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MCB CAMP LEJEUNE
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DRAFT ENGINEERING EVALUATION/COST ASSESSMENT LNAPL REMOVAL OPERABLE UNIT 10 (OU 10) SITE 35 MCB CAMP LEJEUNE NC (DRAFT ACTING AS FINAL)
9/1/2004
CH2M HILL

Draft
Engineering Evaluation/Cost Assessment
LNAPL Removal
Operable Unit 10 (Site 35)

at

Marine Corps Base
Camp Lejeune, North Carolina

Contract Task Order 130

September 2004

Prepared for

Department of the Navy

Atlantic Division

Naval Facilities Engineering Command

Under the

LANTDIV CLEAN II Program

Contract N62470-95-D-6007

Prepared by

CH2MHILL

Executive Summary

Marine Corps Base (MCB) Camp Lejeune is a training base for the United States Marine Corps located in Onslow County, North Carolina. Baker Environmental was tasked by the Atlantic Division of the Naval Facilities Engineering Command (LANTDIV) to perform a Remedial Investigation (RI) at Camp Lejeune Operable Unit No. 10, Site 35, the Former Camp Geiger Area Fuel Farm. Due to the discovery of light non-aqueous phase liquids (LNAPLs), CH2M HILL is now tasked to prepare an Engineering Evaluation/Cost Assessment (EE/CA) in accordance with "*Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*", (USEPA, August 1993) for the LNAPL at Site 35.

Petroleum fuel-related contamination has been identified north of Building G480. LNAPL has been observed in monitoring well MW-67A since 1998, with an average measured thickness of 1.2 ft between May 2003 and July 2004. Benzene and total xylene concentrations in groundwater beneath the LNAPL plume exceed the North Carolina Groundwater Quality Standards (NC 2L Standards), but are less than the gross contamination levels (GCLs) used for the NC UST program cleanup target concentrations.

LNAPL was measured up to 2.2 inches thick in temporary wells installed during an LNAPL investigation in 2004. A plume approximately 1 acre in size was estimated north of Building G480, extending into the US 17 Bypass right-of way. The northern and eastern edges of the plume have not been delineated; their delineation should be part of the scope of the subsequent remedial action. It should be noted that, although a chlorinated hydrocarbon groundwater plume is being addressed elsewhere at Site 35, chlorinated volatile organic compounds (cVOCs) have been were not detected in soil or groundwater within the identified LNAPL plume area.

Three technologies were evaluated to remediate the LNAPL impacted area. Table E-1 is the evaluation summary of the three technologies and Table E-2 is a ranking of these technologies. Based on the effectiveness, implementability, and cost, Vacuum Enhanced Recovery (VER) is the recommended remedial technology for the Site 35 LNAPL.

TABLE **E-1**

Summary of Alternative Comparison; Site 35, Camp Lejeune

Evaluation Criteria	Alternative 1 Air Sparging w/SVE	Alternative 2 Excavation	Alternative 3 Vacuum Enhanced Recovery
EFFECTIVENESS			
Overall Protection of Human Health and the Environment	Technology meets RAOs at sandy sites.	Meets RAOs.	Partially meets RAOs.
Compliance with ARARs	Complies with ARARs. May require air permit.	Complies with ARARs. Contaminated soil would be disposed in a permitted facility; contaminated groundwater would be treated.	Complies with ARARs. Contaminated groundwater would be treated. May require air permit.
Long-term effectiveness and permanence	Technology effectiveness dependent on stratigraphy; expected to not be effective at Site 35.	Most complete removal technology; can visually identify LNAPL during implementation.	Partially complete removal technology; not expected to remove smear zone LNAPL.
Reduction of Toxicity, Mobility or Volume through Treatment	Reduces toxicity, mobility and volume of LNAPL through vapor extraction and treatment, and through biodegradation.	Reduces toxicity, mobility and volume of LNAPL through removal.	Reduces toxicity, mobility and volume of LNAPL through removal and vapor treatment.
Short-Term Effectiveness	In situ removal / destruction technology. Air emissions controlled through treatment.	Removal technology; treatment / disposal offsite. Liquid and solid waste streams easily managed. Worker concerns are air emissions and excavation safety issues. Shortest time to completion.	In situ removal technology. Air emissions controlled through treatment. Liquid waste stream easily managed. Longest time to completion.
IMPLEMENTABILITY			
Technical Feasibility	Technical restraints are shallow aquifer thickness, clay and silt stringers, and low permeability surficial soil for SVE.	No technical restraints.	Technical restraints are ability to remove smear zone LNAPL, and low permeability surficial soil for SVE .
Administrative Feasibility	Traffic management on F Street would be required during well installation. Permits may be required for air emissions.	Traffic rerouting during construction period, road reconstruction required.	Traffic management on F Street would be required during well installation. Permits may be required for air emissions.
Availability of Services and Materials	Services and materials are available.	Services and materials are available.	Services and materials are available.
State and Community Acceptance	This alternative is likely to be acceptable to the community.	This alternative is likely to be acceptable to the community.	This alternative is likely to be acceptable to the community.
COST			
Capital Cost (Direct and Indirect)	No cost prepared	$1,590,000	$902,000
Total O&M Cost	No cost prepared	$95,000 (includes 2 years monitoring)	$546,000 (includes 3 years monitoring)
Present Worth	No cost prepared	$1,680,000	$1,420,000

TABLE E-2
Relative Ranking of Remedial Alternatives; Site 35, Camp Lejeune

Evaluation Criteria	Alternative 1 Air Sparging w/SVE	Alternative 2 Excavation	Alternative 3 Vacuum Enhanced Recovery
Effectiveness	5	2	3
Implementability	2	3	2
Cost	NR	4	3
Total	NR	9	8

This table represents a comparison ranking of the technologies. The factors have equal weighting. The lowest score is the recommended technology.

NR indicates not ranked.

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Acronyms and Abbreviations

AFVR	Aggressive Fluid Vapor Recovery
ARARs	Applicable, Relevant, or Appropriate Requirements
AST	Above Ground Storage Tank
Baker	Baker Environmental, Inc.
Bgs	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
CLEAN	Comprehensive Long-Term Environmental Action Navy
CSA	Comprehensive Site Assessment
cVOC	Chlorinated Volatile Organic Compound
1,2-DCE	1,2-Dichloroethene, 1,2-Dichloroethylene
DoN	Department of the Navy
DRO	Diesel Range Organics
DW	Deep Well
EE/CA	Engineering Evaluation/Cost Assessment
FFA	Federal Facilities Agreement
FFS	Focused Feasibility Study
ft	Feet or Foot
ft/day	Feet per Day
ft/ft	Feet Per Foot
GAC	Granular Activated Carbon
GCL	Gross Contaminant Levels
GRO	Gasoline Range Organics
Hg	Mercury
IAS	In-Site Air Sparge
IR	Installation Restoration
LANTDIV	Atlantic Division of the Naval Facilities Engineering Command
LNAPL	Light Non-Aqueous Phase Liquids
MCB	Marine Corps Base
MIP	Membrane Interface Probe

MSL	Mean Sea Level
MTBE	Methyl-Tert Butyl Ether
MW	Monitoring Well
NCDENR	North Carolina Department of Environment and Natural Resources
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
OHM	OHM Remediation Services Corporation
OSHA	Occupational Safety and Health Administration
O&M	Operation and Maintenance
PID	Photo-Ionization Detector
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goals
RAOs	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SVE	Soil Vapor Extraction
TCE	Trichloroethene
TPH	Total Petroleum Hydrocarbons
USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
VER	Vacuum Enhanced Recovery
VOC	Volatile Organic Compound

1.0 Introduction

Marine Corps Base (MCB), Camp Lejeune was placed on the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) National Priorities List (NPL) effective November 4, 1989 (54 Federal Register 41015, October 4, 1989). Subsequent to this listing, the United States Environmental Protection Agency (USEPA), the United States Department of the Navy (DoN) and the Marine Corps entered into a Federal Facilities Agreement (FFA) for MCB, Camp Lejeune in 1991. The primary purpose of the FFA was to ensure that environmental impacts associated with past and present activities at the MCB are thoroughly investigated, and that appropriate CERCLA response and Resource Conservation and Recovery Act (RCRA) corrective action alternatives are developed and implemented as necessary to protect public health and welfare, and the environment.

Marine Corps Base (MCB) Camp Lejeune is a training base for the United States Marine Corps located in Onslow County, North Carolina. Baker Environmental was tasked by the Atlantic Division of the Naval Facilities Engineering Command (LANTDIV) to perform a Remedial Investigation (RI) at Camp Lejeune Operable Unit No. 10, Site 35, the Former Camp Geiger Area Fuel Farm. Due to the discovery of light non-aqueous phase liquids (LNAPLs), CH2M HILL is now tasked to prepare an Engineering Evaluation/Cost Assessment (EE/CA) in accordance with "*Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*", (USEPA, August 1993) for the LNAPL at Site 35.

Site 35 contains several areas of contamination that have been investigated under the Installation Restoration (IR) Program. Specific "hot spot" areas of groundwater contamination have been identified at the former Fuel Farm location (trichloroethene and degradation products), and north of Building G480 (petroleum fuel-related contamination). This EE/CA focuses on the fuel hot spot north of G480, where LNAPL has been measured.

The remedial alternatives presented and evaluated are designed to address LNAPL only. The actions are intended to remove as much LNAPL and BTEX constituents as technically feasible, to reduce the source for BTEX in the groundwater. However, LNAPL removal is complicated and current technologies are limited. Since this phase of work only addresses the petroleum-based LNAPL present at the site, dissolved contamination will remain. Additional treatment of the dissolved contamination may be required.

1.1 Purpose and Organization of the EE/CA

According to the United States Environmental Protection Agency (USEPA) *Guidance on Conducting Non-Time Critical Removal Actions Under CERCLA* (USEPA, 1993), "an EE/CA is a flexible document tailored to the scope, goals, and objectives of the non-time-critical removal action. It should contain only those data necessary to support the selection of a response alternative, and rely upon existing documentation whenever possible." The goals of an EE/CA are:

- "Satisfy environmental review requirements for removal actions,
- Satisfy administrative record requirements for improved documentation of removal action selection, and
- Provide a framework for evaluating and selecting alternative technologies."

The guidance further notes the following:

- a separate risk assessment is not necessary,
- data collection to characterize the nature and extent of contamination should be limited to those needed to support the specific objectives of the non-time-critical removal action, and
- only a few viable alternatives relevant to the EE/CA objectives should be identified and analyzed.

An EE/CA must be completed for all non-time critical removal actions under CERCLA, as required by section 300.415(b)(4)(i) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The goals of the EE/CA are to identify the objectives of the remedial action and to analyze the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives. Thus, an EE/CA serves an analogous function to, but is more streamlined than, the RI/FS conducted for remedial actions.

This EE/CA is organized as follows:

- **Section 2** contains site characterization information, including site description and background, nature and extent of contamination, analytical data, and a streamlined risk evaluation.

- **Section 3** contains an identification of Remedial Action Objectives (RAOs).
- **Section 4** discusses remedial action alternatives.
- **Section 5** details an analysis of remedial action alternatives based on effectiveness, implementability, and cost.
- **Section 6** compares remedial action alternatives and presents a recommendation for the alternative that best satisfies the RAOs.
- **Section 7** presents reference information.

2.0 Site Characterization

This section contains site characterization information including site description and background, nature and extent of contamination, and a streamlined risk evaluation.

2.1 Facility and Site Description

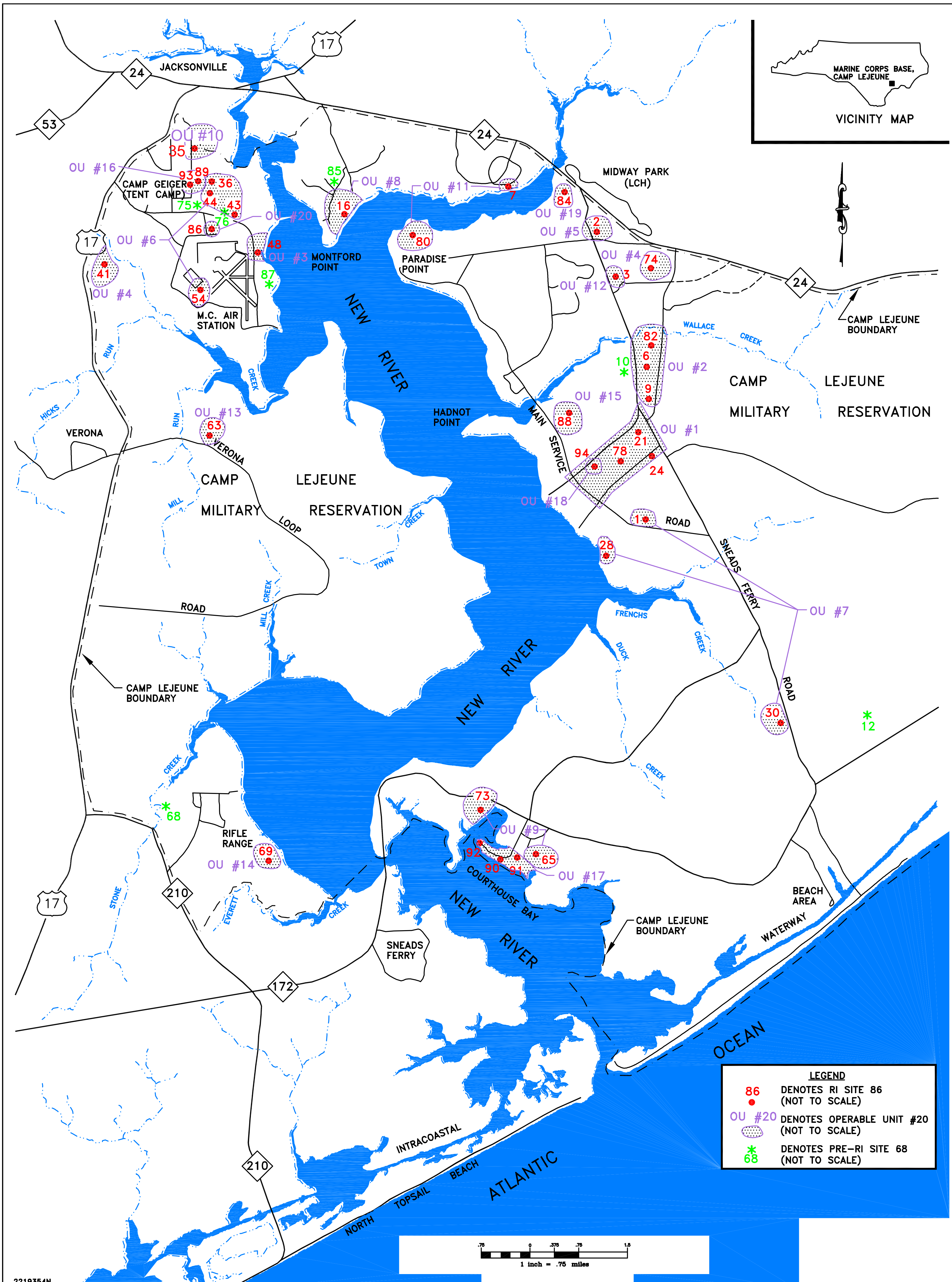
Background information for Site 35 is contained in the *Remedial Investigation of Operable Unit No. 10 (Site 35)* (Baker Environmental, June 1995), the *Hot Spot Characterization Summary Report – Operable Unit No. 10, Site 35* (Baker Environmental, 2003), and the *Final Natural Attenuation Evaluation Report, Operable Unit 10, Site 35, Former Camp Geiger Fuel Farm* (CH2M HILL, et al., 2003). Detailed discussions of the Site background are contained in those reports. This section, as well as Section 2.2, summarizes information contained in these documents.

2.1.1 Facility and Site Physical Setting

MCB Camp Lejeune is located in Onslow County, North Carolina and covers approximately 236 square miles and includes 14 miles of coastline. The Base is bounded to the southeast by the Atlantic Ocean and to the northeast by State Route 24. The town of Jacksonville, North Carolina is located north of the Base (Figure 2-1).

Camp Geiger is located at the northwest corner of Marine Corps Base (MCB), Camp Lejeune (Figure 2-1). The main entrance to Camp Geiger is off U.S. Route 17, approximately 3.5 miles southeast of the City of Jacksonville, North Carolina. Site 35 is situated within Camp Geiger just north of the intersection of Fourth and "G" Streets. Site 35 is the former Camp Geiger Area Fuel Farm (Fuel Farm), and was previously occupied by five 15,000-gallon above ground storage tanks (ASTs), a pump house, a fuel unloading pad, and several underground petroleum distribution lines. The former ASTs previously held No. 6 fuel oil, unleaded gasoline, diesel fuel, and kerosene. The Fuel Farm was decommissioned and removed in 1995 to accommodate a six-lane divided highway (Highway 17 Bypass).

Results of previous investigations have expanded Site 35 beyond the confines of the former Fuel Farm. Site 35 is now bounded on the west by D Street, on the north by Second Street,



SOURCE: Amended Remedial Investigation, Operable Unit No. 20, Site 86 – Tank Area AS419 – AS421, BAKER ENVIRONMENTAL, Inc. May, 2000.

FIGURE 2-1
OPERABLE UNIT AND SITE LOCATION MAP
OPERABLE UNIT NO. 10 - SITE 35
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO-130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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P:/PROJ/EBT/NAVY CLEAN/CTO 253/SITE 86/86 TECH EVALUATION /CADD FILES
CHARLOTTE/PROJECTS/EBL/NAVY CLEAN/CLEAN 2/CTO 130/EECA/FIGURES

on the east by Brinson Creek and on the south by Fifth Street. Figure 2-2 depicts a site plan for Site 35.

The surface of Site 35 is primarily covered with vegetation, however, a significant portion is covered by roads, buildings, and parking areas. Northeastern and eastern portions of the site are bordered by Brinson Creek, wetlands, and woodlands. Highway 17 Bypass was constructed in the northeast portion of Site 35, separating Brinson Creek from the Camp Geiger facilities. Construction activities have eliminated much of the woodlands and wetland vegetation.

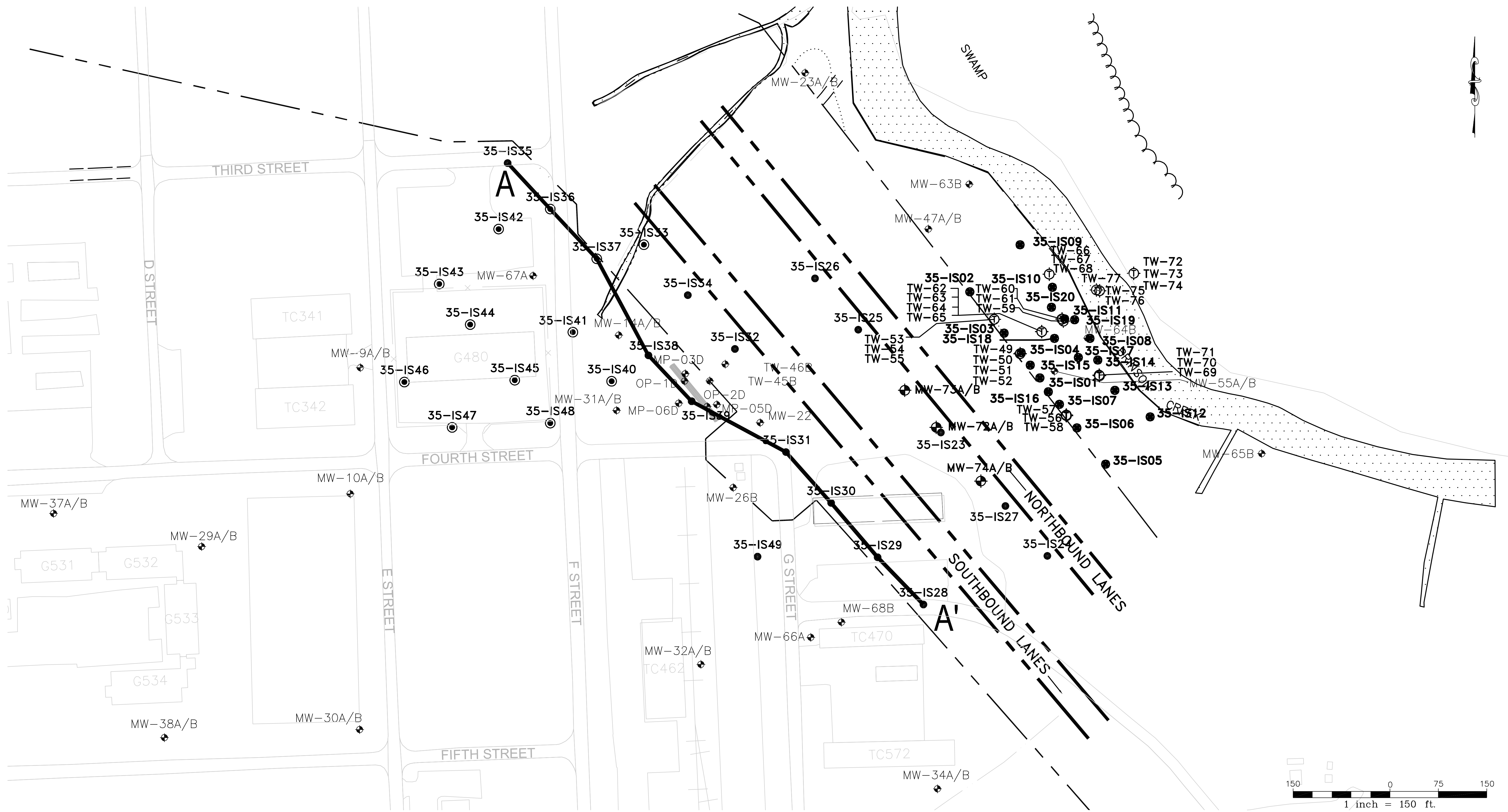
The topography of Site 35 is relatively flat, with elevations between 11 and 18 feet above mean sea level (msl). Changes in elevation are gradual, giving the site a flat appearance. Before the highway construction, the elevation dropped adjacent to Brinson Creek, defining the creek's flood plain. The grade at the Highway 17 Bypass was raised to approximately 17 feet msl. Surface runoff across the study area is primarily toward Brinson Creek via man-made drainage ditches, storm drains and catch basins, and natural drainage patterns. Impervious surfaces such as roadways, paved parking lots, and buildings modify surface runoff and infiltration across the study area.

The petroleum fuel "hot spot" area north of Building G480 is primarily covered with asphaltic pavement, with approximately 30 percent lawn area. The surface elevation in the vicinity of Building G480 is approximately 17 ft msl.

2.1.2 Site History

Construction of MCB Camp Lejeune began in 1941. Construction of Camp Geiger was completed in 1945. In 1945 the Fuel Farm's ASTs stored No. 6 fuel oil, but later stored other petroleum products such as gasoline, diesel fuel, and kerosene. The date of this switch is unknown.

The ASTs at Site 35 supplied fuel to an adjacent dispensing pump. Approximately 30 gallons of gasoline were reportedly lost per day from a leak in an underground line to the pump (Law, 1992). It is unknown how long this leak occurred, but when discovered, the leaking line was sealed and replaced. Other documented petroleum releases date back to 1957. A release of several thousand gallons of fuel from an underground distribution line



LEGEND

MW-14B	MONITORING WELL
●	GROUNDWATER SAMPLING BORING LOCATION
◉	GROUNDWATER AND SOIL SAMPLING BORING LOCATION
▬	IAS TRENCH
A — A'	CROSS-SECTION TRAVERSE
35-IS15 ●	SUPPLEMENTAL IN-SITU GROUNDWATER SAMPLE BORING
35-IS01 ●	INITIAL IN-SITU GROUNDWATER SAMPLE BORING
MW-72A	NEW SHALLOW GROUNDWATER MONITORING WELL
MW-72B	NEW INTERMEDIATE GROUNDWATER MONITORING WELL
TW-72	TEMPORARY WELL
	US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS
	US 17 JACKSONVILLE BYPASS EASEMENT LIMITS (APPROXIMATE FENCE LINE)

FIGURE 2-2
LOCATION MAP
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO-130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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P:\EBL\NAVY CLEAN\CLEAN2\CTO 130\EECA\FIGURES\FIG2-2_LOCATION.DWG

SOURCE: MCB CAMP LEJEUNE, 2000.

occurred between 1957 and 1958. Fuel from this release reportedly migrated to the east and northeast toward Brinson Creek. Interceptor trenches were excavated to capture the fuel, and once captured, the fuel was burned (ESE, 1990).

In 1990, an unauthorized discharge from a tanker truck resulted in an unknown volume of diesel or jet fuel flowing along an unnamed drainage channel north of the Fuel Farm. This spill initiated an emergency clean-up, which included the removal of about 20 cubic yards of soil. Other undocumented fuel and chlorinated solvent releases are suspected to have occurred at Site 35, as both fuel and chlorinated solvent contamination have been discovered in soil and groundwater.

In January 1994, a Fuel Oil No. 2 UST located north of Building G480, the Explosive Ordnance and Disposal Armory, Office Supply Building, was removed. Sampling in the vicinity of the closed UST indicated petroleum contamination in soil at levels below the corrective action levels (CALs) of 40 mg/kg total petroleum hydrocarbons (TPH) as measured by EPA Method 5030/8015 (Low Boiling Point Hydrocarbons) and 160 mg/kg as measured by EPA Method 3550/8015 (High Boiling Point Hydrocarbons).

An abandoned fuel line located approximately 100 ft north of Building G480 transferred Fuel Oil No.6 to a former Mess Hall Heating Plant, located approximately 500 ft west of Building G480. Investigations in the vicinity of the Mess Hall indicated that the UST or the fuel line had leaked, with BTEX and heavier fuel constituents identified in the soil and groundwater. The abandoned fuel line is located in the vicinity of monitoring well MW-67A north of Building G480.

In 1995, soil contaminated with petroleum hydrocarbons was identified between the two unnamed creeks northeast of Building G480, extending westward across F Street and coinciding with the abandoned Mess Hall fuel line. Some soil contamination was also identified near the Building G480 former UST location. However, it was determined that the soil contamination near the building was at levels below the CAL and no remedial action was conducted.

In 1995, the Fuel Farm was demolished to clear the way for the Highway 17 Bypass. In 1995 and 1996, approximately 15,700 tons of contaminated soil were removed from the highway construction site. It is estimated that more than 2/3 of that soil was from the area northeast of Building G480. The excavated areas are shown on Figure 2-3. The excavations were backfilled with stockpiled excavated soil that met the corrective action limits and with soil imported from Base borrow areas.

An in-situ air sparge (IAS) system was installed and baseline groundwater sampling was conducted to determine the impact of the system on natural attenuative processes (Baker, 1999). The IAS, included on Figure 2-3, is cross-gradient to the petroleum fuel "hot spot" addressed by this EE/CA.

2.1.3 Soil and Lithologic Information

A detailed discussion of the soil and lithologies at Site 35 is presented in the RI Report (Baker, 1995). Information pertinent to Site 35 is summarized herein.

A geologic cross-section of Site 35 is presented in Figure 2-4. The uppermost horizon is Quaternary age "undifferentiated" deposits composed of sand, silt, and clay. Beneath the "undifferentiated" deposits is the River Bend Formation and underlying it is the Castle Hayne Formation. The River Bend Formation is composed of fine-to coarse sand containing varying amounts of silt (0-50%), shell and fossil fragments (0-35%), and clay (0-10%). The sand layers in both the Quaternary deposits and River Bend Formation have a relative density of loose to dense. According to field observations using the Unified Soil Classification System (USCS), the sand layers classify as silty sand (SM) and poorly graded sand (SP). The sand is layered with fine-grained (silt and clay) lenses that are plastic to non-plastic, contain various amounts of sand (0-50%) and clay (0-10%), and classify as ML or MH. Standard penetration tests indicate that these lenses have a relative density of loose to dense for the non-plastic, and soft to very stiff for the plastic.

The upper part of the River Bend Formation contains partially cemented, fine to coarse sand and some gravel. The thickness of this unit is not uniform and varies from approximately 4 to 20 feet. Underlying the sand is a very dense to dense, greenish gray, fine sand and silt layer that acts as a semi-confining unit for the Castle Hayne aquifer. The semi-confining unit is approximately 8 to 12 feet thick, and appears to thicken toward the east. The upper part of the Castle Hayne Formation is described as a partially cemented, gray, fine sand with occasional shell and limestone fragments.

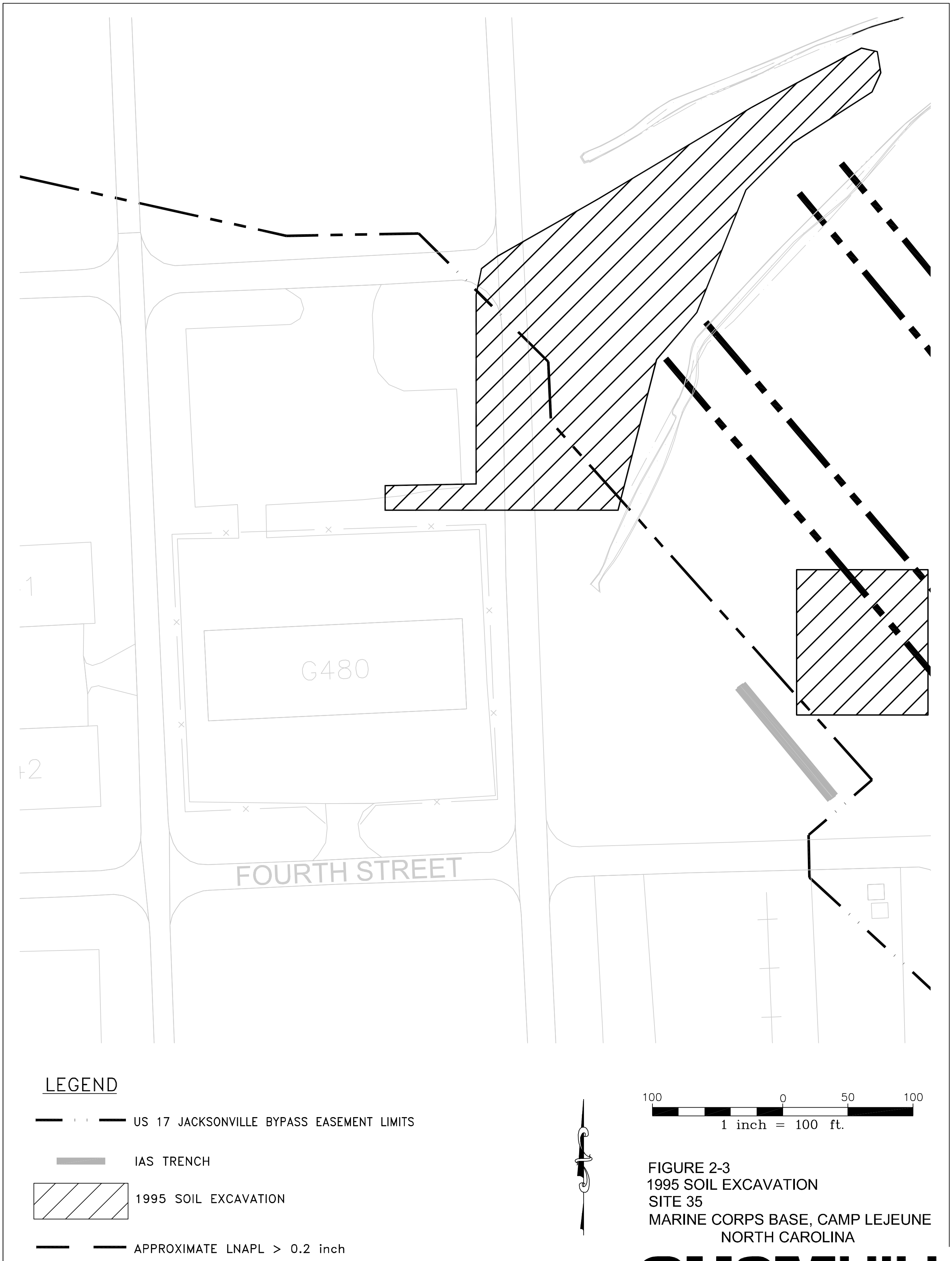

FIGURE 2-3
1995 SOIL EXCAVATION
SITE 35
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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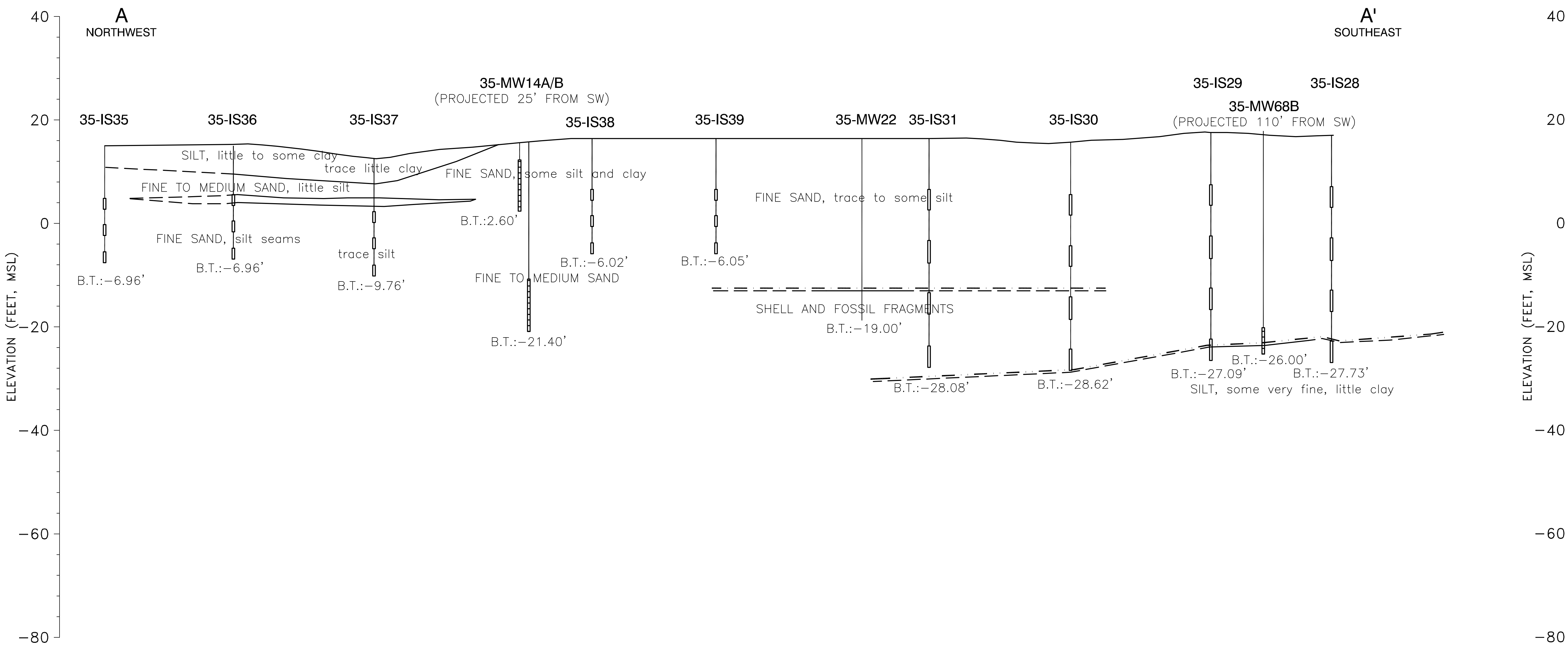
EBL\NavyClean\CLEAN 2\CTO 130\EECA\Figures\FIG2-3_SOIL-EXC.DWG

SOURCE: MCB CAMP LEJEUNE, 2000.



LEGEND

Symbol	Description
▯	SCREENED INTERVAL (GEOPROBE SAMPLER)
▤	SCREENED INTERVAL (PERMANENT AND TEMPORARY WELLS)
∇	GROUNDWATER ENCOUNTERED DURING DRILLING
———	ESTIMATED CONTACT
— — —	PROJECTED CONTACT
—·—·—	TOP OF RIVER BEND FM (CASTLE HAYNE AQUIFER)
—··—··—	TOP OF FIRST SEMI-CONFINING UNIT
B.T.:-27.82'	BORING TERMINATED (ELEVATION IN FEET MSL)

80 0 40 80 120
Horizontal Scale: 1 inch = 80 ft.

20 0 10 20 40
Vertical Scale: 1 inch = 20 ft.

THE SOIL BORING INFORMATION IS CONSIDERED TO BE REPRESENTATIVE OF SUBSURFACE CONDITIONS AT THE RESPECTIVE BORING LOCATIONS. SUBSURFACE CONDITIONS INTERPOLATED BETWEEN BORINGS ARE ESTIMATED BASED ON ACCEPTED SOIL ENGINEERING PRINCIPLES AND GEOLOGIC JUDGEMENT.

SOURCE: MCB CAMP LEJEUNE, 2000.

FIGURE 2-4
GEOLOGIC CROSS SECTION A - A'
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO-130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

CH2MHILL

P:\EBL\NAVY CLEAN\CLEAN 2\CTO 130\EECA\FIG2-4_GEO-XSECT.DWG

2.1.4 Hydrologic and Hydrogeologic Information

The surficial aquifer occurs within the Quaternary deposits and the River Bend Formation. A potentiometric map is shown in Figure 2-5. Groundwater levels measured in April 2002 indicate flow in the surficial aquifer is toward Brinson Creek (northeast across Site 35) under a fairly consistent gradient of approximately 0.01 ft/ft. Tidal and seasonal changes in the water level of Brinson Creek affects wells in the wetlands along the banks of the creek.

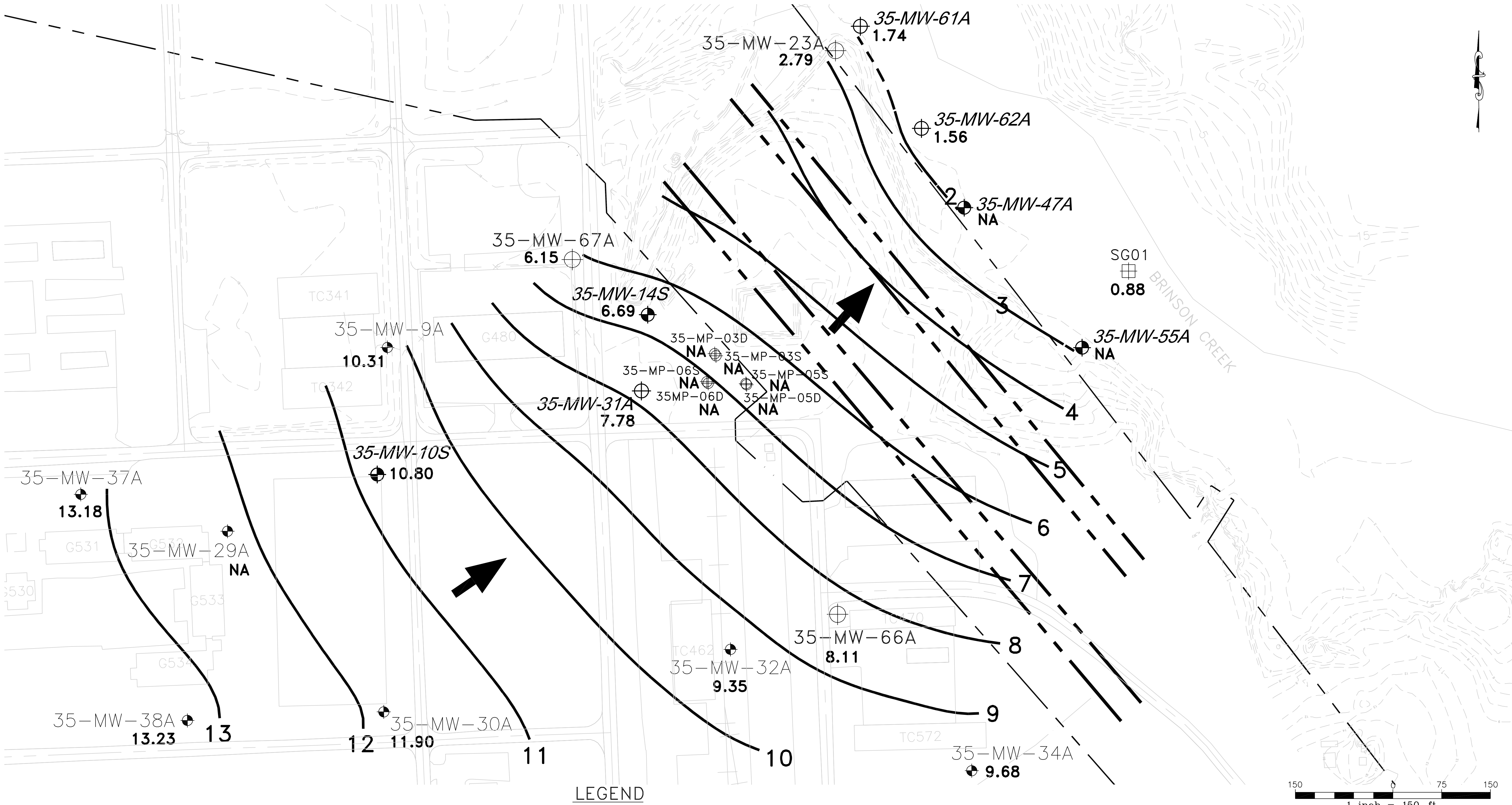
Underlying the surficial aquifer is the Castle Hayne aquifer. A potentiometric map is shown in Figure 2-6. Local groundwater flow in the Castle Hayne aquifer is divergent. Flow in the wetland/Highway 17 Bypass areas is similar in direction and gradient to the surficial aquifer. Groundwater flow south of 7th Street is to the southeast, towards Edwards Creek under a gradient of 0.004 ft/ft.

Hydraulic conductivities from slug tests of wells within the surficial aquifer indicate a range from <1 ft/day for the upper fine-grained units up to 100 ft/day in the lower, coarse sand and gravel units. Groundwater velocities in the surficial aquifer are variable. Based on a local gradient of 0.01 ft/ft, hydraulic conductivity of 1 ft/day (upper) and 100 ft/day (lower), and an assumed effective porosity of 0.28, calculated velocities range from 0.04 ft/day in the upper part to 3.6 ft/day in the lower part.

2.2 Previous Removal Actions

Historical removal actions at Site 35 are described in Section 2.1.2, Site History. The 1995 soil removal partially addressed the site of the petroleum fuel "hot spot" north of Building G480 addressed in this EE/CA. Pilot studies for groundwater treatment of the TCE "hot spot" are currently underway.

More recent removal actions for the petroleum fuel "hot spot" north of Building G480 were initiated in May, 2003 by Shaw Environmental. As of July 21, 2004, thirty Aggressive Fluid Vapor Recovery (AFVR) events have been conducted in monitoring well 35MW-67A. A total recovery of 355 gallons of petroleum product have been measured to date as a result of the AFVR.



LEGEND

SG01 – STAFF GAUGE
35-MW31A – SHALLOW MONITORING WELL
7.78 – GROUNDWATER ELEVATION (MSL), MEASURED ON 04/21/02
– GROUNDWATER CONTOUR
– GROUNDWATER FLOW DIRECTION
NA – DATA NOT AVAILABLE
– HIGHWAY 17 BYPASS RIGHT-OF-WAY
– GROUND SURFACE ELEVATION CONTOUR

SOURCE: MCB CAMP LEJEUNE, 2000.

FIGURE 2-5
SURFICIAL AQUIFER
GROUNDWATER CONTOUR MAP
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO-130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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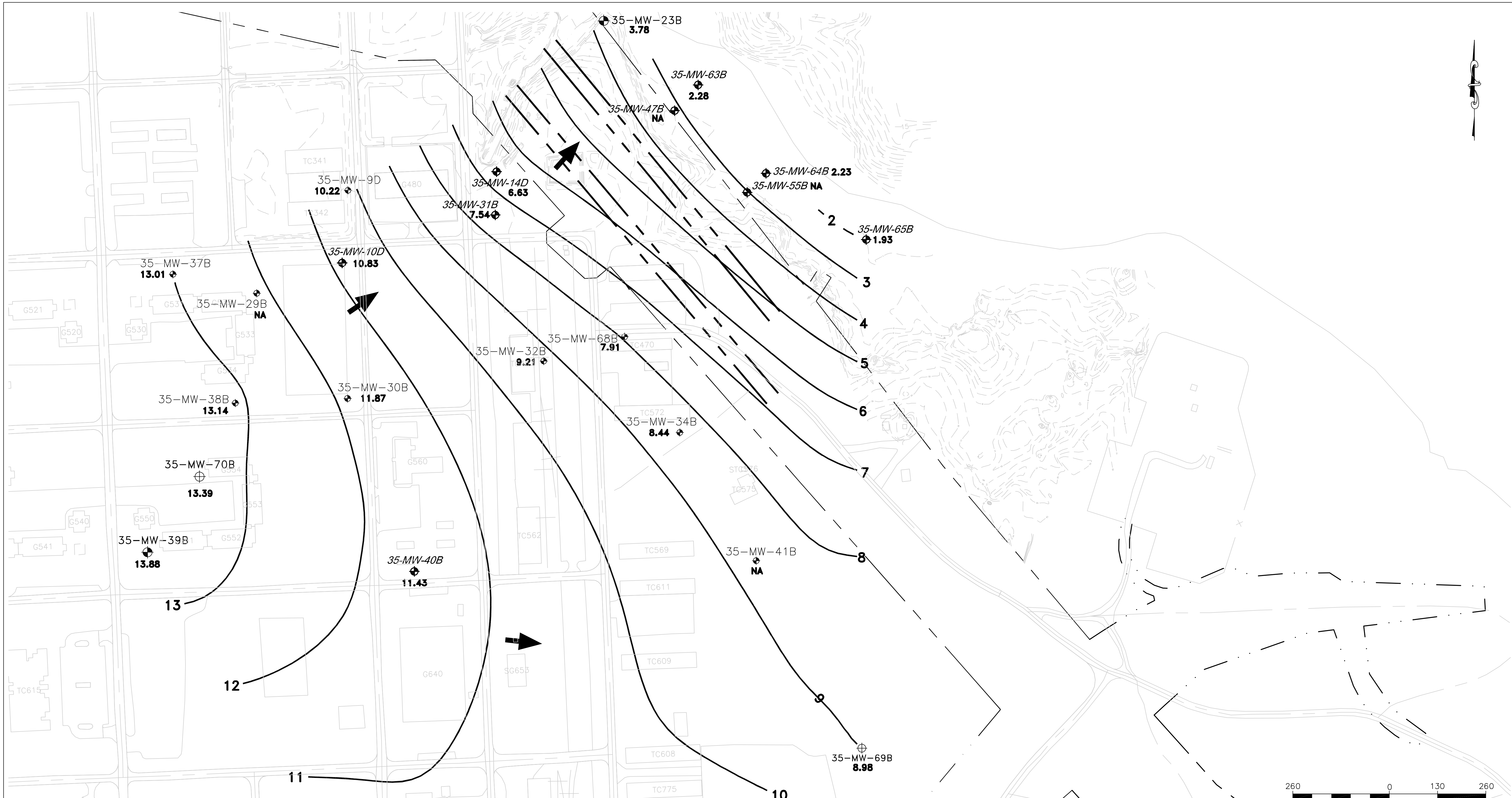
P:\EBL\NAVY CLEAN\CLEAN 2\CTO 130\EECA\FIGURES\FIG2-5_GROUNDWATER.DWG



LEGEND

35-MW32B — INTERMEDIATE MONITORING WELL

9.21 — GROUNDWATER ELEVATION (MSL), MEASURED ON 04/21/02

— GROUNDWATER CONTOUR

— GROUNDWATER FLOW DIRECTION

NA — DATA NOT AVAILABLE

— HIGHWAY 17 BYPASS RIGHT-OF-WAY

— GROUND SURFACE ELEVATION CONTOUR

FIGURE 2-6
UPPER CASTLE HAYNE AQUIFER
GROUNDWATER CONTOUR MAP
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO-130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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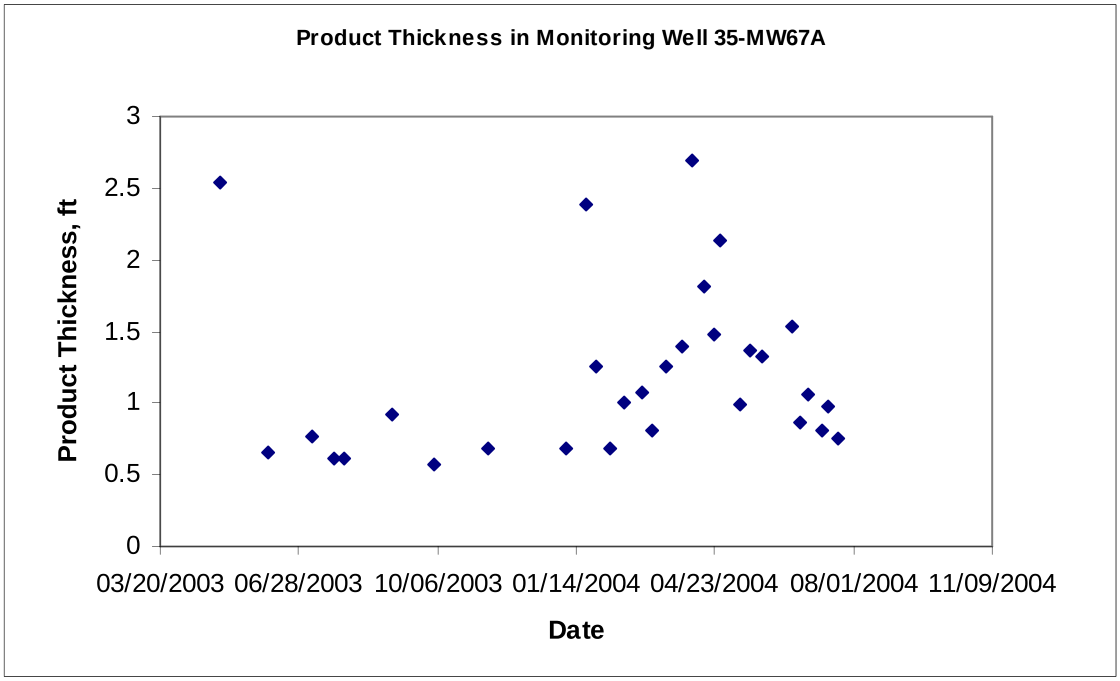
P:\EBL\NAVY CLEAN\CLEAN 2\CTO 130\EECA\FIGURES\FIG2-6_GROUNDWATER.DWG

SOURCE: MCB CAMP LEJEUNE, 2000.



In spite of the AFVR removal efforts during the past year, the LNAPL thickness measured in monitoring well 35-MW67A has a slightly increasing trend with time, as shown in the chart below. Although this trend is likely influenced by seasonal groundwater table fluctuations, it indicates that the AFVR has had minor effect on the LNAPL plume.

2.3 Previous Investigations

Previous site investigations conducted at Site 35 include:

- UST investigations (various dates),
- Initial Assessment Study (Water and Air Research, 1983),
- Site Summary Report (ESE, 1990),
- Focused Feasibility Study (NUS Corporation, 1990),
- Comprehensive Site Assessment (Law, 1992),
- Interim Remedial Action, Remedial Investigation (Baker, 1994),
- Final Remedial Investigation (Baker, 1995),
- Long Term Monitoring (Baker, 1999 – present),
- Natural Attenuation Evaluation (Baker, 2003), and
- Hot Spot Characterization (Baker, 2003).

From 1984 to 1987, a Confirmation Study of the site revealed that oil and grease, as well as benzene, trans-1,2-DCE, and TCE were present in groundwater at the site.

In 1990, a Focused Feasibility Study (FFS) was conducted in the area north of the Fuel Farm. The results of this study were not available; however, in the Comprehensive Site Assessment (CSA) Report, Law reported that, during the FFS, groundwater in one well and soil cuttings from two borings were contaminated with petroleum hydrocarbons (Law, 1992).

In 1991, a CSA was performed by Law. The CSA identified areas of contaminated soil and groundwater. Contamination consisted of chlorinated organic compounds (TCE, trans-1,2-DCE, and vinyl chloride) and petroleum hydrocarbons (total petroleum hydrocarbons [TPH], methyl-tert butyl ether [MTBE], and benzene, toluene, ethylbenzene, and xylenes [BTEX]). The contamination was found in both shallow and deep wells. Several shallow groundwater plumes were identified, including two plumes consisting primarily of petroleum hydrocarbons and two plumes of chlorinated organic compounds. All of the plumes are located north of Fourth Street and east of E Street, except for a portion of a TCE plume that extends southwest beyond the corner of Fourth and E Streets.

In December 1993, Michael Baker, Inc. (Baker) conducted an Interim Remedial Action Remedial Investigation (RI). During this investigation, seven more soil borings were made within and around the groundwater contaminant plume areas identified during the CSA. Thirteen shallow soil samples were taken near Brinson Creek to find the extent of contamination from Site 35. Benzene, toluene, ethylbenzene, xylenes, naphthalene, and 2-methylnaphthalene were detected in the soil samples. In addition, TPH (gasoline and diesel) and oil and grease were also detected. Some detections of lead, chromium, vanadium, and arsenic were found. These results confirmed that contamination in the majority of the soil is associated with a dissolved petroleum hydrocarbon contaminant plume in shallow groundwater. It was also concluded that the oil and grease detections were the result of naturally occurring organics in soils or an upgradient contamination source. On September 15, 1994, an Interim Record of Decision (ROD) was executed for the remediation of contaminated soil along and adjacent to the proposed highway right-of-way at Site 35.

In 1994, Baker conducted a comprehensive RI. Results of the RI indicated the presence of TCE and daughter products located in the surficial aquifer and the lower portion of the surficial aquifer, or intermediate zone. A detailed discussion of these results can be found in the RI Report (Baker, 1995).

Long Term Monitoring of the site began in January 1999. Monitoring has been performed quarterly from the start to October 2000. Since October 2000, monitoring has been conducted semi-annually. During each sampling event, groundwater samples are collected from 39 monitoring wells, and surface water is collected from three locations along the portion of Brinson Creek that borders Site 35 to the northeast. A detailed discussion of analytical and sampling methods can be found in the Long-Term Monitoring and Natural Attenuation Monitoring Work Plan for MCB Camp Lejeune North Carolina (Baker, 2002).

The Natural Attenuation Evaluation (Baker, 2003) showed a BTEX "hot spot" just north of Building G480, and free phase LNAPL in monitoring well 35-MW67A. The report indicated that levels of dissolved BTEX have been steady or declining since 1999, and that BTEX natural attenuation is proceeding at Site 35. However, it was noted that the presence of LNAPL affects the natural attenuation rate.

Baker conducted a "Hot Spot" Characterization at Site 35 to delineate and characterize suspected hot spot areas, and to identify and delineate any continuing sources associated with the hot spots. The field effort was conducted between October 7 and October 26, 2002, and consisted of soil and groundwater sampling of 30 Geoprobe borings. The Site 35 "Hot Spot" Characterization Letter Report (Baker, 2003) provides details regarding investigative methods and results of the investigation. Two hot spots were identified at Site 35. One shallow hot spot near Building G480 contains fuel contamination (BTEX). A second deeper (and larger) hot spot contains chlorinated solvents (primarily TCE and daughter products) and is located beneath the Highway 17 Bypass.

2.4 Nature and Extent of Contamination

A discussion of the nature and extent of contamination south of Building G480 is presented in the RI Report (Baker, 1995). However, the RI Report did not identify the LNAPL measured north of Building G480.

Investigative activities conducted subsequent to the RI included the collection of soil and groundwater samples focusing on the northern and northeastern portions of Site 35. More recently, additional phases of investigation have been conducted to better define the extent of LNAPL and dissolved-phase contamination related to the plume north of Building G480. The information provided below is from the Site 35 "Hot Spot" Characterization Report (Baker, 2003).

2.4.1 Hot Spot Characterization

The "Hot Spot Characterization" at the LNAPL plume consisted of sampling groundwater for selected VOCs and soil for VOCs and petroleum indicator (dye shake tests). The groundwater BTEX hot spot consists of an area surrounding monitoring well MW-67A (Figure 2-7). The most impacted interval is the interval approximately +5 ft to -5 ft msl (approximately 10-20 ft bgs). In this interval total BTEX concentrations range from less than 100 μg/L to 1,282 μg/L. The 'IS' samples were collected using direct push technology (DPT) and the boreholes were then abandoned. LNAPL was not detected in groundwater from any of the IS sample locations. These sample locations also suggest the extent of the LNAPL area "based on visual staining and dye shake tests conducted on recovered soil samples" (Baker, 2003). Table 2-1 summarizes the analytical results from DPT groundwater samples in this area. The maximum benzene and total xylene concentrations exceed the North Carolina 2L standards, but are less than the gross contamination levels (GCLs) used for the NC UST program cleanup target concentrations.

TABLE 2-1
BTEX Hot Spot Results; Site 35, Camp Lejeune
From Hot Spot Characterization Report (Baker, March 2003)

Sample ID	Depth Interval (ft. bgs)	Elevation (ft msl)	Benzene (μg/L)	Toluene (μg/L)	Ethylbenzene (μg/L)	M&P Xylene (μg/L)	O Xylene (μg/L)
35-IS36-01	10-12	4.10	165	2	170	138	2 U
35-IS37-01	10-12	1.24	124	2	250	137	2 U
35-IS44-01	10-12	5.41	104	18	451	362	328
35-IS44-02	15-17	0.41	97	20	446	376	343
35-IS43-01	10-12	4.90	93	2 U	443	218	2 U
35-IS42-01	10-12	4.90	64	17	368	167	2 U
35-IS41-01	10-12	4.54	40	2 U	599	455	2 U

TABLE 2-1
BTEX Hot Spot Results; Site 35, Camp Lejeune
From Hot Spot Characterization Report (Baker, March 2003)

35-IS43-02	15-17	-0.10	16	2 U	452	357	2 U
NC 2L Standard			1.0	1,000	700	530	
NC Gross Contaminant Level			5,000	257,500	29,000	87,500	

U – results below detection limit indicated

NC 2L Standard – North Carolina Groundwater Standard, proposed

The "Hot Spot" Characterization Report also delineated chlorinated solvents in groundwater at Site 35. Figure 2-8 presents areas where TCE and DCE were detected in groundwater in excess of NC 2L standards. It should be noted that, except at 35-IS37, on the eastern edge of the LNAPL plume adjacent to the drainage way, chlorinated compounds were not detected beneath the LNAPL plume. At 35-IS37, the LNAPL and BTEX were detected at the 10-12 ft depth below ground surface, and the TCE and DCE were detected at the 20-22 ft depth.

LNAPL has been observed in monitoring well MW-67A since 1998. Between May 2003 and July 2004, LNAPL thickness has been measured in MW-67A between 0.57 ft and 2.7 ft, with an average measured thickness of 1.2 ft.

2.4.2 LNAPL Investigation

In May and June, 2004, additional investigation was conducted at the LNAPL hot spot. Soil samples were collected at 15 locations by DPT as shown on Figure 2-9. DPT sample locations for the LNAPL investigation were identified as IR35-IS"XXX", with the initial number "XXX" ranging from 101 to 115. Soil samples were screened visually and with a PID for the presence of petroleum products. Soil samples from 11 locations were selected from the most contaminated depths based on field observations, and analyzed for gasoline range and diesel range organics (GRO and DRO) per SW-846 8015, and for VOCs per SW-846 8260B. Groundwater samples were collected in three of the DPT locations and analyzed for DRO and VOCs.

Because the ratio of DRO to GRO for the first four soil samples was greater than 10, it became apparent that the contamination at the site was caused by the longer-chain

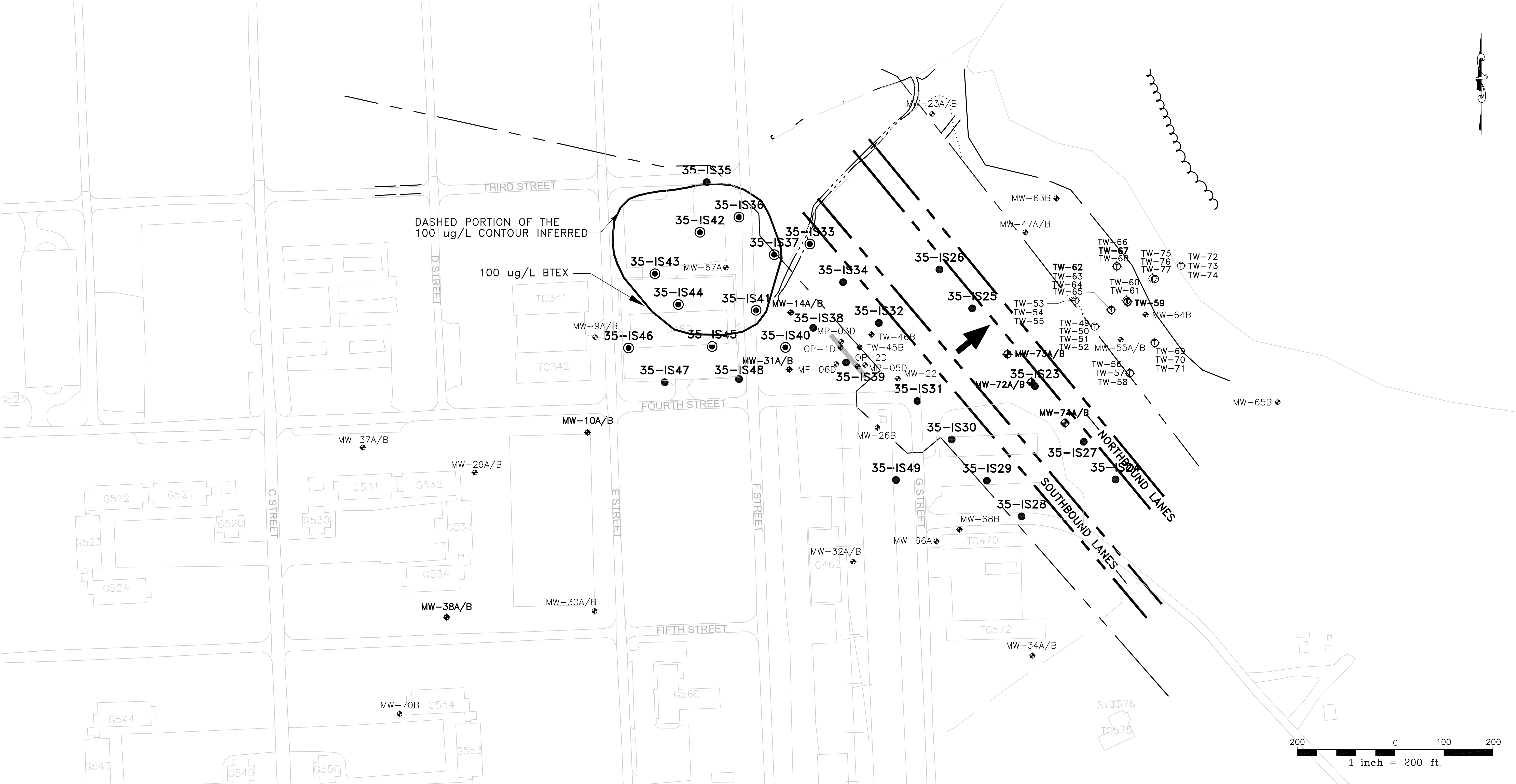


FIGURE 2-7

TOTAL BTEX IN SURFICIAL GROUNDWATER
HOT SPOT INVESTIGATION
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO 130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

LEGEND

- US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS
- US 17 JACKSONVILLE BYPASS EASEMENT LIMITS (APPROXIMATE FENCE LINE)
- MW-14B MONITORING WELL
- TW-49 TEMPORARY WELL FROM FOCUSED NAE STUDY
- GROUNDWATER SAMPLING BORING LOCATION
- GROUNDWATER AND SOIL SAMPLING BORING LOCATION
- IAS TRENCH
- GROUNDWATER FLOW DIRECTION IN THE SURFICIAL AND CASTLE HAYNE AQUIFERS

SOURCE: MCB CAMP LEJEUNE, 2000.

P:\EBL\NAVY CLEAN\CLEAN 2\CTO 130\EECA\FIGURES\FIG2-7_BTEX.DWG

SOURCE: MCB CAMP LEJEUNE, 2000.

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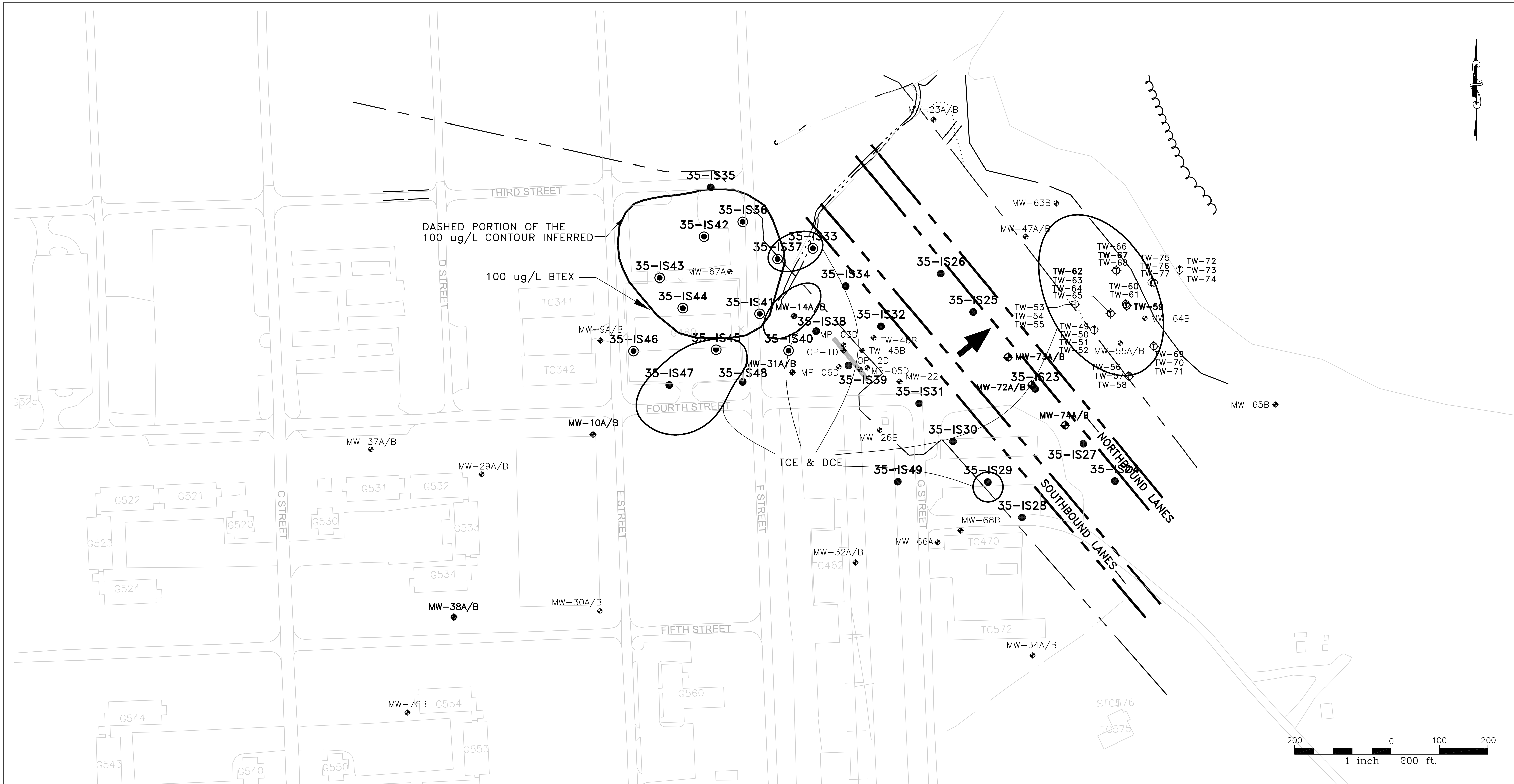

LEGEND

- US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS
- US 17 JACKSONVILLE BYPASS EASEMENT LIMITS (APPROXIMATE FENCE LINE)
- MW-14B MONITORING WELL
- TW-49 TEMPORARY WELL FROM FOCUSED NAE STUDY
- GROUNDWATER SAMPLING BORING LOCATION
- GROUNDWATER AND SOIL SAMPLING BORING LOCATION
- IAS TRENCH
- GROUNDWATER FLOW DIRECTION IN THE SURFICIAL AND CASTLE HAYNE AQUIFERS

SOURCE: MCB CAMP LEJEUNE, 2000.

NOTES:

1. FROM BAKER, 2003
2. +5 T0 -15 FT MSL
3. TCE AND CIS-1,2 -DCE EXCEED 2L STANDARD

FIGURE 2-8
CHLORINATED VOCS IN SURFICIAL GROUNDWATER
HOT SPOT INVESTIGATION
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CATO 130
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

P:\EBL\NAVY CLEAN\CLEAN 2\CTO 130\EECA\FIGURES\FIG2-8_BTEX.DWG

SOURCE: MCB CAMP LEJEUNE, 2000.

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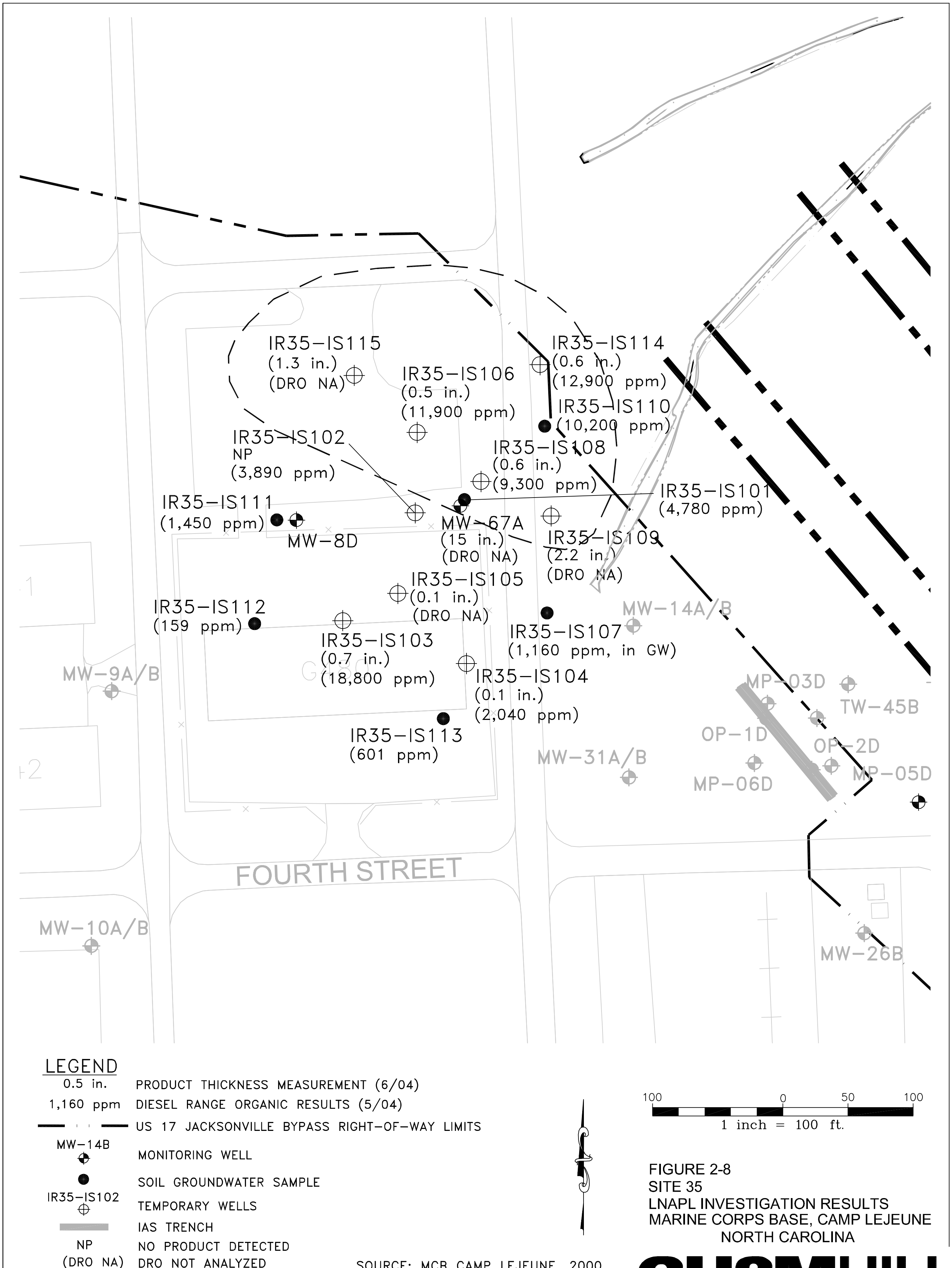

FIGURE 2-8
SITE 35
LNAPL INVESTIGATION RESULTS
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

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EBL\NavyClean\CLEAN 2\CTO 130\EECA\Figures\FIG 2-8_FIELD-RESULTS.DWG hydrocarbons (not gasoline) , consistent with the earlier findings at the site (Baker, 2003). Therefore, DRO was used as an indicator of contamination. Figure 2-9 presents DRO results in soil and groundwater, compared with LNAPL thickness where applicable.

After screening the soil, temporary wells constructed of 1-inch PVC pipe screened from 5 to 15 feet below ground surface (ft bgs) were installed in eight of the DPT locations. Clean sand was inserted as a filter pack from 3 to 15 ft bgs, and a bentonite seal was installed from 0.5 ft to 3 ft bgs. Table 2-2 presents LNAPL thickness measurements in the temporary wells, measured 3 weeks after well installation. Product thicknesses in the temporary wells are likely influenced by borehole smearing from the DPT, and may take several months to equilibrate.

Table 2-3 presents detected constituents in soil and Table 2-4 presents detected constituents in groundwater. No chlorinated solvents or their daughter products (TCE, DCE, etc.) were detected in any of the soil samples. TCE and DCE were detected in groundwater sampled from the south side of Building G480, but not in the samples north and east of the building.

It should be noted that the presence of LNAPL coincides with DRO measurements greater than 4000 mg/kg in soil, and the LNAPL plume is located north of Building G480. According to NC UST regulatory guidance, LNAPL thickness of greater than ¼ inch is to be remediated. The extent of LNAPL with thickness greater than 0.2 inches is estimated on Figure 2-9. Aside from a limited LNAPL area located in the vicinity of the former UST on the north side of Building G480, the LNAPL area with thickness greater than 0.2 inch is located north of the secured area surrounding Building G480. The north and east sides of the plume have not been delineated, although data from the Baker Hot Spot Investigation suggests that the northern edge of the plume does not extend into the highway right-of-way. Plume delineation should be completed before implementation of the removal action.

2.5 Streamlined Risk Evaluation

According to USEPA *Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA*, (1993), "…[f]or the EE/CA, the streamlined risk evaluation should focus on the specific problem that the removal action is intended to address. If the action is intended to address a particular source of contamination, the risk evaluation should address the risks

TABLE 2-2

LNAPL Thickness Measurements in Temporary Wells

LNAPL Investigation; Site 35, Camp Lejeune

Date	Location	Depth to Product	Depth to Water	Thickness of Product	
		(ft)	(ft)	(ft)	(in)
06/16/2004					
*	IS102	NA	7.4	NA	NA
	IS103	7.2	7.26	0.06	0.72
	IS104	7.6	7.61	0.01	0.12
	IS105	7.56	7.57	0.01	0.12
	IS106	7.9	7.94	0.04	0.48
	IS108	7.6	7.65	0.05	0.6
	IS109	7.35	7.53	0.18	2.16
	IS114	7.6	7.65	0.05	0.6
	IS115	7.74	7.85	0.11	1.32
	MW67A	7.34	8.59	1.25	15
05/27/2004					
*	IS102	NA	7.12	NA	NA
	IS103	7.02	7.05	0.03	0.36
*	IS104	NA	7.46	NA	NA
*	IS105	NA	7.34	NA	NA
	IS106	7.74	7.77	0.03	0.36
	IS108	7.52	7.56	0.04	0.48
	IS109	7.34	7.37	0.03	0.36
	MW67A	7.21	8.95	1.74	21

* No product detected

All measurements from top of well, near ground surface

Product thicknesses in the temporary wells are likely influenced by borehole smearing from the DPT, and may take several months to equilibrate.

NA = Not applicable; no product detected

TABLE 2-3

Total Petroleum Hydrocarbons and VOCs detected in Soil
Sampling Dates May 25-28, 2004
LNAPL Investigation; Site 35, Camp Lejeune

Sample ID	IR35-IS101-04B-1	IR35-IS101-04B-2	IR35-IS102-04B-1	IR35-IS103-04B-1	IR35-IS104-04B-1	IR35-IS106-04B-1	IR35-IS108-04B-1	IR35-IS110-04B-1	IR35-IS111-04B-1	IR35-IS112-04B-2	IR35-IS113-04B-2	IR35-IS114-04B-1
Depth, ft bgs	4 - 6	8 - 10	10 - 12	10 - 12	9 - 10	7 - 8	9 - 10	11 - 12	13 - 14	7 - 8	7 - 8	11 - 12
Parameter												
units	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**	**MG/KG**
Diesel Range Organics	203	4780	3890	18800	2040	11900	9300	10200	1450	159	601	12900
Gasoline Range Organics	6.96 U	275	297	516	NS	NS	NS	NS	NS	NS	NS	NS
units	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**	**UG/KG**
n-Butylbenzene	NS	NS	NS	NS	NS	4910	NS	10600	3220	4.56 U	49.8	18100
sec-Butylbenzene	NS	NS	NS	NS	NS	1900	NS	4270	1380	4.56 U	39.0	7070
Ethylbenzene	NS	NS	NS	NS	NS	2260	NS	7600	2690	4.56 U	6.71	16300
Isopropylbenzene	NS	NS	NS	NS	NS	1610	NS	3810	1350	4.56 U	24.3	7780
4-Isopropyltoluene	NS	NS	NS	NS	NS	1600	NS	2780	897	4.56 U	4.46 U	5240
Naphthalene	NS	NS	NS	NS	NS	9780	NS	27500	8300	7.18	580	57900
n-Propyl benzene	NS	NS	NS	NS	NS	3530	NS	7890	2790	4.56 U	40.0	15200
1,2,3-Trichlorobenzene	NS	NS	NS	NS	NS	379 U	NS	1250 U	369 U	4.56 U	4.99	1580 U
1,2,4-Trimethylbenzene	NS	NS	NS	NS	NS	11600	NS	28700	8690	4.56 U	7.38	57200
1,3,5-Trimethylbenzene	NS	NS	NS	NS	NS	4990	NS	9260	2730	4.56 U	4.46 U	17900
m-,p--Xylene	NS	NS	NS	NS	NS	759 U	NS	8990	1900	9.11 U	8.92 U	19000
o-Xylene	NS	NS	NS	NS	NS	2140	NS	1250 U	764	4.56 U	4.46 U	1580 U

Notes:
NS = Not analyzed
U = Not detected; value is quantitation limit

TABLE 2-4

Total Petroleum Hydrocarbons and VOCs detected in Groundwater

Sampling Dates May 25-28, 2004

LNAPL Investigation; Site 35, Camp Lejeune

Sample ID	IR35-IS107-04B-1		IR35-IS112-04B-1		IR35-IS113-04B-1		2L	GCL
Parameter								
units	mg/L		mg/L		mg/L		mg/L	mg/L
Diesel Range Organics	1160		0.5	U	12			
Gasoline Range Organics	NS		NS		NS			
units	ug/L		ug/L		ug/L		ug/L	ug/L
Benzene	20.0		1	U	7.32		1	5000
n-Butylbenzene	20	U	1	U	7.28		70	6900
sec-Butylbenzene	27.2		1	U	5.2		70	8500
cis-1,2-Dichloroethene	20	U	1	U	104		70	70000
trans-1,2-dichloroethene	20	U	1	U	12.0		70	70000
Ethylbenzene	120		1	U	14.8		29	29000
Isopropylbenzene	48.4		1	U	7.28		70	25000
4-Isopropyltoluene	23.8		1	U	4	U		
Naphthalene	678		1	U	45.0		21	15500
n-Propyl benzene	94.8		1	U	8.16		70	30000
Trichloroethene	20	U	1	U	48.3		2.8	2800
1,2,4-Trimethylbenzene	457		1	U	4	U	350	28500
1,3,5-Trimethylbenzene	125		1	U	4	U	350	25000
m-,p--Xylene	162		2	U	11.8		530	87500
o-Xylene	20	U	1	U	4	U	530	87500

Notes:

shaded indicates exceeds NC 2L standards

2L North Carolina Groundwater Quality Standards

GCL Gross Contamination Levels for Groundwater

NS = Not analyzed

U = Not detected; value is quantitation limit related only to that source of contamination." This EE/CA addresses only the removal of the petroleum-related fuel LNAPL "hot spot", which is equated to a source removal action to prevent further contamination in groundwater and potential future release to surface water at the site. The risk evaluation is limited to addressing the free product only.

The LNAPL has not been analyzed to determine its constituents. The known constituents in the underlying groundwater north of Building G480 are benzene, toluene, ethylbenzene, xylenes, and naphthalene. Benzene concentrations listed in Table 2-1 are two orders of magnitude higher than the North Carolina 2L Standard for Groundwater; and xylene concentrations are also above the 2L standards.

The unnamed tributary to Brinson Creek that is located east of the hot spot has evidence (visual and odor) of petroleum contamination, indicating that the groundwater plume is discharging to the surface water. The ecological receptors in the creek and wetlands downstream from the site may be impacted by petroleum constituents.

At Site 35, the potentially exposed human population includes outdoor maintenance workers and adult workers inside Building G480. The current groundwater routes of exposure include vapor inhalation both outdoors and indoors in Building G480. Groundwater is not currently used for drinking or other purposes at Site 35. Therefore, the human exposure pathway to the groundwater at the site is incomplete under current land use conditions. It is possible for the inhalation pathways for indoor or outdoor workers to be complete. However, it is not practical to accurately measure VOCs in wells with free product due to the potential sampling and analytical interference by the free product. Therefore, LNAPL is proposed for removal prior to characterization of the risks from the dissolved portion of the hydrocarbons at the site. The primary goal in conducting the removal action is to remove the continuing source of contamination to groundwater and subsequently the creek from the LNAPL. The human health risk associated with dissolved constituents in groundwater may be assessed after the free product has been removed to acceptable levels and the site reaches steady-state conditions.

3.0 Identification of Remedial Action Objectives

This section identifies the objectives of the non-time-critical removal action at Site 35. Based on information presented in Section 2.0, conditions at Site 35 warrant the evaluation of remedial action objectives (RAOs) for the protection of human health and the environment. The RAOs for the proposed interim corrective action are based upon the threat to groundwater and surface water posed by the presence of LNAPL in the surficial aquifer at Site 35.

The RAOs for Site 35 are:

- Prevent or minimize LNAPL migration to the surficial aquifer and to drainage ways feeding Brinson Creek.
- Remove LNAPL as a source of groundwater contamination.
- Reduce exposure and risk to human health and ecological receptors.

3.1 Statutory Limits on Removal Actions

Non time-critical removal actions funded by EPA have a $2 million and a 12-month statutory limit pursuant to Section 104(c)(1) of Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). Because removal actions at the MCB, Camp Lejeune are not being funded by EPA, these statutory limits do not apply. However, cost effectiveness is a recommended criterion for evaluation of the removal action alternatives.

3.2 Determination of Remedial Action Scope

The selected remedial action is intended to be an interim corrective action implemented at Site 35 to achieve the identified RAOs. The remedial action is intended to significantly reduce the amount of LNAPL present at the site and to eliminate, to the extent possible, the ongoing source of groundwater and surface water contamination. The groundwater contamination resulting from the LNAPL may be within remedial action objectives depending on which regulatory program is followed at the site. Groundwater concentrations are lower than gross contamination levels for the NC UST program; if UST regulations apply then groundwater may not need further remediation, provided it is not used as a drinking water source at the site.

3.3 Determination of Remedial Action Schedule

Factors that may affect the remedial action schedule primarily relate to seasonal restrictions. For example, inclement weather (storms or hurricanes) can delay construction and operation of remedial systems.

Before interim action are implemented, the extent of LNAPL will be more clearly defined. Up to 15 locations will be tested with a membrane interface probe (MIP). After the LNAPL area has been more closely defined, the remedial actions and estimated costs presented in this EE/CA will be reviewed for appropriateness.

If the LNAPL area is close to that assumed in Section 2, then implementation of construction activities could be anticipated to require 2 to 6 months, based on the remedy selected. System operation may last for several years. The NCP requires a minimum public comment period of 30 days for this EE/CA.

4.0 Identification of Remedial Action Alternatives

General response actions that may be used to satisfy the RAOs include institutional controls, removal, containment, treatment, and disposal. In accordance with the EPA *Guidance On Conducting Non-Time-Critical Removal Actions Under CERCLA* (EPA, August, 1993), treatment technologies were selected in favor of capping or land disposal. Based on the removal action scope (Section 3.2), the objective of the interim remedy will be LNAPL mass removal or destruction in the saturated zone. The dissolved plume, and any residual source zone impacts, will be addressed by the final remedy for the site. In accordance with this objective, technologies selected for interim remedy evaluation must be capable of rapid extraction and/or destruction of LNAPL mass, in order to prevent delay of final remedy implementation and project closure. The following is a list of the technologies considered for evaluation in this EE/CA:

1. Air Sparging
2. Excavation and Soil Disposal
3. Vacuum Enhanced Recovery

Descriptions of each alternative are provided in this section. Section 5 contains the results of a detailed evaluation of the alternatives. The applicability of each alternative will ultimately depend on the actual LNAPL extent and the fluid and air flow characteristics of the subsurface.

4.1 Option 1 – Air Sparging with SVE

Air sparging involves injection of air into the saturated zone, at least 10 to 20 feet below the water table interface. Unlike pumping/skimming methods (which only address LNAPL that can be gravity drained from the soil, leaving behind a significant volume of residual, unrecoverable mass) or SVE (which bypasses saturated and nearly saturated soils), air sparging penetrates the entire saturated and unsaturated soil column. The injected air is buoyant and rises (escapes) in a complex and non-uniform series of finger-like channels. If the hydraulic conductivity of the saturated zone is sufficiently high (10^{-4} to 10^{-3} cm/s or greater), air sparging often represents a cost effective remediation method for promoting mass transfer "stripping" of contaminants, and, more importantly, stimulating aerobic bioremediation.

Microbial communities capable of degrading petroleum products are essentially ubiquitous. These native bacteria, if provided with an electron acceptor (oxygen) can rapidly degrade LNAPL (such as BTEX and associated compounds). In order to be available for biodegradation, LNAPL must partition into the groundwater (i.e. be solubilized). Sparging causes mixing/agitation of the groundwater, which increases groundwater partitioning.

Oxygenation via air sparging is limited by solubility to about 8-9 mg/L, and oxygen transfer efficiency is poor. However, the process is inexpensive (air is free), simple, and reliable (air blowers/compressors are very low maintenance). Generally speaking, within a time frame of several months of continuous or pulsed air injection, biomass capable of aerobic petroleum degradation accumulate within the sparge zone. LNAPL is volatilized and biodegraded at a relatively rapid pace, and site restoration can typically be achieved within two years. Furthermore, groundwater is also remediated during the process.

A network of air sparge wells is installed with screen intervals positioned below the contaminated target zone. The well network is connected to a blower or air compressor through above- or below-grade system piping. (Below-grade system piping would be used at Site 35 due to site conditions: vehicular and pedestrian traffic, etc.) The blower is designed to supply air to the sparge wells at a pressure capable of evacuating the water column and at a sufficient flow rate to strip volatile compounds from the groundwater. Several parallel horizontal sparge wells could be installed beneath the plume to provide a continuous area of air supply. Generally more coverage can be obtained from horizontal wells than from vertical sparge wells.

Advantages of Air Sparging with SVE

- Air sparging is a proven technology that treats the entire saturated zone.

- Horizontal sparge wells could treat LNAPL located beneath structures and roadways without surface disturbance.
- Total treatment time would be relatively short and is estimated to be approximately 1 to 2 years.

Limits of Air Sparging with SVE

- Non-uniform air flow is possible in varied or non-uniform site conditions. Stringers and layers of silt and clay may block air flow to the upper portion of the aquifer, where the LNAPL is concentrated. The LNAPL seams at Site 35 are intermingled with silt and clay seams, preventing a continuous flow of air to the target seams.
- Air sparging requires installation of network of injection points, conveyance piping, valves, and monitoring points. Capital costs may be relatively high. Operation and maintenance of the system is required.
- SVE vapor capture may be required to prevent fugitive vapor migration. Successful implementation of SVE may be challenging at Site 35 due to the low permeability of the unsaturated zone. SVE requires installation of a network of vertical SVE wells connected to a vacuum blower through below-grade system piping and treatment of recovered vapors.

Implementation Concerns

- Treatment for extracted vapors would be required.

4.2 Option 2 – Excavation and Soil Disposal

The LNAPL at Site 35 is relatively shallow and limited in area, and could be removed by excavating the petroleum-saturated soil and then removing it for disposal offsite. The estimated volume of LNAPL-saturated soil to be removed is approximately 7000 cubic yards, from 6 to 10 feet below grade. The exposed water within the excavation would be pumped down approximately 2 feet to remove mobile LNAPL and enhance flow of LNAPL from the excavation edges, for its recovery. This would effectively remove LNAPL within the lower smear zone below the water table.

The overlying 6 feet of fine-grained soil is presumed free of LNAPL and would be stockpiled on site and returned to the excavation after the targeted soil is removed. Imported clean soil would be placed on the surface to complete the backfilling. Figure 4-1 shows the estimated area for excavation.

Advantages of Excavation at Site 35

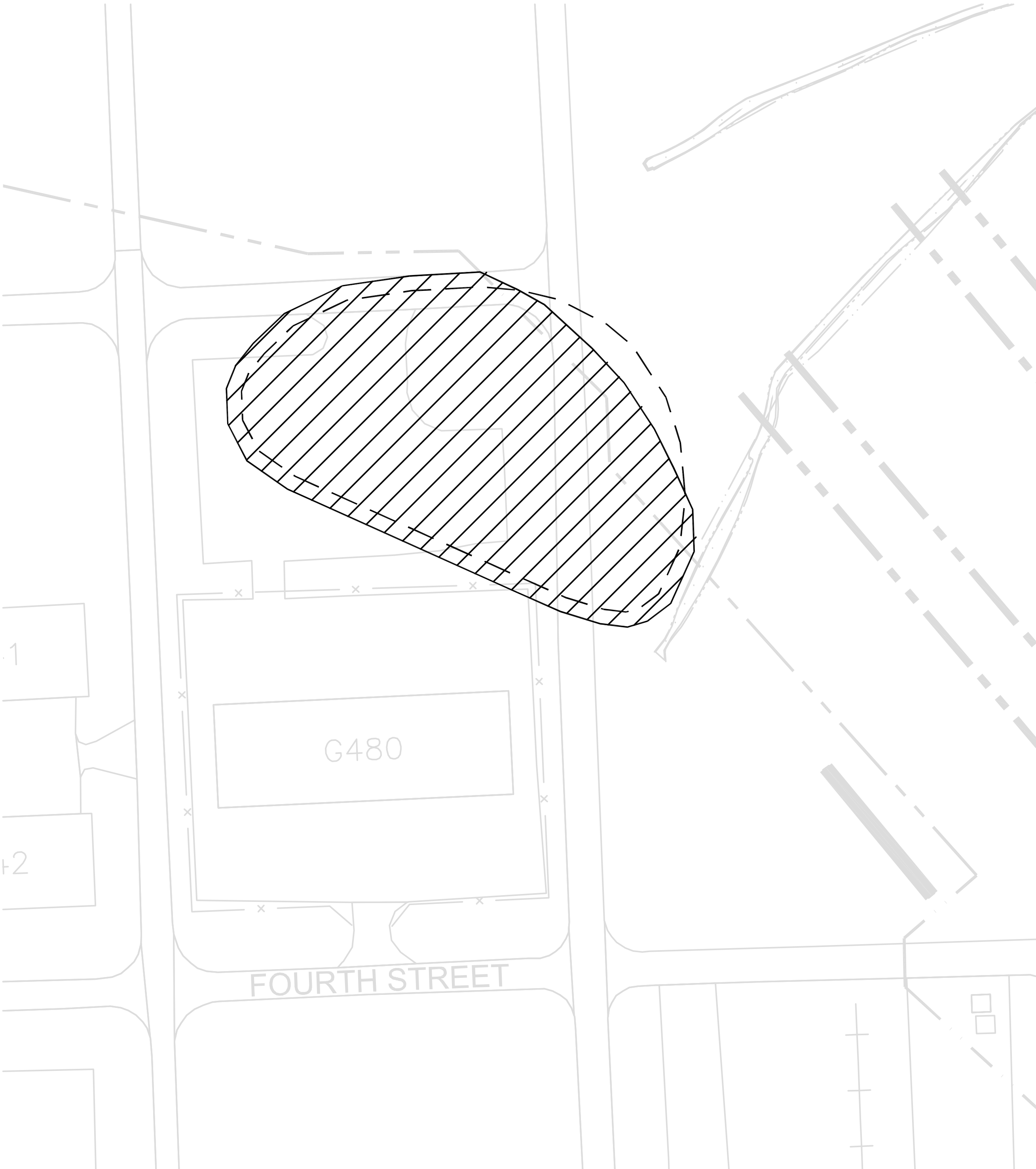
- The LNAPL-saturated soils can be visually identified upon excavation, reducing the uncertainty in determining the plume extent and area to be remediated.
- This alternative is easily implementable.
- LNAPL in the capillary and smear zones would be removed and treated.
- Soil disposal would be relatively inexpensive, as it is not considered hazardous waste.

Limits of Excavating at Site 35

- LNAPL beneath the highway embankment would not be excavated without providing alternative routes for highway traffic. Furthermore, the excavation backfilling beneath the highway would need to be conducted to more rigorous standards. For this reason, LNAPL would not be remediated beneath the highway right of way.
- Groundwater treatment may be costly, if groundwater is not permitted to be discharged to the sanitary sewer.

Implementation Concerns

- Removing the soil above the LNAPL and thereby exposing it would increase volatilization of LNAPL VOCs to the ambient air. Air emissions would be difficult to control during excavation.
- F Street traffic would be rerouted during excavation. After remediation, the road would be reconstructed to support its original traffic design load.
- There would be loss of use of the parking/storage area north of Building G480 during excavation and backfilling.



100 0 50 100
1 inch = 100 ft.

FIGURE 4-1
CONCEPTUAL DESIGN-EXCAVATION
SITE 35, FORMER CAMP GEIGER FUEL FARM
LNAPL REMOVAL EE/CA CTO-130
MARINE CORPS BASE, CAMP LEJEUNE

NORTH CAROLINA

LEGEND

EXCAVATION AREA

APPROXIMATE LNAPL > 0.2 inch

US 17 JACKSONVILLE BYPASS RIGHT-OF-WAY LIMITS

IAS TRENCH

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SOURCE: MCB CAMP LEJEUNE, 2000.

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4.3 Option 3 – Vacuum Enhanced Recovery

Vacuum Enhanced Recovery (VER) is a combination of SVE, water table depression, and free product skimming, using a submersible water table depression pump for groundwater recovery and a positive displacement blower or regenerative blower for vapor extraction. Application of vacuum increases the effective hydraulic gradient to the recovery well. More importantly, as the water table is depressed, vacuum at the wellhead causes air to flow through the newly dewatered "smear zone". This process accelerates volatilization and biodegradation of LNAPL in the vicinity of the recovery well.

The term "vacuum enhanced recovery" can be used to describe several different processes. Bioslurping is a variation of vacuum enhanced recovery. This technology involves combined liquid and vapor extraction from a single pump/blower using a suction pipe, or "slurp tube". A liquid ring pump or piston pump is typically employed to apply sufficient vacuum (25 inches Hg or more) for simultaneous groundwater, LNAPL, and vapor extraction. If the aquifer is permeable (high-yield), bioslurping becomes less efficient, since almost all of the applied vacuum is used to lift groundwater, instead of enhancing vapor recovery and LNAPL migration to the well. In other words, the rate of groundwater recharge is too rapid to enable partial dewatering; therefore, LNAPL entrained in the capillary fringe (smear zone) is not exposed to air flow. Bioslurping is therefore not considered an applicable technology at Site 35.

Another version of vacuum enhanced recovery is AFVR, which has been used at Site 35 for the past year. A mobile AFVR unit applies a high vacuum (as much as 27inches of mercury) and high groundwater pumping rates to the monitoring well and pumps free product, groundwater, and soil vapor for a period up to 8 hours. If the vacuum is too high in the vadose zone, then some short-circuiting may occur through the grass surrounding the recovery well, with little vapor contribution from the areas beneath the pavement, which covers approximately 50 percent of the plume. In addition, in highly permeable formations, a very large volume of groundwater will be extracted compared to the amount of mobile LNAPL removed. Current data indicate that the AFVR at Site 35 has shown minimal success: 355 gallons of LNAPL have been recovered over 30 AFVR events, and LNAPL thickness measurements have not decreased significantly within the recovery well. Therefore, AFVR is not considered an applicable technology at Site 35.

For Site 35, VER would include installing 27 6-inch diameter extraction wells with 25-ft capture radius. (With an impermeable barrier covering the ground, a much greater capture radius may be expected, resulting in fewer VER wells.) A combined free product skimming pump and water table depression pump would be installed in each well. Figure 4-2 shows the estimated location of the 27 VER wells within the assumed LNAPL plume at Site 35.

Extracted groundwater would be pumped to a holding tank and transported daily to a groundwater treatment system located on the main side of Camp Lejeune. Alternative methods to be considered would be to install an onsite treatment system, and to discharge the treated groundwater into the sanitary sewer system. Extracted product would be stored on site and routinely removed for reprocessing.

SVE would be performed at each recovery well via a connection near the top of the recovery well casing. The recovery wells will be manifolded to a single header that will be connected to blowers installed on site. VOCs in the recovered vapor will be removed by carbon adsorption before the vapor is discharged to the atmosphere. To allow for continuing operation behind Building G480, all piping would be placed below grade. Portions of the fence surrounding Building G480 would be temporarily removed and replaced after system installation.

Advantages of Vacuum Enhanced Recovery at Site 35

- It is an in-situ technology with minor surface disturbance and disruption of site operations.
- Can provide hydraulic control of offsite groundwater and LNAPL migration
- Soil vapor extraction removes vadose zone LNAPL and encourages air flow for biological degradation.

Limits of Vacuum Enhanced Recovery at Site 35

- Off-gas treatment for soil vapor would be needed.

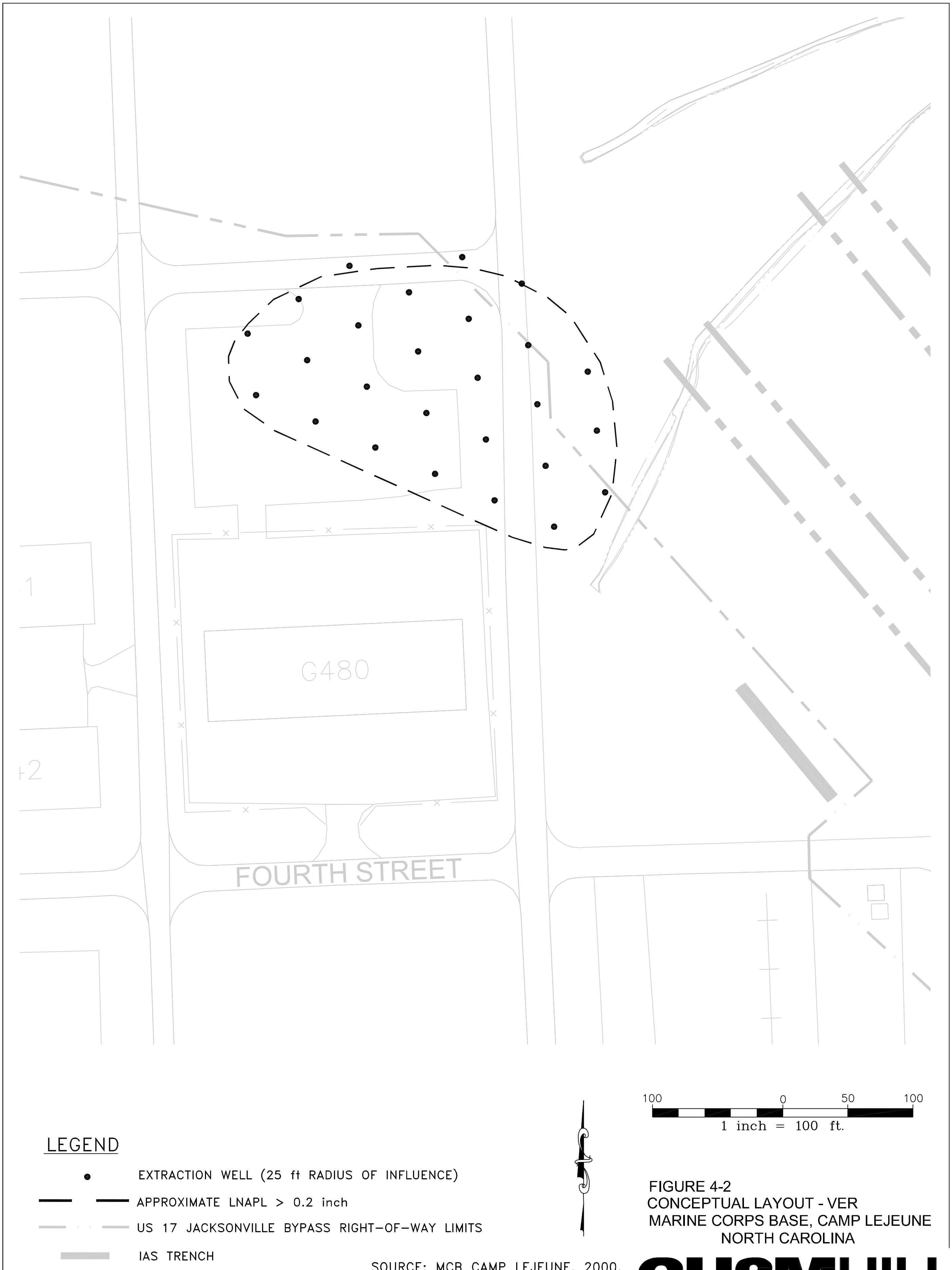

FIGURE 4-2
CONCEPTUAL LAYOUT - VER
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

CH2MHILL

EBL\NavyClean\CLEAN 2\CTO 130\EECA\Figures\FIG4-2_CONCEPT.DWG

- High permeability sand could increase the volume of groundwater pumped and needing offsite treatment.
- LNAPL in the lower portion of smear zone below the water table may remain in place.

Implementation Concerns

- Groundwater collection, transport, and treatment would be an ongoing cost to this remediation system.
- F Street traffic would be rerouted during well installation. It is anticipated that at least one recovery well would need to be placed within the pavement or on the east side of F Street northeast of Building G480 to capture LNAPL before it reaches the drainage ditch. Conduit for well operation and piping for groundwater, LNAPL, and SVE recovery streams would be placed below F Street pavement and below the paved area near Building G480.
- Disruption of operations outside of G480 may occur during system installation.

5.0 Detailed Analysis of Remedial Action Alternatives

The alternatives analysis uses the three main evaluation criteria of effectiveness, implementability, and cost, in accordance with the *U.S. EPA's Guidance on Conducting Non-Time-Critical Removal Actions Under CERCLA* (USEPA, 1993). Each evaluation criterion is described in Table 5-1. Appendix A provides reference information used to develop the cost estimates for the three alternatives.

TABLE 5-1
Evaluation Criteria; Site 35, Camp Lejeune

Effectiveness	
Protection of human health and the environment	The assessment describes how the action achieves and maintains protection of human health and the environment and achieves site-specific objectives both during and after implementation.
Compliance with ARARs	An alternative is assessed in terms of its compliance with ARARs, or if a waiver is required, how it is justified.
Short-term effectiveness	An action is assessed in terms of its effectiveness in protecting human health and the environment during the construction and implementation of a remedy before response action objectives have been met. The duration of time until the response objectives are met is also factored into this criterion.
Long-term effectiveness and permanence	An action is assessed in terms of its long-term effectiveness in maintaining protection of human health and the environment after response action objectives have been met. The magnitude of residual risk and adequacy and reliability of post-removal site controls are taken into consideration.
Reduction of toxicity, mobility or volume through treatment	An action is assessed in terms of anticipated performance of the specific treatment technologies it employs. Factors such as volume of materials destroyed or treated, the degree of expected reductions, the degree to which treatment is irreversible, and the type and quantity of remaining residuals are taken into consideration.
Implementability	
Technical feasibility	The ability of the technology to implement the remedy is evaluated.
Administrative feasibility	The administrative feasibility factor evaluates requirements for permits, zoning variances, impacts on adjoining property, and the ability to impose institutional controls.
Availability of services and materials	The availability of offsite treatment, storage, and disposal capacity, personnel, services and materials, and other resources necessary to implement the alternative will be evaluated.
State and community acceptance	The acceptability of an alternative to the state agency and the community is evaluated.
Cost	
Direct and indirect capital costs	Includes costs for construction, equipment and materials, analytical services, engineering and design, and permit/licenses.
Operation and maintenance costs	Includes ongoing monitoring and maintenance for a specific period.

5.1 Effectiveness

As explained in Section 3, the RAOs for Site 35 are:

- Prevent or minimize LNAPL migration to the surficial aquifer and to drainage ways feeding Brinson Creek.
- Remove LNAPL as a source of groundwater contamination
- Reduce exposure and risk to human health and ecological receptors.

5.1.1 Protection of Human Health and the Environment

The three options presented all meet RAOs for the site. Each is suitable for bulk LNAPL removal from the subsurface and reduction of risk to human and ecological receptors. Option two (excavation and soil disposal) meets RAOs by physically removing media containing LNAPL. Options one and three (air sparging with SVE, and VER), meet RAOs by insitu physical extraction of the LNAPL mass without significant surface disturbance.

For Options one (air sparging) and three (VER), in order to improve vapor capture and mitigate the possible risk of fugitive vapor migration, it may be necessary to install a cover, such as asphalt or a soil-covered geo-synthetic liner, over the existing grassy areas of the site. Vapor control using Option two (excavation) would be very difficult.

5.1.2 Compliance with ARARs and Other Criteria, Advisories, and Guidance

The following list of applicable or relevant or appropriate requirements (ARARs) was developed based on the scope of work expected for potential LNAPL removal actions being evaluated in this EE/CA. All options considered comply with these ARARs.

- Applicable state and federal guidelines for air, surface water, and/or sewer discharge associated with the collection and treatment of soil vapor and impacted groundwater will be complied with, in accordance with NCDENR requirements.
- Materials found to be characterized as a hazardous waste, if any, will be properly managed, stored, manifested, and shipped offsite in accordance with 40 CFR 261 - 268.
- Applicable Occupational Safety and Health Administration (OSHA) health and safety regulations will be followed wherever removal actions are deemed to be necessary. Workers performing the removal actions will be properly trained and under appropriate

medical supervision. Appropriate personal protective equipment (PPE) will be used and appropriate safe work practices will be followed.

- The objective of interim source removal actions will be abatement of LNAPL to the maximum extent possible, in accordance with state guidelines. The dissolved phased contamination will be addressed later. Accordingly, preliminary remediation goals (PRGs) for groundwater, such as NCDENR 2L standards, are not applicable.

5.1.3 Long-Term Effectiveness and Permanence

The three options consist of source removal technologies, which are expected to be permanent LNAPL treatment remedies at Site 35. In general, sparging with SVE is expected to more easily remove the lighter fractions of the LNAPL, with a longer time frame needed for biological degradation of the denser fractions. However, the denser fractions are less soluble, and do not pose as great a risk to groundwater. For Site 35, sparging would be expected to have limited success, due to the intermittent silt and clay seams preventing air flow from treating the LNAPL.

Excavation of the LNAPL saturated soil is a more complete removal technology.. In addition, excavation has the advantage in that it would provide visual evidence of the areal extent of LNAPL, which is currently only estimated. For the other removal options, zones of contamination may be inadvertently missed because of the uncertainty of the LNAPL extent.

5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

This criterion relates to the preference in the CERCLA program for alternatives that include treatment. All three options presented are treatment options designed to reduce the toxicity, mobility, and volume of LNAPL at the site through extraction, mass transfer, and above ground vapor treatment. LNAPL removal is anticipated to be greater for Option 2, excavation, and least for Option 1, air sparging.

5.1.5 Short-Term Effectiveness

Options 1 (Air Sparging with SVE) and 3 (VER) are in situ technologies that are protective of human health and the environment during their construction and operation. Waste streams that are produced (LNAPL, groundwater, and VOC vapors) can be easily managed for minimal exposure. However, the time frame expected in completing the remediation to the extent practicable is relatively long (up to 3 years for VER and 2 years for air sparging).

With Option 2, Excavation, the vapor exposure to workers and bystanders is relatively high upon uncovering and managing the LNAPL and LNAPL saturated soil. However, the LNAPL at Site 35 is primarily in the diesel range, with fewer VOCs than a gasoline plume. In addition, there is an inherent safety concern to the public and workers during excavation and in leaving an open excavation during non-working hours. However, the time frame for completing the excavation is approximately one month, short compared to the in situ remedial options considered.

5.2 Implementability

Implementability consists of technical feasibility, administrative feasibility, availability of services and materials, and state and community acceptance.

5.2.1 Technical Feasibility

The three options have been selected based on their feasibility at Site 35. The primary concern associated with the options presented is ability to recover LNAPL from the smear zone.

Option 1, air sparging with SVE, is marginally suitable for the site, given the multiple silt and clay lenses within the aquifer. Horizontal sparge wells could be feasible within the 10 to 12-ft surficial aquifer, unless the silt beneath the LNAPL-bearing seams prevent access to the sparged air. Vertical sparge wells may be more applicable with this shallow aquifer thickness. Both sparge well variations have low technical feasibility at this site. For this reason, Option 1 is removed from further consideration as a viable alternative.

The excavation alternative (Option 2) physically removes soil in the vadose zone and near the LNAPL/groundwater table, and if groundwater were pumped using well points or other dewatering techniques, the lower smear zone LNAPL could also be removed.

VER (Option 3) would not remove much of the residual LNAPL, and addresses mainly the mobile fraction. However, with bioventing/SVE, the immobile fraction would be subject to enhanced biological degradation. VER may be the most feasible of the available hydraulic fluid recovery technologies. If selected for further evaluation, pilot testing for VER is recommended to verify the groundwater and vapor extraction capture zone, estimate rates of groundwater and vapor extraction, and determine optimum design vacuums/flow rates.

5.2.2 Administrative Feasibility

Administrative feasibility pertains to the requirements for permits, impacts on adjoining property, and other factors which may affect the site usage.

For the present estimate of LNAPL extent, traffic would need to be controlled on F Street for all three options. The traffic disruption may last less than one week for the options involving well and SVE installation. For the excavation option, the road would be closed for the estimated 2 month duration of construction. Similar issues regarding use of land pertain to the plume area north of Building G480. Additionally, administrative restrictions would prevent excavating adjacent to the US 17 Bypass.

For Option 1 and 3, permits may be required for air emissions from the SVE system. Disposal permits for free product collected from the VER and from the excavation would be obtained, along with permits for landfilling the Option 2 excavated soil.

5.2.3 Availability of Services and Materials

The proposed options all use readily available equipment, material, and services for their implementation.

5.2.4 State and Community Acceptance

State and community acceptance will be evaluated continually and the assessment revised accordingly as members and representatives of the State and community provide comments on the remedial action process. These comments will be taken into account in the selection of the remedial action to be implemented.

5.3 Cost

Table 5-2 summarizes the direct and indirect capital costs, as well as long-term operation and maintenance costs (as applicable) for alternatives 2 and 3. Costs for excavation and VER are presented as Options 2 and 3.

Table 5-2

Preliminary Budget Level Cost Estimates for Technology Options; Site 35, Camp Lejeune

Option	Capital Costs	Total Operational Costs	Total Cost	Project Life	Present Worth
Option 2 – Excavation	$1,590,000	$95,000	$1,680,000	< 1 year	$1,680,000
Option 3 – VER	$902,000	$546,000	$1,450,000	3 years	$1,420,000

Notes:

Present worth is based on a 3.2% discount rate. Present worth for Option 2 includes a second year of groundwater monitoring.

For this EE/CA, the LNAPL area is assumed to be as shown on Figure 4-1. Costs to remove LNAPL to the extent practicable from the assumed area are detailed in Appendix A. Direct capital costs pertain to construction, equipment, materials, and subcontractor labor (including overhead and profit). Direct capital costs were estimated based on quotations provided by the vendor and/or estimates by CH2M Hill staff experienced with the technology of concern. Indirect capital costs pertain to design, legal fees and permits, and include contingency/royalty fees, as applicable. Operational costs include professional services, consumables, laboratory fees, etc. These costs are generally used to calculate the "present worth" of the entire project, assuming a discount factor.

For Option 2, the life of the project is expected to be less than two months. However, a second year of groundwater monitoring was included as an O&M cost. For Option 2, the present worth was calculated assuming a two-year project life, with a 3.2% discount rate. Option 3 assumed a 3-year project life. Follow-on remedial actions, including long-term monitoring, to address dissolved phase contamination are not included in the estimates.

All costs presented herein are preliminary estimates, intended for comparison purposes only. Actual costs will depend on the effectiveness of the extraction system, the radius of influence, and the actual size of the area to be remediated. The estimates are not intended to function as guarantees of fixed costs for field implementation or operation. Appendix A contains additional information used to develop these costs.

5.4 Summary of Evaluation

Table 5-3 summarizes the evaluation for each technology.

TABLE 5-3

Summary of Alternatives Comparison; Site 35, Camp Lejeune

Evaluation Criteria	Alternative 1 Air Sparging w/SVE	Alternative 2 Excavation	Alternative 3 Vacuum Enhanced Recovery
EFFECTIVENESS			
Overall Protection of Human Health and the Environment	Technology meets RAOs at sandy sites.	Meets RAOs.	Partially meets RAOs.
Compliance with ARARs	Complies with ARARs. May require air permit.	Complies with ARARs. Contaminated soil would be disposed in a permitted facility; contaminated groundwater would be treated.	Complies with ARARs. Contaminated groundwater would be treated. May require air permit.
Long-term effectiveness and permanence	Technology effectiveness dependent on stratigraphy; expected to not be effective at Site 35.	Most complete removal technology; can visually identify LNAPL during implementation.	Partially complete removal technology; not expected to remove smear zone LNAPL.
Reduction of Toxicity, Mobility or Volume through Treatment	Reduces toxicity, mobility and volume of LNAPL through vapor extraction and treatment, and through biodegradation.	Reduces toxicity, mobility and volume of LNAPL through removal.	Reduces toxicity, mobility and volume of LNAPL through removal and vapor treatment.
Short-Term Effectiveness	In situ removal / destruction technology. Air emissions controlled through treatment.	Removal technology; treatment / disposal offsite. Liquid and solid waste streams easily managed. Worker concerns are air emissions and excavation safety issues. Shortest time to completion.	In situ removal technology. Air emissions controlled through treatment. Liquid waste stream easily managed. Longest time to completion.
IMPLEMENTABILITY			
Technical Feasibility	Technical restraints are shallow aquifer thickness, clay and silt stringers, and low permeability surficial soil for SVE.	No technical restraints.	Technical restraints are ability to remove smear zone LNAPL, and low permeability surficial soil for SVE .
Administrative Feasibility	Traffic management on F Street would be required during well installation. Permits may be required for air emissions.	Traffic rerouting during construction period, road reconstruction required.	Traffic management on F Street would be required during well installation. Permits may be required for air emissions.
Availability of Services and Materials	Services and materials are available.	Services and materials are available.	Services and materials are available.
State and Community Acceptance	This alternative is likely to be acceptable to the community.	This alternative is likely to be acceptable to the community.	This alternative is likely to be acceptable to the community.
COST			
Capital Cost (Direct and Indirect)	No cost prepared	$1,590,000	$902,000
Total O&M Cost	No cost prepared	$95,000 (includes 2 years monitoring)	$546,000 (includes 3 years monitoring)
Present Worth	No cost prepared	$1,680,000	$1,420,000

6.0 Comparative Analysis of Remedial Action Alternatives

The relative effectiveness of each of the options was compared using the three criteria summarized in Section 5: effectiveness, implementability, and cost.

6.1 Effectiveness of Alternatives

Of the three options, air sparging (Option 1) may be expected to be the least effective at treating the LNAPL at Site 35. The sparged air may be expected to develop preferential pathways upon encounter of silt and clay seams, and may not contact LNAPL-saturated sand seams. Therefore, Option 1 is no longer considered for Site 35.

Total removal (Option 2 – Excavation) is achievable with stable soils; some smear zone LNAPL below the water table could remain. However, excavation has the advantage of visually verifying the extent of contamination. Option 2 has the shortest schedule for completion, but the highest safety concerns for air emissions and general excavation safety issues. In addition, potentially contaminated soils adjacent to and beneath the US 17 Bypass would remain in place to provide roadway stability.

In general, Option 3 – VER could be expected to remove a lower percentage of LNAPL than excavation, with the remainder in the smear zone. However, given the stratified nature of the site, this might be the most effective method at accessing LNAPL for treatment or removal, short of excavation. A large volume of groundwater would be generated with this technology; after separation and treatment [bag filter and granulated activated carbon (GAC), or activated clay then GAC], it could be discharged to the sanitary sewer system for treatment.

To summarize, in terms of the predictability and assurance of effectiveness, removal by excavation is considered to be the first choice, followed by VER.

6.2 Implementability of Alternatives

Option 3 – VER requires the use of relatively standard equipment and materials, which may involve relatively high mobilization, set-up, O&M, and demobilization costs. These options also include vapor capture and treatment using soil vapor extraction, which may be slightly difficult at Site 35, considering the low permeability of the vadose zone.

Option 2 – Excavation, is relatively simple and does not involve specialized equipment. However, the safety issues inherent in an open excavation and lack of air emission control cause this option to be less desirable. In addition, Option 2 would include loss of use of the parking area north of Building G480 and F Street during the 2-month implementation period. Option 3 would cause a minimal period for site down time.

6.3 Cost of Alternatives

Table 5-2 compares costs for treatment of the LNAPL plume assumed to be the 1-acre estimated size shown on Figures 4-1 and 4-2. These costs may be adjusted after a more definitive delineation of the LNAPL extent. Costs listed in Table 5-2 also include the installation of four monitoring wells (plus a replacement well for 35-MW67A for Option 2), and monitoring of these wells for a two-year or three-year period.

The capital cost for Option 2 - Excavation is the higher of the options costed, followed by the VER system installation. The number and cost of VER wells may be reduced after the pilot test determines the capture zone beneath an impermeable barrier such as asphalt pavement. O&M costs for Option 2 consist of groundwater monitoring only. O&M costs for Option 3 are relatively high, and may be expected to continue for 3 or more years.

6.4 Recommended Alternative

The plume located approximately 100 ft north of Building G480 should be removed to the extent possible, primarily to reduce migration to the drainage pathways leading to Brinson Creek. The groundwater beneath the plume has VOC concentrations significantly less than the GCL. Free product thickness greater than 0.25 inch should be removed, following the UST guidelines. Due to technology limitations, some LNAPL or petroleum hydrocarbon concentrations in groundwater higher than the 2L standards may remain at some locations.

VER is the recommended technology, because it can be implemented within the US 17 Bypass right-of-way, and because its cost is relatively comparable to excavation. The cost of either alternative is dependent on the actual size of the area to be remediated, and for VER on the site-specific design parameters needed to implement the technology. Plume delineation to the north and east, along with pilot testing of VER, is recommended.

The results of the pilot test and completed delineation should be used to verify the cost comparison and relative ranking presented in Table 6-1 below. The VER may be phased such that the thickest areas are addressed first, and the wells should be operated only to the extent practicable. The system should be re-evaluated after two years of operation, or sooner if production drops off.

TABLE 6-1
Relative Ranking of Remedial Alternatives; Site 35, Camp Lejeune

Option	Effectiveness	Implementability	Cost	Total
Air Sparging – w/SVE	5	2	NR	NR
Excavation	2	3	4	9
VER	3	2	3	8

Note: This table represents a comparison ranking of the technologies and the factors have equal weighting. The lowest score is the recommended technology.
NR indicates parameter Not Ranked.

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Appendix A

Detailed Cost Estimate

REMEDIATION ALTERNATIVE COST ESTIMATE SUMMARY

SITE 35 LNAPL Removal EE/CA

Alternative	Duration	**Total Present Worth**
Excavation	2 *	$1,678,603
VER	3	$1,417,002

* 2nd year for monitoring only

COST ESTIMATE FOR LNAPL EXCAVATION

SITE 35 LNAPL EE/CA, Camp Lejeune

CAPITAL COSTS					
Description	Qty	Unit	Unit Cost	Cost	Comments
Determining LNAPL Extent					
Mobilization/Demobilization	1	LS	$3,000.00	$3,000.00	
MIP, labor and subcontractor, expenses	3	days	$4,500.00	$13,500.00	
Submittals, Work Plan, HASP, Subcontracting	1	LS	$6,500.00	$6,500.00	
Report, Project Management	1	LS	$12,000.00	$12,000.00	
Subtotal *LNAPL Extent*				$35,000.00	
Mobilization/Demobilization- Subcontractor					
Mobilization/Demobilization	1	LS	$10,000.00	$10,000.00	
Pre and Post Construction Survey	1	LS	$15,000.00	$15,000.00	Engineer's Estimate
NPDES Permit Procurement	1	LS	$7,000.00	$7,000.00	
Submittals, Work Plan, HASP	1	LS	$20,000.00	$20,000.00	
Subtotal Mobilization/Demobilization				$52,000.00	
Construction - Subcontractor					
Utility Location	1	LS	$5,000.00	$5,000.00	Engineer's Estimate
Utility Relocation	1	LS	$12,000.00	$12,000.00	Engineer's Estimate
Removal and Disposal of Fence	300	LF	$7.50	$2,250.00	
Remove and Stockpile Clean Overburden	11000	CY	$7.00	$77,000.00	
Construct dewatering/storage pads	2	Each	$7,000.00	$14,000.00	
Dewatering and pumping operations	1	LS	$15,000.00	$15,000.00	
Excavate and stockpile contaminated smear zone material	7000	CY	$7.00	$49,000.00	
Load contaminated material (1.3 fluff factor)	9100	CY	$3.00	$27,300.00	
Transportation and disposal of contaminated material (2600 lbs/yd3)	11800	Tons	$45.00	$531,000.00	
Manage floating product (adsorbent pads)	1	LS	$10,000.00	$10,000.00	
Backfill with No. 57 stone (7000 yd3 @ 2350 lb/yd3)	8225	Tons	$20.00	$164,500.00	
Backfill and compact stockpiled clean overburden	11000	CY	$4.00	$44,000.00	
Hydroseeding	10000	SF	$0.06	$600.00	
Replace Fence	300	LF	$15.00	$4,500.00	
Repave street and parking	24300	SF	$1.50	$36,450.00	
Monitoring Well Installation Subcontractor	5	wells	$2,200.00	$11,000.00	Conventional monitoring wells + soil disposal
Miscellaneous restoration	1	LS	$5,000.00	$5,000.00	
Subtotal *Construction - Subcontractor*				$1,008,600.00	
Mark-Up on Direct Costs			10%	$100,860.00	
Contingency			10%	$100,860.00	
Total *Construction - Subcontractor*				$1,210,320.00	

COST ESTIMATE FOR LNAPL EXCAVATION

SITE 35 LNAPL EE/CA, Camp Lejeune

Construction - CH2M Hill			
Project Management	3%	$36,309.60	
Remedial Design	2%	$24,206.40	
Construction Management and Procurement	4%	$48,412.80	
Overhead and Profit	15%	$181,548.00	
Subtotal *Construction - CH2M HILL*		$290,476.80	
TOTAL CAPITAL COST		**$1,587,797**	

YEAR 1 OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Groundwater Sampling (Quarterly)					
Sample Labor, Travel, Perdiem	4	events	$4,800.00	$19,200.00	
Sample Analysis - Subcontractor	32	sample	$145.00	$4,640.00	8 samples/round BTEX and TPH
Sampling Supplies	4	rounds	$150.00	$600.00	
GW Sampling Equipment Rental	4	rounds	$600.00	$2,400.00	
Subtotal *Groundwater Sampling*				$26,840.00	
Reporting (Construction Completion Report and Semiannual Reports)					
Reporting Labor (annual status report)	1	rpt	$5,200.00	$5,200.00	
Reporting Labor (construction completion report)	1	rpt	$9,000.00	$9,000.00	
Subtotal *Reporting*				$14,200.00	
Subtotal				$41,040.00	
Contingency			10%	$4,104.00	
Project Management			10%	$4,104.00	
Technical Support			10%	$4,104.00	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST				**$53,352.00**	

SUBSEQUENT YEARS OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Groundwater Sampling (Quarterly)					
Sample Labor, Travel, Perdiem	4	events	$4,800.00	$19,200.00	
Sample Analysis - Subcontractor	32	samples	$145.00	$4,640.00	8 samples/round BTEX and TPH
Sampling Supplies	4	rounds	$150.00	$600.00	
GW Sampling Equipment Rental	4	rounds	$600.00	$2,400.00	
Subtotal *Groundwater Sampling*				$26,840.00	

COST ESTIMATE FOR LNAPL EXCAVATION

SITE 35 LNAPL EE/CA, Camp Lejeune

Reporting (Semiannual Reports)			
Reporting Labor	1 rpt	$5,200.00	$5,200.00
Subtotal *Reporting*			$5,200.00
Subtotal			$32,040.00
Contingency		10%	$3,204.00
Project Management		10%	$3,204.00
Technical Support		10%	$3,204.00
SUBSEQUENT YEARS OPERATIONS AND MAINTENANCE COST			**$41,652.00**

PRESENT WORTH ANALYSIS		
Number of Years of Operation =	2 years	
Effective Interest Rate =	3.2%	
		Present Worth
Capital Cost =	$1,587,797	$1,587,797
Year1 O&M Cost =	$53,352	$51,698
Subsequent Years O&M Cost =	$41,652	$39,109
TOTAL PRESENT WORTH COST		**$1,678,603**

COST ESTIMATE FOR VACUUM ENHANCED RECOVERY

SITE 35 LNAPL EE/CA, Camp Lejeune

CAPITAL COSTS

Description	Qty	Unit	Unit Cost	Cost	Comments
Determining LNAPL Extent					
Mobilization/Demobilization	1	LS	$3,000.00	$3,000.00	
MIP, labor and subcontractor, expenses	3	days	$4,500.00	$13,500.00	
Submittals, Work Plan, HASP, Subcontracting	1	LS	$6,500.00	$6,500.00	
Report, Project Management	1	LS	$12,000.00	$12,000.00	
Subtotal *LNAPL Extent*				$35,000.00	
VER Pilot Test					
One week pilot including mobilization, drilling four new wells, equipment rental, project management, groundwater and vapor sampling, analysis, data reduction, and report preparation	1	LS	$55,000.00	$55,000.00	Engineer's Estimate
Subtotal Mobilization/Demobilization				$55,000.00	
Mobilization/Demobilization- Subcontractor					
Mobilization/Demobilization	1	LS	$12,000.00	$12,000.00	
Pre and Post Construction Survey	1	LS	$7,500.00	$7,500.00	Engineer's Estimate
Submittals, Work Plan, HASP	1	LS	$20,000.00	$20,000.00	
Subtotal Mobilization/Demobilization				$39,500.00	
Construction - Subcontractor					
Utility Location	1	LS	$5,000.00	$5,000.00	Engineer's Estimate
Monitoring Well Installation Subcontractor	3	wells	$2,200.00	$6,600.00	Conventional monitoring wells + soil disposal
Recovery Well Installation Subcontractor	27	wells	$2,200.00	$59,400.00	Four inch diameter recovery wells + soil disposal
Installation of 24" Well Vaults/ Wellhead Connections	27	ea	$1,600.00	$43,200.00	Based on verbal estimate by ProTerra
Field Sawcut/Trenching/Piping/Manifolding/Backfill	1,450	LF	$50.00	$72,500.00	Engineer's Estimate
Disposal of soil from trenching activity	200	tons	$40.00	$8,000.00	Engineer's Estimate
Asphal paving of grass areas, including surface prep and gravel base course	22,000	sq ft	$1.50	$33,000.00	Engineer's Estimate
Trailer Mounted VER/Groundwater Treatment System 27 Leg Groundwater TF Recovery Manifold w/ Throttle Valves and Appurtenances, two 500 cfm Liquid Ring Pumps (exterior mount) Conrol Panel w/ Telemetry, 12' x 18' heated trailer	1	LS	$165,000.00	$165,000.00	Based on verbal estimate by Onion Equipment
Low profile air stripper and activated carbon treatment	1	LS	$25,000.00	$25,000.00	Engineer's Estimate
Concrete pad and awning to protect liquid ring pumps	1	LS	$7,500.00	$7,500.00	Engineer's Estimate
Remediation System Installation (incl delivery, set-up, instalaltion of liquid ring pumps, and one week of start-up assistance)	1	LS	$18,000.00	$18,000.00	Based on verbal estimate by ProTerra
General Electrical (480 V, 3ph, 400 A service and disconnect, rigid conduit for external equipment, permits, etc) and start-up assistance)	1	LS	$30,000.00	$30,000.00	Engineer's Estimate
Subtotal *Construction - Subcontractor*				$473,200.00	
Mark-Up on Direct Costs			10%	$47,320.00	
Contingency			10%	$47,320.00	
Total *Construction - Subcontractor*				$567,840.00	

COST ESTIMATE FOR VACUUM ENHANCED RECOVERY

SITE 35 LNAPL EE/CA, Camp Lejeune

Construction - CH2M Hill				
Project Management		5%	$28,392.00	
Remedial Design		8%	$45,427.20	
Construction Management and Procurement		8%	$45,427.20	
Overhead and Profit		15%	$85,176.00	
Subtotal *Construction - CH2M HILL*			$204,422.40	
TOTAL CAPITAL COST			**$901,762**	

YEAR 1 OPERATIONS AND MAINTENANCE

Item/Activity	Qty Unit	Unit Cost	Cost	Comments
Groundwater Sampling (Quarterly)				
Sample Labor, Travel, Perdiem	4 events	$4,800.00	$19,200.00	
Sample Analysis - Subcontractor	32 sample	$145.00	$4,640.00	8 samples/round BTEX and TPH
Sampling Supplies	4 round	$150.00	$600.00	
GW Sampling Equipment Rental	4 round	$600.00	$2,400.00	
Subtotal *Groundwater Sampling*			$26,840.00	
Reporting (Construction Completion Report and Semiannual Reports)				
Reporting Labor (semiannual reports)	2 rpts	$5,200.00	$10,400.00	
Reporting Labor (construction completion report)	1 rpt	$9,000.00	$9,000.00	
Subtotal *Reporting*			$19,400.00	
System Startup				
Labor	2 weeks	$7,200.00	$14,400.00	
Startup Equipment Rental	2 weeks	$300.00	$600.00	
Travel and Perdiem	2 weeks	$2,000.00	$4,000.00	
Subtotal *System Startup*			$19,000.00	
Routine System O&M				
Weekly O&M Labor + Travel (Subcontractor)	52 events	$750.00	$39,000.00	
Quarterly "Heavy" Maintenance	4 events	$2,800.00	$11,200.00	
O&M Supplies	1 LS	$5,000.00	$5,000.00	
Subtotal *Routine System O&M*			$55,200.00	
Consumeables				
Electrical usage ($0.075/kw-hr, 100 hp peak motor rating)	1 year	$48,946.00	$48,946.00	
Carbon usage (3200#/year)	3200 lbs	$1.85	$5,920.00	
Subtotal *Consumeables*			$54,866.00	
Subtotal			$175,306.00	
Contingency		10%	$17,530.60	
Project Management		10%	$17,530.60	
Technical Support		10%	$17,530.60	
TOTAL YEAR 1 OPERATIONS AND MAINTENANCE COST			**$227,897.80**	

COST ESTIMATE FOR VACUUM ENHANCED RECOVERY

SITE 35 LNAPL EE/CA, Camp Lejeune

SUBSEQUENT YEARS OPERATIONS AND MAINTENANCE

Item/Activity	Qty	Unit	Unit Cost	Cost	Comments
Groundwater Sampling (Annual)					
Sample Labor, Travel, Perdiem	1	event	$4,800.00	$4,800.00	
Sample Analysis - Subcontractor	32	sample	$145.00	$4,640.00	8 samples/round BTEX and TPH
Sampling Supplies	1	round	$150.00	$150.00	
GW Sampling Equipment Rental	1	round	$600.00	$600.00	
Subtotal *Groundwater Sampling*				$10,190.00	
Reporting (Semiannual Reports)					
Reporting Labor	1	rpt	$5,200.00	$5,200.00	
Subtotal *Reporting*				$5,200.00	
Routine System O&M					
Weekly O&M Labor + Travel (Subcontractor)	52	events	$750.00	$39,000.00	
Quarterly "Heavy" Maintenance	4	events	$2,800.00	$11,200.00	
O&M Supplies	1	LS	$5,000.00	$5,000.00	
Subtotal *Routine System O&M*				$55,200.00	
Consumeables					
Electrical usage ($0.075/kw-hr, 100 hp peak motor rating)	1	year	$48,946.00	$48,946.00	
Carbon usage (1600#/year)	1600	lbs	$1.85	$2,960.00	
Subtotal *Consumeables*				$51,906.00	
Subtotal				$122,496.00	
Contingency			10%	$12,249.60	
Project Management			10%	$12,249.60	
Technical Support			10%	$12,249.60	
SUBSEQUENT YEARS OPERATIONS AND MAINTENANCE COST				**$159,244.80**	

PRESENT WORTH ANALYSIS

Number of Years of Operation =	3	years	
Effective Interest Rate =	3.2%		
			Present Worth
Capital Cost =	$901,762		$901,762
Year1 O&M Cost =	$227,898		$220,831
Subsequent Years O&M Cost =	$159,245		$294,408
TOTAL PRESENT WORTH COST			**$1,417,002**