3)	--(5)	32.19	--	--	--	--	--	--
MW-2(4)	--	29.68	--	--	--	--	--	--
MW-3S(4)	04/22/92	30.73	50.0	25.0	15.0 - 25.0	12.3 - 25.0	9.4 - 12.3	2.1
MW-8(4)	04/21/92	30.62	50.0	25.0	15.0 - 25.0	13.0 - 25.0	11.2 - 13.0	2.1
MW-9(4)	04/22/92	39.98	50.0	25.0	15.0 - 25.0	11.9 - 25.0	9.9 - 11.9	2.1
BP-6(4)	04/21/92	37.41	25.0	25.0	15.0 - 25.0	13.0 - 25.0	11.0 - 13.0	2.1

Notes: (1) msl - mean sea level
(2) Monitoring well installed by ES&E - Site 6
(3) Monitoring well installed by NUS - Site 82
(4) Monitoring well installed by SM&E - East of Site 6
(5) -- Information unavailable

A second sampling round was conducted in January 1987. Both rounds of samples were analyzed for volatile organic compounds (VOCs) and the o,p- and p,p-isomers of DDD, DDE, and DDT. DDD, DDE, and DDT were not detected in any groundwater sample in either round. One VOC was detected in the first round of sampling: chloromethane (6.5 µg/l) was detected in well 6GW6 (ESE, 1990a).

In January 1991, the four existing monitoring wells were sampled and analyzed for full TCL parameters. This sampling was conducted by ESE as part of the Supplemental Characterization Investigation (ESE, 1991). Carbon disulfide was detected at a concentration of 10 µg/l in well 6GW6. No semivolatile compounds (SVOCs) or pesticides were detected in any of the groundwater samples. The following inorganic parameters were detected in concentrations exceeding the North Carolina Water Quality Standards (NCWQS): iron, manganese, chromium, lead, and barium. One or more of these inorganic constituents were observed in all four shallow wells.

In November 1986, as part of the Characterization Step, four shallow monitoring wells (wells 6GW1, 6GW2, 6GW3, and 6GW4) were installed and sampled to monitor groundwater quality near Lot 203. A second sampling round was conducted in January 1987. Both rounds of samples were analyzed for VOCs and the o,p- and p,p-isomers of DDD, DDE, DDT. DDD, DDE, and DDT were not detected in any groundwater sample in either round. Only two VOCs were detected in the first round of sampling in well 6GW1: benzene (3.1 µg/l) and 1,1,2,2-tetrachloroethane (63 µg/l) (ESE, 1990a).

In January 1991, three of the four existing monitoring wells and two water supply wells were sampled to assess groundwater quality at Lot 203. The fourth monitoring well was dry and therefore could not be sampled (ESE, 1991). The sampling was conducted by ESE as part of the Supplemental Characterization Investigation. The samples were analyzed for full Target Compound List (TCL) parameters. Detectable concentrations of VOCs were identified only in the water supply wells: acetone (12 µg/l); vinyl chloride (70 µg/l); 1,2-dichloroethene (75 µg/l); trichloroethene (TCE) (13 µg/l); and tetrachloroethene (PCE) (53 µg/l). The water supply wells (HP-651 and HP-653) are located across Piney Green Road, east of Lot 203 and north of Site 6. No SVOCs or pesticides were detected in any of the groundwater samples, including those samples collected from the potable water supply wells. Several inorganic parameters were detected in concentrations exceeding the NCWQS. These compounds included: iron, manganese, chromium, lead, cadmium, and zinc. Every monitoring well had at least one or more elevated inorganic compound.

Surface Water Sampling

As part of the Characterization Step in November 1986, one upstream and one downstream (from OU No. 2) surface water sample were collected in Bear Head Creek. These samples were analyzed for VOCs, and the o,p- and p,p-isomers of DDD, DDE, and DDT (ESE, 1991). No analyzed compounds were detected in the surface water samples collected in Bear Head Creek.

As part of the Characterization Step in November 1986, one upstream and one downstream (from OU No. 2) surface water sample were collected in Wallace Creek. These samples were analyzed for VOCs, and the o,p- and p,p-isomers of DDD,DDE, and DDT (ESE, 1991). The following VOCs were detected: trans-1,2-dichloroethene (6.4-35 µg/l), TCE (<3-26 µg/l), and vinyl chloride (1.9-3.6 µg/l). The downstream concentrations of each of these VOCs were higher than the upstream concentrations. DDD, DDE, and DDT were not detected in any sample.

As part of the Supplemental Characterization Investigation in January 1991, two surface water samples were collected from Wallace Creek. The upstream location was at Piney Green Road, and the downstream location was at Holcomb Boulevard. The samples were analyzed for full TCL parameters. In addition, field measurements of pH, specific conductance, and temperature were made (ESE, 1991). One VOC was detected in the downstream sample: TCE (5 µg/l). SVOCs and pesticides were not detected in any sample. Most of the detected inorganics (aluminum, calcium, magnesium, potassium, sodium, and zinc) all increased in concentration from upstream to downstream. Iron was the only detected inorganic which decreased in concentration upstream to downstream.

Sediment Sampling

As part of the Characterization Step in November 1986, one upstream and one downstream sediment sample were collected in Bear Head Creek. These samples were analyzed for VOCs, and the o,p- and p,p-isomers of DDD, DDE, and DDT (ESE, 1991). VOCs were not detected in any sample. The p,p-isomers of DDE, and DDT were detected in the sediments collected from Bear Head Creek at levels of 0.0758 µg/g (or ppm) and 0.0131 µg/g, respectively. The upstream concentrations of these two isomers were higher than the downstream concentrations. The source of upstream sediment contamination was not reported and is presently unknown.

Historical mosquito control practices may have resulted in the presence of these pesticides in Bear Head Creek sediments.

As part of the Characterization Step in November 1986, one upstream and one downstream sediment sample were collected in Wallace Creek. These samples were analyzed for VOCs, and the o,p- and p,p-isomers of DDD, DDE, and DDT (ESE, 1991). No compounds were detected in either of the samples.

As part of the Supplemental Characterization Investigation in January 1991, two sediment samples were collected from Wallace Creek. The upstream location was at Piney Green Road, and the downstream location was at Holcomb Boulevard. The samples were analyzed for full TCL parameters. In addition, field measurements of pH, specific conductance, and temperature were made (ESE, 1991). Two common laboratory solvents (acetone and methylene chloride) were the only VOCs detected in the samples. SVOCs were not detected in the upstream sediment sample. In the downstream sample, four semivolatiles were detected: chrysene (420 µg/kg), benzo(b)fluoranthene (600 µg/kg), benzo(k)fluoranthene (510 µg/kg), and benzo(a)pyrene (460 µg/kg). Pesticides were not detected in either sample. With respect to inorganic compounds, aluminum, calcium, chromium, iron, manganese, and zinc were detected in the upstream sediments. Of these, calcium and manganese were not detected downstream. In general, the upstream concentrations were higher than the downstream concentrations.

1.3.2.2 Site 9

Previous investigations at Site 9 only focused on groundwater. No soil investigations or supplemental investigations of Bear Head Creek (i.e., over and above the studies conducted on Bear Head Creek that were associated with Site 6) have been conducted.

Two monitoring wells (9GW1 and 9GW2) were installed in 1984 to characterize groundwater quality (see Figure 2-16). Well construction details (e.g., screen lengths and intervals) for these wells are unknown but are believed to be installed at 25 feet below ground surface and screen between 15 and 25 feet. A water supply well (HP-635) located just east of Piney Green Road was also included in the investigation. The two shallow wells and the water supply wells were sampled on July 5, 1984 and analyzed for cadmium, chromium, lead, oil and grease, volatile organics, and total phenols.

In November 1986, a third shallow well was installed at the northeastern corner of the site downgradient of the pit. Samples were collected from all three shallow wells between November 18 and 19, 1986 and analyzed for total xylenes, methyl ethyl ketone, methyl isobutyl ketone, ethylene dibromide, and hexavalent chromium.

Chromium, lead, and phenols were detected in wells 9GW1 and 9GW2 during the 1984 sampling round. As shown on Figure 2-16, these wells are located in the southeastern and northeastern corner of the site, respectively. No target analytes were detected in the water supply well. The water supply well was only sampled in 1984.

The sampling round of 1986 also exhibited the presence of these contaminants in well 9GW1. Well 9GW2 did not exhibit lead above 22 µg/l (it is not known whether this is the instrument or the method detection level); however, both chromium and phenols were detected again in this well. Well 9GW3 exhibited phenols and 1,2-dibromoethane (ethylene dibromide). Well 9GW3 was again sampled in January 1987 (the other two wells were not sampled) and exhibited low levels of chromium and lead (below Federal or State water quality standards) (ESE, 1990).

The analytical methods or quality of data were not reported in the reference documents and therefore are currently unknown.

1.3.2.3 Site 82

A site investigation was conducted at Site 82 in June, 1991 by Halliburton NUS Environmental Corporation (NUS). The investigation was initiated based on results from an Environmental Science and Engineering (ES&E) field investigation in 1986 (the investigation was conducted as part of a study for Site 6). During this investigation, surface water samples collected from Wallace Creek contained VOCs. It was determined that the source of the VOCs in Wallace Creek most likely did not originate from Site 6 (Lot 203). Subsequently a new site, Site 82, was created to investigate the source of the VOCs (NUS, 1992).

The investigation conducted by NUS consisted of installing six shallow soil borings and three shallow monitoring wells, soil and groundwater sampling, and surface water and sediment sampling (Wallace Creek). Results from the investigation indicated positive detections of organic contamination in all of the media sampled. Pesticides (4,4'-DDD, 4,4'-DDE, 4,4'-DDT, endosulfan II, and dieldrin) were detected in soil (33 to 110 µg/kg) and sediment (12 to 69

µg/kg) samples with lower levels in surface water and groundwater. PCB (PCB-1260 and PCB-1242) contamination was also present in soil (150-1,900 µg/kg), groundwater (15 µg/l), surface water (80 µg/l), and sediments (220-700 µg/kg). Further, levels of TCE (3 to 74 µg/l), 1,2-dichloroethene (6 to 64 µg/l), and vinyl chloride (11 µg/l) were detected in surface water samples. Note that concentrations of VOCs were not detected in any of the wells sampled.

1.3.3 Site Assessment Report

A Site Assessment Report was prepared by Environmental Science and Engineering, Inc. (ESE) in March 1992. This report contained a summary of the Confirmation Study done by ESE at an earlier date and a preliminary risk evaluation for Site 6. The Site Assessment Report recommended that a full human health and ecological risk assessment be performed at Site 6.

1.3.4 Additional Studies at OU No. 2

Site Survey Report - February 1989

The purpose of this investigation was to identify the presence of volatile organic compounds using soil gas analysis that may potentially affect personnel working at Storage Lot 203.

The results of the testing found that "no imminent hazards were observed" and that all of the tests were negative except for a localized soil stain from a former spill.

The area of stained soil is located near the north central portion of Lot 203 along the fenceline.

1.4 Report Organization

The following sections are presented in this RI report.

- Section 2.0 Study Area Investigation
- Section 3.0 Physical Characteristics of the Study Area
- Section 4.0 Nature and Extent of Contamination
- Section 5.0 Contaminant Fate and Transport
- Section 6.0 Baseline Human Health Risk Assessment
- Section 7.0 Summary and Conclusions

- Section 8.0 References

Section 2.0 describes the Phase I and II field sampling activities conducted during the RI at OU No. 2. This section describes the purpose of the sampling procedures, sampling grids, and sampling locations for all media. Figures are included to show sampling locations, drilling logs and well installation information. These figures, along with all other figures presented in this report, are provided in two separate volumes (figures for Sections 1.0, 2.0 and 3.0 are presented in Volume I; figures for Sections 4.0 and 6.0 are presented in Volume II). This section also discusses quality control conducted during the sampling events.

Section 3.0 addresses the physical features of OU No. 2. This section discusses the surface features, meteorology, surface water hydrology, geology, soils, hydrogeology, demography and land use, the ecology in and around OU No. 2, and water supply wells identified within the vicinity of OU No. 2.

Section 4.0 presents the nature and the extent of the contamination found at OU No. 2. This section presents the results of the Phase I and II field sampling activities conducted as part of this RI. The results of the sampling activities are presented in the first part of this section. Also included in this section is a discussion of the extent of contamination, a summary of the contaminants detected and a discussion of the potential sources.

Section 5.0 characterizes the contaminants found at OU No. 2. This characterization includes: potential routes of contaminant migration, contaminant persistence, and contaminant migration.

Section 6.0 contains the Baseline Risk Assessment (RA) conducted for the site. The RA contains a human health evaluation and an environmental evaluation. An ecological risk assessment has bee provided under separate cover.

Section 7.0 includes the Summary and Conclusions. This section summarizes the nature and extent of contamination, contaminant fate and transport, and the RA. In addition, the conclusions address any data limitations and recommended remedial action objectives.

Section 8.0 includes references cited in this report.

This RI report is being submitted in eight volumes: the RI report is presented in two volumes; the figures are presented in two volumes; and the appendices are presented in four volumes.

2.0 STUDY AREA INVESTIGATION

2.1 Introduction

The field programs at Sites 6, 9, and 82 [Operable Unit No. 2 (OU No. 2)] were initiated to characterize potential environmental impacts and threats to human health resulting from previous storage, operation, and disposal activities. The following are brief descriptions of each area investigated, site-specific objectives, criteria for meeting the objectives, and general investigative methods for OU No. 2. Specific field investigative methods are discussed in Sections 2.3 through 2.7.

The wooded area between Wallace Creek and the northern boundary of Lot 203 was originally described in the Final RI/FS Work Plan as the "wooded area north of Lot 203". This area is known as "Site 82" (also referred to as "The Piney Green Road VOC Site"), which is a site previously investigated at MCB Camp Lejeune (described in Section 1.0). Accordingly, this area is referred to as Site 82 for this RI investigation. Note that the discussion of the field investigative methods is combined for Sites 6 and 82 because these two sites are essentially continuous.

2.1.1 Site Descriptions and Objectives - Sites 6 and 82

2.1.1.1 Site 6

Sites 6 is located approximately 1.75 miles east of the New River and 2 miles south of Route 24 on the Mainside portion of Camp Lejeune (refer to Figure 1-3). Site 6 is bordered to the west by Holcomb Boulevard, to the north by Site 82, to the east by Piney Green Road, and to the south by Site 9 (Fire Training Area). Site 6 comprises two storage lots, Lot 201 and 203, which are surrounded by woodlands. The combined area of Site 6 encompasses approximately 177 acres.

Open Storage Lot 201

Open Storage Lot 201 (Lot 201) is located in the south-central portion of OU No. 2. This lot, which is actively used to store military equipment (e.g., vehicles, lumber, hydraulic oils and lubricants, non-PCB transformers and other supplies), is bordered by woods on all directions with Holcomb Boulevard further to the west, Piney Green Road further to the east, and Bear Head Creek further to the south (refer to Figure 1-3). This lot is approximately 25 acres in size

(ESE, 1991) as shown on Figure 2-1 (note that all figures are provided in separate volumes from text). The former pesticide storage areas are located near the northeastern and southeastern portions of Lot 201. Further, the former PCB storage area is located near the southwestern portion of the lot.

The objectives, criteria for meeting these objectives, and general investigative methods for the RI performed at Lot 201 are presented on Table 2-1.

Open Storage Lot 203

Open Storage Lot 203 (Lot 203) is situated in the northern portion of Site 6, just north of Lot 201. Lot 203 is bordered to the west by Holcomb Boulevard, the north (at Site 82) and south by woodlands, and to the east by Piney Green Road (refer to Figure 1-3). As shown on Figure 2-2, a fence is present around the lot; however, the actual area of the storage lot may slightly exceed the fenceline. This lot is approximately 46 acres in size (ESE, 1990).

The project objectives, criteria for meeting these objectives, and general investigative methods for the RI performed at Lot 203 are presented on Table 2-2.

Wooded Area and the Ravine

Woodlands and open fields which surround both lots, and the ravine area make up the remaining areas of Site 6 (Figure 2-3). The fields and woodlands are littered throughout (randomly) with debris including spent ammunition casings, and empty and rusted drums (1-, 5-, and 55-gallon in size). Markings were noted on some of the drums such as "lubrication oil" and "decontamination agents". Most of the drums, however, could not be identified due to their condition and age. Many of the drums were only fragments as opposed to "whole" drums. Discarded material was also noted in the ravine, such as drums, pails, battery packs, and miscellaneous garbage (e.g., foot lockers). Some 5-gallon rusted pails were noted along the northwestern bank of the ravine which were marked as "DDT."

The project objectives, criteria for meeting these objectives, and general investigative methods for the RI performed in the wooded areas and the ravine are presented on Table 2-2.

TABLE 2-1

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES FOR STORAGE LOT 201
SITE 6
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objectives	Criteria for Meeting Objectives	Proposed Investigation/Study
1. Soil	1a. Assess the extent of soil contamination at former pesticide storage areas (Grids A and B).	Determine pesticide levels in surface and subsurface soils at former storage areas.	Soil Investigation
	1b. Assess the extent of soil contamination at the former PCB storage area (Grid C).	Determine PCB levels in surface and subsurface soils at the former storage area.	Soil Investigation
	1c. Assess human health and ecological risks associated with exposure to surface soils.	Determine contaminant levels in surface and subsurface soils.	Soil Investigation Risk Assessment
	1d. Assess areas of surface soil contamination due to site runoff.	Characterize contaminant levels in surface soils at downslope drainage areas.	Soil Investigation
2. Groundwater	2a. Assess health risks posed by future usage of the shallow groundwater near Lot 201.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess potential impact to groundwater from pesticide-contaminated soil or unknown releases.	Characterize on-site groundwater quality and groundwater quality downgradient from Lot 201.	Groundwater Investigation
	2c. Evaluate hydrogeologic characteristics.	Estimate hydrogeologic characteristics of the surficial water-bearing zone (flow direction, groundwater gradient, etc.).	Groundwater Investigation Surface water level measurements in Bear Head Creek

TABLE 2-1 (Continued)

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES FOR STORAGE LOT 201
SITE 6
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objectives	Criteria for Meeting Objectives	Proposed Investigation/Study
3. Sediment	3a. Assess human health and ecological risks associated with exposure to contaminated sediments.	Evaluate the nature and extent of contamination in sediment.	Sediment Investigation in Bear Head Creek Risk Assessment
	3b. Assess potential ecological impacts posed by contaminated sediments.	Evaluate stress to benthic and fish communities.	Aquatic Study in Bear Head Creek
		Identify the presence or absence of contaminants in fish tissue.	Fish Collection and Tissue Analysis Risk Assessment
	3c. Determine the extent of sediment contamination for purposes of identifying areas of remediation.	Identify extent of sediment contamination where contaminant levels exceed risk-based action levels or EPA Region IV TBCs for sediment.	Sediment Investigation (Bear Head Creek) Risk Assessment
4. Surface Water	4a. Assess the presence or absence of surface water contamination in Bear Head Creek.	Determine surface water quality along Bear Head Creek.	Surface Water Investigation
	4b. Assess impacts to Bear Head Creek from groundwater discharge from Site 6, Lot 201 and wooded areas.	Determine surface water quality in Bear Head Creek.	Surface Water Investigation
		Assess groundwater quality from Site 6 or EPA Region IV TBCs for sediment.	Groundwater Investigation

TABLE 2-2

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES FOR STORAGE LOT 203, THE WOODED AREAS, THE RAVINE AND SITE 82
SITES 6 and 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objectives	Criteria for Meeting Objectives	Proposed Investigation/Study
1. Surface Drums	1a. Determine appropriate treatment/disposal methods of all surface drums.	Identify waste type, contents, and hazardous waste characteristics.	Drum Investigation
	1b. Assess potential impact to soils in drum storage areas.	Characterize surface and subsurface soil contaminant levels in the storage area.	Soil Investigation (Test Pits)
	1c. Assess potential impact to shallow groundwater in drum storage areas.	Characterize on-site surficial groundwater quality.	Groundwater Investigation
2. Buried Waste and/or Drums	2a. Determine and confirm the locations where drums or wastes may be buried.	Identify subsurface anomalies associated with drums or bulk wastes.	Review of Historical Photographs Geophysical Investigation Test Pit Investigation
	2b. Pending the identification of potential buried drums or bulk wastes, determine appropriate treatment/ disposal methods.	Identify waste types, contents, and hazardous waste characteristics.	Drum/Waste Sampling Program
3. Soil	3a. Assess human health and ecological risks associated with exposure to surface soil.	Characterize the nature of soil contamination at Lot 203.	Soil Investigation Risk Assessment
	3b. Assess the potential extent of surface soil contamination due to potential surface runoff.	Determine the presence or absence of soil contamination in downslope or drainage areas.	Soil Investigation Sediment Investigation
	3c. Pending the presence of buried drums/waste, assess the impact to subsurface soil.	Characterize the nature and extent of subsurface contaminant levels at drum/waste disposal areas.	Test Pit Investigation Soil Investigation
	3d. Assess potential impacts to soil from past disposal/ storage activities.	Characterize the nature and extent of soil contamination at Lot 203.	Soil Investigation

TABLE 2-2 (Continued)

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES FOR STORAGE LOT 203, THE WOODED AREAS, THE RAVINE AND SITE 82
SITES 6 and 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objectives	Criteria for Meeting Objectives	Proposed Investigation/Study
4. Groundwater	4a. Assess human health and ecological risks posed by potential usage or migration of shallow groundwater near Lot 203.	Evaluate on-site and off-site groundwater quality.	Groundwater Investigation Risk Assessment
	4b. Determine the presence or absence of off-site ground-water contamination.	Characterize off-site groundwater quality between Lot 203 and Wallace Creek.	Groundwater Investigation
	4c. Assess on-site groundwater quality at both known and unsuspected disposal areas.	Characterize on-site groundwater quality where disposal practices are known to have occurred.	Geophysical Investigation Groundwater Investigation
	4d. Assess the extent of vertical contaminated groundwater quality in areas where the shallow aquifer has been impacted.	Determine the quality of groundwater in the deeper aquifer.	Groundwater Investigation
5. Sediment	5a. Assess human health and ecological risks posed by sediment contamination in Wallace Creek.	Characterize areas of sediment contamination in Wallace Creek.	Sediment Investigation Risk Assessment
	5b. Assess potential ecological impacts posed by contaminated sediment.	Evaluate stress to benthic and fish communities.	Aquatic Survey (Wallace Creek)
	5c. Identify possible source of semivolatile contamination in Wallace Creek sediments and delineate areas of remediation, if necessary.	Identify extent of sediment contamination in Wallace Creek.	Sediment Investigation (Wallace Creek and the Ravine Area)

TABLE 2-2 (Continued)

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES FOR STORAGE LOT 203, THE WOODED AREAS, THE RAVINE AND SITE 82
SITES 6 and 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objectives	Criteria for Meeting Objectives	Proposed Investigation/Study
6. Surface Water (Wallace Creek)	6a. Assess human health and ecological risks associated with exposure to surface water.	Evaluate surface water quality throughout Wallace Creek.	Surface Water Investigation Risk Assessment
	6b. Assess ecological impacts from contaminated surface water.	Determine stress to fish or benthic communities.	Aquatic Survey
7. Surface or Subsurface Ordnance Debris	7a. Define areas where ordnance is located and notify DoN for subsequent removal by CLEJ personnel.	Visual inspection by qualified ordnance specialist.	Review of Historical Photographs Site Reconnaissance Geophysical Investigation

2.1.1.2 Site 82

Site 82 [referred to as "The Piney Green Road VOC Site," (NUS, 1991-1992)] is situated in the wooded area between Lot 203 and Wallace Creek. It is estimated to be 30 acres in size. This site was identified by results from a field investigation (conducted in 1986 by ESE). Portions of the site may have been disturbed by excavation activities (based on the topography and vegetative cover of this area. The debris (which included spent ammunition casings and drums/drum fragments) were noted to be protruding from the ground surface in some of the areas.

The project objectives, criteria for meeting these objectives, and general investigative methods for the RI performed at Site 82 are presented on Table 2-2. Note that the project objectives, criteria for meeting these objectives, etc., for Site 82 are presented together with Site 6 (e.g., Lot 203) because these two sites are essentially continuous (i.e., both sites share a common boundary).

2.2 Aerial Photographic Investigation

In August of 1992, an interim aerial photographic investigation report was completed by the USEPA's Environmental Photographic Interpretation Center (EPIC) in Warrenton, Virginia, of the Advanced Monitoring Systems Division in Las Vegas, Nevada. The investigation was performed at the request of the Superfund Support Section of EPA Region IV. The aerial photographs detail operations at OU No. 2 during the period from 1938 to 1990. Investigation results were employed to locate and assess potential sources of contamination, and to document past waste disposal and storage activities within the study area.

Information supplied by EPA Region IV identified areas of concern within each site and verified the occurrence of waste handling, disposal, and storage activities. Where possible, such activities were noted in the EPIC report and annotated on the photographs.

Black-and-white aerial photographs from 1938, 1944, 1949, 1952, 1956, 1960, 1964, 1970, 1980, 1988, and 1990 were used for the analysis of OU No. 2. The 1938 round of photographs established a basis of comparison, prior to development of the Camp Lejeune Military Reservation.

The analysis was performed by viewing backlit transparencies of aerial photographs through a stereoscope. Stereoscopic viewing of aerial photographs creates a perceived three-dimensional effect which enables the analyst to identify visible characteristics (e.g., color, tone, shadow, texture, size, shape, and pattern). These visible characteristics permit a specific object or condition to be recognized on aerial photographs (EPIC, 1992).

The following subsections describe selected aerial photographs from the photographic investigation. Appendix V contains reproductions of those annotated photographs that best illustrate conditions and delineate areas of concern within the study area.

2.2.1 Aerial Photograph - October 1949

The cleared area of Lot 203 is visible in the northern portion of Site 6 (see Appendix V.1). Probable refuse, material, and debris line the railroad spur that extends into the northwest corner of the cleared area. A building and possible dark-toned stain are noted within the cleared area at the terminus of the railroad spur.

The open storage area of Lot 201 is fenced and noted in the 1949 photograph. A graded area east of Lot 201 is also indicated. This portion of the study area may have been used for temporary housing prior to 1949. Numerous rectangular objects (not further/andannotated) probable housing units are uniformly arranged along the four parallel roads east of Lot 201.

2.2.2 Aerial Photograph - February 1956

The 1956 aerial photograph, see Appendix V.2, shows a marked increase in activity since the 1949 photograph. A large portion of the cleared area is now fenced and used to store military vehicles and equipment. The cleared areas that surround Lot 203 extend south toward Lot 201. Probable stacked containers and dark-toned material have been noted to the north of Lot 203. Trenches, containers, probable refuse, and debris are located throughout the open storage area. An excavated pit is also noted immediately to the south of Lot 203.

2.2.3 Aerial Photograph - November 1960

A dark-toned material, probably topsoil, has been noted to the north and southwest of Lot 203, see Appendix V.3. Trenches and linear ground scars have also been noted to the south and

southwest. Probable refuse and dark-toned objects are located in the vicinity of the railroad spur that extends into the clear area.

Probable staining has been indicated within the open storage area of Lot 201. Grading and the same dark-toned material found in the northern portion of the study area is evident to the east of Lot 201.

2.2.4 Aerial Photograph - December 1988

Numerous piles of refuse and raw materials are visible in the northwestern section of Lot 203, see Appendix V.4. Trenches, grading, and other ground scars are no longer evident in the study area. The disturbed areas are almost entirely revegetated. Rows of dark-toned objects, similar to those seen in earlier years, are visible in the northeastern section of the open storage area. Most of this area is now fenced, and vehicles, equipment, and other materials are stored in the open storage area of Lot 203.

Approximately 40 cylindrical objects and a debris pile are visible in the northern portion of Lot 201. Roads and buildings (not further/and annotated) are now seen in the formerly graded area east of Lot 201.

2.3 Preliminary Site Survey

Prior to initiating the drilling and sampling program at OU No. 2, a preliminary survey of each site was conducted, and the locations of the proposed soil borings and monitoring wells were surveyed. The proposed locations were established by using horizontal and vertical control points near the site which are tied into the North Carolina State Plane Coordinate System (NCSPCS). Hoggard-Eure Associates (Hoggard-Eure), a registered surveyor in the State of North Carolina, was retained to perform the survey. The preliminary survey was completed on September 10, 1992.

Sampling grids of boring locations for the soil investigation were established within each of the areas within OU No. 2. The sampling points within each grid area were spaced at varying distances depending on such factors as size of the area, contaminant of concern, and drilling accessibility. Table 2-3 summarizes sampling grid locations, sample spacings for each area investigated, the number of borings per grid, and the contaminants of concern.

TABLE 2-3

SOIL INVESTIGATION SAMPLING GRID SUMMARY
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Site/Area	Sample Grid Designation	Grid Spacing (feet)	Number of Borings in Grid	Primary Contaminant of Concern
Site 6/Lot 201	201A	50/100	39	Pesticides
Site 6/Lot 201	201B	50/100	39	Pesticides
Site 6/Lot 201	201C	50/100	41	PCBs
Site 6/Lot 203	DDT	100	34	Pesticides
Site 6/Lot 203	PCB	100	15	PCBs
Site 6/Lot 203	OSA(1)	300	44	Organics/Inorganics
Site 6/Ravine	RAV	Random	16	Organics/Inorganics
Site 6/Wooded Area	201N	300	12	Organics/Inorganics
Site 6/Wooded Area	201E	300	21	Organics/Inorganics
Site 6/ Wooded Area	201S	300	12	Organics/Inorganics
Site 82	OSA(2)	300	20	Organics/Inorganics
Site 9	Entire Site	25	57	Petroleum Hydrocarbons/ Organics/Inorganics

Notes: (1) Lot 203 grid OSA soil borings SB21 through SB44
(2) Site 82 grid OSA soil borings SB1 through SB20

Samples collected at soil borings SB11 and SB12 (both located at grid "201N") are considered as background samples.

Refer to Figures 2-5, 2-6, and 2-7 for soil sample locations.

Refer to Appendix C for summary of sample depths and analytical parameters tested.

Note that soil borings for monitoring well installation are not represented on this table.

Selection of the proposed soil boring and monitoring well locations for OU No. 2 was based upon review of several sources of information. These sources included results of previous investigations (NUS, 1992; ESE, 1990; and ESE, 1991) performed at OU No. 2, and records obtained from Camp Lejeune Activity personnel and the Navy which describe previous waste handling and disposal at the sites. Additionally, historical aerial photographs supplied from the EPIC were reviewed and interpreted to identify areas which may have been used in the past for disposal activities (i.e., Lot 203 within Site 6) as described in Section 2.2.

2.4 Phase I RI Field Investigations Performed at Sites 6 and 82

The Phase I field investigations performed at Sites 6 and 82 commenced on August 21 and continued through November 10, 1992. The field program implemented during the Phase I investigation consisted of a preliminary site survey; an unexploded ordnance (UXO) survey; a geophysical survey; a soil investigation including drilling and sampling; a groundwater investigation including monitoring well installation (shallow and deep wells) and sampling; drum waste sampling; test pit excavations and soil sampling; surface water and sediment investigations; and an aquatic and ecological survey. The following sections discuss these investigative activities.

2.4.1 Unexploded Ordnance Survey

During the pre-investigation site visit (August, 1991), numerous large caliper expended cartridges and small arms expended cartridges were noted exposed on the surface throughout sections of Sites 6 and 82. Accordingly, an unexploded ordnance (UXO) survey was conducted by the firm of Geo-Centers, Inc., (Geo-Centers) at several areas within Sites 6 and 82 prior to initiating the drilling and sampling programs. The UXO survey was conducted within Lot 203, areas south of Lot 203 (wooded areas), areas east of Lot 201 (wooded areas), and portions of Site 82. The survey was performed in two phases. Phase I included a UXO reconnaissance, a UXO geophysical survey, and a soil borehole/monitoring well UXO. Phase I tasks commenced on August 21, 1992 and were completed in two weeks.

Phase II was initiated on September 27, 1992, and continued for one week. Phase II tasks consisted of test pit excavations. A copy of Geo-Centers' UXO Surface and Subsurface Investigation and Removal Report, which includes the investigative methods and results, is presented in Appendix A.

2.4.2 Geophysical Investigations

A geophysical survey was conducted within Lot 203 and portions of the wooded area north of Lot 203 on August 29 and 30, 1992. Originally in the RI/FS Study Work Plan (submitted in May 1992), the survey was planned to extend into the southern portion of Site 82. Because of extensive overgrowth throughout Site 82, however, most of the area was not investigated. The survey was conducted to investigate areas within Lot 203 that appeared to have been excavated and backfilled as depicted on historical aerial photographs supplied by EPIC. It was believed that the trenches observed in the photographs may have been utilized for disposal of miscellaneous wastes (possibly drums of pesticides) while the storage area was active. The firm of Weston Geophysical Corporation (Weston) was retained to perform the survey.

Prior to the survey, a geophysical survey grid was established within Lot 203 by the surveying firm of Hoggard-Eure that consisted of parallel traverses spaced approximately 100-feet. Figure 2-4 shows the location of the survey grid.

Several geophysical techniques were employed during the investigation including electromagnetic terrain conductivity (ETC), magnetometry, and ground penetrating radar (GPR). ETC profiling was performed to map the lateral extent of buried material and to identify buried metal objects and other debris. The magnetometry survey was performed to complement the ETC interpretation of subsurface objects and debris. Lastly, GPR techniques were initiated to reveal a graphic cross-sectional view of subsurface stratigraphy and buried objects such as drums, pipelines, and tanks.

Results of the survey indicate a widespread area containing buried metal exists in the southern portion of the site, inside the perimeter fence and approximately parallel to the southern perimeter road as shown on Figure 2-4.

Buried metal was also detected in the wooded area on the eastern portion of the site, as shown on Figure 2-4. Additional geophysical lines of coverage were added to better define potential areas of disposal within the woods. One area is centered near grid coordinates 15+00E/6+00N, and its shape is characteristic of a trench.

Magnetic measurements were generally erratic across the entire site, due in part to the presence of surface metal objects and scattered scrap metal and debris. Areas of buried metal

delineated on Figure 2-4 were coincident with anomalously high magnetic intensities, indicating the presence of buried ferrous metallic objects.

Several geophysical lines were extended to the north beyond the perimeter fence. As shown on Figure 2-4, conductivity measurements indicate that fill materials or buried debris may extend beyond the perimeter fence in the northeast corner of the lot.

Appendix B contains the report prepared by Weston (a subsidiary of Baker Environmental, Inc.) for the geophysical survey at Site 6.

2.4.3 Soil Investigation

The soil investigation implemented at Sites 6 and 82 was intended to identify contaminants of concern [i.e., pesticides, polychlorinated biophenyls (PCBs), etc.] and evaluate their distribution at the site (refer to Tables 2-1 and 2-2 for specific objectives). Moreover, the investigation was performed to evaluate potential human health risks and ecological impacts associated with the contaminants of concern. As shown on Table 2-3, several sample grids were established within Sites 6 and 82 to assist in sample collection.

2.4.3.1 Analytical Sequences and Quality Control

Field procedures and sampling methods employed for this study were implemented in accordance with EPA Region IV standard operating procedures (USEPA, 1991). These procedures also include sample handling and preservation, documentation, and chain-of-custody procedures. Specific sampling procedures are outlined in the Final RI/FS Work Plan for Site 6 (Baker, 1992).

Validation of analytical data, performed under DQO Level IV, (i.e., CLP organics, CLP inorganics and EPA Methods 601 and 602) was performed by an independent subcontractor. The data validation process involved reviewing the data for completeness of submission, a technical evaluation, and a site-specific evaluation to determine the usability of the data.

The technical data validation is a systematic procedure of reviewing analytical data against a set of established criteria set froth in the USEPAs Laboratory Data Validation National Functional Guidelines for Evaluating Inorganic and Organic Analyses.

As a result of validation there were no analytical values rejected "R". Several values, are considered to be estimated and have been assigned J qualifiers. The J qualifier is the most commonly encountered data qualifier in CLP packages. Consistent with USEPA guidance, J-qualified data are to be used as positive data that are unqualified.

Blank inorganic or organic contaminants detected in a sample are considered as positive only if the concentration of the containment in the site sample is five times the maximum amount detected in any blank. For common lab contaminants (i.e., acetone, 2-butanone, methylene chloride, toluene and phthalate esters), the sample concentration must be ten times the maximum amount detected in any blank. Organic contaminants with a B-qualifier are attributable to blank contamination and have not been incorporated as data points. The soil investigation conducted at Sites 6 and 82 included shallow soil borings, soil sampling, field screening and air monitoring. These activities and analytical sequences are discussed in the following sections.

2.4.3.2 Drilling Procedures

The Phase I drilling activities at Sites 6 and 82 commenced on August 24 and continued through November 7, 1992. Hardin and Huber, Inc., (HHI) was retained to perform the drilling services. The drilling and sampling programs implemented at Sites 6 and 82 were intended to investigate shallow and deep physical (i.e., geologic and hydrogeologic) and chemical (i.e., contaminant distribution) conditions.

Site 6 was subdivided into three areas (grid locations) for the drilling program, including: Lot 201; Lot 203; and the wooded areas (north, east, and south of Lot 201) along with the ravine (north of Lot 203). Site 82 was considered as one entire grid area and consisted of 20 sample locations (soil borings OSA-SB1 through OSA-SB20). These areas were subdivided into grid areas based on the suspected contaminants of concern (from past disposal activities and previous military operations) and their geographical locations. Figures 2-5, 2-6, and 2-7 depict drilling locations for Lot 201; Lot 203; and the wooded areas, (the ravine, and Site 82, respectively.

The following sections describe the drilling procedures employed for advancing the shallow (i.e., less than 35 feet) and deep (greater than 100 feet) boreholes.

Shallow Drilling Procedures

Shallow boreholes were advanced using a truck-mounted drill rig using hollow-stem auger (HSA). During drilling, 3-1/4 inch inside diameter (ID) augers were used to advance the boreholes. Split-spoon samples were collected from inside the augers according to ASTM Method D 1586-84 (ASTM, 1984). Soil cuttings obtained during the drilling program were contained and handled according to the procedures outlined in Section 2.8. Drilling and sampling activities were performed using Level D personal protection. [Note that upgraded levels of protection (e.g., Level D to Level C personal protection) were not required during the drilling program.]

Two different schemes were employed for samples collected from exploratory soil borings and borings advanced for monitoring well installation. Soil samples obtained exploratory from soil borings were collected from the surface (ground surface to six-inches) and then at continuous two-foot intervals (starting at one-foot) until the borings were terminated at the approximate depth of the water table; in some cases where potential wetting fronts were suspected (i.e., perched water table), an additional split-spoon was collected below the water table to confirm groundwater depth. Two-foot samples were obtained to ensure a sufficient quantity of sample was retained for laboratory analysis and classification.

Samples collected from borings advanced for monitoring well installation were obtained at continuous two-foot intervals (from the ground surface) to just below the water table, then at approximate 5-foot intervals thereafter until the borings were terminated [approximately 20 to 35 feet below ground surface (bgs)]. A summary of the sample numbers, boring depths, and sampling intervals is provided in Appendix C (C.1 through C.11).

Each split-spoon sample was classified visually by the site geologist. Soils were classified in the field using a general Unified Soil Classification System (USCS) lithologic description. Lithologic descriptions were recorded in a field logbook and later transferred onto boring log records. Soil classifications included characterization of soil type, grain size, color, moisture content, relative density, plasticity, and other pertinent information such as indications of contamination. Lithologic descriptions of site soils are provided on the Test Boring Records in Appendix D (D.1 through D.10) and the Test Boring and Well Construction Records in Appendix E (E.1 and E.2).

Additionally, some samples (e.g., ravine area) were obtained utilizing a hand auger where access with a drill rig was not possible. The auger bucket was advanced to the desired sampling depth and a new, decontaminated bucket was installed to collect the grab sample. The auger buckets were also decontaminated prior to sample collection according to the procedures outlined in Section 2.7.

Deep Drilling Procedures

Five deep soil borings (6GW1D, 6GW2D, 6GW7D, 6GW27D, and 6GW28D) were advanced from 107 feet (6GW7D) to 122 feet (6GW2D) bgs and converted into deep monitoring wells. The borings were initially advanced with 3-1/4 inch ID HSA to just below the water table, then further advanced using mud rotary drilling until the borehole was terminated. Mud rotary drilling was employed because of the unconsolidated soil conditions and the drilling depth limitations of augers. Continuous two-foot split-spoon samples were collected to just below the water table (for laboratory analysis), then at approximate 5-foot intervals. Soils were visually classified by the site geologist as described in the previous paragraph.

The drilling fluid (i.e., mud) used for the deep borings consisted of a mixture of sodium bentonite. Potable water from a nearby fire hydrant at Site 9 was used to mix the materials. Field blanks of the potable water source, drilling fluid, and mixing tube (collected after the tube was decontaminated) were collected for quality control/quality assurance (QA/QC) purposes. Drilling fluids (along with the soil cuttings) were temporarily stored in 55-gallon drums and later emptied into rolloff boxes staged on site at a secure area (see Section 2.8 for details on Investigative Derived Wastes).

2.4.3.2 Soil Sampling

The following sections summarize soil sampling locations, procedures, and analytical methods employed for the soil investigation.

Sampling Locations

Soil samples were collected throughout Sites 6 and 82 for soil classification purposes and analytical testing. Figures 2-5, 2-6, and 2-7 depict soil sample locations for Lot 201; Lot 203; and the wooded areas, the ravine, and Site 82, respectively. Table 2-3 summarizes the sample

locations, grid designations, grid spacings, the number of borings per grid, and primary contaminant of concern for each area.

Sampling Procedures

Surface (0 to 6 inches bgs) and subsurface (deeper than one foot) soil samples were collected for laboratory analysis. Surface samples were collected for risk assessment evaluation while subsurface samples were collected to evaluate the horizontal and vertical extent of potentially impacted soils. Appendix C (C.1 through C.11) summarize the sample depths, sample numbers, and parameters analyzed.

Soil samples were obtained via a drill rig (i.e., split-spoon samples) or hand auger as described in Section 2.4.3.1. Surface samples were obtained by advancing the HSA to approximately six inches bgs so that the soil cuttings could be retained for the grab sample. The first few inches of top soil or matted roots were removed prior to advancing the augers (some areas were covered with grass or humus material). Deeper subsurface grab soil samples were collected with a split-spoon sampler in accordance with ASTM Method D 1586-84 as detailed in Section 2.4.3.1. Both the HSA and split-spoon samplers were decontaminated prior to sample collection according to the procedures outlined in Section 2.7.

In general, samples retained for laboratory analysis were collected from the surface and just above the water table (i.e., typically two samples per borehole were submitted for analysis). In some cases, a third sample from a borehole was also submitted for analysis if evidence of contamination (i.e., elevated PID readings) was noted or if the boring was deeper than 10 feet. Samples retained from borings advanced for monitoring well installation were collected from just above and just below the water table. This sampling methodology was implemented so that groundwater results could be correlated with soil conditions.

Soil samples retained for analysis were prepared according to EPA Region IV SOPs. Samples collected for volatile organic analysis were extracted with a stainless-steel spoon from different sections of the split-spoon or auger bucket, representing the entire sampling interval. Precautions were taken not to aerate the sample, to minimize volatilization. Samples retained for other analytical parameters [i.e., semivolatiles, PCBs, pesticides, toxicity characteristic leaching procedure (TCLP) compounds, and engineering parameters] were first thoroughly mixed and then placed in the appropriate laboratory containers. Samples on which grain-size

analysis were performed were collected by advancing the hollow-stem augers and retaining the soil cuttings.

Following sample collection, each sample retained for laboratory analysis was stored with ice in a cooler. Sample preparation also included documentation of sample number, depth, location, date, time, and analytical parameters in a field log book. Chain-of-custody documentation, which included information such as sample number, date, time of sampling, and sampling personnel, accompanied the samples to the laboratory. Samples were shipped via Federal Express to Ceimic Corporation (Ceimic) in Narragansatt, RI.

Analytical Requirements

Analytical methods are summarized on Tables 2-4 and 2-5 for organic and inorganic analyses, respectively. Samples were analyzed for contaminants of concern within each grid area (refer to Table 2-3). For example, in grid 201A, the contaminants of concern are pesticides. Accordingly, most of the samples from this grid were analyzed for TCL pesticides; other random samples from this grid (i.e., generally at sample points located on the perimeter and center of grid) were analyzed for full TCL organics (volatiles, semivolatiles, pesticides, and PCBs) and Target Analyte List (TAL) inorganics (total metals). Selected samples (from grids located within Lot 201) were also analyzed for residual chloride, total fluoride, organic nitrogen, and total alkalinity (engineering parameters); total TCLP; and RCRA hazardous waste characteristics (i.e., flashpoint, ignitability, etc.) to evaluate general soil conditions for potential treatment and disposal options. These samples were collected near the center of each grid or in areas where indications of contamination (i.e., PID readings or analytical results) were noted. Samples were also collected at selected locations (generally near center of grid) for grain-size analysis to evaluate subsurface physical conditions. Appendix C (C.1 through C.11) provides a summary of the analytical program for the various grid areas.

Quality Assurance and Quality Control Samples

Field quality assurance and quality control (QA/QC) samples were also collected during the sampling program. These samples were obtained to: 1) ensure that decontamination procedures were properly implemented (i.e., equipment rinsate samples); 2) evaluate field methodology (i.e., duplicate samples); 3) establish field background conditions (i.e., field blanks); and 4) evaluate whether cross-contamination occurred during sampling and/or shipping (i.e., trip blanks). Data Quality Objectives (DQOs) for the QA/QC samples were

TABLE 2-4

SUMMARY OF METHOD PERFORMANCE LIMITS - ORGANICS
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Volatiles by CLP Protocol	Quantitation Limits*		
	Water µg/L	Low Soil µg//Kg	Med. Soil µg/Kg
1. Chloromethane	10	10	1200
2. Bromomethane	10	10	1200
3. Vinyl Chloride	10	10	1200
4. Chloroethane	10	10	1200
5. Methylene Chloride	10	10	1200
6. Acetone	10	10	1200
7. Carbon Disulfide	10	10	1200
8. 1,1,-Dichloroethene	10	10	1200
9. 1,1-Dichloroethane	10	10	1200
10. 1,2-Dichloroethene (total)	10	10	1200
11. Chloroform	10	10	1200
12. 1,2-Dichloroethane	10	10	1200
13. 2-Butanone	10	10	1200
14. 1,1,1-Trichloroethane	10	10	1200
15. Carbon Tetrachloride	10	10	1200
16. Bromodichloromethane	10	10	1200
17. 1,2-Dichloropropane	10	10	1200
18. cis-1,3-Dichloropropene	10	10	1200
19. Trichloroethene	10	10	1200
20. Dibromochloromethane	10	10	1200
21. 1,1,2-Trichloroethane	10	10	1200
22. Benzene	10	10	1200
23. trans-1,3-Dichloropropene	10	10	1200
24. Bromoform	10	10	1200
25. 4-Methyl-2-pentanone	10	10	1200
26. 2-Hexanone	10	10	1200
27. Tetrachloroethene	10	10	1200
28. Toluene	10	10	1200
29. 1,1,2,2-Tetrachloroethane	10	10	1200
30. Chlorobenzene	10	10	1200
31. Ethyl Benzene	10	10	1200
32. Styrene	10	10	1200
33. Xylenes (Total)	10	10	1200

Note: * Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

TABLE 2-4 (Continued)

SUMMARY OF METHOD PERFORMANCE LIMITS - ORGANICS
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Semivolatiles by CLP Protocol	Quantitation Limits*		
	Water µg/L	Low Soil µg//Kg	Med. Soil µg/Kg
34. Phenol	10	330	10000
35. bis (2-Chloroethyl) ether	10	330	10000
36. 2-Chlorophenol	10	330	10000
37. 1,3-Dichlorobenzene	10	330	10000
38. 1,4-Dichlorobenzene	10	330	10000
39. 1,2-Dichlorobenzene	10	330	10000
40. 2-Methylphenol	10	330	10000
41. 2,2'-oxybis (1-Chloropropane)#	10	330	10000
42. 4-Methylphenol	10	330	10000
43. N-Nitroso-di-n-propylamine	10	330	10000
44. Hexachloroethane	10	330	10000
45. Nitrobenzene	10	330	10000
46. Isophorone	10	330	10000
47. 2-Nitrophenol	10	330	10000
48. 2,4-Dimethyphenol	10	330	10000
49. bix (2-Chloroethoxy) methane	10	330	10000
50. 2,4-Dichlorophenol	10	330	10000
51. 1,2,4-Trichlorobenzene	10	330	10000
52. Naphthalene	10	330	10000
53. 4-Chloroaniline	10	330	10000
54. Hexachlorobutadiene	10	330	10000
55. 4-Chloro-3-methylphenol	10	330	10000
56. 2-Methylnaphthalene	10	330	10000
57. Hexachlorocyclopentadiene	10	330	10000
58. 2,4,6-Trichlorophenol	10	330	10000
59. 2,4,5-Trichlorophenol	25	800	25000
60. 2-Chloronaphthalene	10	330	10000
61. 2-Nitroaniline	25	800	25000
62. Dimethylphthalate	10	330	10000
63. Acenaphthylene	10	330	10000
64. 2,6-Dinitrotoluene	10	330	10000
65. 3-Nitroaniline	25	800	25000
66. Acenaphthene	10	330	10000

Notes: * Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

\# Previously known by the name bis (2-Chloroisopropyl) ether

TABLE 2-4 (Continued)

SUMMARY OF METHOD PERFORMANCE LIMITS - ORGANICS
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Semivolatiles by CLP Protocol	Quantitation Limits*		
	Water µg/L	Low Soil µg//Kg	Med. Soil µg/Kg
67. 2,4-Dinitrophenol	25	800	25000
68. 4-Nitrophenol	25	800	25000
69. Dibenzofuran	10	330	10000
70. 2,4-Dinitrotoluene	10	330	10000
71. Diethylphthalate	10	330	10000
72. 4-Chlorophenyl-phenyl ether	10	330	10000
73. Fluorene	10	330	10000
74. 4-Nitroaniline	25	800	25000
75. 4,6-Dinitro-2-methylphenol	25	800	25000
76. N-nitrosodiphenylamine	10	330	10000
77. 4-Bromophenyl-phenylether	10	330	10000
78. Hexachlorobenzene	10	330	10000
79. Pentachlorophenol	25	800	25000
80. Phenanthrene	10	330	10000
81. Anthracene	10	330	10000
82. Carbazole	10	330	10000
83. Di-n-butylphthalate	10	330	10000
84. Fluoranthene	10	330	10000
85. Pyrene	10	330	10000
86. Butylbenzylphthalate	10	330	10000
87. 3,3'-Dichlorobenzidine	10	330	10000
88. Benzo(a)anthracene	10	330	10000
89. Chrysene	10	330	10000
90. bis (2-Ethylhexyl) phthalate	10	330	10000
91. Di-n-octylphthalate	10	330	10000
92. Benzo (b) fluoranthene	10	330	10000
93. Benzo (k) fluoranthene	10	330	10000
94. Benzo (a) pyrene	10	330	10000
95. Indeno (1,2,3-cd) pyrene	10	330	10000
96. Dibenz (a,h) anthracene	10	330	10000
97. Benzo (g,h,i) perylene	10	330	10000

Notes: * Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

\# Previously known by the name bis (2-Chloroisopropyl) ether

TABLE 2-4 (Continued)

SUMMARY OF METHOD PERFORMANCE LIMITS - ORGANICS
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Pesticides/PCBs by CLP Protocol	Quantitation Limits*	
	Water µg/L	Soil µg//Kg
98. alpha-BHC	0.05	1.7
99. beta-BHC	0.05	1.7
100. delta-BHC	0.05	1.7
101. gamma-BHC (lindane)	0.05	1.7
102. Heptachlor	0.05	1.7
103. Aldrin	0.05	1.7
104. Heptachlor epoxide	0.05	1.7
105. Eudosulfan I	0.05	1.7
106. Dieldrin	0.10	3.3
107. 4,4'-DDE	0.10	3.3
108. Endrin	0.10	3.3
109. Endosulfan II	0.10	3.3
110. 4,4'-DDD	0.10	3.3
111. Endosulfan sulfate	0.10	3.3
112. 4,4'-DDT	0.10	3.3
113. Methoxychlor	0.50	17.0
114. Endrin ketone	0.10	3.3
115. Endrin aldehyde	0.10	3.3
116. alpha-Chlordane	0.05	1.7
117. gamma-Chlordane	0.05	1.7
118. Toxaphene	5.0	170.0
119. PCB-1016	1.0	33.0
120. PCB-1221	2.0	67.0
121. PCB-1232	1.0	33.0
122. PCB-1242	1.0	33.0
123. PCB-1248	1.0	33.0
124. PCB-1254	1.0	33.0
125. PCB-1260	1.0	33.0

Notes: * Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

There is no differentiation between the preparation of low and medium soil samples in this method for the analysis of Pesticides/Aroclors.

TABLE 2-5

SUMMARY OF METHOD PERFORMANCE
LIMITS - INORGANICS
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Analyte	Contract Required Detection Limit
Aluminum	200
Antimony	60
Arsenic	10
Barium	200
Beryllium	5
Cadmium	5
Calcium	5000
Chromium	10
Cobalt	50
Copper	25
Iron	100
Lead	3
Magnesium	5000
Manganese	15
Mercury	0.2
Nickel	40
Potassium	5000
Selenium	5
Silver	10
Sodium	5000
Thallium	10
Vanadium	50
Zinc	20

Notes: * Quantitation limits listed for soil/sediment are based on wet weight. The quantitation limits calculated by the laboratory for soil/sediment, calculated on dry weight basis, will be higher.

Previously known by the name bis (2-Chloroisopropyl) ether

implemented in accordance with DQO Level IV as defined in the Environmental Compliance Branch Standard Operating Procedures (SOPs) and Quality Assurance Manual, EPA Region IV (1991). This DQO Level is equivalent to Naval Energy and Environmental Support Agency DQO Level D, as specified in the "Sampling and Chemical Analysis Quality Assurance Requirements for the Navy Installation Restoration Programs" document (1988).

Several types of field QA/QC samples were collected and analyzed including duplicate samples, equipment rinsates, field blanks, and trip blanks. These sampling definitions are listed below (USEPA, 1991):

- Duplicate Sample: Two or more samples collected simultaneously into separate containers from the same source under identical conditions.

- Equipment Blanks: Equipment field blanks are defined as samples which are obtained by running organic-free water over/through sample collection equipment after it has been cleaned. These samples will be used to determine if cleaning procedures were adequate. (The equipment could have been cleaned in the field or prior to the field operation.) Equipment blanks are collected daily but only samples collected on every other day are analyzed.

- Field Blanks: Organic-free water is taken to the field in sealed containers and poured into the appropriate sample containers at designated locations. This is done to determine if contaminants present in the area may have an affect on the sample integrity. Field blanks should be collected in dusty environments and/or from areas where volatile organic contamination is present in the atmosphere and originating from a source other than the source being sampled.

- Trip Blanks: Trip blanks are prepared prior to the sampling event in the actual sample container and are kept with the investigative samples throughout the sampling event. They are then packaged for shipment with the other samples and sent for analysis. At no time after their preparation are the sample containers to be opened before they return to the laboratory. Field sampling teams utilize volatile organic trip blanks to determine if samples were contaminated during storage and transportation back to the laboratory. If samples are to be shipped, trip blanks are to be provided for each shipment but not necessarily for each cooler.

TABLE 2-6

SUMMARY OF FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM FOR THE PHASE I SOIL INVESTIGATION SITES 6 and 82 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample (1)	Frequency of Collection	Number of Samples	Analytical Parameters (3)
Trip Blanks (2)	One per Cooler	48	TCL Volatiles
Field Blanks	One per Event (4)	3	TCL Organics/TAL Inorganics
Equipment Rinsates (5)	One per Day	33	TCL Organics/TAL Inorganics
Field Duplicates (6)	10% of Sample Frequency	(6)	TCL Organics/TAL Inorganics

Notes:
(1) QA/QC sample types defined on pages 2-12 and 2-13 in text.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Parameters analyzed according to procedures outlined on Tables 2-5 and 2-6.
(4) An event is defined as one 14 day period. Field blank includes a sample of drilling mud (6-GW1D-FB-03).
(5) Equipment rinsates collected from various sampling equipment (e.g., split spoons, stainless steel spoons, hollow stem augers, etc.). Note that samples were collected daily but were analyzed every other day of the sampling event. Accordingly, the number of samples presented represents the number of samples analyzed.
(6) Field duplicate samples collected from soil borings presented in Appendix N.

Table 2-6 summarizes field QA/QC sample types, sample frequencies, the number of QA/QC samples, and analytical methods. Equipment rinsate samples were collected by pouring laboratory-prepared deionized water over the sampling device (e.g., split-spoon sampler) and collecting the sample in laboratory containers. [Note that equipment rinsate samples were collected daily (from each field team), but the samples were analyzed every other day (USEPA, 1991).] Field blanks were collected during the soil investigation by filling sample containers with laboratory-prepared deionized water. The field blanks were collected in the vicinity of "DDT" and "PCB" sampling grids.

2.4.3.3 Field Screening and Air Monitoring

Several air monitoring and field screening procedures were implemented during drilling and sampling activities for health and safety and initial contaminant monitoring. During drilling, ambient air monitoring in the vicinity of the borehole was performed with a lower explosive limit (LEL) meter, a flame ionization detector (FID) or photoionization detector (PID), and a radiation meter to monitor for airborne contaminants. Samples (i.e., split-spoon samples) were screened with a PID or FID, and the radiation meter to measure for volatile organic vapor and radioactive particles, (note that radioactive particles were not suspected at site) respectively. Measurements obtained in the field was recorded in a field log book. Prior to daily monitoring, the instruments were calibrated and documentation was recorded in field log books and on calibration forms (retained by Baker). PID/FID measurements are provided on the Test Boring Records, and Test Boring and Well Construction Records in Appendices D (D.1 through D.10) and E (E.1 and E.2).

2.4.4 Groundwater Investigation

The groundwater investigation implemented at Sites 6 and 82 was intended to identify contaminants of concern and evaluate their distribution at the site. The primary objectives of this investigation are summarized on Tables 2-1 through 2-2.

In general, the field procedures and sampling methods employed for this study were implemented in accordance with EPA Region IV SOPs. These procedures also included sample handling and preservation, documentation, and chain-of-custody procedures. Specific sampling procedures are outlined in the Final RI/FS Work Plan for Site 6.

The following sections describe monitoring well installation for both shallow and deep wells, well development, groundwater sampling, and water level measurement procedures.

2.4.4.1 Monitoring Well Installation

The following sections describe monitoring well installation procedures for both the shallow and deep monitoring wells.

Shallow Well Installation

Nineteen shallow Type II (i.e., monitoring well was installed without outer casing to seal off a confining layer) monitoring wells (denoted as 6GW9 through 6GW23, 6GW25, 6GW26, 6GW28S, and 6GW30S) were installed at Sites 6 and 82 at the locations shown on Figure 2-8. The monitoring wells were installed to collect surficial groundwater samples for characterizing the nature and horizontal extent of potentially impacted groundwater and to evaluate groundwater flow patterns at the site. As stated previously, the locations of the wells were based on review of previous investigation data, past disposal practices, and historical aerial photographs. Table 2-7 provides a summary for the rationale of the well locations.

Initially in the Final RI/FS Work Plan two other monitoring wells, 6GW24 and 6GW29, were proposed east of Piney Green Road to serve as site-specific background monitoring wells. During a reconnaissance of the area (during the RI investigation) five existing shallow wells (denoted as 6MW2, 6MW3, 6MW8, 6MW9, and 6BP6 installed by SM&E in April 1992), were noted east of Piney Green Road. The SM&E wells (25 feet in depth) were installed as part of a preliminary investigation for a proposed landfill in the area (report submitted by Dewberry and Davis, September 1992). Accordingly, wells 6GW29 and 6GW24 were not installed and the five existing wells were substituted in their place to serve as site-specific background wells.

Additionally, several other monitoring wells including 6GW11, 6GW15, 6GW16 and 6GW23 were proposed in the wooded areas south and east of Lot 201, and east of Piney Green Road. Monitoring wells 6GW11, 6GW15, and 6GW23 were relocated within Lot 203 while 6GW16 was relocated to the wooded area between Lots 201 and 203. These wells were moved to new locations during the investigation because aerial photographs (acquired in September 1992) revealed past activities (e.g., ground scars) in some of these areas. Additionally, well 6GW16

TABLE 2-7

PHASE I MONITORING WELL SUMMARY AND RATIONALE
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Site No.	Well Designation	General Location	Purpose
82	6GW1S*, 82MW1*, 82MW2*, 82MW3*, 6GW26, 6GW27S, and 6GW28S	Site 82	Monitor shallow groundwater quality downgradient from Lot 203.
82	6GW1D, 6GW27D, and 6GW28D	Site 82	Monitor deep groundwater quality downgradient from Lot 203.
6	6GW3*	Lot 203 near the Ravine Area	Monitor shallow groundwater quality on both sides of the ravine Area.
	6GW30	North of Site 82	Monitor groundwater quality across Wallace Creek to assess other potential contaminant plumes from other unknown sources or to assess the extent of horizontal migration from Lot 203.
	6GW2S*, 6MW3*, 82MW30*, 6MW9*, 6MW2*, 6MW8*, and 6BP6*	East of Lot 203/Piney Green Road	Monitor upgradient shallow groundwater quality.
	6GW2D	East of Lot 203/Piney Green Road	Monitor upgradient deep groundwater quality.
	6GW4*, 6GW20, 6GW21, 6GW25, 6GW19, and 6GW16	South of Lot 203 and North of Lot 201 in a wooded portion of Site 6	Monitor groundwater quality in this portion of site where random disposal of wastes may have occurred. These wells also will assess upgradient conditions with respect to Lot 201.
	6GW5* and 6GW22	Area A, Lot 201	Monitor upgradient and downgradient groundwater quality in the surficial aquifer.
	6GW14, 6GW18, 6GW6*, and 6GW17	East of Lot 201 in a wooded portion of Site 6	Monitor groundwater quality in the surficial aquifer upgradient of Lot 201 and monitor groundwater quality in this portion of the site where random dumping has occurred.
	6GW8*, 6GW7S*, 6GW12, and 6GW13	Downgradient from Area B and Area C, Lot 201	Monitor shallow groundwater quality downgradient of the former pesticide and PCB storage areas.
	6GW7D	Downgradient of Lot 201 and Area C	Monitor deep groundwater quality downgradient of Lot 201.
	6GW9, and 6GW10	South of Bear Head Creek	Monitor shallow groundwater quality in this wooded portion of Site 6 where random disposal has occurred. These wells will also serve to assess groundwater quality downgradient from Site 9.
	6GW11, 6GW1S, and 6GW23	Lot 203	Monitor shallow groundwater quality within Lot 203 where random disposal of wastes may have occurred.

Note: * - Denotes existing monitoring well.

was repositioned because indications of shallow soil contamination (i.e., 5-gallon pails of suspected solvent material) were uncovered during test pit activities.

Prior to well installation, a permit for the Construction of a Well or Well System was obtained from the North Carolina Environmental Commission, Department of Environmental, Health and Natural Resources (NC DEHNR) of Raleigh, North Carolina. A copy of the permit is provided in Appendix F.

The shallow monitoring wells were installed upon completion of advancing the boreholes (refer to Section 2.4.3.1 for drilling procedures). Each borehole was over-drilled with 8-1/4 inch ID HSA prior to well installation. Well depths ranged from 17.6 feet bgs (6GW17) to 32 feet bgs (6GW28S). In general, the wells were installed approximately 15 feet below the water table encountered during initial drilling. Further, the wells were installed at depths and with interception intervals sufficient to compensate for seasonal variations in the water table (known to range from 2 to 4 feet).

Well construction details for the Phase I shallow wells are summarized on Table 2-8, and well construction diagrams are shown on the Test Boring and Well Construction Records provided in Appendix E. Note that well construction details for existing site wells are summarized on Table 1-1 in Section 1.0.

The wells are constructed of 4-inch nominal diameter Schedule 40, flush-joint and threaded PVC casing with 15-foot long No. 10 slotted screen sections (note that a 5- and 10-foot section of screen were screwed together to make up the 15-foot long screen). Four-inch diameter wells were selected so that the wells could also be used to extract groundwater for treatment, if necessary. A 15-foot long screen was used to compensate for seasonal variations (ranges from 2 to 4 feet) in the water table. A medium-grained sand pack (Number 2 silica sand), extending approximately 2-feet (where conditions permitted) above the top of the screen, was placed in the annulus between the screen and the borehole wall (12-inch borehole diameter) from inside the HSA. A 1-to 2-foot sodium bentonite pellet seal was then placed (by dropping the material down the borehole) above the sand pack and hydrated with potable water (from the same water source as described in Section 2.4.3.1). The seal was installed to prevent cement or surface water run-off from intruding onto the sand pack. The remaining annular space (approximately one to two feet in most cases) was backfilled with a mixture of Portland cement and 5 percent bentonite for construction of the pad. An above ground steel protective casing and PVC locking cap were fitted at the top of each well. Well 6GW22 was completed with a

TABLE 2-8

SUMMARY OF PHASE I SHALLOW WELL CONSTRUCTION DETAILS
SITES 6 and 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (1) (feet, above msl)	Ground Surface Elevation (feet, above msl)	Boring Depth (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)	Stick-Up (feet, above ground surface)
6GW9	9/24/92	21.11	18.6	20.0	19.1	5.3-18.7	3.0	1.0	2.5
6GW10	9/23/92	19.88	17.2	18.5	18.0	3.8-17.5	2.0	1.0	2.6
6GW11	10/10/92	35.05	32.4	19.5	18.7	4.0-18.4	2.5	1.0	2.6
6GW12	9/24/92	18.29	17.0	18.5	18.0	3.8-17.6	2.4	1.0	1.3
6GW13	9/24/92	20.10	18.1	18.5	18.0	3.8-17.6	2.0	1.0	2.0
6GW14	10/6/92	28.49	25.5	23.0	22.0	7.5-21.7	5.0	3.2	3.0
6GW15S	10/11/92	29.07	26.1	20.5	20.0	5.4-19.7	3.0	1.5	2.9
6GW16	10/11/92	27.63	24.9	20.0	20.0	5.4-19.8	3.0	1.6	2.7
6GW17	9/25/92	28.10	25.7	18.5	17.6	2.3-17.1	1.5	0.5	2.4
6GW18	9/25/92	29.70	26.5	19.5	18.5	3.9-18.1	2.0	1.0	3.2
6GW19	10/6/92	27.95	25.2	20.5	20.0	5.2-19.3	3.0	1.6	2.75
6GW20	10/8/92	25.08	22.5	24.0	19.7	4.8-19.4	2.1	1.1	2.58
6GW21	9/24/92	30.30	27.9	24.0	22.5	8.0-22.0	6.0	4.5	2.4
6GW22	9/24/92	24.13	24.5	20.0	19.5	4.5-19.0	3.0	2.0	NA (2)
6GW23	10/12/92	26.96	24.5	22.0	21.0	8.4-22.7	5.0	3.0	2.56
6GW25	10/8/92	34.30	32.1	24.0	23.5	8.9-23.2	6.0	4.2	2.2
6GW26	10/9/92	23.66	20.9	20.0	20.0	5.0-19.7	3.0	1.4	2.7
6GW28S	10/10/92	30.20	27.6	32.5	32.0	17.5-31.7	15.0	13.3	2.6
6GW30S	10/10/92	12.60	9.9	21.0	20.0	5.3-19.7	3.0	1.0	2.7

Notes: (1) msl - mean sea level
(2) NA = Not Applicable; flush-mounted well
Horizontal positions are referenced to N.C. State Plane Coordinate System (NAD 27) CF = 0.9999216 from USMC Monument Toney. Vertical datum NGVD 29.

flush-mounted cover because of the high traffic conditions in Lot 201. The wells were tagged with the North Carolina well permit information and marked "Caution -- Not Potable Water". Typical well construction details are shown on Figure 2-9.

Deep Well Installation

Five deep monitoring wells (6GW1D, 6GW2D, 6GW7D, 6GW27D, and 6GW28D) were installed to investigate deep hydrogeologic and geologic conditions, and to evaluate contaminant impact on the deeper water-bearing zones underlying the site [i.e., to evaluate whether contaminants have migrated downward from the shallow water-bearing zones to the main water supply aquifer for Camp Lejeune (Castle Hayne aquifer)]. The wells were installed at depths ranging from 100.5 feet bgs (6GW7D) to 119 feet bgs (6GW2D). The selection of well depth was based on geologic conditions encountered in the field. These wells were screened within the upper portion of a sandy-gravelly limestone which is considered to contain the upper portion of the main water supply aquifer (Castle Hayne Aquifer) for Camp Lejeune (Harned, et al., 1989).

The locations of the deep wells were selected based on the results of previous investigations (ESE, 1986; and NUS, 1992) and on information relating to past disposal or storage activities. In general, the deep wells were installed adjacent to shallow well locations (i.e., well clusters) where contamination was noted in the past, or in areas where previous disposal (or storage of hazardous materials) activities were reported. Table 2-7 provides a summary for the rationale of deep well locations. The locations of these wells are shown on Figure 2-8.

The deep monitoring wells are constructed of 4-inch nominal diameter Schedule 40, flush-joint and threaded PVC casing with a 10-foot long No. 10 slotted screen section. A medium-grained sand pack (Number 2 silica sand) extending at a minimum of 2-feet above the top of the screen, was placed in the annulus between the screen the borehole wall (12-inch borehole diameter) by pouring the sand down the borehole (sand pack was not tremmied in place because of the possibility of bridging off the borehole wall). A sodium bentonite pellet seal was then placed (by dropping the material down the borehole) above the sand pack and hydrated with potable water (same source as described in Section 2.4.3.1. The remaining annular space was backfilled (via a tremmie pipe) with a mixture of Portland cement and 5 percent sodium bentonite. An above ground steel protective casing and PVC locking cap were fitted at the top of each well (refer to Figure 2-9). Table 2-9 provides a summary of the Phase I deep monitoring well construction details.

TABLE 2-9

SUMMARY OF PHASE I DEEP WELL CONSTRUCTION DETAILS
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (1) (feet, above msl)	Ground Surface Elevation (feet, above msl)	Boring Depth (feet, below ground surface)	Depth of Outer Casing (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)	Stick-Up (feet, above ground surface)
6GW1D	10/7-8/92	35.31	32.8	117.0	NA (2)	112.5	102.7-111.7	99.5	96.0	2.5
6GW2D	10/10/92 10/13-14/92	37.61	35.1	122.0	26.0	119.0	108.1-118.1	105.0	101.0	2.5
6GW7D	10/6-7/92	20.08	17.4	107.0	NA	100.5	90.5-99.5	86.5	83.0	2.6
6GW27D	10/11-12/92	24.47	22.5	112.0	NA	110.0	100.1-109.1	97.0	94.5	1.9
6GW28D	10/20-21/92	31.74	28.7	115.0	NA	114.5	104.0-113.6	99.0	95.0	3.0

Notes: (1) msl - mean sea level
(2) NA = Not Applicable; outer casing not installed
Horizontal positions are referenced to N.C. State Plane Coordinate System (NAD 27) CF = 0.9999216 from U.S.M.C. Monument Toney. Vertical datum NGVD 29.

One of the deep wells, 6GW2D, was constructed in a different manner as described above (i.e., a Type III well). As illustrated on Figure 2-10, an 8-inch steel (steel was used because it is more durable than PVC) outer casing was installed and grouted in place (at 26 feet bgs). This casing was installed because a clay layer (i.e., layer of lower hydraulic conductivity material) approximately two-feet in thickness was encountered from 25 feet to 27 feet bgs. This layer was cased-off to minimize the possibility of cross-contaminating the deeper drinking water aquifer.

2.4.4.2 Well Development Procedures

Following well construction and curing of the bentonite seal, each newly installed shallow and deep well was developed to remove fine-grained sediment from the screen and to establish interconnection between the well and the formation. Shallow wells were developed by a combination of surging and pumping (centrifugal pump). Typically, 50 gallons of water were evacuated from the wells, followed by 10 minutes of surging, then continued pumping. Deep wells were developed by forcing air into the well using an air compressor and allowing the water to flow to the surface. [Note that an air filter was installed on the compressor to prevent oil and grease from entering the well.] Groundwater recovered during well development was temporarily stored in drums then transferred into an on-site tanker. Pumping hoses (constructed of flexible PVC) were dedicated for each well to minimize the potential for cross contamination.

Three to five well volumes were removed from each well (where conditions permitted) until the water was essentially sediment-free. Measurements of pH, specific conductance, and temperature were recorded to assist in determining well stabilization. Periodic flow and volume measurements were also recorded during development to evaluate flow rates of the shallow and deep water-bearing zones. Well Development Forms summarizing this information are provided in Appendix G (G.1 and G.2).

2.4.4.3 Water Level Measurements

Static water level measurements were collected from top-of-PVC casing (TOC) reference points (marked on PVC casing) at each existing and newly installed well (refer to Tables 3-5 and 3-10 in Section 3.7.2 for results). Phase I groundwater data was collected from the shallow

wells on September 30, October 26, and November 7, 1992; data was collected from the deep wells on October 26 and November 7, 1992.

Groundwater measurements were recorded using an electric measuring tape. Measurements were recorded to the nearest 0.01-foot from TOC. Water level data were collected within a two hour period. Additionally, the water level was monitored at wells 6GW28S and 6GW28D over a 24-hour period with a data logger to evaluate daily changes in the shallow and deep groundwater, respectively.

All newly installed and existing monitoring wells were surveyed to establish vertical elevation in relationship to mean sea level (msl) and horizontal control. Hoggard-Eure was retained for the survey. Vertical accuracy of each well (established to TOC at each well or top of staff gauge) was measured to 0.01 feet and horizontal accuracy within 0.1 foot. Control was established by using horizontal and vertical control points near the site which are tied into the North Carolina State Plane Coordinate System (NCSPCS). In cases where the points could not be established, temporary benchmarks were established from the closest United States Geological Survey (USGS) benchmark.

2.4.4.4 Staff Gauge Installation

Three staff gauges (BHSG1, BHSG2, and BHSG3) were installed in Bear Head Creek to evaluate surface water fluctuations and to assist in determining surficial groundwater flow patterns in the area. The locations of the gauges are shown on Figure 2-8. The staff gauges were surveyed (both horizontal and vertical from top of staff gauge) in place following installation. Measurements were recorded by reading the stream levels on the calibrated (0.1-feet) gauges (refer to Table 3-7 in Section 3.7.2).

2.4.4.5 Groundwater Sampling

This section describes the sampling procedures and analytical methods employed for the groundwater sampling program.

Sampling Locations

Groundwater samples (Phase I - Round One) were collected from existing shallow (17), and newly installed shallow (19) and deep (5) wells at Sites 6 and 82. Monitoring well 82MW30

(background well for the Site 82 investigation) could not be sampled because an obstruction was encountered inside the well. Figure 2-8 shows the locations of the monitoring wells sampled. Rationale for the well locations are summarized on Table 2-7.

Sampling Procedures

Samples were collected to confirm the presence or absence of contaminants of concern and evaluate overall groundwater chemistry in the shallow and deep groundwater. Groundwater sampling procedures were performed in accordance with EPA Region IV SOPs and as outlined in the Final RI/FS Work Plan.

Prior to groundwater purging, water levels from each well were measured according to procedures outlined in Section 2.4.4.3. The total well depth was also recorded from each well to the nearest 0.1-foot using decontaminated a steel tape. Water level and well depth measurements were used to calculate the volume of water in each well and the minimum volume of water necessary to purge the well.

Following well volume calculations, a minimum of three to five well volumes were purged from each well prior to sampling. Water was purged from each well using a decontaminated submersible pump and teflon hoses. A flow rate of 1 to 2 gallons per minute (GPM) was maintained during purging. Measurements of pH, specific conductance, and temperature were made prior to purging and after each well volume was removed to ensure that the groundwater was stabilized before sampling. These measurements were recorded in a field log book (refer to Tables 4-25 and 26 in Section 4.1.2.2 for results). Purge water was containerized and handled as described in the Section 2.7.

Groundwater samples were collected using decontaminated teflon bailers (i.e., bottom loading bailer) equipped with a teflon-coated leader. The samples were introduced directly from the bailer into laboratory-prepared, preserved sample containers (where appropriate) and stored on ice. Samples bottles for the volatile organic analysis were filled first, followed by semivolatiles, PCBs, pesticides, TAL metals (total and dissolved), and cyanides. Samples analyzed for volatiles were collected by slowly pouring water from the bailer into 40 ml vials (acidified with HCl) to minimize volatilization. Samples analyzed for dissolved metals were collected in laboratory-prepared bottles and filtered prior to placement in preserved bottles (acidified to pH <2 with HNO_3). The samples were filtered in the field through a disposable

0.45 micron membrane which was attached to teflon tubing. A peristaltic pump was used for the filtering procedure.

Preparation of groundwater samples incorporated similar procedures as to those described for soil samples. Sample collection information including well number, sample identification, time, date, samplers, analytical parameters, and required laboratory turnaround time were recorded in a field log book and on the sample labels. Chain-of-custody documentation (provided in Appendix S) accompanied the samples to Ceimic.

Analytical Requirements

Groundwater samples were analyzed for TCL organics and TAL inorganic (total and dissolved metals, and cyanide). EPA Methods 601 and 602 were implemented for analysis of volatiles. Additionally, a groundwater sample was collected from monitoring well 6GW1D for analysis of biological oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), and total volatile solids (TVS) to evaluate the general groundwater chemistry for potential treatment options.

Several types of field QA/QC samples were collected and analyzed during the groundwater investigation, including duplicate samples, equipment rinsates, field blanks, and trip blanks. These sample types were defined in Section 2.4.3.2. Equipment rinsate samples were collected from a bailer following decontamination procedures. Laboratory prepared deionized water was poured into the bailer and the water was collected in sample bottles. A field blank was collected in the vicinity of monitoring well 6GW1S during the groundwater investigation. Table 2-10 summarizes field QA/QC sample types, frequencies, and analytical parameters.

2.4.5 Drum Waste Sampling

In September 1992, Baker personnel performed a preliminary investigation of containerized waste at Site 6 (including Lot 203, the ravine area, the wooded areas, and Site 82). Upon completing the investigation, a majority of drums and miscellaneous containers at Site 6 were identified as potentially containing materials which would require sampling for disposal. It should be noted that above-ground storage tanks in Lot 203 were not addressed as part of this study. In addition, containers in the ravine area were only preliminarily classified due to the limitations imposed by the terrain and thick vegetation.

TABLE 2-10

SUMMARY OF FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM FOR THE GROUNDWATER INVESTIGATION SITES 6 and 82 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample (1)	Frequency of Collection	Number of Samples	Analytical Parameters (3)
Trip Blanks (2)	One per Cooler	3	TCL Volatiles
Field Blanks	One per Event (4)	1	TCL Organics/TAL Inorganics
Equipment Rinsates (5)	One per Day	1	TCL Organics/TAL Inorganics
Field Duplicates (6)	10% of Sample Frequency	(6)	TCL Organics/TAL Inorganics

Notes:
(1) QA/QC sample types defined on pages 2-12 and 2-13 in text.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Parameters analyzed according to procedures outlined on Tables 2-5 and 2-6.
(4) An event is defined as one 14 day period.
(5) Equipment rinsates collected from various sampling equipment (e.g., bailer). Note that samples were collected daily but were analyzed every other day of sampling event. Accordingly, the number of samples presented represents the number of samples analyzed.
(6) Field duplicate sample locations are summarized in Appendix N.

Drums classified as "RCRA empty" were deemed to contain less than one inch of material or residual material in the bottom. All other drums were classified as having known or unknown material and were sampled accordingly. Many of the drums/containers had been subject to the elements and were in very poor condition (i.e., corroded, rusty, over-pressurized, missing bungs and lids etc.).

2.4.5.1 Sampling Locations

Drums/containers were scattered throughout Lot 203, the ravine area, and Site 82. Additionally drums were located in the wooded area south of Lot 203. Figure 2-11 presents approximate locations of drum/container storage areas. Many of the drums were located in clusters within Lot 203; however, some were also found in isolated areas.

2.4.5.2 Sampling Procedures

Prior to opening any containers, monitoring was performed with a radiation meter, a combustible gas indicator (CGI) and OVA or PID. Drum documentation was performed via Baker drum logs concurrently with drum sampling activities. See Appendix H for a complete list of drum logs. The drums were sampled in the following manner (in compliance with Baker's Standard Operating Procedure for Drum Sampling):

1. The container was opened utilizing a bung wrench or drum deheader, and a sample extracted from the container in level B personal protection.

2. Liquid sample collection

    a. A clean glass tube (drum thief) was inserted into the opening of the container;

    b. The liquid in the drum represents a core of the drum contents, and was extracted utilizing the glass tube. Phase separation/differentiation was described where applicable.

    c. The liquid in the tube was transferred repeatedly into an 8-ounce jar until it was approximately three-quarters full.

    d. The mouth of the jar was then sealed with a teflon lid and securely tightened.

e. The outside of the jar was then wiped clean of any gross contamination.

3. The container was then resealed (i.e., bung replaced) or covered with polyethylene wrap if the bung was missing or lid damaged.

4. Each sample was noted on a chain-of-custody form and reported in the appropriate drum log sheet and/or field log book.

5. The samples were then sent to the laboratory for analysis. QA/QC samples (e.g., trip blanks, equipment rinsates, field blanks, and duplicates) were not submitted for this part of the study as they were not applicable.

It should be noted that solid samples were collected in a similar manner utilizing a stainless steel trowel to extract the sample.

In order to properly classify and composite containerized waste, field compatibility analyses were performed on all samples obtained from drums/containers. Compatibility testing was conducted to separate and classify the drum/container materials into compatible groups. The tests were performed using a HAZCAT® kit. The materials were separated into the following general classifications:

Flammable Liquid

Combustible Liquid

Base Neutral Liquid

Base Neutral Liquid with Solids

Flammable Solid

Corrosive Solid

Base Neutral Solid

Compatibility testing was performed on each drum, separating and classifying various unknown containerized waste materials into compatible groups based on their physical and chemical characteristics. RCRA hazardous waste characteristics (ignitability, corrosivity, and reactivity) were identified at a minimum during these tests. Appendix I provides a complete list of parameters tested and the corresponding qualitative result.

Following the physical/chemical testing (via the HAZCAT KIT) aliquots from samples of the same/similar waste stream were combined in a documented sequence. For purposes of compositing, a controlled amount from each sample within a compatible grouping was combined in a separate container, one at a time, and observed closely for a reaction. Visual observations, (i.e., color, precipitation, or phase separation) and temperature measurements (to test for chemical reactions) were performed.

Forty-eight drums/containers were sampled and composited into 11 samples for shipment to the laboratory. Per laboratory requirements, two quarts of liquid/solid material (64 oz. of composite sample) were required. One quart was utilized for sample analysis and one quart was archived (for 1 year) for future analysis, if required. This methodology will eliminate resampling for disposal analyses, provided disposal occurs within the one year statute of limitation.

2.4.5.3 Analytical Requirements

Many of the 48 drums were determined to be 1/4 to 3/4 full. Therefore, field analyses were performed for compositing samples to limit the amount of laboratory analytical cost.

Samples collected during the field program were shipped for laboratory analysis to Wadsworth Alert Laboratories located in Canton, Ohio. Wadsworth Alert Laboratories is a member of the USEPA Contract Laboratory Program (CLP) and is also certified by the Naval Energy and Environmental Support Activity (NEESA). Sample analysis performed by Wadsworth Alert included RCRA characteristics (ignitability, corrosivity, reactivity and full TCLP analysis) to evaluate the nature of the wastes and to evaluate possible disposal options if required.

2.4.6 Test Pit Activities

Based on studies by EPIC, aerial photographs indicate potential disposal and fill areas. These areas were surveyed by Hoggard-Eure. Excavations were then performed perpendicular to the

transect (surveyed trench and fill locations) to ensure trenches were properly identified and to allow for error in surveyed points.

In general, test pit operations were performed as an exploratory excavation to assess the contents of past disposal/burial operations.

Test pits varied in length and depth, and were primarily dependent on:

- Space limitations imposed by the site (i.e., wooded areas limited movement of backhoe).
- The capabilities and limitations of the excavation equipment (i.e., depth of excavation was limited to the length of the boom on the backhoe).
- The amount and type of debris excavated (i.e., large amount of communication wire).
- The depth of the water table.

Air monitoring was performed with a radiation meter, CGI, and FID or PID. Test pitting operations were modified due to the potential of unexploded ordnance or the potential rupture of containerized waste.

2.4.6.1 Sampling Locations

As stated previously, studies by EPIC and aerial photographs were analyzed, and transects surveyed at suspected trench and fill areas.

A surface geophysical survey was also conducted from August 24 through September 3, 1992, to delineate areas of suspected disposal and to identify locations of buried debris. Anomalies detected as part of the geophysical investigation which did not correlate to trench and fill operations from the aerial photographs were also examined during the test pit investigation.

A total of 29 primary excavations were performed as part of this study. In addition, six extra excavations were also performed along transects from primary excavations where samples were obtained for laboratory analysis (total of 35 excavations).

Sampling locations were determined in the field based on visual observation and air monitoring results. Samples were collected at areas suspected to be contaminated and at the bottom of the trench. Trench locations are depicted on Figure 2-12.

2.4.6.2 Sampling Procedures

Exploratory trenching operations were performed from September 27 through October 1, 1992, throughout Site 6. Exploratory trenching operations focussed primarily on Lot 203 (the Open Storage Area).

Before any excavation began, a specialized, two-person crew performed a survey of the area with a magnetometer and provided guidance with respect to potentially buried unexploded ordnance (UXO). The magnetometer survey correlated the interpretations of the aerial photographs by confirming the presence of buried debris.

Upon delineation of work zones, activities commenced with a Case 580 backhoe (excavator) equipped with a three-foot bucket. Test pits were excavated approximately 20 feet in length and 9 feet in depth. After visual inspection and sample collection, a sample number was affixed to each sample container.

Grab and composite sampling methods were implemented. Test pit soil samples were chosen based on visual observation or readings obtained from real time air monitoring instrumentation. In addition, test pits which had samples obtained based on visual observations or air monitoring also had soil samples obtained from the bottom of the pit. Two samples were obtained from each test pit suspected of containing contaminants. All information regarding sample depth and findings were recorded in a field log book and transcribed to test pit logs. Appendix D (D.12) provides test pit logs with descriptions of material encountered and approximate depth. No geological characterization was performed on test pits, as several soil borings and well installation boreholes in the area provided a detailed subsurface description. However, soil samples were collected every two feet for future geologic classification purposes.

Excavated soil was stockpiled on the side and the trench backfilled upon completion.

2.4.6.3 Analytical Requirements

Samples collected during the field program were shipped for laboratory analysis to Ceimic Laboratory. Sample analysis included RCRA characteristics (ignitability, corrosivity, and reactivity) and full TCLP analysis.

2.4.7 Surface Water and Sediment Investigations

This section discusses the surface water and sediment investigations conducted at OU No. 2. Included in this section are the sampling methodologies, procedures, locations, and results of the surface water and sediment sampling.

2.4.7.1 Surface Water and Sediment Sampling Methodology

Surface water and sediment sampling was conducted to determine if contamination attributable to OU No. 2 exists in Wallace Creek, Bear Head Creek, or the ravine which had an intermittent tributary to Wallace Creek. Surface water samples were collected at twenty-four stations at OU No. 2, while sediment samples were collected at twenty-six stations (see Figure 2-13). The majority of the samples were collected from August 22 to August 30, 1992, with one sample collected on October 23, 1992 due to site access problems.

The following information from each station was recorded in the field logbook:

- Project location, date and time
- Weather
- Sample location number and identification number
- Flow conditions (i.e., high, low, in flood, etc.)
- On-site water quality measurements
- Visual description of water (i.e., clear, cloudy, muddy, etc.)
- Description of biotic community (i.e., flora, fauna, etc.)
- Sketch of sampling location including boundaries of the water body, sample location (and depth), relative position with respect to the site, location of wood identifier stake
- Names of sampling personnel
- Sampling technique, procedure, and equipment used

The on-site water quality measurements consisted of temperature, pH, specific conductance, salinity, and dissolved oxygen. These measurements were collected immediately following sample collection.

Field QA/QC samples were also collected during the surface water and sediment investigations. The QA/QC sample types and sample collection frequencies are the same as those described in Section 2.4.3. Table 2-11 summarizes the QA/QC sampling program for the surface water and sediment samples.

Surface Water

The following sections describe the stations where surface water samples were collected and the procedures used for collecting the samples.

Station Locations

Forty-eight surface water samples were collected from twenty-four stations at OU No. 2 (see Figure 2-13 for station locations). Twenty-eight samples (eleven stations) were collected from Wallace Creek, fourteen samples (seven stations) were collected from Bear Head Creek, and six samples (six stations) were collected from the ravine (two other ravine sampling stations were dry at the time samples were collected). Tables 2-12, 2-13, and 2-14 contain a summary of the station numbers and locations, and sample numbers for surface and sediment collected at those stations.

The surface water sample numbers were designated as 6-WC"X"-SW-06B; the 6 indicates that the samples were collected at OU No. 2, WC stands for Wallace Creek (BH stands for Bear Head Creek and RV stands for the ravine), "X" stands for the station number, SW stands for surface water, 06 stands for a sample collected at the surface (312 for a sample collected at the surface water/sediment interface), and B stands for a sample collected at the creek bank (M stands for a sample collected in the middle of the creek).

Sampling Procedures

At stations where the water was more than three feet deep, samples were collected at the surface by dipping the sample bottles directly into the water and at one foot above the sediment by using a kemmerer sampler. To determine the designated depth, a marked

TABLE 2-11

SUMMARY OF FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM FOR THE SURFACE WATER AND SEDIMENT INVESTIGATIONS
SITE 6
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample (1)	Frequency of Collection	Number of Samples	Analytical Parameters (3)
Trip Blanks (2)	One per Cooler	6	TCL Volatiles
Field Blanks	One per Event (4)	2	TCL Organics/TAL Inorganics
Equipment Rinsates (5)	One per Day	6	TCL Organics/TAL Inorganics
Field Duplicates (6)	10% of Sample Frequency	(6)	TCL Organics/TAL Inorganics

Notes:
(1) QA/QC sample types defined on pages 2-12 and 2-13 in text.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Parameters analyzed according to procedures outlined on Tables 2-5 and 2-6.
(4) An event is defined as one 14 day period. Field blanks collected during surface water and sediment investigations in the vicinity of sample stations BH06 (Bear Head Creek) and WC04 (Wallace Creek).
(5) Equipment rinsates collected from various sampling equipment (e.g., stainless steel spoons, sediment cores, etc.).
(6) Field duplicate samples presented in Appendix N.

TABLE 2-12

BEAR HEAD CREEK SURFACE WATER AND SEDIMENT STATION AND SAMPLE NUMBERS AND LOCATIONS SITE 6 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Station Number	Station Location	Surface Water Sample Number	Sediment Sample Number
6-BH01-SW/SD	Headwaters of Bear Head Creek	6-BH01-SW-06B 6-BH01-SW-06M	6-BH01-SD-06B 6-BH01-SD-612B 6-BH01-SD-06M 6-BH01-SD-612M
6-BH02-SW/SD	Upstream of Sites 6 and 9	6-BH02-SW-06M (A)	6-BH02-SD-06M 6-BH02-SD-612M (A)
6-BH03-SW/SD	Approx. 100 feet upstream of Piney Creek Road	6-BH03-SW-06B 6-BH03-SW-06M	6-BH03-SD-06B 6-BH03-SD-612B 6-BH03-SD-06M 6-BH03-SD-612M
6-BH04-SW/SD	Adjacent to Sites 6 and 9	6-BH04-SW-06B 6-BH04-SW-06M	6-BH04-SD-06B 6-BH04-SD-612B 6-BH04-SD-06M 6-BH04-SD-612M
6-BH05-SW/SD	Between Lejeune Railroad and Holcomb Boulevard	6-BH05-SW-06B 6-BH05-SW-06M	6-BH05-SD-06B (B) 6-BH05-SD-06M (B)
6-BH06-SW/SD	Approx. 1000 feet Downstream of Holcomb Boulevard	6-BH06-SW-06B 6-BH06-SW-06M	6-BH06-SD-06B (B) 6-BH06-SD-06M (B)
6-BH07-SW/SD	Downstream of Sites 6 and 9	6-BH07-SW-06B 6-BH07-SW-06M 6-BH07-SW-312M	6-BH07-SD-06B (B) 6-BH07-SD-06M (B)

Notes: B - Sample was collected from the north bank
M - Sample was collected from the middle of the creek
SW-06 - Sample was collected from the water surface (or mid-vertical point if a deeper water sample was not collected at this station).
SW-312 - Sample was collected from the water/sediment interface
SD-06 - Sample was collected from the top six inches of the sediment
SD-612 - Sample was collected from six to twelve inches of the sediment
(A) - Creek was narrow and shallow; only middle sample was collected
(B) - Sediments were flocculant; 6-12 inch sample could not be collected

TABLE 2-13

WALLACE CREEK SURFACE WATER AND SEDIMENT STATION AND SAMPLE NUMBERS AND LOCATIONS SITE 6 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Station Number	Station Location	Surface Water Sample Number	Sediment Sample Number
6-WC01-SW/SD	North Branch of Wallace Creek	6-WC01-SW-06B 6-WC01-SW-06M (A)	6-WC01-SD-06B 6-WC01-SD-612B (B)
6-WC02-SW/SD	South Branch of Wallace Creek	6-WC02-SW-06B (B)	6-WC02-SD-06B 6-WC02-SD-612B (B)
6-WC03-SW/SD	Approx. 2000 feet downstream of north and south branch	6-WC03-SW-06B 6-WC03-SW-06M 6-WC03-SW-312M	6-WC03-SD-06B 6-WC03-SD-612B 6-WC03-SD-06M (C)
6-WC04-SW/SD	Approx. 250 feet upstream of Piney Creek Road	6-WC04-SW-06B 6-WC04-SW-06M	6-WC04-SD-06B 6-WC04-SD-612B 6-WC04-SD-06M (D)
6-WC05-SW/SD	Approx. 250 feet downstream of Piney Creek Road	6-WC05-SW-06B 6-WC05-SW-06M 6-WC05-SW-312M	6-WC05-SD-06B 6-WC05-SD-612B 6-WC05-SD-06M (D)
6-WC06-SW/SD	Adjacent to Sites 6 and 9	6-WC06-SW-06B 6-WC06-SW-06M	6-WC06-SD-06B 6-WC06-SD-612B 6-WC06-SD-06M 6-WC06-SD-612M
6-WC07-SW/SD	Adjacent to Sites 6 and 9	6-WC07-SW-06B 6-WC07-SW-06M 6-WC07-SW-312M	6-WC07-SD-06B (D) 6-WC07-SD-06M 6-WC07-SD-612M
6-WC08-SW/SD	Between Lejeune Railroad and Holcomb Boulevard	6-WC08-SW-06B 6-WC08-SW-06M 6-WC08-SW-312M	6-WC08-SD-06B 6-WC08-SD-612B 6-WC08-SD-06M
6-WC09-SW/SD	Approx. 1000 feet Downstream of Holcomb Boulevard	6-WC09-SW-06B 6-WC09-SW-06M 6-WC09-SW-312M	6-WC09-SD-06B 6-WC09-SD-612B 6-WC09-SD-06M 6-WC09-SD-612M
6-WC10-SW/SD	Downstream of Sites 6 and 9	6-WC10-SW-06B 6-WC10-SW-06M 6-WC10-SW-312M	6-WC10-SD-06B (D) 6-WC10-SD-06M 6-WC10-SD-612M
6-WC11-SW/SD	Approx. 500 feet Downstream of Confluence with Bear Head Creek	6-WC11-SW-06B 6-WC11-SW-06M 6-WC11-SW-312M	6-WC11-SD-06B (D) 6-WC11-SD-06M (D)

Notes: B - Sample was collected from the south bank
M - Sample was collected from the middle of the creek
SW-06 - Sample was collected from the water surface (or mid-vertical point if a deeper water sample was not collected at this station).
SW-312 - Sample was collected from the water/sediment interface
SD-06 - Sample was collected from the top six inches of the sediment
SD-612 - Sample was collected from six to twelve inches of the sediment
(A) - Samples were collected from shore; depth sample could not be collected
(B) - Samples were collected from shore; middle samples could not be collected
(C) - Sampler refusal at 3-4 inches; 6-12 inch sample could not be collected
(D) - Sediments were flocculant; 6-12 inch sample could not be collected

TABLE 2-14

RAVINE AREA SURFACE WATER AND SEDIMENT STATION AND SAMPLE NUMBERS AND LOCATIONS SITE 6 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Station Number	Station location	Surface Water Sample Number	Sediment Sample Number
6-RV1-SD	Ravine	(A)	6-RV1-SD-06 (B)
6-RV2-SW/SD	Ravine	6-RV2-SW-06	6-RV2-SD-06 (B)
6-RV3-SW/SD	Ravine	6-RV3-SW-06	6-RV3-SD-06 6-RV3-SD-612
6-RV4-SD	Ravine	(A)	6-RV4-SD-06 6-RV4-SD-612
6-RV5-SW/SD	Ravine	6-RV5-SW-06	6-RV5-SD-06 (B)
6-RV6-SW/SD	Ravine	6-RV6-SW-06	6-RV6-SD-06 (B)
6-RV7-SW/SD	Ravine	6-RV7-SW-06	6-RV7-SD-06 6-RV7-SD-612
6-RV8-SW/SD	Ravine	6-RV8-SW-06	6-RV8-SD-06 (B)

Notes: SW-06 - Sample was collected from the water surface
SD-06 - Sample was collected from the top six inches of the sediment
SD-612 - Sample was collected from six to twelve inches of the sediment
(A) - No water was present at this station; water sample was not collected
(B) - Sampler refusal at 6 inches; 6-12 inch sample was not collected

weighted line was lowered into the water with the depth to the sediments recorded. At stations where the water was less than three feet deep, samples were collected at the approximate vertical mid-point by dipping the sample bottles directly into the water.

Care was taken when collecting samples for analysis of VOCs to avoid excessive agitation that could result in loss of VOCs. Samples for the VOC analysis were collected prior to the collection of the samples for analysis of the other parameters.

The samples were collected in clean containers provided by the analytical laboratory. Sampling personnel wore clean PVC gloves at each sampling station. For those sample bottles already containing preservative (e.g., sulfuric acid), the water was collected in a clean container and then slowly poured into the sample bottle. All sample containers not containing preservative were rinsed at least once with the sample water prior to sample collection.

The downstream water samples were collected first, with subsequent samples taken while moving upstream. Any sediment or biological samples were collected after the water samples were taken to minimize sediment resuspension that might contaminate the water samples.

The sampling locations were marked by placing a wooden stake and bright colored flagging at the nearest bank or shore. The sample number was marked on the stake with indelible ink. Photographs were taken to document the physical and biological characteristics of the sampling location.

Sediment

The following sections describe the stations where sediment samples were collected and the procedures used for collecting the samples.

Station Locations

Sixty-three sediment samples were collected from twenty-six stations at OU No. 2 (see Figure 2-13 for station locations); thirty-two samples (eleven stations) were located in Wallace Creek, twenty samples (seven stations) were located in Bear Head Creek, and eleven samples (eight stations) were located in the ravine. Tables 2-12, 2-13, and 2-14 contain a summary of the station numbers and locations, and sample numbers collected at those stations.

The sediment sample numbers were designated as 6-WC"X"-SD-06B; the 6 indicates that the for to designate samples were collected at OU No. 2, WC stands for Wallace Creek (BH stands for Bear Head Creek and RV stands for the ravine), "X" stands for the station number, SD stands for sediment, 06 stands for a sample collected from the top six inches of the sediment (612 stands for a sample collected from six to twelve inches of the sediment), and B stands for a sample collected at the creek bank (M stands for a sample collected in the middle of the creek).

Sampling Procedures

At each station, sediment samples were collected at the surface (0-6 inches) and at depth (6-12 inches) using a stainless steel hand-held coring instrument. A new disposable clear plastic liner tube, fitted with a disposable eggshell catcher to prevent sample loss, was used at each station.

The coring device was pushed into the sediments to a maximum depth of fifteen to twenty inches, or until refusal. The liner was removed from the sampler and the sediments were extruded into the appropriate sample jars using a decontaminated extruder. The liners were not cut in half as stated in the work plan because the plastic shavings may have contaminated the sediments.

2.4.8 Ecological and Aquatic Survey

Biological samples collected at OU No. 2 consisted of fish, crabs and benthic macroinvertebrates. Prior to initiating the sampling event at each station, the following information describing the site was recorded in the field log book:

- Average width, depth and velocity of the water body
- Description of substrate
- Description of "abiotic" characteristics of the reach such as pools, riffles, runs, channel shape, degree of bank erosion, and shade/sun exposure
- Description of "biotic" characteristics of the reach including aquatic and riparian vegetation and wetlands

Water quality measurements were collected during the benthic macroinvertebrate sampling, at a minimum, and during collection of some of the fish samples. On-site water quality

measurements at these stations consisted of temperature, pH, specific conductance, salinity and dissolved oxygen. These measurements were conducted prior to sample collection.

The Remedial Investigation/Feasibility Study, Sampling and Analysis Plan (SAP) for Sites 6,9,48, and 69 limited the sampling references sites to two stations in the White Oak River Basin (Baker, 1992). One of the stations was to be used as the reference for the marine stations, and the other was to be used as the reference for the freshwater station. The reference stations were selected to be as ecologically similar to the sampling stations for Sites 6, 9, 48, and 69. The reference fish and benthic macroinvertebrate station for OU No. 2 was established in Pettiford Creek (freshwater) which is located in the White Oak River Basin (see Figure 4-1 in the Ecological Risk Assessment).

The White Oak River watershed is smaller than the New River watershed (see Figure 4-1 in the Ecological Risk Assessment). It begins in the Hoffman Forest and flows approximately 48 miles and empties into the Atlantic Ocean. Approximately 77 percent of the watershed is within the Hoffman Forest and the Croatan National Forest. This watershed has very little development, with Swansboro being the largest town. Therefore, because there is not much development in this watershed, it was chosen as a good reference station.

Pettiford Creek was chosen as the location for the reference station. This station is similar to the stations in Wallace Creek in that it has a salinity gradient from fresh to mesohaline at its mouth.

2.4.8.1 Fish and Crabs

This section discusses collection of the fish and crab samples in Wallace Creek, Bear Head Creek, and Pettiford Creek.

A literature review was conducted to determine the fish species that may potentially be exposed to contaminants in the surface water/sediment exposure pathway. This review included compiling information from State and Federal natural resources agencies. In addition, Baker's experience in sampling similar areas formed a basis for a database of expected species for the area.

Originally, three species of fish were to be sampled, with each species being a representative of one of three trophic (feeding) groups, which included a first order predator, a second order

predator, and a third order predator. In addition, a minimum of ten individuals per specie, if available, of adult fish of preferably uniform size were to be composited and analyzed for whole body burden and fillet burden of chemicals, with the same species of fish being sampled from each station. A fish species was successfully collected if the above requirements were satisfied. These requirements were identified to Baker by the U.S. Fish and Wildlife Service as part of the Work Plan review.

Sampling variability can prevent the same species of fish from being sampled at each station because either the preferred species was not captured, or adequate numbers of uniform-size individuals were not captured. Therefore, if the preferred species was not successfully collected to satisfy the above requirements, a substitute species was collected that, if possible, exhibiting a similar trophic position in the estuarine ecosystem.

Wallace Creek

This section discusses collection of the fish and crab samples in Wallace Creek including the station locations and sampling procedures.

Station Locations

Fish and crabs were collected from four stations in Wallace Creek. One station was located upstream of OU No. 2 (6-WC4A), one station was located adjacent to OU No. 2 (6-WC6A), and two stations were located downstream of OU No. 2 (6-WC9A and 6-WC11A) (see Figure 2-13).

Station 6-WC4A was located on Wallace Creek approximately 100 feet upstream of Piney Green Road. This station was relocated downstream from the proposed station location (see the Sampling and Analysis Plan [SAP] [Baker, 1992]) because debris obstructed upstream boat access during the time of sampling. Station 6-WC6A was located on Wallace Creek between Piney Green Road and Holcomb Boulevard. Station 6-WC9A was located on Wallace Creek approximately 1000-1500 feet downstream of Holcomb Boulevard, while Station 6-WC11A was located on Wallace Creek approximately 500 feet downstream of it's confluence with Bear Head Creek.

Sampling Procedures

Fish were collected in Wallace Creek using gill nets and a boat-mounted electrofisher. The electrofisher was used when the salinity was in the appropriate salinity range. See Table 4-1 in the Ecological Risk Assessment for a listing of the sampling procedure used at each station.

The fish sampling via electroshocking was conducted using a Smith-Root, Inc. electrofisher powered by a 5,000-watt portable generator. A DC current was applied utilizing the boat as a cathode and a hand-held electrode as the anode. The length of shocking time per subsection was recorded as seconds of applied current. Stunned fish were collected with one-inch mesh or smaller dip nets handled by members of the field sampling team.

The gill nets were six feet deep by 50 feet long with two-inch square mesh and an approximate twine break strength of 29 pounds. The nets were deployed approximately at the locations shown on Figure 2-13. Weights were attached to the nets to secure them on the bottom of the stream and yellow bouys marked with "Baker Environmental" were attached to the tops of the nets. The nets were deployed in the morning or evening, and they were checked for fish within twelve hours after deployment.

The collected fish species were identified, measured, and counted. The small fish (less than 20 mm) were weighed in groups of 10 or 20 because of their low individual weight; the larger fish were weighed individually. In addition, blue crabs that were captured in the gill nets were collected, measured, and weighed. The proportion of individuals as hybrids and the proportion of individuals with disease, tumors, fin damage, and skeletal anomalies was recorded at each station.

Most of the fish species were processed in the field and returned alive to the creeks. Some specimens that presented taxonomic difficulties were preserved in 10% formalin and transported to the Baker Ecological Services Laboratory for taxonomic work. At a minimum, one representative fish from each species was preserved in 10% formalin as a voucher specimen.

An attempt was made to collect ten individuals from three different species with each species being a representative of one of the three trophic groups for the tissue analysis. However this success rate was not achieved at any of the stations. The fish were placed individually into clean ziploc or plastic garbage bags and stored on ice for whole body or fillet tissue analysis.

The blue crabs were placed individually into clean ziploc bags and stored on ice for whole-body analysis. The bags were labeled with the date and station location. The fish and crabs were frozen prior to being shipped to Ceimic, Inc. for chemical analysis. Table 4-2 in the Ecological Risk Assessment shows the number and total weight of the fish and blue crab samples sent to Ceimic.

Bear Head Creek

This section discusses collection of the fish and crab samples in Bear Head Creek including the station locations and sampling procedures.

Station Locations

Fish and crabs were collected from three stations in Bear Head Creek. One station was located upstream of OU No. 2 (6-BH2A), one station was located adjacent to site OU No. 2 (6-BH4A), and one station was located downstream of OU No. 2 (6-BH6A) (see Figure 2-13).

Station 6-BH2A was located on Bear Head Creek approximately 1,000 feet upstream of Piney Green Road. This station was located further downstream than proposed in the sampling and analysis plan (Baker, 1992) because the proposed sampling location could not be accessed due to vegetation overgrowth. Station 6-BH4A was located on Bear Head Creek between Piney Green Road and Holcomb Boulevard. Finally, Station 6-BH6A was located on the Bear Head Creek approximately 1,500 to 2,000 feet downstream of Holcomb Boulevard.

Sampling Procedures

Fish were collected in Bear Head Creek using gill nets and a backpack electrofisher. The electrofisher was used when the salinity was in the appropriate salinity range for use of the electrofisher.

The fish sampling via electroshocking was conducted using a Smith-Root, Inc. electrofisher powered by a 300-watt portable generator. A DC current was applied utilizing a "rattail" as the cathode and a hand-held electrode as the anode. Blocking seines were placed downstream and upstream of the shocking areas to aid in the collection of the fish. The length of shocking time per subsection was recorded as seconds of applied current. Stunned fish were collected with one-inch mesh or smaller dip nets handled by members of the field sampling team.

Gill nets, similar to those used in Wallace Creek, were used to collect fish in Bear Head Creek. The same sample collection and sample processing procedures used in Wallace Creek were conducted in Bear Head Creek. Fish that were collected were processed for population statistics and tissue analysis.

Ravine

The ravine receives only runoff from Sites 6 and 82 and therefore, it is only intermittent in nature. No fish collection was proposed for this area in the SAP (Baker, 1992).

Pettiford Creek

This section discusses collection of the fish and crab samples in Pettiford Creek including the station locations and sampling procedures.

Station Location

The fish station was located upstream on Pettiford Creek where the salinity was close to zero. Several locations with good electrofishing potential (based on salinity) were shocked, however, the yield was very low. Gill nets were not proposed for this station in the SAP (Baker, 1992).

Sampling Procedures

Fish were collected in Pettiford Creek using a boat-mounted electrofisher. The same sample collection and sample processing procedures used in Wallace Creek were conducted at the Pettiford Creek station. All fish that were collected were processed for population statistics; no fish at this station were collected for tissue analysis.

2.4.8.2 Benthic Macroinvertebrate

This section discusses collection of benthic macroinvertebrate samples in Wallace Creek, Bear Head Creek, and Pettiford Creek.

Wallace Creek

This section discusses collection of the benthic macroinvertebrate samples in Wallace Creek including the station locations and sampling procedures.

Station Locations

Benthic macroinvertebrates were collected from four stations in Wallace Creek. One station was located upstream of OU No. 2 (6-WC3A), one station was located adjacent to OU No. 2 (6-WC6A), and two stations were located downstream of OU No. 2 (6-WC9A and 6-WC11A) (see Figure 2-13).

Station 6-WC3A was located on Wallace Creek approximately 3,000 to 4,000 feet upstream of Piney Green Road. At the time this sample was collected, the path in the water was not being obstructed as it was when the fish sample was collected. Station 6-WC6A was located on Wallace Creek, between Piney Green Road and Holcomb Boulevard. Station 6-WC9A was located on Wallace Creek approximately 1,000-1,500 feet downstream of Holcomb Boulevard, and Station 6-WC11A was located on Wallace Creek approximately 500 feet downstream of its confluence with Bear Head Creek.

Sampling Procedures

Benthic macroinvertebrates were collected from a boat using a standard ponar grab. The dimensions of the ponar are 23 x 23 cm (9 x 9 in.) for a sampling area of 529 cm^2 or 0.0529 m^2 (81 in^2).

The ponar was deployed from the boat, which was positioned in slightly different locations for each replicate to prevent the ponar from re-sampling the same area. After retrieving the ponar with a sediment sample, it was opened into a clean tub and the sediments were removed with a teflon spatula. The sediments were transferred to a 0.5 mm sieve that was agitated (by hand) in a tub half-full of water to remove the small particles. The remaining contents in the sieve were transferred into 16-ounce plastic sample jars. The jars were filled up to one-half full with sediments and buffered formalin solution (10% by weight) was added to the remainder of the jar to preserve the benthic macroinvertebrates contained in the sediments. A 100% cotton paper label, marked in pencil with the sample number, was placed inside the jar.

The outside of the jar was labeled with the sample number using a black permanent marker to identify the sample containers.

After all the benthic sampling at OU No. 2 was completed, the sample jars were transported to the Baker Ecological Laboratory for sample processing. Sample processing included washing each sample through a 0.5 mm sieve, transferring the washed sample back into the jar, and adding 70% isopropyl alcohol, as a preservative, to the washed sample in the jar. A small amount of rose bengal was added to each jar to stain the benthic macroinvertebrates a pink-red color to aid in the sorting process. The rose bengal stains the tissue cells of the organisms and helped to distinguish them from plant and other materials in the sediments.

The benthic macroinvertebrates were stained for at least 24 hours prior to sorting under a dissecting microscope. The benthic macroinvertebrates were removed from the sediments using a pair of forceps, and placed into glass vials containing 70% isopropyl alcohol and a 100% cotton paper label marked in pencil with the sample number. A one-fourth aliquot of sample 6-WC3A was sorted because of its large sample volume. The number of individuals from that aliquot was multiplied by four to obtain the total number of individuals in the sample. The vials were sealed with cotton and placed into a jar containing 70% isopropyl alcohol. The date, sorting time, approximate number of benthic macroinvertebrates collected, and the name of the person who sorted the sample were recorded on a sample processing log sheet.

The same sorting procedures outlined above were repeated as a QA/QC measure, with any additional species identified being placed into their respective vials. A senior environmental scientist was employed to perform this QA/QC measure. Fifty-percent of a sample was resorted. If more than five percent of the individuals were missed during the initial sorting, than the rest of the sample was resorted. If less than five percent of the individuals were missed during the initial sorting, than the rest of the sample was not resorted.

The date, sorting time, number and type of additional organisms found and percent of sample that was QA/QCed were recorded on the sample processing log sheet. The vials containing the benthic macroinvertebrates were sent to RMC Environmental Services for taxonomic identification.

Bear Head Creek

This section discusses collection of the benthic macroinvertebrate samples in Bear Head Creek including the station locations and sampling procedures.

Station Locations

Benthic macroinvertebrates were collected from three stations in Bear Head Creek. One station was located upstream of OU No. 2 (6-BH2A), one station was located adjacent to OU No. 2 (6-BH4A), and two stations were located downstream of OU No. 2 (6-BH6A) (see Figure 2-13).

Station 6-BH2A was located on Bear Head Creek approximately 1,000 feet upstream of Piney Green Road. This station was located further downstream than proposed in the SAP (Baker, 1992) because the proposed location could not be accessed due to vegetation overgrowth. Station 6-BH4A was located on Bear Head Creek between Piney Green Road and Holcomb Boulevard. Finally, Station 6-BH6A was located on Bear Head Creek, approximately 1,500-2,000 feet downstream of Holcomb Boulevard.

Sampling Procedures

Benthic macroinvertebrates were collected using the same procedures used in Wallace Creek. The only deviation from the procedures occurred at Stations 6-BH2A and 6-BH4A. The ponar samples collected at these stations were collected by standing in the creek and releasing the ponar, as opposed to deploying the ponar from the boat. The sample processing procedures remained the same for these samples.

A one-fourth aliquot of sample 6-BH6A was sorted because of its large sample volume. The number of individuals from that aliquot was multiplied by four to obtain the total number of individuals in the sample.

Pettiford Creek

This section discusses collection of the benthic macroinvertebrate samples in Pettiford Creek including the station location and sampling procedures.

Station Locations

Pettiford Creek, located within the White Oak Watershed was chosen as the location for the reference station.

Sampling Procedures

Benthic macroinvertebrates were collected in Pettiford Creek using the ponar grab deployed from the boat. The same sample collection and sample processing procedures used in Wallace Creek were conducted at the Pettiford Creek station.

2.5 RI Field Investigations Performed at Site 9

The field investigations performed at Site 9 commenced on September 10, 1992 and continued through November 10, 1992. The field program implemented at Site 9 consisted of a Preliminary Site Survey (discussed in Section 2.3); a soil investigation including drilling and sampling; and a groundwater investigation including monitoring well installation (shallow and deep wells) and groundwater sampling. Table 2-15 summarizes the project objectives, criteria for meeting the objectives, and general investigative methods for the RI performed at Site 9. The following sections discuss these investigative activities.

Site 9 is located between Piney Green Road and Holcomb Boulevard along the southern border of OU No. 2 (refer to Figure 1-3). Bear Head Creek is located approximately 500 feet to the north of the site. The site is bordered by unnamed streets (unpaved roads) to the east and west and encompasses an area of approximately 2.6 acres. An asphalt-lined pit is present at this site. This pit is currently used to conduct training exercises for extinguishing fires. An oil/water separator is located just south of the pit as shown on Figure 2-14. The oil/water separator is used to collect water from fire pit training exercises and storm water that falls into the pit. The recovered product collected in the oil/water separator is disposed of off site. Two groups of above ground storage tanks (two tanks in each group) are located just west-northwest of the training pit.

2.5.1 Soil Investigation

The soil investigation performed at Site 9 was intended to identify contaminants of concern (i.e., petroleum hydrocarbons, solvents, etc.) and evaluate their distribution at the site. The

TABLE 2-15

SUMMARY OF REMEDIAL INVESTIGATION OBJECTIVES FOR FIRE FIGHTING PIT
SITE 9
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Medium or Area of Concern	RI Objective	Criteria for Meeting Objective	Proposed Investigation/Study
1. Soil	1a. Assess the extent of soil contamination at the training pit and surrounding area.	Determine contaminant levels in surface and subsurface soils at former storage areas.	Soil Investigation
	1b. Assess human health and ecological risks associated with exposure to surface soils.	Determine contaminant levels in surface and subsurface soils.	Soil Investigation Risk Assessment
	1c. Assess areas of surface soil contamination due to site runoff.	Determine contaminant levels in surface soils at downslope drainage areas.	Soil Investigation
2. Groundwater	2a. Assess health risks posed by future usage of the shallow groundwater near Site 6.	Evaluate groundwater quality and compare to ARARs and health-based action levels.	Groundwater Investigation Risk Assessment
	2b. Assess potential impact to groundwater from fuel-contaminated soil.	Characterize on-site groundwater quality and groundwater quality downgradient from Site 6.	Groundwater Investigation
	2c. Evaluate hydrogeologic characteristics.	Estimate hydrogeologic characteristics of the shallow aquifer (flow direction, groundwter gradient, etc.).	Surface water level measurements in Bear Head Creek

investigation performed was also to evaluate potential human health risks and ecological impacts associated with previous and ongoing fire training activities. Table 2-15 summarizes the specific RI objectives for the soil investigation.

2.5.1.1 Drilling Procedures

Drilling activities at Site 9 commenced on September 16, 1992 and continued through September 26, 1992. The drilling program implemented at Site 9 was intended to investigate shallow and deep physical (i.e., geologic and hydrogeologic) and chemical (i.e., contaminant distribution) conditions. Figure 2-15 depicts the drilling locations at Site 9. Appendix C (C.12 and C.13) summarizes the number of soil borings and depths.

Drilling procedures (including sampling intervals, air monitoring, level of personal protection, decontamination procedures, handling of investigative derived wastes, etc.) implemented at Site 9 were the similar as those discussed for Sites 6 and 82 in Section 2.4.3.1 for both shallow and deep drilling. As described in Section 2.4.3.1, shallow drilling was accomplished using the HSA technique while deep drilling was accomplished using the mud-rotary technique. Test Boring Log Records and Test Boring and Well Construction Records, describing soil conditions at Site 9 are presented in Appendices D (D.11) and E (E.3).

2.5.1.2 Soil Sampling

Soil samples were collected throughout Site 9 for soil classification purposes and analytical testing. This sections provides a summary of sampling locations, procedures, and analytical methods for Site 9 sampling activities.

Sampling Locations

Figure 2-15 depicts the sampling locations at Site 9. As shown on Figure 2-15, sampling grids were established within Site 9 at approximate 25-foot centers (refer to Table 2-3). The grids encompass the AST areas, the fire training pit, and the oil/water separator. These areas were selected since those structures serve as potential sources of contamination. Note that samples collected at 9GW4 (soil boring advanced for monitoring well installation) served as site-specific background samples. Appendix C (C.12 and C.13) provides a summary of the number of samples collected, their depths, and analytical parameters tested.

Originally in the Final RI/FS Work Plan, 39 soil borings (SB1 through SB39) were proposed at Site 9. Samples collected from soil borings SB18, SB19, SB23, SB26, SB29, SB33, SB37, SB38, and SB39, which were obtained in September 1992, exhibited elevated total petroleum hydrocarbon (TPH) concentrations (i.e., above 100 mg/kg). Accordingly, 16 additional surface soil samples collected and analyzed for TPH (selected samples were also analyzed for full TCL organics and TAL inorganics) in order to further evaluate the extent of TPH contaminated soils. These additional borings are located south of the oil/water separator and east of the fire training pit. Note that only surface soils were collected because the TPH were predominantly detected in surface soils from the borings mentioned above.

Sampling Procedures

Soil samples obtained at Site 9 were collected by employing the same techniques as described in Section 2.4.3.2. As mentioned in Section 2.4.3.2, samples were collected via a drill rig (i.e., inside augers and split-spoons) or a hand auger. Samples retained for laboratory analyses from soil borings were collected from the surface and just above the water table (a third sample was also submitted if evidence of contamination was noted); samples retained for laboratory analysis from soil borings advanced for monitoring well installation were obtained from just above and just below the water table. Sampling depths are summarized in Appendix C (C.12 and C.13). Note that the sample preparation procedures implemented at Site 9 were the same as those described for Sites 6 and 82.

Analytical Requirements

As shown in Appendix C (C.12 and C.13), 78 of the samples collected at Site 9 were analyzed for TPH and 30 samples were analyzed for full TCL organics and TAL inorganic (refer to Tables 2-5 and 2-6 for analytical methods). Soil samples collected from soil borings were analyzed for TPH or TCL organics/TAL inorganics, while samples collected from soil borings advanced for monitoring well installation were analyzed for TCL organics/TAL inorganics only. TPH analyses were performed using EPA Method 418.1. Two samples were also collected (AST-SB18) for grain size analysis to evaluate subsurface physical conditions.

Quality Assurance and Quality Control Samples

Field quality assurance and quality control (QA/QC) samples were also collected during the sampling program at Site 9. The frequencies and types of QA/QC samples obtained were the

same as those described for Sites 6 and 82 in Section 2.4.3.2 (refer to Table 2-4). Table 2-16 summarizes the QA/QC sampling program implemented for the soil investigation.

2.5.1.3 Field Screening and Air Monitoring

Air monitoring and field screening procedures were implemented during drilling and sampling activities for health and safety and initial contaminant monitoring. The procedures implemented were the same as those described in Section 2.4.3.3.

2.5.2 Groundwater Investigation

The groundwater investigation performed at Site 9 was intended to identify contaminants of concern and evaluate their distribution at the site, and evaluate groundwater flow patterns. Specific objectives of the groundwater investigation are summarized on Table 2-15. The following discusses monitoring well installation, well development, and water level measurement procedures, as well as groundwater sampling activities.

2.5.2.1 Monitoring Well Installation

Six shallow (denoted as 9GW4 through 9GW8) and one deep (6GW7D) monitoring well were installed at Site 9 [three existing wells (9GW1, 9GW2, and 9GW3) are present at the site]. The locations of the existing and newly installed wells are shown on Figure 2-16. The monitoring wells were installed to collect shallow and deep groundwater samples for characterizing the nature and horizontal extent of potentially impacted groundwater and to evaluate groundwater flow patterns at the site. Location selection of the newly installed wells was based on the results of a previous investigations (ESE, 1991) and groundwater flow patterns at the site. Table 2-17 provides a summary of the rationale for the monitoring well locations at Site 9.

Monitoring well installation procedures (i.e., drilling procedures, well construction and materials, screen lengths, well diameter, etc.) implemented at Site 9 for both the shallow and deep wells were the same as those described in Sections 2.4.4.1 for Sites 6 and 82 (refer to Figure 2-9 for typical well completion details). The shallow wells were installed at depths ranging from 18.4 (9GW8) to 21.5 feet bgs (9GW7S) while deep well 9GW7D was installed at 110 feet bgs. Well construction details for the newly installed shallow and deep wells are summarized on Table 2-18 and well construction diagrams are shown on the Test Boring and

TABLE 2-16

SUMMARY OF FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM FOR THE SOIL INVESTIGATION SITE 9 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample (1)	Frequency of Collection	Number of Samples	Analytical Parameters (3)
Trip Blanks (2)	One per Cooler	7	TCL Volatiles
Field Blanks	One per Event (4)	1	TCL Organics/TAL Inorganics
Equipment Rinsates (5)	One per Day	4	TCL Organics/TAL Inorganics
Field Duplicates (6)	10% of Sample Frequency	(6)	TCL Organics/TAL Inorganics/ TPH

Notes:
(1) QA/QC sample types defined on pages 2-12 and 2-13 in text.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Parameters analyzed according to procedures outlined on Tables 2-5 and 2-6.
(4) An event is defined as one 14 day period. Field blank collected from a potable water source used for decontamination of heavy equipment. Source was a fire hydrant located at Site 9.
(5) Equipment rinsates collected from various sampling equipment (e.g., split spoons, stainless steel spoons, hollow stem augers, etc.). Note that samples were collected daily but were analyzed every other day of sampling event. Accordingly, the number of samples presented represents the number of samples analyzed.
(6) Field duplicate samples collected from soil borings presented in Appendix N.

TABLE 2-17

PHASE I MONITORING WELL SUMMARY AND RATIONALE
SITES 9
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Site No.	Well Designation	General Location	Purpose
9	9GW1*, 9GW6, 9GW7S, and 9GW8	Near the fire training pit and oil water separator	Monitor on-site groundwater quality in the surficial/aquifer where ongoing fire training exercises occur.
	9GW2*, 9GW3*, and 9GW7	North of the fire training area	Monitor downgradient groundwater quality in the surficial aquifer.
	9GW7D	North of the training area	Monitor downgradient groundwater quality in the deep aquifer.
	9GW4	Southeast of Site 9	Monitor upgradient (site-specific background well) groundwater quality.

Note: * - Denotes existing monitoring well.

TABLE 2-18

SUMMARY OF NEWLY INSTALLED WELL CONSTRUCTION DETAILS
SITE 9
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (1) (feet, above msl)	Ground Surface Elevation (feet, above msl)	Boring Depth (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)	Stick-Up (feet, above ground surface)
9GW4	9/23/92	30.70	28.3	21.3	21.0	6.3-20.3	4.0	2.3	2.4
9GW5	9/22/92	30.81	28.0	19.5	18.9	4.2-18.5	2.2	1.0	2.8
9GW6	9/23/92	31.31	28.7	20.2	19.7	4.9-19.3	2.9	1.9	2.6
9GW7S	9/23/92	28.76	26.2	22.0	21.5	7.1-21.0	5.0	3.0	2.56
9GW7D(2)	9/29/92	29.10	26.6	110.0	110.0	100-109	98.5	93.0	2.5
9GW8	9/23/92	28.39	26.0	19.0	18.4	3.5-18.0	2.0	1.0	2.4

Notes: (1) msl - mean sea level
(2) Deep Monitoring Well

Horizontal positions are referenced to N.C. State Plane Coordinate System (NAD27) CF = 0.9999216 from U.S.M.C. Monument Toney.
Vertical datum NGVD 29.

Well Construction Records provided in Appendix E (E.3).

2.5.2.2 Well Development Procedures

Following well construction and curing of the bentonite seal, each newly installed shallow and deep well were developed to remove fine-grained sediment from the screen and to establish interconnection between the well and the formation. Well development procedures employed at Site 9 were the same as those described in Section 2.4.4.2.

Well Development Forms summarizing this information are provided in Appendix G (G.3).

2.5.2.3 Water Level Measurements

Static water level measurements were collected from top-of-PVC casing (TOC) reference points at each existing and newly installed well at Site 9. Phase I groundwater data were collected from all site wells on September 15 and 30, and October 26, 1992. Water level measurements were obtained using the same methods as described in Section 2.4.4.3.

All newly installed monitoring wells were surveyed to establish vertical elevation in relationship to mean sea level (msl) and horizontal control as described in Section 2.4.4.3.

2.5.2.4 Groundwater Sampling

The following section discusses sampling locations, sampling procedures, analytical requirements, QA/QC samples for the groundwater sampling program. Note that the sampling procedures employed at Site 9 were the same as those employed at Sites 6 and 82.

Sampling Locations

Groundwater samples were collected from all existing (3 wells total) and newly installed monitoring wells (6 wells total) at Site 9. Figure 2-16 shows the locations of monitoring wells. Note that monitoring well 9GW4, located south of Site 9, served as a site-specific background well (refer to Table 2-17 for sample location rationale).

Sampling Procedures

Groundwater sampling procedures (i.e., including bailing procedures, field measurements, sampling, handling, etc.) implemented at Site 9 were the same as those described in Section 2.4.4.5.

Analytical Requirements

Groundwater samples were analyzed for TCL organics and TAL inorganic (total and dissolved metals, cyanide). EPA Methods 601 and 602 were implemented for analysis of volatiles. Additionally, a groundwater sample was collected from monitoring well 9GW8 for analysis of BOD, COD, TSS, TDS, TS, and TVS to evaluate the general groundwater chemistry for potential treatment options.

Quality Assurance and Quality Control Samples

Field QA/QC samples were also collected during the groundwater sampling program. The sample types are defined in Section 2.4.3. Table 2-19 summarizes the field QA/QC sampling program for the groundwater investigation.

2.6 Phase II Field Investigations Performed at Sites 6 and 82

A second phase of field investigations (Phase II) was initiated at Sites 6 and 82 in February, 1993. The Phase II field investigation was initiated based on the results of the Phase I field investigation. In general, the Phase I investigation indicated that deep groundwater in the vicinity of Sites 6 and 82 is impacted by chlorinated hydrocarbons (note that the results of the Phase I investigation are presented in Section 4.0). Concentrations of chlorinated hydrocarbons are also present in the vicinity of Site 82 in the surficial groundwater, but less significant in magnitude than the deeper groundwater. Accordingly, the Phase II investigation focused on the surficial and deep groundwater quality in the vicinities of Sites 6 and 82. Phase II also further investigated potential source areas associated with the contamination identified during Phase I.

The Phase II field investigation consisted of a soil gas survey, test pit sampling, soil borings, shallow and deep monitoring well installation, and soil and groundwater sampling. The Phase II field investigation commenced on February 18, 1993 and continued through

TABLE 2-19

SUMMARY OF FIELD QUALITY ASSURANCE/QUALITY CONTROL SAMPLING PROGRAM FOR THE GROUNDWATER INVESTIGATION SITE 9 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

QA/QC Sample (1)	Frequency of Collection	Number of Samples	Analytical Parameters (3)
Trip Blanks (2)	One per Cooler	1	TCL Volatiles
Field Blanks	One per Event (4)	0	TCL Organics/TAL Inorganics
Equipment Rinsates (5)	One per Day	1	TCL Organics/TAL Inorganics
Field Duplicates (6)	10% of Sample Frequency	(6)	TCL Organics/TAL Inorganics

Notes:
(1) QA/QC sample types defined on pages 2-12 and 2-13 in text.
(2) Trip blanks submitted with coolers which contained samples for volatile analysis. Samples analyzed for TCL Volatiles only.
(3) Parameters analyzed according to procedures outlined on Tables 2-5 and 2-6.
(4) An event is defined as one 14 day period. Field blank was collected during groundwater sampling activities at Site 6 (same 14 day period).
(5) Equipment rinsates collected from various sampling equipment (e.g., bailers, etc.). Note that samples were collected daily but were analyzed every other day of sampling event. Accordingly, the number of samples presented represents the number of samples analyzed.
(6) Field duplicate samples collected from monitoring wells presented in Appendix N.

May 3, 1993. The following sections provide a detailed description of the field methods employed. Note that many of the field methods employed during Phase II are the same as those employed during Phase I. Therefore, abbreviated descriptions may be used to summarize the Phase II field procedures in some cases.

2.6.1 Soil Gas Survey

A soil gas survey was conducted in portions of Sites 6 and 82 from February 18 through February 23, 1993. The purposes of performing the survey in these areas were to: 1) identify potential source areas which may have contributed to the surficial contamination; 2) evaluate the horizontal extent and distribution of contaminants in the surficial soil and groundwater; and 3) provide real-time data which were used to position the additional shallow monitoring wells installed during Phase II. The survey was performed by TARGET Environmental Services, Inc. (TARGET) and was supervised by Baker personnel. A copy of TARGET's report is provided in Appendix U. The following provides a detailed description of the soil gas field procedures and results.

2.6.1.1 Sampling Locations

Soil gas samples and groundwater headspace samples were collected at the locations shown on Figure 2-17. Three grids were established (referred at grids A, B, and C) to assist in the sample collection. Grid A is located north of Site 82 and Wallace Creek and was established to evaluate potential contaminant migration into Wallace Creek from off-site. Grid B is located in portions of Sites 6 and 82 and was established to: 1) evaluate the extent and distribution of known contamination in the area; 2) identify the source or sources of this contamination; and 3) determine if contaminants are migrating downgradient into Wallace Creek from the south direction. Lastly, grid C is located east of Lot 203 across Piney Green Road and was established to evaluate potential contamination upgradient from Sites 6 and 82. A total of 144 soil gas samples and six groundwater headspace samples were collected during the survey.

2.6.1.2 Sampling Procedures

Prior to sample collection, the three sampling grids were laid out. Sampling points within each grid were established at approximately 100-foot spacings. The groundwater sampling points, however, were placed at random locations within grid B based on the groundwater analytical results from Phase I and from the preliminary soil gas results.

Soil gas samples were collected by employing several steps. A 1/2-inch hole was produced to a depth of approximately six feet by using a drive rod and slide hammer (also commonly referred to as a "slam bar"). The entire sampling system was purged with ambient air drawn through an organic vapor filter cartridge, and a stainless-steel probe was inserted to the full length of the hole and sealed off from the atmosphere. A sample of in-situ soil gas was then withdrawn through the probe and used to purge atmospheric air from the sampling system. A second sample of soil gas was withdrawn through the probe and encapsulated in a pre-evacuated glass vial at two atmospheres of pressure [15 pounds per square (psi)]. The self-sealing vial was detached from the sampling system, packaged, labeled, and stored for laboratory analysis. Sampling depths varied from two to six feet due to the presence of shallow groundwater. Excess soil was used to backfill the sampling holes.

Groundwater samples were collected in slightly different manner than the soil gas samples. A stainless-steel rod was driven into the water table and a sample of groundwater was extracted through dedicated teflon tubing. The samples were collected in clean vials. Fifteen ml of the sample was then placed into a 30 ml vial and sealed with a teflon-faced butyl rubber septum for headspace analysis.

Prior to the day's field activities, all sampling equipment including the side hammer rods and probes were decontaminated by washing with an Alconox soap solution and rinsing thoroughly with distilled water. Internal surfaces were flushed dry using prepurified nitrogen or filtered ambient air, and external surfaces were wiped clean using clean paper towels.

Field control samples were collected at the beginning and end of each day's field activities, and after every twentieth soil gas sample. These QA/QC samples were obtained by inserting the probe tip into a tube flushed by a 20 psi flow of pre-purified nitrogen and encapsulated as described above. The laboratory results of the analysis of these samples are reported on Table 1 in Appendix U. Concentrations of all analytes were below the reporting limit in all field control samples, indicating that the QA/QC measures employed were sufficient to prevent cross-contamination of the samples during collection.

2.6.1.3 Analytical Requirements

All of the soil gas samples and the headspace groundwater samples collected during the field phase of the survey were analyzed according to EPA Method 601 on a gas chromatograph

equipped with an electron capture detector (ECD), and using direct injection of the soil gas or prepared headspace. As described in the previous section, groundwater samples were prepared for analysis by pouring 15 ml of the sample into a 30 ml vial. The vial was heated for 10 minutes to volatilize hydrocarbons from the water. Specific analytes standardized for the ECD analysis were:

- 1,1 dichloroethene (1,1 DCE)
- methylene chloride (CH2 Cl2)
- trans-1,2-dichloroethene (t1,2-DCE)
- chloroform (CHCl3)
- 1,1-dichloroethane (11-DCE)
- carbon tetrachloride (CCl4)
- cis-1,2-dichloroethene (c1,2-DCE)
- 1,1,1-trichloroethane (1,1,1 TCA)
- trichloroethane (TCE)
- 1,1,2-trichloroethane (1,1,2-TCE)
- tetrachloroethene (PCE)

The chlorinated hyrdocarbons in this suite were chosen based on the analytical results from Phase I.

In addition, selected samples (I2, H2D, G3, H3, and I5) were submitted to Maryland Spectral Services, Inc. (MSS) in Baltimore, Maryland for analysis by gas chromatography/mass spectroscopy (GC/MS). These samples were selected for laboratory analysis because elevated contaminant levels were detected in them using the ECD in the field.

2.6.1.4 Results

Results of the soil gas sampling (and samples submitted for laboratory analysis) are summarized on Table 1 in Appendix U. Positive detections of volatile organic compounds (VOCs) were detected at 17 soil gas sample points within grid B. VOC concentrations ranged from 1.1 to 1,360 micrograms per liter (ug/l). Tetrachloroethane (PCE) was the most commonly detected VOC. Note that concentrations of VOC were not detected in either grids A or C.

The distribution of PCE detected during the survey gas survey is presented on Figure 2-18. A major occurrence of PCE is centered at sample point I5 (1,360 ug/l) which is located near the southern portion of Site 82 in the vicinity of well cluster 6GW1S/1D. Overall, the TCE concentrations generally decreased (to 1.1 ug/l) north (or downgradient) of I5 with the exception of sample point G6 (81 ug/l). South (or upgradient) of I5, the TCE concentrations also decreased but remained somewhat elevated (1.6 to 221 ug/l).

Overall, TCE contamination (based on the soil gas results) appears to be limited to grid B. The full extent of the contamination south of grid B toward Lot 203, however, was not defined. Based on TCE levels detected in samples K1 and L1, it appears that contaminants may be impacting Wallace Creek.

Groundwater headspace screening results are also provided on Table 1 in Appendix U. Concentrations of 1,1-DCE, t-1,2-DCE, c-1,2-DCE, TCE, 1,1,2-TCA, and PCE were detected in groundwater samples W2, W3, and W5 (not all compounds were detected in all samples). Of the detected VOCs, t-1,2-DCE and c-1,2-DCE were the most commonly detected. Total VOC concentrations (sum of all positively detected volatile organic compounds) ranged from not detected to 792.8 ug/l (W5).

The distribution of total VOCs in headspace groundwater samples is shown on Figure 2-19. The highest concentration of VOCs were detected in sample W5 which is located near the northern portion of grid B, just south of Wallace Creek. Note that the soil gas samples and groundwater sample W4, which is located nearby W5, did not contain any VOC levels. A second major occurrence of VOCs is also present at sample W3 (324.8 ug/l of total VOCs). This sample is located in the vicinity of sample I5 where elevated levels of TCE were detected from soil gas.

2.6.2 Test Pit Activities

Under Phase II field investigation, an area near the southern boundary of Site 82 was investigated. This investigation was conducted after review of following: historical aerial photographs, information collected during a reconnaissance of a suspected source area, and magnetometer survey data conducted by Geo-Centers (Baker's UXO subcontractor). From the aerial photography it was observed that activity once occurred in the general vicinity of the area to be investigated (just north of Lot 203). Reconnaissance of this area conducted in January of 1993, revealed numerous 5-gallon containers of unknown material (believed to be

lubrication oil). In January of 1993, Geo-Centers (under the supervision of Baker personnel) performed a magnetometer survey of this area and discovered at least seven distinct magnetic anomalies present at this area. Accordingly, test pits were recommended in this area to identify the source of the magnetic anomalies and a potential organic contamination source.

On March 2, 1993, Geo-Centers (under the supervision of Baker personnel) identified seven northern and southern poles of the magnetic anomalies in this area. These seven locations were then marked, and perpendicular transects were staked out at each location. Test pit operations for these seven locations were conducted on March 3, 1993 and were primarily conducted as exploratory excavations to assess the contents of past disposal/burial operations. Test pits varied in length and depth, and were dependent upon the following conditions:

- Space limitations imposed by the site (i.e., wooded areas limited movement of backhoe)
- The capabilities and limitations of the excavation equipment (i.e., depth of excavation was limited to the length of the boom on the backhoe)
- The amount and type of debris excavated (i.e., large amounts of communication wire were encountered during the excavations)
- The depth of the water table

Air monitoring was performed during the teat pit operations with a radiation meter, and a PID meter. On site personnel performing the test pit excavations were required to maintain a Health and Safety Level of Protection, requiring at a minimum chemical resistant Saranex overalls, and Self Contained Breathing Apparatus's (SCBAs). Geo-Center personnel, if the conditions warranted, were to identify unexploded ordnance unearthed during the excavations.

2.6.2.1 Sampling Locations

As stated previously, the review of aerial photographs, a site reconnaissance, and the magnetometer survey were the basis for both the investigation and the corresponding sample locations.

A total of seven trenches (6-TB1 through 6-TB7) were identified in the investigation area. Trenches 6-TB5 and 6-TB6 when excavated, however, were joined into one long trench due to their proximity to each other.

Soil sampling locations, within each trench, were determined in the field based on visual observations and PID air monitoring results. Samples were collected at areas were elevated PID readings occurred. The investigation area and the corresponding trench locations are depicted in Figure 2-15.

2.6.2.2 Sampling Procedures

Upon delineation of the buried material, and the staking of perpendicular trench transects, trench excavation activities were initiated. Excavation was conducted with a Case 580 backhoe, equipped with a three-foot long bucket. Due to the heavily wooded area, which restricted back hoe access, trenches were no more than 10 feet in length and 10 feet in depth.

Samples were collected utilizing both grab and compositing methods. One sample was collected from each of the following test pits: 6TP2, 6-TP3, 6-TP4, 6-TP5, and 6-TP7. A duplicate sample was collected from test pit 6-TP5, and was given the sample designation of 6-TP5D. A sample was not collected from 6-TP1 because no PID readings or no visible soil staining and/or contamination. Test pit 6-TP5 had several, 1 and 5-gallon containers buried within it and an additional sample was taken of the waste material present in the container. Information regarding sample depth and findings were recorded in a field log book and transcribed onto Test Pit Logs. Appendix D (D.12) provides Test Pit Logs with descriptions of material encountered and approximate depth. No geological characterization was performed on test pits because several soil borings and well installation boreholes in the area provided a detailed subsurface description.

Excavated soil was stockpiled on the side and the trench backfilled upon completion. Also, the backhoe bucket was decontaminated with high-pressure steam before excavation activities were initiated and upon completion of each trench.

2.6.2.3 Analytical Requirements

Samples collected from the trenches were shipped for laboratory analysis to Ceimic. Sample were analyzed for full TCL (i.e., volatiles, semi-volatiles, pesticides, and PCBs) and full TAL

(i.e., total metals) parameters. Both the TCL and TAL parameters were performed under Contract Laboratory Protocol and Level IV data quality. The second sample from test pit 6-TP5-02 was also sent to Ceimic, but had an Infrared Spectroscopy scan performed on it. All analytical results are presented in Appendix L.

2.6.3 Soil Investigation

The Phase II soil investigation was initiated to further evaluate areas of concern which were identified during the Phase I investigation and soil gas survey. The investigation consisted of drilling/installing five shallow soil borings (less than 10 feet bgs), and four shallow and seven deep soil borings which were completed as monitoring wells. The five soil borings were installed near the northern boundary of Site 82 to evaluate potentially impacted soils downgradient from a suspected source area (area identified from soil gas survey and Phase I analytical results). Moreover, the monitoring wells were installed within and adjacent to Sites 6 and 82. The following sections describe the field methods employed for the investigation.

2.6.3.1 Drilling Procedures

Drilling activities for the Phase II investigation commenced on March 3, 1993 and continued through April 13, 1993. The shallow soil borings were advanced by using a hand auger according to the procedures outlined in section Section 2.4.3.1. A hand auger was used to install these borings because access with a drill rig was not possible due to the marshy conditions near the borings. Soil borings advanced for shallow and deep monitoring well installation were completed using the same methods (i.e., shallow borings advanced using hollow stem augers and deep borings advanced using a combination of augers and mud rotary drilling) as those described in Section 2.4.3.1. Phase II drilling locations are shown on Figure 2-8 and the borings depths are provided in Appendix C (C.6 and C.11).

Two of the deep soil borings advanced for monitoring well installation, (referred to as "6GW15D Boring" in Appendix E, 6GW15D, and 6GW1DA, experienced difficulties drilling and well installation. The initial boring for deep well 6GW15D was advanced to 52 feet on March 290 and 31, 1993. The boring, however, could not be advanced below this depth because the drilling mud could not be circulated in the borehole (i.e., loss of circulation). Several attempts were made to advance this boring but were unsuccessful. Accordingly, a second boring (referred to as "6GW15D well" in Appendix E) was advanced to a depth of 160 feet in

the vicinity of the initial boring for the installation of well 6GW15D. Note that the abandoned boring was backfilled to ground surface with a bentonite/grout slurry.

A similar situation also occurred at boring 6GW1DA (referred to as "6GW1DA Boring" in Appendix E). On April 3, 1993, the initial soil boring for deep well 6GW1DA was advanced to 127 feet but also experienced a loss of circulation. Accordingly, this boring was abandoned (i.e., backfilled with a bentonite/grout slurry) and a second boring (referred to as "6GW1DA well" in Appendix E) was advanced to a depth of 236.5 feet for the installation of well 6GW1DA.

2.6.3.2 Soil Sampling

Soil samples were collected from the shallow soil borings and the shallow and deep soil borings advanced for monitoring well installation. The locations of the soil samples are shown on Figure 2-8. The sampling procedures implemented during the Phase II investigation were the same as those described in Section 2.4.3.2. Samples collected from the hand auger borings were obtained from the surface and from just above the water table. Moreover, samples collected from the shallow and deep soil borings advanced for monitoring well installation were obtained from just above and just below the water table. Sample depths are summarized in Appendix C (C.6 and C.11). All samples were analyzed for TCL volatiles only because these compounds were the contaminants of concern identified during the Phase I investigation. Additionally, field QA/QC samples (i.e., trip blanks, field blanks, equipment rinsates, and duplicate samples) were collected at the same frequencies as those described on Table 2-6.

2.6.4 Groundwater Investigation

The Phase II groundwater investigation was initiated based on the analytical results from the Phase I investigation. The investigation consisted of monitoring well installation, staff gauge installation, water level measurements, and groundwater sampling. The following sections describe the methods employed during the investigation.

2.6.4.1 Monitoring Well Installation

Additional shallow (6GW31, 6GW32, 6GW33, and 6GW34) and deep (6GW1DA, 6GW30D, 6MW3D, 6GW15D, 6GW35D, 6GW36D, and 6GW37D) monitoring wells were installed at Sites 6 and 82 to further evaluate the horizontal extent of surficial VOC impacted

groundwater, and the horizontal and vertical extent of deep VOC impacted groundwater. Three temporary shallow wells (TW-1, TW-2, and TW-3) were also installed to evaluate potential contaminant migration into Wallace Creek. As stated previously, the location of the Phase II monitoring wells was based on Phase I analytical data, and the soil gas survey. Table 2-20 provides a summary of well location rational for the Phase II wells.

Shallow Wells

Shallow monitoring wells 6GW32, 6GW33, and 6GW34 are located within Site 82 while 6GW31 is located within Lot 203 as shown on Figure 2-8. Wells 6GW32, 6GW33, and 6GW34 were installed to evaluate surficial groundwater quality downgradient from a suspected source area (believed to be located just north of Lot 203). Well 6GW31 was installed due to a surface spill (approximately 500 gallons was released) from a steel tank which contained well purge and development water from the Phase I groundwater investigation. Groundwater samples were collected from this well to confirm the presence or absence of contamination from the release.

The four shallow monitoring wells were installed by employing the same procedures (i.e., 3-1/4 and 8-1/4 inch HSA) as those described in Section 2.4.4.1. Further, the wells are constructed of the same materials (i.e., Schedule 40 PVC, 15-foot No. 10 slotted screen) as the Phase I wells, with the exception that 2-inch monitoring wells were installed. Two-inch wells were installed in lieu of 4-inch wells because the purpose of these wells was to collect representative groundwater samples, and were not intended to serve as recovery wells. The wells range in depth from 22 feet (6GW33) to 35 feet (6GW34). Well construction details are summarized on Table 2-21 and Test Boring and Well Construction Records are provided in Appendix E.

Three temporary wells were also installed during the Phase II investigation to evaluate surficial groundwater quality prior to discharging into Wallace Creek. The temporary wells located just south of Wallace Creek, and north of well 6GW32 as shown on Figure 2-8. The location of these temporary wells were based on information obtained from the soil gas survey, and from analytical data obtained from 6GW32 (Phase II monitoring well).

The temporary wells were installed at approximately 4-feet bgs with a hand auger. The wells were constructed of 2-inch, screened PVC. The space between the well screen and borehole was backfilled with a sand pack (Number 2 silica sand) to the ground surface. Following groundwater sample collection, the wells were removed and backfilled with sand.

TABLE 2-20

PHASE II MONITORING WELL SUMMARY AND RATIONALE
SITES 6 and 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Site No.	Well Designation	General Location	Purpose
6	6GW31	Western portion of Lot 203	Evaluate potentially impacted surficial groundwater from surface release
82	6GW32, 6GW33, and 6GW34	Northern, central and eastern portions of Site 82	Surficial groundwater quality downgradient from a potential source area
6	6GW15D and 6MW3D	Northwestern portion of Lot 203; east of Piney Green Road	Deep groundwater quality upgradient - horizontal extent
82	6GW30D, 6GW35D, 6GW36D, and 6GW37D	North, northwest, and west of Site 82	Deep groundwater quality downgradient - horizontal extent
6	6GW1DA	Southeastern portion of Site 82	Deep groundwater quality - vertical extent

TABLE 2-21

SUMMARY OF PHASE II SHALLOW AND DEEP WELL CONSTRUCTION DETAILS
SITES 6 and 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Date Installed	Top of PVC Casing Elevation (1) (feet, above msl)	Ground Surface Elevation (feet, above msl)	Boring Depth (feet, below ground surface)	Well Depth (feet, below ground surface)	Screen Interval Depth (feet, below ground surface)	Depth to Sand Pack (feet, below ground surface)	Depth to Bentonite (feet, below ground surface)	Stick-Up (feet, above ground surface)
6GW31 (2)	03/02/93	30.26	27.8	27.0	25.5	11.4 - 24.6	9.4	7.4	2.4
6GW32 (2)	03/06/93	21.79	19.6	27.0	27.0	11.3 - 26.6	10.0	7.0	2.2
6GW33 (2)	03/03/93	22.42	20.0	22.0	22.0	6.2 - 21.6	4.5	3.0	2.4
6GW34 (2)	03/03 - 03/05/93	32.01	29.0	35.0	35.0	19.3 - 34.6	17.5	15.0	3.0
6GW1DA (3)	04/13/93	35.23	32.7	236.5	230.0	220.1 - 229.6	215.0	190.0	2.5
6GW15D (3)	04/06/93	28.20	25.2	160.0	155.0	145.0 - 154.6	141.0	139.0	3.0
6GW30D (2)	03/03 - 03/04/93	11.90	9.9	161.9	100.0	90 - 99.6	83.0	76.5	1.4
6GW35D (3)	03/05 - 03/07/93	14.29	12.0	201.0	105.0	95.0 - 104.6	90.0	87.0	2.3
6GW36D (3)	03/18 - 03/19/93	17.61	15.6	201.5	95.0	73.3 - 94.6	66.0	62.0	2.0
6GW37D (3)	03/09/93	15.96	14.0	111.5	95.0	76.1 - 94.6	73.0	70.0	1.9
6MW3D (3)	03/20; 03/31/93	35.18	34.2	201.5	118.0	97.5 - 117.6	94.0	88.0	1.0

Notes: (1) msl - mean sea level. Note that top of casing for well 6GW1DA was stainless-steel, not PVC.
(2) Shallow Well
(3) Deep Well
Horizontal positions are referenced to N.C. State Plane Coordinate System (NAD27) CF = 0.9999216 from USMC Monument Toney. Vertical datum NGVD 29.

Deep Wells

Seven deep wells were installed during the Phase II investigation. Monitoring wells 6GW15D (upgradient well), 6MW3D (upgradient well), 6GW30D (downgradient well), 6GW35D (downgradient well), 6GW36D (downgradient well), and 6GW37D (downgradient well) were installed to evaluate the horizontal extent of contamination while 6GW1DA (installed in an area believed to be near the contamination source) was installed to evaluate the vertical extent of contamination. The locations of these wells were selected based on analytical data from the Phase I groundwater investigation. The locations of these wells are shown on Figure 2-8.

The Phase II deep monitoring wells were installed by employing the same drilling techniques (i.e., combination of hollow-stem augers and mud rotary) as implemented for the Phase I deep wells. Several items, however, were changed or modified regarding the well construction. All Phase II deep wells are constructed of 2-inch PVC with the exception of 6GW1DA which is constructed of 2-inch stainless-steel. Stainless steel was utilized because of the greater depth of this well (stainless-steel is more durable than PVC) and because the well was installed in a potentially highly contaminated area (which may cause vinyl chloride to leach from the PVC) based on the analytical results of 6GW1D. Note that 10- to 20-foot length screens (No. 10 slotted) were used to allow for monitoring of the varying thicknesses of the higher water-producing zones. Table 2-21 provides a summary of the well construction details and Test Boring and Well Construction Records are provided in Appendix E.

Determination of the final well depth for the Phase II deep wells was based on several factors which were evaluated in the field during the drilling program. These factors included: (1) the depth (bottom elevation) of known contamination; and (2) volatile organic levels in soil samples (split-spoon samples collected during drilling) based on PID measurements. The following provides an explanation of the procedures employed for determining the final well depth.

The borings advanced for the Phase II deep wells (i.e., wells installed to evaluate the horizontal extent) were first advanced from approximately 110 to 200 feet bgs. Split-spoon soil samples were collected at approximate 5 to 15-ft intervals during drilling. Samples were collected to these depths because contamination was known to exist at these depths based on contaminant levels exhibited in former supply well HP-651 [which is located just east of

Lot 203 (refer to Section 3.10 for additional information on this supply well)] and from the results of the Phase I Investigation. The soil samples upon collection were placed in eight ounce jars, sealed with aluminum foil and the jar lid, and heated in a crock pot for approximately 10 minutes. The headspace of the sample was then screened with a PID or OVA meter to measure for the presence or absence of volatile organic vapor. Subsequently, these measurements were used to determine the final well depth.

The following scenarios were encountered with the final determination of well depth as explained below:

- In cases where volatiles were not detected by PID or OVA screening to a depth of 200 feet, the borings were backfilled (with a grout/bentonite slurry) to an approximate bottom elevation of Phase I deep well 6GW1D (since contamination is known to exist at this elevation). The wells were then screened at the approximate elevation as 6GW1D.

- In cases where volatiles were detected below 200 feet by PID or OVA screening, the wells were installed approximately 10 to 15 feet below where the level of volatiles decreased to background concentrations.

Selection of the final well depth for monitoring well 6GW1DA, which was installed to evaluate the vertical extent of contamination, was based on a combination of field screening measurements and the lithology of the soils encountered. This well was installed just above a clay unit which was encountered at 230 feet bgs. As described above, this well is constructed of 2-inch stainless-steel.

2.6.4.2 Staff Gauge Installation

Two staff gauges (SGWC1 and SGWC2) were installed in Wallace Creek to evaluate surface water fluctuations and to assist in determining surficial groundwater flow patterns in the area. The gauges are located near the intersections of Wallace Creek and Piney Green Road (SCWC1) and Wallace Creek and Holcomb Boulevard (SGWC2) as shown on Figure 2-8. Further, the gauges were surveyed in place (both vertical and horizontal) according to the procedures outlined in Section 2.4.4.3.

2.6.4.3 Well Development Procedures

The newly installed shallow and deep monitoring wells were developed following well construction and curing of the bentonite/grout seal. The wells were developed by employing the same procedures as those mentioned in Section 2.4.4.2 for both shallow and deep wells. Well Development Forms summarizing well development information in provided in Appendix G.

2.6.4.4 Water Level Measurements

Static water level measurements were collected from the Phase I and II (with the exception of wells 6GW1DA and 6GW15D because these wells were not completed) shallow and deep wells, and existing shallow wells on April 1, 1993. Additionally, staff gauge measurements were also obtained on April 1, 1993 from Wallace Creek and Bear Head Creek. The measurements were collected using the same procedures as those described in Section 2.4.4.3.

2.6.4.5 Groundwater Sampling

Groundwater samples were obtained from all Phase II monitoring wells (round one for Phase II wells) from March 18 to May 3, 1993. Additionally, a second round of groundwater samples were also obtained from all Phase I (Sites 6, 9, and 82 shallow and deep wells) and existing wells from March 18 through March 23, 1993.

The Phase II wells (along the Phase I and existing wells) were sampled by employing the same procedures as those described in Section 2.4.4.5. The groundwater samples were analyzed for parameters based on the Phase I groundwater results. The following summarizes the analytical program:

- Site 9 (round 2) - volatiles (601 and 602):
  - semivolatiles
  - pesticides/PCBs
  - TAL total metals
  - TAL dissolved metals

- Sites 6 and 82 (round 2) - volatiles (601 and 602)

- Sites 6 and 82 (Phase II wells):

- Shallow wells - volatiles (601 and 602):
  - semivolatiles
  - pesticides/PCBs
  - TAL total metals
  - TAL dissolved metals

- Deep wells - volatiles (601 and 602):

  - Field QA/QC samples (i.e., trip blanks, field blanks, equipment rinsates, and duplicate samples) were also collected during the Phase II groundwater field program at the same frequencies as described in Section 2.4.4.5.

Note that the groundwater samples from the Phase II deep wells were only analyzed for volatiles because these compounds are the contaminants of concern in the deep groundwater based on the based on the Phase I results. Additionally note that two samples, one from the top of the water column and one from the bottom of the well, were collected from well 6GW1DA to evaluate the vertical distribution of contaminants. A teflon constructed point source bailer was used to obtain these samples which allowed for discrete interval sampling from within the well. It should be noted that although discrete depths were sampled from this well, the samples may not accurately depict contaminant levels at those depths because of the vertical intermixing of groundwater within the aquifer.

2.7 Decontamination Procedures

Decontamination procedures performed in the field were initiated in accordance with EPA Region IV guidelines. In general, sampling and drilling equipment were divided into two decontamination groups: heavy equipment and routine sample collection equipment. Heavy equipment included: the drill rig, hollow-stem augers, and drill rods; routine sample collection equipment included: split-spoons, stainless-steel spoons and bowls, bailers, bailer wire, hand auger bucket, and sediment corer, etc..

For heavy equipment, the following procedures were implemented:

- Removal of caked-on soil with brush;
- Steam clean with high-pressure steam; and
- Air dry

Note that the well screens for each well were also steam cleaned with high-pressure steam prior to installation.

For routine sample collection equipment, the following procedures were implemented:

- Clean with potable water and laboratory phosphate-free detergent (Alconox soap solution);
- Rinse thoroughly with potable water;
- Rinse thoroughly with deionized water;
- Rinse twice with 10 percent nitric acid;
- Rinse thoroughly with deionized water;
- Rinse twice with pesticide-grade isopropanol alcohol;
- Air dry; and
- Wrap in aluminum foil, if appropriate

Temporary decontamination pads, constructed of wood and plastic, were constructed to minimize spillage onto the ground surface. Decontamination fluids generated during the field program were containerized and handled according to the procedures outlined in Section 2.7.

2.8 Investigative Derived Waste (IDW) Handling

A large volume of solids (approximately 20 cubic yards) and liquids (approximately 6,000 gallons) were generated during the field program at OU No. 2. Solid IDW included soil cuttings, excess split-spoon samples and drilling mud; liquid IDW included well development and purge water, and decontamination fluids (i.e., water, Alconox soap solution, isopropanol alcohol, and 10 percent nitric acid).

Containerization and handling of solids were performed in two phases. At the completion of drilling activities, soils were temporarily stockpiled on plastic sheeting and covered or placed in 55-gallon drums. Afterwards, the soils and drilling mud were transported and emptied into

a roll-off (staged on site in a secure area) box for final containerization. Composite samples were then collected from the roll-off box for disposal purposes. The analyses performed were full TCLP and RCRA hazardous waste characteristics.

Liquid IDW generated the field program were also containerized and handled in two phases. Liquids were initially contained in 55-gallon steel drums, then pumped into a tanker for final containerization. Groundwater removed from monitoring wells in which contamination was suspected (based on PID readings or odor) remained in the drums until final disposal. Decontamination fluids also remained in drums because of the isopropanol alcohol and nitric acid content. Samples of the generated fluids were also collected and analyzed for disposal purposes. These analyses included TCL organics and TAL inorganics (total only). The IDW characterization results and recommended disposal options are provided in Appendix J. These options were implemented at MCB Camp Lejeune the week of February 21, 1993.

3.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

This section contains a discussion of the physical characteristics of Sites 6 and 9 (refer to as Operable Unit No. 2 or OU No. 2) including: surface features, meteorology, hydrology, geology, soils, hydrogeology, land use, ecology, and water supply well inventories. This information was obtained from the RI field activities and available literature pertaining to MCB Camp Lejeune.

3.1 Surface Features

The topography of MCB Camp Lejeune is relatively flat with ground surface elevations ranging from mean sea level (msl) to 72 feet above msl. Most of MCB Camp Lejeune lies between 20 and 40 feet msl. The terrain of Camp Lejeune is typical of the North Carolina Coastal Plain. Drainage is generally to the New River and the Atlantic Ocean via the Intracoastal Waterway.

OU No. 2 is dominantly a flat area with some elevation variations occurring near the northern portion of Site 82. Overall, the surface elevation at OU No. 2 ranges between 5 to 30 feet above msl (Figure 3-1). The highest elevations of OU No. 2 are encountered in the vicinity of Site 82 where the elevation increases to approximately 30 feet above msl. Elevations drop off sharply at the banks of Wallace Creek located along the northern portion of Site 82 and Bear Head Creek located in the wooded area south of Lot 201. The terrain near the northern portion of Site 82 indicates that drainage would be toward Wallace Creek while the terrain near the southern portion of Site 6 (or northern portion of Site 9) indicates that drainage would be toward Bear Head Creek.

Several major land surface features are present at OU No. 2. These features include a large ravine area, a smaller ravine area, surface depressions, and mounds as shown on Figure 3-1. The large ravine area, which has been discussed throughout this report (refer to Section 2.1.1.3), is located north of Lot 203. This larger ravine is approximately 40 feet in width at its widest point (southern end) and extends from just north of Lot 203 to Wallace Creek (approximately 1,250 feet in length). A smaller ravine area is also located near the eastern boundary of Site 82, northeast of monitoring well 6GW1S. This smaller ravine is approximately 20 feet in width at its widest point and extends approximately 600 feet in the north to south directions. Surface water was noted in the larger ravine periodically while surface water was not noted in the smaller ravine.

A series of depressions and mounded areas are also present near the southern portion of Site 82. Some of these features do not appear to be naturally occurring land features. The depressions appear to be former excavation areas while the mounded areas appear to be associated with excavations. Within some of these mounds, a large number of 5-gallon pails were noted. These pails contain suspected solvents or lubrication oils.

3.2 Meteorology

MCB Camp Lejeune is located within the Coastal Plain physiographic division of North Carolina. Coastal Plain elevations range from 200 feet above msl at the western boundary to generally 30 feet or less in areas of tidal influence to the east. The tidal portion of the Coastal Plain, where Camp Lejeune is situated, is generally flat and swampy.

Although coastal North Carolina lacks distinct wet and dry seasons, there is some seasonal variation in average precipitation. July tends to receive the most precipitation and rainfall amounts during summer are generally the greatest. Daily showers during the summer are not uncommon, nor are periods of one or two weeks without rain. Convective showers and thunderstorms contribute to the variability of precipitation during the summer months. October tends to receive the least amount of precipitation, on average. Throughout the winter and spring months precipitation occurs primarily in the form of migratory low pressure storms. Camp Lejeune's average yearly rainfall is approximately 52 inches. Table 3-1 presents a climatic summary of data collected during 27 years (January 1955 to December 1982) of observations at Marine Corps Air Station (MCAS) New River.

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

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

TABLE 3-1

CLIMATIC DATA SUMMARY FOR MCAS NEW RIVER
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

	Precipitation (Inches)			Relative Humidity (Percent)	Temperature (Fahrenheit)			Mean Number of Days With				
								Precipitation		Temperature		
	Maximum	Minimum	Average		Maximum	Minimum	Average	>=0.01"	>=0.5"	>=90 F	>=75 F	<=32 F
January	7.5	1.4	4.2	76	54	34	44	11	2	0	1	14
February	7.0	1.5	3.8	74	57	36	46	9	3	0	1	11
March	8.0	0.8	3.5	78	64	42	53	10	2	0	5	7
April	6.5	0.5	3.0	79	73	51	62	8	2	--	14	--
May	8.4	1.7	4.3	86	80	60	70	10	3	2	25	0
June	11.8	2.4	5.8	85	85	67	76	11	4	6	29	0
July	14.3	4.5	8.0	85	88	72	80	14	5	12	31	0
August	12.6	1.7	6.1	87	87	71	80	12	4	11	31	0
September	12.2	1.4	4.7	87	83	66	75	9	3	3	27	0
October	6.5	0.7	2.8	82	74	54	64	7	2	--	16	--
November	5.7	0.6	2.6	80	66	44	55	7	1	0	6	4
December	6.1	0.4	4.0	77	58	37	48	9	2	0	2	11
Annual	14.3	0.4	52.8	81	72	53	63	117	33	34	188	47

-- Less than 0.5 days
Source: Naval Oceanography Command Detachment, Asheville, North Carolina. Measurements obtained from January 1955 to December 1982.

Observations of sky conditions indicate yearly averages of approximately 112 days clear, 105 partly cloudy, and 148 cloudy. Measurable amounts of rainfall occur 120 days per year, on the average. Prevailing winds are generally from the south-southwest 10 months of the year, and from the north-northwest during September and October. The average wind speed for MCAS New River is 6.9 m.p.h.

3.3 Surface Water Hydrology

The majority of MCB Camp Lejeune is nearly level with wide, undissected interstream areas in which drainage is poor and water movement is slow. The New River is the dominant surface water feature and receives drainage from most of the base. It flows in a southerly direction and empties into the Atlantic Ocean through the New River Inlet.

OU No. 2 is located approximately 1.75 miles east of the New River and 12.5 miles north of the New River's outlet into the Atlantic Ocean. Two drainages exist within and adjacent to OU No. 2. Wallace Creek forms the northern border of Site 82 and flows in a southwesterly direction toward the New River. Wallace Creek is surrounded by marsh that exhibits extensive surface ponding. Bear Head Creek lies within the southern portion of Site 6 and empties into Wallace Creek approximately 0.75 miles downstream from the site.

The NC DEHNR classifies bodies of water within the state according to their designated use. Wallace Creek from its source to the New River and Bear Head Creek from its source to Wallace Creek are designated as Class SB NSW surface waters. The Class SB NSW designation denotes tidal saltwaters protected for primary recreation, fishing and for the propagation and survival of aquatic life.

Tide data was obtained from the National Oceanic and Atmospheric Administration's (NOAA) Hampton Roads, Virginia station in order to quantify tidal effects on the New River and associated tributaries. A correction factor for the New River was applied to tidal data collected from August 1, 1992 to September 18, 1992. High and Low tide data are summarized on Table 3-2.

TABLE 3-2

TIDE DATA FOR THE NEW RIVER IN JACKSONVILLE, NORTH CAROLINA
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Date	High Tide		Low Tide	
	Time	Height (feet)	Time	Height (feet)
08/01/92	13.1	1.74	7.9	0.88
	NA	NA	20.3	0.92
08/02/92	1.5	1.62	NA	NA
	14.1	1.62	8.8	0.84
	NA	NA	21.2	0.90
08/03/92	2.5	1.55	9.5	0.93
	15.0	1.64	22.2	0.92
08/04/92	3.3	1.52	10.1	0.95
	16.5	1.67	22.6	1.05
08/05/92	4.5	1.54	11.4	1.05
	16.9	1.62	NA	NA
08/06/92	NA	NA	0.4	1.02
	5.4	1.47	12.4	1.03
	18.1	1.59	NA	NA
08/07/92	NA	NA	1.3	1.04
	6.3	1.49	13.3	1.04
	19.0	1.59	NA	NA
08/08/92	NA	NA	2.0	1.08
	7.3	1.47	14.4	1.02
	20.1	1.58	NA	NA
08/09/92	8.6	1.44	3.4	1.02
	20.8	1.55	15.4	1.03
08/10/92	9.6	1.50	4.1	1.02
	21.8	1.59	16.2	1.01
08/11/92	10.2	1.52	4.9	1.03
	NA	NA	16.9	1.02
08/12/92	0.3	1.72	NA	NA
	11.1	1.57	5.7	0.99
	22.8	1.59	17.6	0.96
08/13/92	11.4	1.59	6.1	1.02
	NA	NA	18.0	1.06
08/14/92	.04	1.81	NA	NA
	11.9	1.76	6.4	1.19
	NA	NA	19.0	1.21
08/15/92	0.4	1.84	NA	NA
	12.6	1.79	8.0	1.27
	NA	NA	19.7	1.20
08/16/92	1.0	1.76	NA	NA
	13.0	1.73	7.7	1.22
	NA	NA	19.9	1.16
08/17/92	1.4	1.67	NA	NA
	13.7	1.66	8.2	1.11
	NA	NA	20.4	1.14
08/18/92	1.9	1.62	NA	NA
	14.5	1.65	8.6	1.09
	NA	NA	21.4	1.12
08/19/92	2.7	1.55	9.3	1.05
	15.2	1.64	22.2	1.13
08/20/92	3.7	1.54	10.0	1.12
	15.4	1.66	23.3	1.17
08/21/92	4.2	1.55	11.2	1.13
	16.6	1.64	NA	NA
08/22/92	NA	NA	0.2	1.14
	5.0	1.51	12.0	1.06
	17.6	1.58	NA	NA
08/23/92	NA	NA	0.9	1.07
	6.1	1.48	13.1	1.02
	18.7	1.60	NA	NA
08/24/92	NA	NA	2.0	1.05
	7.3	1.52	14.2	1.01
	20.0	1.64	NA	NA
08/25/92	NA	NA	3.1	1.02
	8.4	1.56	15.1	0.95
	21.0	1.65	NA	NA
08/26/92	9.2	1.59	4.0	0.95
	21.8	1.71	16.2	0.90
08/27/92	10.3	1.71	5.0	0.97
	22.5	1.74	17.3	0.95
08/28/92	11.2	1.73	6.0	0.95
	NA	NA	18.5	0.89
08/29/92	0.5	1.64	NA	NA
	12.5	1.81	6.9	0.97
	NA	NA	19.5	0.96
08/30/92	0.9	1.74	NA	NA
	12.9	1.75	7.7	0.96
	NA	NA	20.2	0.93
08/31/92	1.4	1.57	NA	NA
	14.1	1.61	8.5	0.84
	NA	NA	21.0	0.91
09/01/92	2.5	1.56	NA	NA
		NA	9.2	0.96
	14.8	1.65	21.9	1.00
09/02/92	3.1	1.52	10.4	0.94
	15.6	1.59	22.8	0.98
09/03/92	4.1	1.45	11.0	0.95
	16.7	1.55	NA	NA
09/04/92	NA	NA	0.2	1.02
	4.8	1.39	12.0	0.99
	17.7	1.53	NA	NA
09/05/92	NA	NA	0.7	1.02
	6.2	1.44	13.2	1.04
	18.8	1.58	NA	NA
09/06/92	NA	NA	1.7	1.15
	7.2	1.60	14.1	1.15
	19.9	1.68	NA	NA
09/07/92	NA	NA	2.7	1.23
	8.1	1.62	14.9	1.17
	20.4	1.66	NA	NA
09/08/92	8.8	1.55	3.4	1.12
	21.1	1.59	15.7	1.08
09/09/92	9.6	1.55	4.0	1.04
	21.9	1.57	16.5	1.04
09/10/92	10.4	1.54	4.8	0.99
	22.5	1.55	17.2	1.02
09/11/92	10.8	1.66	4.8	1.05
	23.3	1.66	18.1	1.12
09/12/92	11.4	1.71	6.1	1.14
	23.7	1.64	18.5	1.12
09/13/92	12.1	1.69	6.7	1.09
	NA	NA	18.9	1.10
09/14/92	0.3	1.64	NA	NA
	12.7	1.70	7.0	1.08
	NA	NA	19.8	1.11
09/15/92	0.9	1.61	NA	NA
	13.1	1.69	7.6	1.07
	NA	NA	20.2	1.11
09/16/92	1.4	1.58	NA	NA
	13.9	1.62	8.1	1.05
	NA	NA	21.0	1.04
09/17/92	2.2	1.50	9.1	1.00
	14.6	1.57	21.8	1.02
09/18/92	2.9	1.43	9.8	0.96
	15.4	1.56	22.8	1.03

Source: NOAA Tide Station in Hampton Roads, Virginia
NA - Not Available

3.4 Geology

The following sections contain the regional geology of MCB Camp Lejeune and the site-specific geology of OU No. 2.

3.4.1 Regional Geology

MCB Camp Lejeune is located in the Atlantic Coastal Plain physiographic province. The sediments of the Atlantic Coastal Plain consist of interbedded sands, clays, calcareous clays, shell beds, sandstone, and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast. Regionally, they comprise 10 aquifers and nine confining units which overlie igneous and metamorphic basement rocks of pre-Cretaceous age. These sediments were deposited in marine or near-marine environments and range in age from early Cretaceous to Quaternary time. Table 3-3 presents a generalized stratigraphic column for Jones and Onslow Counties, North Carolina (Harned et al., 1989).

United State Geological Survey (USGS) studies at MCB Camp Lejeune indicate that the area is underlain by sand and limestone aquifers separated by confining units of silt and clay. These include the water table (surficial), Castle Hayne, Beaufort, Peedee, Black Creek, and upper and lower Cape Fear aquifers. The combined thickness of these sediments is approximately 1,500 feet. Less permeable clay and silt beds function as confining units or semi-confining units which separate the aquifers and impede the flow of groundwater between aquifers. A generalized hydrogeologic cross-section of this area is presented in Figure 3-2. This cross-section illustrates the relationship between the aquifers in this area (Harned et al., 1989).

3.4.2 Site Geology

Numerous soil borings were advanced in the surficial (depth less than 25 feet bgs) and deep (depth greater than 100 feet) soils within the vicinity of OU No. 2. The following provides a detailed description of the surficial and deeper subsurface soils.

3.4.2.1 Surficial Soil Conditions

Surficial soil conditions are generally uniform throughout OU No. 2. In general, surficial soils consist of unconsolidated deposits of silty and clayey sand, silt, and clay. These soils represent

TABLE 3-3

GEOLOGIC AND HYDROGEOLOGIC UNITS IN THE COASTAL PLAIN OF NORTH CAROLINA REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

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

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

Source: Harned et al., 1989

the Quaternary "undifferentiated" formation which characterize the surficial aquifer. Sands are fine to coarse-grained and contain varied amounts of silt (5% to 50%) and clay (5% to 20%). Results of standard penetration tests (commonly referred to as "blow counts," ASTM 1586), indicate that the sands have a relative density of loose to dense. Further, the sands classify as SM and/or SC according to the Unified Soil Classification System (USCS). Silts are generally inorganic (ML) with the exception of organic silts encountered near Wallace Creek, Bear Head Creek, and the ravine (saturated conditions). Clays are plastic to nonplastic, contain varied amounts of silt and sand (5% to 25 %), and classify as CL (inorganic clays). Standard penetration results for cohesive soils (clays and silts) indicate a relative density of medium stiff to stiff.

Several areas investigated within OU No. 2 contain large amounts of fill or reworked material. These materials were encountered throughout Lot 201, Lot 203, and portions of Site 9. Historical aerial photographs revealed that soils within and adjacent to the Lot 203 have been excavated and reworked extensively over the years. Soil boring data indicates that fill material exists in these areas to depths greater than five feet bgs in some cases.

Geologic cross-sections depicting surficial soil conditions underlying OU No. 2 were developed based on information obtained during the Phase I and Phase II drilling programs. As shown on Figure 3-3, two cross-sections within OU No. 2 were traversed for the surficial soils. In general, cross-section A to A' traverses north to south (soil borings 6GW30 to 9GW4) while cross-section B to B' traverses west to east (soil borings 6GW21 to 6GW25).

Geologic cross-section A-A' is presented on Figure 3-4. Surficial soils encountered traversing north to south across OU No. 2 are generally uniform. This area is predominantly underlain by silty sand (SM) with thin interbedded layers of silt (ML or MH) and clay (CL). The sand was typically encountered from just below the ground surface to approximately 25 feet bgs where the shallow borings were terminated. Thin laterally discontinuous layers of silt (1 to 3 feet thick) are present near the northern and southern boundaries of OU No. 2. Additionally, a thin laterally discontinuous layer of clay is present in the vicinity of soils boring 9GW6.

Surficial soils encountered along the general northwest to southeast direction across the site are illustrated on Figure 3-5. Soils encountered along the B-B' traverse are similar to those described for the A-A' traverse. Silty sands underlie the area with thin interbedded layers of silt. The silty sands were encountered to a depth of approximately 25 feet bgs where the borings were terminated. Thin laterally discontinuous layers of silt (approximately 1 to 2.5

feet thick) were encountered in soil borings 6GW21 (located west of Lot 203) and 6GW18 (located in the wooded area east of Lot 201).

Overall, the surficial soils encountered at OU No. 2 were generally consistent throughout. The dominant soil type encountered was a silty sand. Within the area investigated, a laterally continuous confining layer (i.e., one which displays a low enough permeability to impede the migration of contaminants to any stratigraphically lower water-bearing zones) was not encountered.

3.4.2.2 Deep Soil Conditions

Soils were classified during the Phase I and Phase II drilling programs to a maximum depth of 236 feet bgs. Additional information on deep subsurface soil conditions to 310 feet bgs was also obtained from boring logs of supply wells (Hadnot Point supply wells) in the area. The following summarizes deep subsurface soil conditions underlying OU No. 2.

Deeper subsurface soils (below 25 feet) are also generally consistent throughout the site. In general, the deeper subsurface soils consist of fine to medium-grained silty sand, silt, silty-sandy clay, and sandy-marly limestone fragments (gravel size). The appearance and classification (SM) of the deeper sands are similar to that described for the surficial sands. Below a depth of 50 to 60 feet, however, the sands become very dense to hard (blow counts above 50). Large amounts of shell fragments were noted frequently in the sands. Thin lenses of clay are interbedded within the sands. The clays contain trace (up to 10 percent) to little (10 percent to 20 percent) amounts of silt and sand, and are non-plastic to slightly plastic. Limestone is interbedded within the sands or occurs as separate units. The limestone contains mixtures of sand and limey mud (marl). This sandy-marly limestone is reported in the literature as representing the Castle Hayne aquifer (Harned, et al, 1989).

Geologic cross-sections depicting deeper subsurface soil conditions underlying OU No. 2 were also developed (refer to Figure 3-3). In general, cross section C to C' traverses north to south (supply well borings HP-653 to HP-635) while cross-section D to D' traverses west to east (supply well borings HP-633 to deep monitoring well boring 6MW3D).

Geologic cross-section C-C' is shown on Figure 3-6. In general, deeper subsurface soils along this traverse consist of silty sand, clay, and limestone fragments (referred to as limestone, sandy limestone, and marly limestone because of its varied nature).

The upper silty sand unit, which is encountered from the ground surface, ranges in thickness from approximately 40 to 140 feet. This silty sand unit is thickest in the southern portion of the site and decreases toward the northern portion of the site. Within the upper silty sand unit, thin laterally discontinuous layers of clay (borings HP-653 and 6GW2D) and limestone (boring HP-635) are present. The clay varies in thickness from approximately 2 to 10 feet while the limestone varies in thickness from approximately 3 to 5 feet.

Underlying the upper silty sand is a limestone unit. The limestone unit varies in thickness from approximately 5 feet near the southern portion of the site to 80 feet near the northern portion of the site.

Silty sands (lower unit) underlie the limestone unit to a depth of 310 feet bgs (estimated depth). At boring location HP-651, laterally discontinuous layers of clay (approximately 10 feet thick) and limestone (approximately 10 feet) are present at 230 feet and 250 feet deep, respectively.

Geologic cross-section D to D' is shown on Figure 3-7. In general, deeper subsurface soils along this traverse also consist of silty sand, silt, clay, and limestone. Silty sands (upper silty sand unit), which are also encountered from ground surface, range in thickness from 40 feet near the eastern portion of the site (HP-651) to 120 feet just west of Holcomb Boulevard (HP-633). Within the upper silty sand unit, discontinuous to partly continuous interbedded layers of clay (boring 6GW1D and HP-653 ranging in thickness from approximately 1 to 20 feet), silt (boring 6GW28D approximately 5 feet thick), and limestone (boring 6GW1D approximately 10 feet thick) are present. The clay layer within the upper silty sand unit is partly continuous across the site since it is present from borings HP-653 to 6GW2D and at boring 6GW1D (very thin).

A limestone unit (upper limestone unit) is present underlying the upper silty sand unit. This unit varies in thickness from approximately 20 feet just west of Holcomb Boulevard to approximately 140 feet just east of Piney Green Road. Subsequently, the limestone unit appears to decrease in thickness westward across the site.

Underlying the upper limestone unit are alternating sequences of silty sand (approximately 30 feet thick), limestone (approximately 3 to 35 feet thick), and silty sand (approximately 20 to 80 feet thick) to a depth of approximately 310 feet bgs. In general, the limestone unit which separates the silty sands is thinner compared to the silty sands. Moreover, this limestone unit generally becomes thinner eastward across the site.

3.5 Test Pits

3.5.1 Phase I Test Pits

The Phase I exploratory excavations (test pits) completed in September 1992, revealed the presence of buried debris. The material unearthed has been classified as "Military/Construction Debris" for purposes of this study. Buried debris was encountered at several locations and consisted primarily of the following:

- Communication wire
- Spent casings (95 to 105 mm cartridges)
- Scrap metal
- Rebar and wire
- Battery packs
- 5-gallon Buckets

In addition, isolated areas contained burned material/residue within the test pit. Some anomalies identified in the geophysical survey, which did not correlate with trench and fill locations depicted on aerial photographs, were also investigated. The test pits associated with the anomalies revealed buried wood and trace amounts of scrap metal in some cases. It should be noted that these areas were not surveyed in and may have deviated from the actual anomaly detected in the geophysical survey. A detailed description of contents encountered and the approximate depth is illustrated on the test pit logs presented in Appendix D.12.

3.5.2 Phase II Test Pits

The Phase II test pits completed in April 1993, also revealed the presence of buried debris. Communication wire was noted in four (6-TP1, 6-TP2, 6-TP3, and 6-TP4) of the six excavations. In test pits 6-TP5 and 6-TP7, numerous 1- and 5-gallon containers were noted in the excavations. The materials present in the containers appeared to be grease or a

lubrication oil, which was greenish-blue in color. Samples of the material were retained for laboratory analysis. Appendix D.12 contains the Test Pit Records which describe the materials encountered during the excavations.

3.6 Soils

Information regarding site soil conditions was obtained from the Soil Survey publication prepared by the U.S. Department of Agriculture - Soil Conservation Service (SCS) for Camp Lejeune, North Carolina (SCS, 1984). As part of the RI, a limited number of soil samples were evaluated for geotechnical properties and classified according to the Universal Soil Classification System (USCS). The findings of that evaluation were used to confirm SCS survey results. Due to past burial and excavation activities at OU No. 2, however, the soils described in the SCS publication may differ from current site conditions.

According to the SCS Soil Survey, OU No. 2 is underlain by a number of distinct soil units. The Baymeade (BaB) urban land complex, which underlies Site 9 and Lot 201, is typically found in areas where the original soil has been cut, filled, or graded. Soil properties of this unit have been altered through slope modification and smoothing. Due to its rapid infiltration rate and well drained nature, Baymeade soil tends to be used for parking lots and light-duty urban areas. The soil series found within Lot 203 and extending southward is characteristic of excavated areas. Excavated soils (Pt) commonly range from 5 to 15 feet in depth and are subject to surface ponding.

The wooded areas that surround both Lots 201 and 203 are underlain by either Kureb (KuB) or Leon (Ln) fine sands. Kureb and Leon fine sands are typically found on uplands near large drainages and on convex divides. Kureb soils are well drained and range from 1 to 6 percent slopes. The Leon fine sand unit, unlike the Kureb, is poorly drained and tends to be nearly level.

Wallace and Bear Head Creeks are bordered by Muckalee (Mk) loam soils that tend to be poorly drained and found on flood plains. The Muckalee unit is frequently flooded for brief periods and is subject to ponding. Marvyn (MaC) loamy fine sands are found upland of the Muckalee unit on side slopes near large drainages. Marvyn soil areas are long and narrow, ranging from 6 to 15 percent in slope.

Generally soils identified by the SCS at OU No. 2 are moderately to strongly acidic in nature (see Table 3-4). With the exception of the Muckalee unit, soils at the site are generally classified under USCS as SM or SP-SM (fine sand or loamy fine sand). Muckalee soils are classified as being ML (loam). Sieve analysis results from the limited number of samples collected during the field investigation are consistent with the SCS Soil Survey (see Appendix P).

3.7 Hydrogeology

The following sections discuss the regional and site-specific hydrogeologic conditions. The information presented on the regional hydrogeology is from literature; site-specific hydrogeologic information presented is from data collected during the field investigation.

3.7.1 Regional Hydrogeology

The surficial aquifer lies in a series of sediments, primarily sand and clay, which commonly extend to depths of 50 to 100 feet. This unit is not used for water supply at MCB Camp Lejeune.

The principal water supply aquifer for the Base lies in a series of sand and limestone beds between 50 and 300 feet below land surface. This series of sediments generally is known as the Castle Hayne formation. The Castle Hayne formation is about 150 to 350 feet thick in the area and contains the most productive aquifer in North Carolina. Estimated transmissivity (T) and hydraulic conductivity (K) values for the Castle Hayne Aquifer range from 4,300 to 24,500 $feet^2$/day (32,200 to 183,300 gallons/day/feet) and 14 to 82 feet/day, respectively (Harned et al., 1989).

Onslow County and Camp Lejeune lie in an area where the Castle Hayne aquifer contains freshwater, although the proximity of saltwater in deeper layers just below the aquifer and in the New River estuary is of concern in managing water withdrawals from the aquifer. Overpumping of the deeper parts of the aquifer could cause intrusion saltwater. The aquifer contains water having less than 250 milligrams per liter (mg/l) chloride throughout the area of the Base (Harned et al., 1989).

TABLE 3-4

SUMMARY OF SOIL PHYSICAL PROPERTIES
OPERABLE UNIT NO. 2
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Soil Name	Soil Symbol	USCS Classification	Depth (inches)	Moist Bulk Density (g/cc)	Permeability (cm/s)	Soil Reaction (pH)	Shrink-Swell Potential	Organic Matter (percent)
Baymeade	BaB	SM, SP-SM	0-30	1.60 - 1.75	4.2×10^{-3} - 1.37×10^{-2}	4.5 - 6.5	Low	0.5 - 1.0
Kureb	KuB	SP, SP-SM	0-80	1.60 - 1.80	4.2×10^{-3} - 1.37×10^{-2}	4.5 - 7.3	Low	<2.0
Leon	Ln	SP, SP-SM	0-17	1.40 - 1.65	4.2×10^{-3} - 1.37×10^{-2}	3.6 - 5.5	Low	0.5 - 4.0
Marvyn	MaC	SM	0-12	--	1.37×10^{-3} - 4.2×10^{-3}	4.5 - 6.0	Low	<2.0
Muckalee	Mk	ML	0-28	--	4.2×10^{-4} - 1.37×10^{-3}	5.1 - 7.3	Low	0.5 - 2.0

Source: Soil Survey: Camp Lejeune, North Carolina, U.S. Department of Agriculture - Soil Conservation Service

Notes:
- ML - Loam
- SM - Loamy Fine Sand
- SP - Fine Sand
- -- - Not Estimated

The aquifers that lie below the Castle Hayne saturate thick sequences of sand and clay. Although some of these aquifers are used for water supply elsewhere in the Coastal Plain, they contain saltwater in the Camp Lejeune area and are not used (Harned et al., 1989).

Rainfall in the Camp Lejeune area enters the ground in recharge areas, infiltrates the soil, and moves downward until it reaches the water table, which is the top of the saturated zone. In the saturated zone, groundwater flows in the direction of lower hydraulic head, moving through the system to discharge areas like the New River and its tributaries or the ocean (Harned et al., 1989).

Water levels in wells tapping the surficial aquifer vary seasonally. The surficial aquifer receives more recharge in the winter than in the summer when much of the water evaporates or is transpired by plants before it can reach the water table. Therefore, the water table generally is highest in the winter months and lowest in summer or early fall (Harned et al., 1989).

In semi-confined aquifers, water is under excess head and the level to which it rises in a tightly cased well is called the potentiometric surface. The hydraulic head in the semi-confined Castle Hayne aquifer, shows a different pattern of variation over time. Some seasonal variation also is common in the potentiometric surface of the Castle Hayne aquifer, but the changes tend to be slower and over a smaller range than for water table wells (Harned et al., 1989).

3.7.2 Site Hydrogeology

As described in Section 3.4.2, the OU No. 2 is underlain by unconsolidated deposits of sand, silty sand, silt, clay, and limestone fragments which characterize the surficial and deep water-bearing zones. These conditions are consistent with the regional hydrogeologic framework described in USGS publications. The following describes groundwater conditions for both the surficial and deeper water-bearing zones.

3.7.2.1 Surficial Groundwater

Surficial groundwater flow patterns in the vicinity of OU No. 2 were evaluated by a network of previously existing and newly installed shallow monitoring wells (less than 33 feet), and staff gauges installed in Bear Head Creek and Wallace Creek. The shallow monitoring well

network extends from north of Wallace Creek to south of Site 9, and east of Piney Green Road to Holcomb Boulevard. Monitoring well and staff gauge locations are shown on Figure 2-8.

Groundwater was encountered during the drilling program at varying depths throughout OU No. 2. This variation in groundwater depths is attributed to topographic (i.e., land surface elevations) changes. A high water table (i.e., less than 2 feet bgs) was typically encountered near the banks of Wallace Creek and Bear Head Creek while a lower (i.e., greater than 15 feet bgs) water table was encountered north of Lot 203 in the vicinities of well clusters 6GW1S/D and 6GW28S/D. An average depth of groundwater across OU No. 2 is approximately 8 feet.

Four rounds of groundwater level measurements were obtained from the shallow monitoring wells at Sites 6 and 82 (September 30, 1992; October 26, 1992; November 7, 1992; and April 1, 1993), and Site 9 (September 15, 1992; September 30, 1992; and October 26, 1992; and April 1, 1993) during the Phase I and II field investigation as shown on Tables 3-5 and 3-6, respectively. Staff gauge surface water measurements from Bear Head Creek (September 30, 1992 and April 1, 1993) and Wallace Creek (April 1, 1993) are shown on Table 3-7.

Groundwater elevations (measured from top of PVC casing reference points) ranged from 1.03 feet [well 82MW2 (10/26/92) located near Wallace Creek] to 29.39 [well 6GW2S (4/1/93) located east of Lot 203 across Piney Green Road] feet above msl. Water levels fluctuated between 0.7 and 5.59 feet over a seven month period. Well 6GW1S exhibited the largest fluctuation in water level of 5.59 feet. In general, the highest water levels were noted on April 1, 1993 and the lowest water levels were noted on November 7, 1992.

Water level data was collected over a 24-hour period from monitoring well 6GW28S. As shown on Table 3-8, water levels were fairly constant over a 24-hour period as a change of only 0.06-feet was observed. This very small change in water level is most likely the result of normal daily fluctuations.

Surficial groundwater flow patterns in the vicinity of OU No. 2 on September 30, 1992 are depicted on Figure 3-8. As shown on Figure 3-8, a groundwater divide occurs near the north-central portion of OU No. 2. Groundwater on the north side of the divide is flowing northwest toward Wallace Creek while groundwater on the south side of the divide is flowing southwest toward Bear Head Creek. The groundwater flow patterns within these areas appear to be influenced by surface elevation changes. The data (i.e., ground surface and groundwater

TABLE 3-5

SUMMARY OF WATER LEVEL MEASUREMENTS FROM SHALLOW MONITORING WELLS ON SEPTEMBER 30, 1992, OCTOBER 26, 1992, NOVEMBER 7, 1992, AND APRIL 1, 1993
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Top of PVC Casing Elevation(1) (feet, above msl)	Depth to Groundwater (feet, below top of casing) (9/30/92)	Depth to Groundwater (feet, below top of casing) (10/26/92)	Depth to Groundwater (feet, below top of casing) (11/7/92)	Depth to Groundwater (feet, below top of casing) (4/1/93)	Groundwater Elevation (feet, above msl) (9/30/92)	Groundwater Elevation (feet, above msl) (10/26/92)	Groundwater Elevation (feet, above msl) (11/7/92)	Groundwater Elevation (feet, above msl) (4/1/93)
6GW1S(2)	35.18	18.75	19.55	19.86	15.34	16.43	15.63	15.32	19.84
6GW2S(2)	38.37	13.98	14.57	14.91	8.98	24.39	23.80	23.46	29.39
6GW3(2)	31.32	14.84	15.37	15.68	13.03	16.48	15.95	15.64	18.29
6GW4(2)	27.99	7.53	7.85	8.27	4.48	20.46	20.14	19.72	23.51
6GW5(2)	25.67	6.18	6.77	7.01	3.31	19.49	18.90	18.66	22.36
6GW6(2)	26.74	7.70	8.56	8.76	4.45	19.04	18.18	17.98	22.29
6GW7S(2)	17.83	5.49	6.68	6.76	3.34	12.34	11.15	11.07	14.49
6GW8(2)	22.35	6.36	6.82	7.25	4.03	15.99	15.53	15.10	18.32
6GW9(3)	21.11	9.08	9.59	10.03	7.27	12.03	11.52	11.08	13.84
6GW10(3)	19.88	7.30	7.75	8.12	6.22	12.58	12.13	11.76	13.66
6GW11(3)	35.05	--(7)	18.16	18.47	16.88	--	16.89	16.58	18.17
6GW12(3)	18.28	6.45	6.67	6.73	6.30	11.84	11.62	11.56	11.98
6GW13(3)	20.10	5.70	7.56	7.65	4.21	14.40	12.54	12.45	15.89

Notes: (1) - mean sea level
(2) Existing monitoring well installed by ESE, Inc., November 1986.
(3) Phasse I monitoring well installed by Baker Environmental, Inc., September-October 1992.
(4) Phase II monitoring well installed by Baker Environmental, Inc., February-March 1993.
(5) Existing monitoring well installed by NUS Corporation, June 1991.
(6) Existing monitoring well installed by S&ME, April 1992.
(7) -- = Data not collected.

TABLE 3-1 (CONTINUED)

SUMMARY OF WATER LEVEL MEASUREMENTS FROM SHALLOW MONITORING WELLS ON SEPTEMBER 30, 1992, OCTOBER 26, 1992, NOVEMBER 7, 1992, AND APRIL 1, 1993
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Top of PVC Casing Elevation[1] (feet, above msl)	Depth to Groundwater (feet, below top of casing) (9/30/92)	Depth to Groundwater (feet, below top of casing) (10/26/92)	Depth to Groundwater (feet, below top of casing) (11/7/92)	Depth to Groundwater (feet, below top of casing) (4/1/93)	Groundwater Elevation (feet, above msl) (9/30/92)	Groundwater Elevation (feet, above msl) (10/26/92)	Groundwater Elevation (feet, above msl) (11/7/92)	Groundwater Elevation (feet, above msl) (4/1/93)
6GW14[3]	28.49	--	11.50	11.90	7.70	--	16.99	16.59	20.79
6GW15S[3]	29.07	--	11.09	11.27	6.78	--	17.98	17.80	22.29
6GW16[3]	27.63	--	8.05	8.48	4.60	--	19.58	19.15	23.03
6GW17[3]	28.10	7.82	8.18	8.64	4.30	20.28	19.92	19.46	23.80
6GW18[3]	29.70	8.58	7.99	9.58	5.61	21.12	21.71	20.12	24.09
6GW19[3]	27.95	--	7.49	7.90	3.95	--	20.46	20.05	24.00
6GW20[3]	25.08	--	6.28	6.67	2.61	--	18.80	18.41	22.47
6GW21[3]	30.30	12.82	13.30	13.63	10.74	17.48	17.00	16.67	19.56
6GW22[3]	24.13	6.32	5.84	--	3.00	17.81	18.29	--	21.13
6GW23[3]	26.96	--	7.56	7.93	4.60	--	19.40	19.03	22.36
6GW25[3]	34.30	--	11.88	12.24	8.10	--	22.42	22.06	26.20
6GW26[3]	23.66	--	10.28	10.53	9.09	--	13.38	13.13	14.57
6GW28S[3]	30.20	--	21.63	21.84	17.93	--	8.57	8.36	12.27
6GW30S[3]	12.60	--	6.07	6.05	3.60	--	6.53	6.55	9.00
6GW31[4]	30.26	--	--	--	11.34	--	--	--	18.92

Notes:
(1) msl - mean sea level
(2) Existing monitoring well installed by ESE, Inc., November 1986.
(3) Newly installed monitoring well by Baker Environmental, Inc., September-October 1992.
(4) Newly installed monitoring well by Baker Environmental, Inc., February-March, 1993.
(5) Existing monitoring well installed by NUS Corporation, June 1991.
(6) Existing monitoring well installed by S&ME, April 1992.
(7) -- = Data not collected.

TABLE 3-f)NTINUED)

SUMMARY OF WATER LEVEL MEASUREMENTS FROM SHALLOW MONITORING WELLS ON SEPTEMBER 30, 1992, OCTOBER 26, 1992, NOVEMBER 7, 1992, AND APRIL 1, 1993
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Top of PVC Casing Elevation[1] (feet, above msl)	Depth to Groundwater (feet, below top of casing) (9/30/92)	Depth to Groundwater (feet, below top of casing) (10/26/92)	Depth to Groundwater (feet, below top of casing) (11/7/92)	Depth to Groundwater (feet, below top of casing) (4/1/93)	Groundwater Elevation (feet, above msl) (9/30/92)	Groundwater Elevation (feet, above msl) (10/26/92)	Groundwater Elevation (feet, above msl) (11/7/92)	Groundwater Elevation (feet, above msl) (4/1/93)
6GW32[4]	21.79	--	--	--	14.29	--	--	--	7.50
6GW33[4]	22.42	--	--	--	7.04	--	--		15.38
6GW34[4]	32.01	--	--	--	17.00	--	--	--	15.01
82MW1[5]	8.58	4.00	4.18	4.17	3.35	4.58	4.40	4.41	5.23
82MW2[5]	6.03	--	5.00	4.17	4.30	--	1.03	1.86	1.73
82MW3[5]	24.31	13.95	15.42	14.59	10.13	10.36	8.89	9.72	14.18
82MW30[5]	32.19	9.29	11.68	12.10	8.46	22.90	20.51	20.09	23.73
6MW2[6]	29.68	--	--	8.36	4.20	--	--	21.32	25.48
6MW3S[6]	30.73	--	9.24	9.42	7.94	--	21.49	21.31	22.79
6MW8[6]	30.62	--	--	10.05	5.93	--	--	20.57	24.69
6MW9[6]	39.98	--	16.01	16.33	11.17	--	23.97	23.65	28.81
6BP-6[6]	37.41	--	--	16.67	12.10	--	--	20.74	25.31

Notes: (1) msl - mean sea level
(2) Existing monitoring well installed by ESE, Inc., November 1986.
(3) Newly installed monitoring well by Baker Environmental, Inc., September-October 1992.
(4) Newly installed monitoring well by Baker Environmental, Inc., February-March, 1993.
(5) Existing monitoring well installed by NUS Corporation, June 1991.
(6) Existing monitoring well installed by S&ME, April 1992.
(7) -- = Data not collected.

TABLE 3-6

SUMMARY OF WATER LEVEL MEASUREMENTS ON SEPTEMBER 15, 1992, SEPTEMBER 30, 1992, OCTOBER 26, 1992, AND APRIL 1, 1993
SITE 9
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Top of PVC Casing Elevation[1] (feet, above msl)	Depth to Groundwater (feet, below top of casing) (9/15/92)	Depth to Groundwater (feet, below top of casing) (9/30/92)	Depth to Groundwater (feet, below top of casing) (10/26/92)	Depth to Groundwater (feet, below top of casing) (4/1/93)	Groundwater Elevation (feet, above msl) (9/15/92)	Groundwater Elevation (feet, above msl) (9/30/92)	Groundwater Elevation (feet, above msl) (10/26/92)	Groundwater Elevation (feet, above msl) (4/1/93)
9GW1[2]	30.70	8.85	9.41	10.03	7.18	21.85	21.29	20.67	23.52
9GW2[2]	27.82	8.45	8.97	9.57	6.25	19.37	18.85	18.25	21.57
9GW3[2]	26.42	9.72	10.40	10.99	8.40	16.70	16.02	15.43	18.02
9GW4[2]	30.70	--	9.20	9.69	4.96	--	21.50	21.01	25.74
9GW5[3]	30.81	--	10.24	10.81	8.10	--	20.57	20.00	22.71
9GW6[3]	31.31	--	10.30	11.25	8.16	--	21.01	20.06	23.15
9GW7S[3]	28.76	--	11.13	11.69	8.90	--	17.63	17.07	19.86
9GW7D[3][4]	29.10	--	13.56	18.40	15.10	--	15.54	10.70	14.00
9GW8[3]	28.39	--	7.93	8.65	5.65	--	20.46	19.74	22.74

Notes: (1) msl - mean sea level
(2) Existing monitoring well installed by ESE, Inc., November 1986.
(3) Phase I monitoring well installed by Baker Environmental, Inc., September 1992. Note that no additional wells were installed during the Phase II investigation.
(4) Deep monitoring well.

TABLE 3-7

SUMMARY OF STAFF GAUGE READINGS ON SEPTEMBER 30, 1992 AND APRIL 1, 1993 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Staff Gauge No.	Top of Staff Gauge Elevation[1] (feet, above msl)	Height of Staff Gauge (feet)	Staff Gauge Reading (feet) (09/30/93)	Staff Gauge Reading (feet) (04/01/93)	Top of Water Elevation (feet, above msl) (09/30/93)	Top of Water Elevation (feet, above msl) (04/01/93)
BH-SG1[2]	8.1	2.5	0.30	0.60	5.90	6.20
BH-SG2[2]	7.5	2.5	0.20	0.20	5.20	5.20
BH-SG3[2]	6.4	2.5	0.25	--	4.15	--
SGWC1[3]	2.5	2.5	--	1.20	--	1.20[4]
SGWC2[3]	2.5	2.5	--	1.00	--	1.00[4]

Notes: (1) msl - mean sea level
(2) Bear Head Creek staff gauge
(3) Wallace Creek staff gauge
(4) Elevations are direct readings in Wallace Creek

TABLE 3-8

SUMMARY OF WATER LEVEL MEASUREMENTS OVER A 24-HOUR PERIOD AT SHALLOW MONITORING WELL 6GW28S SITE 6 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Time From Start (Min)	Depth to Water (Feet, bgs.)	Time From Start (Min)	Depth to Water (Feet, bgs.)	Time From Start (Min)	Depth to Water (Feet, bgs.)
0.000	21.860 (1)	490.000	21.906	980.000	21.906
10.000	21.906	500.000	21.906	990.000	21.906
20.000	21.906	510.000	21.906	1000.000	21.891
30.000	21.906	520.000	21.906	1010.000	21.906
40.000	21.906	530.000	21.906	1020.000	21.891
50.000	21.906	540.000	21.906	1030.000	21.891
60.000	21.891	550.000	21.906	1040.000	21.906
70.000	21.906	560.000	21.922(2)	1050.000	21.891
80.000	21.906	570.000	21.906	1060.000	21.891
90.000	21.906	580.000	21.906	1070.000	21.891
100.000	21.906	590.000	21.906	1080.000	21.891
110.000	21.906	600.000	21.906	1090.000	21.906
120.000	21.906	610.000	21.906	1100.000	21.906
130.000	21.906	620.000	21.906	1110.000	21.891
140.000	21.906	630.000	21.906	1120.000	21.891
150.000	21.906	640.000	21.906	1130.000	21.891
160.000	21.906	650.000	21.906	1140.000	21.906
170.000	21.906	660.000	21.906	1150.000	21.891
180.000	21.906	670.000	21.906	1160.000	21.891
190.000	21.906	680.000	21.906	1170.000	21.891
200.000	21.906	690.000	21.906	1180.000	21.906
210.000	21.906	700.000	21.906	1190.000	21.906
220.000	21.906	710.000	21.906	1200.000	21.906
230.000	21.891	720.000	21.906	1210.000	21.906
240.000	21.906	730.000	21.906	1220.000	21.906
250.000	21.891	740.000	21.906	1230.000	21.906
260.000	21.891	750.000	21.906	1240.000	21.891
270.000	21.891	760.000	21.906	1250.000	21.906
280.000	21.891	770.000	21.906	1260.000	21.906
290.000	21.906	780.000	21.906	1270.000	21.906
300.000	21.891	790.000	21.906	1280.000	21.906
310.000	21.891	800.000	21.906	1290.000	21.906
320.000	21.891	810.000	21.891	1300.000	21.906
330.000	21.906	820.000	21.891	1310.000	21.891
340.000	21.891	830.000	21.906	1320.000	21.891
350.000	21.891	840.000	21.906	1330.000	21.906
360.000	21.906	850.000	21.891	1340.000	21.906
370.000	21.891	860.000	21.891	1350.000	21.906
380.000	21.891	870.000	21.906	1360.000	21.906
390.000	21.906	880.000	21.891	1370.000	21.906
400.000	21.906	890.000	21.891	1380.000	21.891
410.000	21.906	900.000	21.891	1390.000	21.906
420.000	21.906	910.000	21.906	1400.000	21.906
430.000	21.891	920.000	21.891	1410.000	21.906
440.000	21.906	930.000	21.891		
450.000	21.906	940.000	21.906		
460.000	21.906	950.000	21.891		
470.000	21.906	960.000	21.906		
480.000	21.906	970.000	21.906		

Notes: (1) Minimum Water Level Recorded
(2) Maximum Water Level Recorded

elevations) also suggests that groundwater is recharging in the vicinity well 6GW2S and discharging in the vicinity of Wallace Creek. Flow patterns near the southern portion of OU No. 2 indicate that groundwater is discharging into Bear Head Creek as indicated by surface water staff gauge measurements. This drainage area appears to cover portions of Site 6 (grid areas "201S" and "201E") and all of Site 9.

Surficial groundwater flow patterns on November 7, 1992 and April 1, 1993 are shown on Figures 3-9 and 3-10, respectively. Generally, the groundwater flow patterns on these dates are similar to those described for September 30, 1992.

Estimates of groundwater gradients (i) were calculated from September 30 and November 7, 1992 groundwater elevation data. As shown on Table 3-9, the gradient varies by an order of magnitude across the site. In the vicinity of Wallace Creek and Bear Head Creek, the estimated gradient is approximately 0.01 (range of 0.012 to 0.022). In the north-central portion of the site (northeast of Lot 201), however, the estimated gradient is approximately 0.001 (average of 0.0042). The steeper gradient near Wallace Creek and Bear Head Creek reflects decreasing surface elevations in these areas. Moreover, the data suggest that groundwater velocities near Wallace Creek and Bear Head Creek may be increasing (given that K remained constant) because of the steeper groundwater surface.

Surficial (and deep) aquifer hydraulic characteristics [K, T, and storativity (S)] were not evaluated during this investigation. A recent hydrogeologic investigation conducted by Baker (February, 1993) at Hadnot Point (less than 1/2 miles from OU No. 2) provided estimates of T, S, and K within the surficial water-bearing zones.

Aquifer pump and recovery test results indicate an average T of 561 gallons/day/feet (75 $feet^2$/day), an average K of 21 gallons/day/feet (2.8 $feet^2$/day or 8.0×10^{-4} cm/sec), and an average S of 0.015 for the surficial silty-sands (10 to 25 feet bgs). A very low flow rate of 1.2 gpm was maintained during this test. Slightly higher flow rates of 2 to 4 gpm were observed from shallow well development during the field investigation at OU No. 2.

3.7.2.2 Deep Groundwater

Deep groundwater flow patterns in the vicinity of OU No. 2 were evaluated by a network of deep monitoring wells (maximum depth of 230 feet bgs). The deep monitoring well network extends from north of Wallace Creek to Site 9, and east of Piney Green Road to Holcomb

TABLE 3-9

SUMMARY OF ESTIMATED GROUNDWATER GRADIENT VALUES FOR SURFICIAL AND DEEP WATER-BEARING ZONES OPERABLE UNIT NO. 2 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Surficial Water-Bearing Zones

Date	General Area		
	Vicinity of Wallace Creek	North-Central Portion of Site	Vicinity of Bear Head Creek
9/30/92	1.2×10^{-2}	3.7×10^{-3}	2.2×10^{-2}
11/7/92	1.2×10^{-2}	4.6×10^{-3}	Not Determined
Average	1.2×10^{-2}	4.2×10^{-3}	2.2×10^{-2}

Deep Water-Bearing Zones

Date	General Area		
	Vicinity of Wallace Creek	North-Central Portion of Site	Vicinity of Bear Head Creek
10/26/92	3.5×10^{-3}	4.4×10^{-3}	Not Determined
11/7/92	3.0×10^{-3}	4.0×10^{-3}	Not Determined
Average	3.3×10^{-3}	4.2×10^{-3}	Not Determined

Notes: Values expressed in feet/feet.
Values represent an average of three measurements.

Boulevard (refer to Figure 2-8). Additionally, aquifer hydraulic characteristic data from the deeper water-bearing zones were obtained from well production tests (i.e., also commonly referred to as "well acceptance tests") performed on water supply wells HP-651 and HP-636 which are located along Piney Green Road.

Three rounds of groundwater level measurements were obtained from the deep monitoring wells at Site 9 (September 30, 1992; and October 26, 1992; and April 1, 1993) and Sites 6 and 82; (October 26, 1992; and November 7, 1992; and April 1, 1993) as shown on Tables 3-6 and 3-10, respectively. Groundwater elevations (measured from top of casing reference points) ranged from 9.06 [well 6GW37D (4/1/93) located near the western boundary of Site 82] to 19.13 [well 6GW2D (4/1/93) located east of Piney Green Road] feet above msl. Water levels fluctuated between 2.20 and 5.17 feet over a six month period. Well 6GW2D exhibited the largest fluctuation in water level of 5.17 feet.

Water level data were also collected over a 24-hour period from deep monitoring well 6GW28D. As shown on Table 3-11, the water level was also fairly constant over a 24-hour period as a change of only 0.05-feet was observed. This very small change in water level is most likely the result of normal daily fluctuations.

Figures 3-11, 3-12, and 3-13 depict groundwater flow patterns on October 26, 1992; November 7, 1992; and April 1, 1993 for the deeper water-bearing zones. As shown on these figures, groundwater is flowing toward the west with local penetrations toward the general directions of Wallace Creek and Bear Head Creek. The groundwater flow pattern on November 7 exhibits a similar trend except that flow toward the southeast is not as pronounced. Most likely this trend on November 7 is the result of incomplete water level (i.e., measurements were not taken on this date) data from well 9GW7D.

Estimates of the groundwater gradient for the deep water-bearing zones are presented on Table 3-9. The estimated groundwater gradients calculated are within the same magnitude across OU No. 2. The average groundwater gradients in the vicinity of Wallace Creek and the north-central portion of the site are 0.0030 and 0.0042, respectively.

Overall, the deep and surficial groundwater flow patterns at OU No. 2 exhibit a similar trend. Subsequently, this trend may suggest that the surficial and deeper water-bearing zones are at least partly hydraulically interconnected. Although some clay layers underlie the site (i.e., boring 6GW2D from 25 to 27 feet bgs) which may impede vertical groundwater movement,

TABLE 3-10

SUMMARY OF WATER LEVEL MEASUREMENTS FROM DEEP MONITORING WELLS ON OCTOBER 26, 1992, NOVEMBER 7, 1992, AND APRIL 1, 1993
SITES 6 AND 82
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	Top of PVC Casing Elevation[1] (feet, above msl)	Depth to Groundwater (feet, below top of casing) (10/26/92)	Depth to Groundwater (feet, below top of casing) (11/07/92)	Depth to Groundwater (feet, below top of casing) (04/01/93)	Groundwater Elevation (feet, above msl) (10/26/92)	Groundwater Elevation (feet, above msl) (11/07/92)	Groundwater Elevation (feet, above msl) (04/01/93)
6GW1D	35.31	23.07	23.32	19.90	12.24	11.99	15.41
6GW2D	37.61	22.15	22.27	18.48	15.46	15.34	19.13
6GW7D	20.08	10.89	8.94	5.72	9.19	11.14	14.36
6MW3D	35.18	--	--	16.92	--	--	18.26
6GW27D	24.47	15.35	15.17	12.50	9.12	9.30	11.97
6GW28D	31.74	22.05	22.10	19.90	9.69	9.64	11.84
6GW30D	11.90	--	--	1.79	--	--	10.11
6GW35D	14.29	--	--	5.18	--	--	9.11
6GW36D	17.61	--	--	5.67	--	--	11.94
6GW37D	15.96	--	--	6.90	--	--	9.06

Notes: [1] msl - mean sea water levels from Phase II
Note that deep wells 6GW1DA and 6GW15D were not obtained because they were installed after April 1, 1993.

TABLE 3-11

SUMMARY OF WATER LEVEL MEASUREMENTS OVER A 24-HOUR PERIOD AT DEEP MONITORING WELL 6GW28D SITE 6 REMEDIAL INVESTIGATION CTO-0133 MCB CAMP LEJEUNE, NORTH CAROLINA

Time From Start (Min)	Depth to Water (Feet, bgs.)	Time From Start (Min)	Depth to Water (Feet, bgs.)	Time From Start (Min)	Depth to Water (Feet, bgs.)
0.000	21.914 (1)	490.000	21.961 (2)	980.000	21.945
10.000	21.945	500.000	21.961	990.000	21.945
20.000	21.945	510.000	21.961	1000.000	21.945
30.000	21.945	520.000	21.945	1010.000	21.945
40.000	21.945	530.000	21.961	1020.000	21.945
50.000	21.945	540.000	21.961	1030.000	21.945
60.000	21.945	550.000	21.945	1040.000	21.945
70.000	21.945	560.000	21.961	1050.000	21.930
80.000	21.945	570.000	21.961	1060.000	21.930
90.000	21.945	580.000	21.961	1070.000	21.930
100.000	21.945	590.000	21.961	1080.000	21.945
110.000	21.945	600.000	21.945	1090.000	21.945
120.000	21.945	610.000	21.961	1100.000	21.930
130.000	21.945	620.000	21.961	1110.000	21.945
140.000	21.945	630.000	21.961	1120.000	21.945
150.000	21.945	640.000	21.961	1130.000	21.930
160.000	21.945	650.000	21.945	1140.000	21.930
170.000	21.945	660.000	21.961	1150.000	21.930
180.000	21.945	670.000	21.961	1160.000	21.930
190.000	21.945	680.000	21.945	1170.000	21.930
200.000	21.945	690.000	21.961	1180.000	21.930
210.000	21.945	700.000	21.945	1190.000	21.930
220.000	21.945	710.000	21.961	1200.000	21.930
230.000	21.930	720.000	21.945	1210.000	21.930
240.000	21.945	730.000	21.945	1220.000	21.930
250.000	21.945	740.000	21.961	1230.000	21.930
260.000	21.945	750.000	21.945	1240.000	21.930
270.000	21.945	760.000	21.945	1250.000	21.930
280.000	21.945	770.000	21.945	1260.000	21.930
290.000	21.945	780.000	21.961	1270.000	21.930
300.000	21.930	790.000	21.945	1280.000	21.930
310.000	21.945	800.000	21.945	1290.000	21.930
320.000	21.945	810.000	21.945	1300.000	21.930
330.000	21.945	820.000	21.945	1310.000	21.930
340.000	21.945	830.000	21.945	1320.000	21.930
350.000	21.945	840.000	21.945	1330.000	21.930
360.000	21.945	850.000	21.945	1340.000	21.930
370.000	21.945	860.000	21.945	1350.000	21.914
380.000	21.930	870.000	21.945	1360.000	21.930
390.000	21.945	880.000	21.945	1370.000	21.930
400.000	21.945	890.000	21.945	1380.000	21.930
410.000	21.945	900.000	21.945	1390.000	21.914
420.000	21.945	910.000	21.945	1400.000	21.914
430.000	21.945	920.000	21.945	1410.000	21.914
440.000	21.945	930.000	21.945		
450.000	21.945	940.000	21.945		
460.000	21.945	950.000	21.945		
470.000	21.945	960.000	21.945		
480.000	21.945	970.000	21.945		

Notes: (1) Minimum Water Level Recorded
(2) Maximum Water Level Recorded

these clay layers are laterally discontinuous and are characterized as leaky semi-confining. Accordingly groundwater recharging the surficial water-bearing zones will, over time, migrate vertically into the deeper soils.

Groundwater elevation differentials (top of casing reference points were used as the datum reference) between the surficial and deeper water-bearing zones were evaluated from the October 26, 1992 groundwater elevation data. These groundwater differentials are presented on Figure 3-14. Negative groundwater values represent downward heads (at well clusters) and positive values represent upward heads. At well cluster 6GW2S/D, a high downward head (-8.34) is observed. A high downward head would be expected at this cluster since groundwater is recharging in this area. At well clusters 82MW3/6GW27D and 6GW28S/D, upward heads (+ 0.23 and + 1.12) are observed. Upward heads at these clusters would be expected since groundwater is discharging in these areas.

As mentioned in Section 3.7.2.1, aquifer hydraulic characteristics were not evaluated during this investigation. Estimates of specific capacity, T and groundwater flow rates (i.e., discharge rates) are available from well performance tests performed on water supply wells HP-651 and HP-636 (well depth and screen intervals for these wells are shown on Table 3-15 in Section 3.10). Estimated specific capacity values from HP-651 and HP-636 are 3.8 and 6.8 gallons/minute/foot (of drawdown), respectively. Transmissivity values from HP-636 and HP-651 are 6,900 and 7,300 feet^2/day (51,600 to 54,600 gallons/day/feet), respectively. Estimates of T and K from other Camp Lejeune water supply wells (in the Castle Hayne aquifer) range from 4,300 to 24,500 feet^2/day (32,200 to 183,000 gallons/day/feet) and 14 to 82 feet/day, respectively (Harned, et. al., 1989). Groundwater flow rates within well HP-651 ranged from 50 gpm (screened from 189 to 194 feet bgs) to 150 gpm (screened from 140 to 155 feet bgs) during testing.

3.8 Land Use and Demography

MCB Camp Lejeune encompasses an area of approximately 170 square miles (108,800 acres), and comprises several distinct areas of development including Hadnot Point, MCAS/Camp Geiger, French Creek, and Courthouse Bay. The installation border is approximately 70 miles in length, which includes 14 miles of ocean front and Intracoastal Waterway.

The New River, which bisects the installation, provides both a commercial and recreational source of fish and shellfish for human consumption. The NC DEHNR reports that during the

years 1989 and 1990 over 2.7 million pounds of fish and shellfish were caught commercially in the New River.

Land use within Camp Lejeune is influenced by the topography of the land itself, by established environmental policy, and by base operational requirements. Soil drainage is the most critical factor which determines the suitability of a site for development. Much of the land area found within the facility consists of freshwater swamps that are wooded and largely unsuitable for development. In addition, approximately 3,000 acres of sensitive estuary and other areas set aside for the protection of threatened and endangered species are to remain undeveloped. Operational restrictions and regulations, such as explosive quantity safety distances, impact-weighted noise thresholds, and aircraft landing and clearance zones, may also greatly constrain and influence development (Master Plan, Camp Lejeune Complex, North Carolina, 1988).

The vast majority of Camp Lejeune is used as training ranges and maneuver areas. Although interspersed throughout the installation, these areas are generally concentrated between Sneads Ferry Road and the eastern border of the base.

The combined military and civilian population of the Camp Lejeune/Jacksonville area is approximately 60,000. At the present time nearly 90 percent of the surrounding population resides within urbanized areas. As evidenced by the rapid population growth of Jacksonville and adjacent communities, particularly during the period from 1940 to 1960, Camp Lejeune continues to have a direct effect on regional population growth and development.

3.9 Regional Ecology

MCB Camp Lejeune, North Carolina, is approximately 108,800 acres, with 84 percent of the area covered by forests (USMC, 1987). The base drains primarily to the New River or its tributaries including Northeast Creek, Southwest Creek, Wallace Creek, French Creek, Bear Head Creek, Freeman Creek, and Duck Creek. The soil types range from sandy loams to fine sand and muck, with the dominant series being sandy loam (USMC, 1987).

Vegetation at MCB Camp Lejeune, North Carolina, includes pure pine stands of loblolly and longleaf pine in the drier upland soils, pure pond pine stands in high organic wet soils, pine-hardwood and pure hardwood stands in streamside zones and in more productive soils, and bottomland hardwoods in the floodplains of the major creeks (USMC, 1987). Wildlife on the

base includes white-tailed deer, wild turkey, and black bear along with numerous small game species (e.g., bobwhite quail, morning dove, rabbit) (USMC, 1987).

Wallace Creek and Bear Head Creek are designated as Class SB by the North Carolina Department of Environment, Health, and Natural Resources (NC DEHNR), which are saltwaters protected for primary recreation (swimming on a frequent basis), fishing, and aquatic life including propagation and survival (NC DEHNR, 1992a, 1992b). These creeks are classified as Nutrient Sensitive Waters which are waters subject to growths of microscopic or macroscopic vegetation requiring limitations on nutrient inputs (NC DEHNR, 1992a, 1992b). Wallace Creek is classified as Inland Waters above, and Coastal Waters below the first bridge upstream from its mouth (NCMFC, 1992). Wallace Creek and Bear Head Creek are classified as Inland Waters at all the sample stations.

The New River, downstream of OU No. 2, is designated as Class SC: which are saltwaters protected for secondary recreation, fishing, and aquatic life including propagation and survival (NC DEHNR, 1992a, 1992b). All saltwaters in North Carolina are classified to protect these uses at a minimum (NC DEHNR, 1992a, 1992b). This section of the New River also is classified as a Nutrient Sensitive Water (NC DEHNR, 1992a, 1992b).

3.9.1 Sensitive Environments

This section describes the sensitive environments that were evaluated at OU No. 2. These sensitive environments include wetlands, protected species, and other potentially sensitive environments.

3.9.1.1 Wetlands

The NC DEHNR's, Division of Environmental Management (DEM) has developed guidance pertaining to activities that may impact wetlands (NC DEHNR, 1992c). In addition, certain activities impacting wetlands also are regulated by the U.S. Corps of Engineers.

The U.S. Fish and Wildlife Service (FWS) prepared a National Wetlands Inventory (NWI) map for the Camp Lejeune, North Carolina quadrangle by stereoscopic analysis of high altitude aerial photographs (USDI, 1982). OU No. 2 is included in this map (see Appendix A in the Ecological Risk Assessment for a copy of the NWI map). The wetlands were identified on the photographs based on vegetation, visible hydrology, and geography in accordance with

Classification of Wetland and Deep-Water Habitats of the United States (Cowardin, et al, 1979). NWI maps are intended for a initial identification of wetland areas. They cannot be substituted for an actual wetland delineation that may be required by Federal, state and/or local regulatory agencies.

Several types of wetlands have been identified adjacent to Wallace Creek and Bear Head Creek from the NWI map. The wetlands along the creeks primarily are palustine forested wetlands consisting of pond, longleaf or loblolly pines, along with oaks, black gum and baldcypress (NC DNRCD, 1988). [See the NWI map in Appendix A in the Ecological Risk Assessment for the wetland classifications and their locations].

3.9.1.2 Threatened and Endangered Species

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

Table 3-12 lists the protected faunal species (either endangered, threatened, or special concern) and the only federally endangered or threatened floral species that have been identified in previous studies within the boundaries of MCB Camp Lejeune (USMC, 1991; LeBlond, 1991; Fussell, 1991; and Walters, 1991). The following paragraphs discuss the protected species observed at MCB Camp Lejeune during previous studies.

A Peregrine falcon was spotted approximately five miles southeast of OU No. 2 (Fussell, 1991). These birds potentially may inhabit or feed in areas surrounding OU No. 2 because of their large foraging range. Black skimmers and piping plovers were observed near the New River Inlet (Fussell, 1991). However, these birds primarily inhabit shore line areas and, therefore, are not expected to be found at OU No. 2. Bachmans sparrows and Red-cockaded woodpeckers were observed at numerous locations throughout southern MCB Camp Lejeune. None of these species were observed at OU No. 2 during intensive investigations previously conducted for

TABLE 3-12

OPERABLE UNIT NO. 2
PROTECTED SPECIES WITHIN MCB CAMP LEJEUNE
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Species	Protected Classification
American alligator (Alligator mississippienis)	T(f), T(s)
Bachmans sparrow (Aimophilia aestivalis)	SC
Black skimmer (Rhynochops niger)	SC
Green (Atlantic) turtle (Chelonia m. mydas)	T(f), T(s)
Loggerhead turtle (Caretta caretta)	T(f), T(s)
Peregrine Falcon (*)	(*)
Piping plover (Charadrius melodus)	T(f), T(s)
Red-cockaded woodpecker (Picoides borealis)	E(f), E(s)
Rough-leaf loosestrife (Lysimachia asperulifolia)	E(f), E(s)

Legend: SC = State Special Concern
E(f) = Federal Endangered
E(s) = State Endangered
T(f) = Federal Threatened
T(s) = State Threatened

* The observer did not differentiate between the American eastern peregrine Falcon [E (f), E (s)] or the Artic peregrine Falcon [T(f), T(s)].

MCB Camp Lejeune, therefore, there is a low potential for them to exist at OU No. 2 (Fussell, 1991; Walters, 1991).

Sea turtles and sea turtle nests have been observed downstream of OU No. 2 in the New River on Onslow Beach. Sea turtles do not swim very far up the New River because of the low salinity, therefore, they are not expected to inhabit areas of OU No. 2 (USMC, 1991). During the ecological investigation conducted in August and September 1992, an alligator was observed in Wallace Creek. In addition, signs were posted at the boat launching ramp in Wallace Creek warning of the American alligators presence in the creek.

A protected floral species and special-interest community survey previously was conducted at Camp Lejeune (LeBlond, 1991). From this list, the Rough-leaf loosestrife was the only Federally threatened or endangered plant species found on the Marine Corp Base. Several State endangered or threatened and Federal and State candidate species were found on the MCB. A road meadow, inhabited by the state watch species Lugwigia microcarpa, was located upstream of OU No. 2 on Wallace Creek (see Appendix B in the Ecological Risk Assessment).

Also upstream of OU No. 2 on Wallace Creek, a state registered natural resource area has been identified (see Appendix B in the Ecological Risk Assessment). The general landscape consists of a broad floodplain and former mill pond on Wallace Creek which is dominated by a Cypress-Gum Swamp Community which grades upstream into a Coastal Plain Small Stream Swamp Community. The Cypress-Gum Swamp Community is dominated by Taxodium distichum, Nyssa biflora, Acer rubrum, Ulmus alata, and Fraxinus pennsylvanica. The Plain Small Stream Swamp Community is dominated by Taxodium distichum, Nyssa biflora, Fraxinus pennsylvanica, Ulmus americana, Acer rubrum, and Liquidambar styraciflua.

3.9.1.3 Other Sensitive Environments

In addition to wetlands and protected species, the presence of other sensitive environments, including those listed in 40 CFR Part 300, were evaluated. These sensitive environments are evaluated when assessing potential hazardous waste sites using the Hazard Ranking System. These sensitive environments and their presence or absence at OU No. 2 are discussed below.

- Marine Sanctuary - OU No. 2 is not located within a Marine Sanctuary (NCMFC, 1992).

- National Park - OU No. 2 is not located within a National Park (NPS, 1991).

- Designated Federal Wilderness Area - OU No. 2 is not located within a Designated Federal Wilderness Area (WS, 1989).

- Areas Identified under the Coastal Zone Management Act - The North Carolina Coastal Area Management Act (CAMA) regulates various types of Areas of Environmental Concern including estuarine waters, coastal wetlands, public trust areas, and estuarine shoreline through the establishment of unified policies, criteria, standards, methods, and processes (CAMA, 1974). Bear Head Creek, the inland portion of Wallace Creek, and any coastal wetlands associated with these waters are regulated under CAMA. The tidal portion of Wallace Creek along with 75 feet adjacent to the mean water line also are regulated under CAMA (NC DEHNR, 1993a).

- Sensitive Areas Identified under the National Estuary Program (NEP) or Near Coastal Waters Program (NCWP) - OU No. 2 is not located within a Sensitive Area identified under the NEP or NCWP (USEPA, 1993).

- Critical Areas Identified under the Clean Lakes Program - OU No. 2 is not located within a Critical Area identified under the Clean Lakes Program (NPS, 1991).

- National Monument - OU No. 2 is not located within a National Monument (NPS, 1991).

- National Seashore Recreational Area - OU No. 2 is not located within a National Seashore Recreational Area (NPS, 1991).

- National Lakeshore Recreational Area - OU No. 2 is not located within a National Lakeshore Recreational Area (NPS, 1991).

- National Preserve - OU No. 2 is not located within a National Preserve (NPS, 1991).

- National or State Wildlife Refuge - OU No. 2 is not located within a National or State Wildlife Refuge (NC WRC, 1992).

- Unit of the Coastal Barrier Resource Program - OU No. 2 is not located within a unit of the Coastal Barrier Resource Program (USDI, 1993).

- Administratively Proposed Federal Wilderness Area - OU No. 2 is not located within an Administratively Proposed Federal Wilderness Area (WS, 1989, 1993).

- Spawning Areas Critical for the maintenance of fish/shellfish species within river, lake, or coastal tidal waters - OU No. 2 is not located within a spawning area critical for the maintenance of fish/shellfish species (Sholar, 1975).

- Migratory pathways and feeding areas critical for maintenance of anadromous fish species within river reaches or areas in lakes or coastal tidal waters in which fish spend extended periods of time - OU No. 2 is not a migratory pathway or feeding area critical for maintenance of anadromous fish species (NC DEHNR, 1993b). There is not a significant population of anadromous fish in Wallace Creek, Bear Head Creek, or the New River downstream of Wallace Creek.

- Terrestrial areas utilized for breeding by large or dense aggregations of animals - A study of the terrestrial species was not conducted at OU No. 2. However, OU No. 2 probably is not utilized for breeding by large or dense aggregations of animals because the land is open and there is frequent military activity on the land.

- National river reach designated as Recreational - Wallace Creek, Bear Head Creek, or the New River downstream of Wallace Creek are not designated as National Recreational Rivers (NPS, 1990, 1993).

- Federal designated Scenic or Wild River - Wallace Creek, Bear Head Creek, or the New River downstream of Wallace Creek are not Federally designated Scenic or Wild Rivers (NPS, 1990, 1993).

- State land designated for wildlife or game management - OU No. 2 is not located within a State game land (NC WRC, 1992).

- State designated Scenic or Wild River - Wallace Creek, Bear Head Creek, or the New River downstream of Wallace Creek are not State designated Scenic or Wild Rivers (NC MFC, 1992).

- State designated Natural Area - OU No. 2 is not located within a State designated Natural Area or Area of Significant Value (LeBlond, 1991).

- State designated areas for protection or maintenance of aquatic life - No areas within the boundaries of OU No. 2 are designated as primary nursery areas or are unique or special waters of exceptional state or national recreational or ecological significance which require special protection to maintain existing uses (NC DEHNR, 1992b).

- Areas of Significant Value - OU No. 2 is not located within a State Area of Significant Value (LeBlond, 1991).

- State Registered Natural Resource Area - The Wallace Creek Natural Resource Area is located upstream of OU No.2.

3.10 Identification of Water Supply Wells

Potable water supply wells within a one-mile radius of Sites 6 and 82, and Site 9 were identified as shown on Figures 3-15 and 3-16, respectively. Information on well depths, screen intervals, aquifer characteristics (specific capacity and T), well distances and directions is provided on Tables 3-13 and 3-14 for Sites 6 and 82, and Site 9, respectively. Supply well information was obtained in the report entitled, "U.S.G.S. Water Resources Investigation Report 89-4096" (Harned, et al., 1989).

As shown on Table 3-13, eight wells were identified within a one-mile radius of Sites 6 and 82. Wells HP-635 and HP-636 are the closest active supply wells to Sites 6 and 82. These wells are located approximately 80 feet east-southeast across Piney Green Road. These wells are screened between 65 and 227 feet bgs. Based on groundwater flow patterns in the area, these wells are generally upgradient from Sites 6 and 82. Well HP-633 is the closest operating water supply well situated down gradient from Sites 6 and 82. This well is located approximately 1,590 feet northwest and is screened between 55 and 205 feet bgs.

Three supply wells in the area, HP-651 (located approximately 80 feet east) and HP-653 (located approximately 1,950 north), and HP-637 (located approximately 450 feet southwest) are currently out of service due to organic contamination. According to Camp Lejeune Water and Sewer Department personnel, HP-651 was shut down in February 1985. It is unknown when HP-653 and HP-637 were shut down. Groundwater quality data from well HP-651 (prior

TABLE 3-13

SUMMARY OF WATER SUPPLY WELLS WITHIN A ONE-MILE RADIUS OF SITES 6 AND 82[1]
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	USGS Identification Number	Total Depth (feet)	Screen Interval (feet)	Specific Capacity (gal/min/foot)	Estimated Transmissivities ($feet^2$/day)	Approximate Distance/Direction from Site[4] (feet)
HP-633	3441580772006.1	205	55-65 75-80 95-105 123-133 138-143 158-168 178-183 195-205	-- [2]	-- [2]	1,390/northwest
HP-635	3440550771933.1	215	65-75 93-108 122-127 136-146 150-155 170-175 185-190 210-215	-- [2]	-- [2]	80/southeast
HP-636	3441190771933.1	227	90-100 115-125 130-135 140-150 158-163 170-175 185-190 200-210 222-227	6.8	6,900	80/east

Notes: (1) Information obtained from "Assessment of Hydrogeologic and Hydraulic Data at Camp Lejeune Marine Corps Base, North Carolina," 1989.
(2) Information not available.
(3) Supply well currently not in service.
(4) Distance measured from closest boundary point at Site 6.

TABLE 3-13 (CONTINUED)

SUMMARY OF WATER SUPPLY WELLS WITHIN A ONE-MILE RADIUS OF SITES 6 AND 82[1]
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	USGS Identification Number	Total Depth (feet)	Screen Interval (feet)	Specific Capacity (gal/min/foot)	Estimated Transmissivities ($feet^2$/day)	Approximate Distance/Direction from Site[4] (feet)
HP-637[3]	3440390771954.1	172	90-98 102-114 120-128 140-148 156-172	-- [2]	-- [2]	450/southwest
HP-641	3440390771954.1	178	108-118 128-150 158-168	-- [2]	-- [2]	4,100/north
HP-651[3]	3442290771922.1	199	125-135 140-155 189-194	3.8	7,300	80/east
HP-653[3]	3442100771925.1	270	-- [2]	-- [2]	-- [2]	1,950/north
HP-709	3442130771854.1	140	70-90 110-140	4.4	8,500	2,380/northeast

Notes: (1) Information obtained from "Assessment of Hydrogeologic and Hydraulic Data at Camp Lejeune Marine Corps Base, North Carolina," 1989.
(2) Information not available.
(3) Supply well currently not in service.
(4) Distance measured from closest boundary point at Site 6.

TABLE 3-14

SUMMARY OF WATER SUPPLY WELLS WITHIN A ONE-MILE RADIUS OF SITE 9[1]
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	USGS Identification Number	Total Depth (feet)	Screen Interval (feet)	Specific Capacity (gal/min/foot)	Estimated Transmissivities ($feet^2$/day)	Approximate Distance/Direction from Site[4] (feet)
HP-601[3]	3440180772020.1	195	45-60 95-100 115-130 175-195	-- [2]	-- [2]	3,960/southwest
HP-602[3]	3440180772007.1	160	70-80 100-105 120-125 145-150 155-160	-- [2]	-- [2]	3,300/southwest
HP-634[3]	3440300771935.1	225	63-70 73-78 83-88 107-117 124-129 135-140 153-163 170-175 195-200 215-225	4.5	4,300	2,310/south
HP-642	3443040772100.1	210	112-124 136-144 153-163 174-178 188-196	-- [2]	-- [2]	5,200/south

Notes: (1) Information obtained from "Assessment of Hydrogeologic and Hydraulic Data at Camp Lejeune Marine Corps Base, North Carolina," 1989.
(2) Information not available.
(3) Supply well currently not in service.
(4) Distance measured from closest boundary point at Site 9.

TABLE 3-14 (Continued)

SUMMARY OF WATER SUPPLY WELLS WITHIN A ONE-MILE RADIUS OF SITE 9[1]
REMEDIAL INVESTIGATION CTO-0133
MCB CAMP LEJEUNE, NORTH CAROLINA

Well No.	USGS Identification Number	Total Depth (feet)	Screen Interval (feet)	Specific Capacity (gal/min/foot)	Estimated Transmissivities ($feet^2$/day)	Approximate Distance/Direction from Site[4] (feet)
HP-635	3440550771933.1	215	65-75 93-108 122-127 136-146 150-155 170-175 185-190 210-215	-- [2]	-- [2]	800/east
HP-636	3441190771933.1	227	90-100 115-125 130-135 140-150 158-163 170-175 185-190 200-210 222-227	6.8	6,900	2,000/northeast
HP-637 [3]	3440390771954.1	172	90-98 102-114 120-128 140-148 156-172	-- [2]	-- [2]	1,000/southwest
HP-651 [3]	3442290771922.1	199	125-135 140-155 189-194	3.8	7,300	5,000/northeast

Notes: (1) Information obtained from "Assessment of Hydrogeologic and Hydraulic Data at Camp Lejeune Marine Corps Base, North Carolina," 1989.
(2) Information not available.
(3) Supply well currently not in service.
(4) Distance measured from closest boundary point at Site 9.

to being shut down) indicated 18,000 micrograms per liter (µg/l) of trichloroethane (TCE), 1,580 µg/l of 1,2-dichloroethene (DCE), and 400 µg/l of tetrachloroethene (PCE). Recent data from HP-651 (ESE, 1991) indicated positive detections of vinyl chloride (70 µg/l), DCE (75 µg/l), TCE (13 µg/l), and PCE (53 µg/l). Groundwater quality data from January 1985 indicated TCE levels of 9.0 µg/l in well HP-652. The source of the contamination impacting these wells was not identified by Camp Lejeune personnel.

Eight wells were identified within a one-mile radius of Site 9 (wells HP-635, HP-636, HP-637, and HP-651 were also within a one-mile radius of Sites 6 and 82), as shown on Figure 3-16. Three of these supply wells including HP-601, HP-602, and HP-634 have been shut down since 1984 due to organic contamination. The source of the contamination impacting these wells was also not identified by Camp Lejeune personnel, but it is believed that the source may be related to waste handling, disposal activities at the Hadnot Point Industrial Area (HPIA). The following contaminant levels were detected:

- HP-601 - DCE (8.8 to 99 µg/l)
  - TCE (26 to 230 µg/l)
  - PCE (1.5 to 5.0 µg/l)
- HP-602 - DCE (110 to 630 µg/l)
  - TCE (300 to 1,600 µg/l)
  - PCE (24 µg/l)
  - toluene (5.4 to 12 µg/l)
  - vinyl chloride (18 µg/l)
- HP-634 - DCE (2.3 to 700 µg/l)
  - TCE (10 µg/l)
  - vinyl chloride (6.8 µg/l)

Well HP-635 is the closest active supply well to Site 9. This well is located approximately 400 feet up gradient (east)