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FINAL

Pilot Study Work Plan
Site 82, Operable Unit No. 2

Marine Corps Base Camp Lejeune
Jacksonville, North Carolina

NAVFAC
Naval Facilities Engineering Command

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Mid Atlantic Division
Norfolk, Virginia

Contract No.
N62470-02-D-3052
CTO-0105
Navy Clean III

January 2007

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CH2MHILL

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Executive Summary

This Work Plan describes the objectives and activities for a pilot study that will be conducted at Operable Unit (OU) No. 2, Site 82, Marine Corps Base (MCB) Camp Lejeune, Jacksonville, North Carolina. Groundwater at Site 82 is impacted by chlorinated volatile organic compounds (cVOCs). The purpose of this pilot study is to evaluate the performance and effectiveness of injection of a substrate blend (emulsified soybean oil and ethyl lactate) to stimulate enhanced reductive dechlorination (ERD) of chlorinated solvent impacts in groundwater. As documented in the January 2005 Technical Memorandum entitled *Review of Groundwater Remediation Activities, Operable Unit 2 (Site 82)*, the current pump and treat system is not considered to be a suitable long-term treatment approach, or a potential closure strategy for this Site. Site remediation via ERD has the potential to treat the remaining chlorinated solvent contamination in a timely manner and effectively move the site toward closure.

The target area for the pilot study was selected based on the area of highest cVOC concentrations, and will utilize an existing recovery well (6-DRW01) as the injection point for the selected ERD substrate blend. The target depth is 80 to 100 feet bgs, which is the predominant depth with the greatest extent of cVOC contamination. The proposed injection well (6-DRW01) contains the highest concentrations of cVOCs, and accounts for only 10% to 15% of the total groundwater flow into the existing groundwater pump and treat system. As a result, temporary deactivation of this well is not expected to have a significant effect on the plume containment aspect of remediation system performance. With the exception of 6-DRW01, the current pump and treat system will remain in operation during the pilot study.

The selected remedial technology, injection of an electron donor substrate in order to stimulate ERD is a potentially effective approach for remediation of dissolved chlorinated solvent contamination at Site 82. The goal of the pilot study is to assess the degree to which reductive dechlorination can be stimulated by addition of a suitable electron donor. To accomplish this goal, a mixture of emulsified oil and ethyl lactate will be injected**.** A field microcosm study will also be conducted in conjunction with injection activities, to determine whether a natural bacterial consortium is present that can achieve complete dechlorination of the VOCs. The scope of work for the pilot study consists of the following:

- Temporary deactivation of the submersible pump in recovery well 6-DRW01 to allow anaerobic conditions to develop
- Installation and development of six new monitoring wells
- Collection of baseline groundwater samples
- Completion of a field microcosm study
- Injection of substrate for field-scale pilot study
- Performance monitoring
- Report preparation

The monitoring plan for the pilot study at Site 82 will address groundwater from baseline to six months following injection (conducted at two month intervals). A pilot study report will be prepared after completion of the study to summarize installation, implementation, and monitoring results.

The effectiveness of the pilot study will be evaluated according to the following criteria:

1. Reductions in the concentration of the parent VOC(s) [e.g., tetrachloroethene (PCE) or TCE] and increases in the ratio of daughter products to parent products. Pre-and post-treatment groundwater samples will be used to make this determination.
2. Changes in geochemical parameters that indicate a shift towards a more reducing environment (such as the development of iron-reducing, sulfate-reducing, or methanogenic conditions).

Depending on the results of the pilot study and subsequent evaluation of the technology per the above criteria, injection of the substrate blend may be used on a larger scale to address dissolved groundwater contamination at Site 82. A decision to use the technology in other areas of the Site will be subject to the approval of the Partnering Team.

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Acronyms and Abbreviations

µg/L	microgram per liter
ARAR	Applicable or Relevant and Appropriate Requirement
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-Dichloroethene
cVOC	Chlorinated Volatile Organic Compound
DO	Dissolved Oxygen
EMR	Experience Modification Rate
EOS®	Edible Oil Substrate
ERD	Enhanced Reductive Dechlorination
ft/day	feet per day
ft/ft	feet per foot
FTL	Field Team Leader
gpd	gallons per day
gpm	gallons per minute
HSP	Health and Safety Plan
IDW	Investigation-Derived Waste
L.G.	Licensed Geologist
LTM	Long-Term Monitoring
MCB	Marine Corps Base
MSDS	Material Safety Data Sheet
MS/MSD	Matrix Spike/Matrix Spike Duplicate
NAIP	Natural Attenuation Indicator Parameter
NAVFAC	Naval Facilities Engineering Command
NCDENR	North Carolina Department of Environment and Natural Resources
NCGWQS	North Carolina Groundwater Quality Standard
ORP	Oxidation Reduction Potential
OSHA	Occupational Safety and Health Administration
OU	Operable Unit
PCE	Tetrachloroethene
P.E.	Professional Engineer
PHSM	Project Health and Safety Manager

PM	Project Manager
PPE	Personal Protective Equipment
psi	pounds per square inch
P&T	Pump and Treat
PVC	Polyvinyl Chloride
QA/QC	Quality Assurance/ Quality Control
QAPP	Quality Assurance Project Plan
qPCR	Quantitative Polymerase Chain Reaction
RAC	Remedial Action Contractor
RI	Remedial Investigation
ROI	Radius of Influence
SAP	Sampling and Analysis Plan
SHSP	Site-Specific Health and Safety Plan
SOP	Standard Operating Procedure
SOW	Scope of Work
SSC	Site Safety Coordinator
TCE	Trichloroethene
TOC	Total Organic Carbon
UIC	Underground Injection Control
USGS	United States Geological Survey
USEPA	United States Environmental Protection Agency
UTM	Universal Transverse Mercator
VOC	Volatile Organic Compound

1. Introduction

This Work Plan describes the objectives and activities for a pilot study that will be conducted at Operable Unit (OU) No. 2, Site 82, Marine Corps Base (MCB) Camp Lejeune, Jacksonville, North Carolina. Groundwater at Site 82 is impacted by chlorinated volatile organic compounds (cVOCs). The purpose of this document is to serve as the work plan for the pilot study that will evaluate the performance and effectiveness of injection of a substrate blend (emulsified soybean oil and ethyl lactate) to stimulate enhanced reductive dechlorination (ERD) of chlorinated solvent impacts in groundwater. As documented in the January 2005 Technical Memorandum entitled *Review of Groundwater Remediation Activities, Operable Unit 2 (Site 82)*, the current pump and treat system is not considered to be a suitable long-term treatment approach, or a potential closure strategy for this Site. Site remediation via ERD has the potential to treat the remaining chlorinated solvent contamination in a timely manner and effectively move the site toward closure.

This Work Plan is organized as follows:

- **Introduction (Section 1) –** Presents an overview of the project and work plan.
- **Site Background (Section 2) –** Presents the Site background, conditions, and the pilot study area information.
- **Pilot Study Design (Section 3) –** Presents an overview of pilot study objectives, goals, and conceptual technical approach.
- **Pilot Study Implementation (Section 4) –** Discusses how the pilot study will be conducted.
- **Health and Safety Considerations (Section 5)** - Outlines issues to be presented in the Site Health and Safety Plan for the project.
- **Site Activity Considerations (Section 6)** - Outlines the site-specific requirements and constraints applicable during project implementation.
- **Submittal Requests (Section 7)** - Outlines submittals that will be requested from prospective bidders to complete the scope of work (SOW).
- **Reporting (Section 8)** - Provides the reporting that will occur for the project.
- **Schedule (Section 9)** - Provides the project schedule.
- **References (Section 10)** - Provides the references used in this document.

Figures accompanying the main text of this plan are at the end of each section. This Work Plan is to be used in conjunction with the Master Project Plans (CH2M HILL, 2005b), including the Master Sampling and Analysis Plan (SAP), Master Quality Assurance Project Plan (QAPP), and Master Health and Safety Plan (HSP). A site-specific health and safety plan (SHSP) for this pilot study will developed for this effort and issued separately.

2. Site Background

Base-wide background information including location, geology, hydrogeology, topography and meteorology is included in the Master Project Plans (CH2M HILL, 2005b), and is not repeated in this document. Information concerning contaminant concentrations, plume distribution, and subsurface geology/hydrogeology at Site 82 is documented in the *Final Remedial Investigation Report for Operable Unit No. 2 (Sites 6, 9, and 82), MCB Camp Lejeune, North Carolina* (Baker, 1993) and the *Annual Long-Term Monitoring Report, Operable Unit No. 2 – Sites 6 & 82, Marine Corps Base Camp Lejeune, North Carolina* (CH2M HILL, 2006) and is summarized below.

2.1 Site Description

OU 2, which includes Site 6 and Site 82, is located in the east-central portion of MCB Camp Lejeune ('Mainside'), approximately two miles east of the New River and two miles south of State Route 24, as shown on **Figure 2-1.** Site 82, the Piney Green Road VOC Site, encompasses the wooded area between Lot 203 and Wallace Creek and is bounded by Holcomb Boulevard on the west, Wallace Creek on the north, Piney Green Road on the east, and Site 6 on the south. A treatment plant building which houses the existing pump and treat remediation system is located southeast of the Site. Site 82 primarily consists of woodlands and a large open field with marshy areas along the northern edge, bordering Wallace Creek. Railroad tracks cross the western edge of the Site in a northwest to southeast orientation. Site 82 is predominantly flat, with a sharp drop-off in elevation near the banks of Wallace Creek. **Figure 2-2** depicts a site plan for Site 82.

Site 82 was identified in 1986 during an assessment of Site 6. No organized disposal operations were documented from the Site; however, Site 82 was randomly littered with debris. It appears Site 82 was used for disposal of miscellaneous debris from Lot 203, located southeast of Site 82 (Baker, 1993). There are no historical records indicating disposal of volatile organic compounds (VOCs) or solvents. However, chlorinated solvents have been found in the groundwater as deep as 240 feet below ground surface (bgs). A total of nineteen VOCs, including tetrachloroethene (PCE) and trichloroethene (TCE) have been reported. A groundwater pump and treat (P&T) system has been in operation at the Site since July 1996.

2.2 Site Geology and Hydrogeology

The Remedial Investigation (RI) report (Baker, 1993) and the 2005 Long-Term Monitoring (LTM) report (CH2M HILL, 2006) provides details regarding site-specific geology and hydrogeology at Site 82. The following sections briefly summarize the information.

2.2.1 Site Geology

The uppermost horizon is Quaternary age "undifferentiated" deposits composed of sand, silt, and clay. In several areas the uppermost five feet of soil have been reworked over the years and contain much fill material.

Beneath the "undifferentiated" deposits is the River Bend Formation. The River Bend Formation is composed of fine-to medium sand containing varying amounts of silt and clay and also containing large amounts of shell and fossil fragments. The upper silty sand units comprising the Quaternary deposits and River Bend Formation range in thickness from 40 feet thick in the southern portion of the Site to 140 feet thick in the northern portion. Within this unit, discontinuous clay lenses varying in thickness from two to ten feet and limestone lenses varying from three to five feet are interbedded within the sands. The proposed injection zone, extending from 80 to 100 feet bgs, predominantly consists of medium-grained, poorly graded, greenish gray silty sands with shell fragments. Within this zone, the percentage of shell material was noted to increase with depth.

Underlying the River Bend Formation is the Castle Hayne Formation which consists of a limestone unit varying in thickness from five feet in the southern portion of the Site to 80 feet in the northern portion of the Site. Silty sands underlie the limestone unit to an estimated depth of 310 feet.

2.2.2 Site Hydrogeology

The surficial aquifer occurs within the Quaternary deposits and the River Bend Formation. Groundwater levels measured in September 2005 as part of the LTM program indicate groundwater flow in the surficial aquifer is northwest towards Wallace Creek and groundwater flow in the Castle Hayne aquifer is west-southwest towards the New River. Groundwater elevation data and approximate flow direction for the surficial and Castle Hayne aquifers are illustrated on **Figures 2-3 and 2-4**, respectively**.** Data collected as part of the RI, suggests that there is no tidal influence on groundwater elevations in the area of Site 82 (Baker, 1993). September 2005 groundwater elevation data and flow direction are consistent with historical data and previous investigations.

According to water elevation data collected during the RI, the average horizontal hydraulic gradient in the vicinity of Site 82 is 0.012 feet per foot (ft/ft) in the surficial aquifer and 0.0033 ft/ft in the Castle Hayne aquifer (Baker, 1993). According to the RI (Baker, 1993), hydraulic conductivity averages 3.35 feet per day (ft/day) in the surficial aquifer and 35 ft/day in the Castle Hayne aquifer; and transmissivity averages 500 gallons per day per foot (gpd/ft) in the surficial aquifer and $9.6x10^3$ gpd/ft in the Castle Hayne aquifer.

2.2.3 Description of Existing Pump and Treatment System and Pilot Study Location

The groundwater P&T system at OU 2 has been in operation since July 1996. The system includes six shallow recovery wells (6-SRW01 through 6-SRW06) and four deep recovery wells (6-DRW01 through 6-DRW04). Locations of the recovery wells at Site 82 are shown in **Figure 2-5**.

Pumping rates for the shallow recovery wells are low, in the range of 1 to 4 gallons per minute (gpm) or less, because of the relatively low transmissivity of the surficial aquifer. Pumping rates for the deep recovery wells range from 30 to 150 gpm. Deep recovery well DRW-04, screened in high transmsisivity fractured limestone approximately 150 feet bgs, pumps the majority (60%) of the total flow from the deep wells, estimated to be about 250 gpm. Deep recovery well DRW-01 is located in the area of highest contaminant impacts, and therefore was selected for the subject pilot study. DRW-01 is approximately 100 feet deep, with 20 feet of 0.020-inch slot screen. Heaving sands prevented DRW-01 from being installed to the original intended depth, and infiltration of fines into the well compromised its performance over time, in terms of pumping rate.

Groundwater samples are collected on an annual basis from 6-DRW01 as part of the LTM program. Analytical results from the 2005 annual LTM sampling event are summarized in **Table 2-1.**

TABLE 2-1
Summary of VOCs Detected in 6-DRW01 (September 2005)
Site 82 Pilot Study Work Plan
MCB Camp Lejeune, North Carolina

VOCs Detected in 6-DRW01 (September 27, 2005)	**NCGWQS (µg/L)**	**Concentration (µg/L)**
1,1,2,2-Tetrachloroethane	0.17	2,400
1,1,2-Trichloroethane	--	41 J
Tetrachloroethene	0.7	790
Trichloroethene	2.8	9,200
cis-1,2-dichloroethene	70	1,600
trans-1,2-dichloroethene	100	330
Vinyl chloride	0.015	33 J

Note:

NCGWQS – North Carolina Groundwater Quality Standard
J – Reported value is estimated
µg/L – micrograms per liter

3. Pilot Study Overview and Objectives

3.1 Pilot Study Overview

The January 2005 Technical Memorandum (CH2M HILL, 2005a) identified three potential electron donors for the subject pilot test, including both soluble and insoluble liquids: lactate, emulsified soybean oil, and vegetable oil. Although a laboratory evaluation of these potential donors was originally considered, such studies do not necessarily correlate to field conditions and the laboratory evaluation has since been omitted. The goal of the field study is to assess the degree to which reductive dechlorination can be stimulated by addition of a suitable electron donor. To accomplish this goal, a mixture of emulsified oil and ethyl lactate will be injected**.** A field microcosm study will also be conducted in conjunction with injection activities, to determine whether a natural bacterial consortium is present that can achieve complete dechlorination of the VOCs. If not, bioaugmentation with a commercial dechlorinating culture may be necessary.

The lactate and emulsified oil mixture will be introduced into the aquifer in a single injection event using existing recovery well 6-DRW01 as a temporary injection well. Injection of the substrate into the highest cVOC concentration area will facilitate evaluation of performance in achieving reducing conditions, generally favorable to ERD.

The scope of work for the pilot study consists of the following:

- Temporary deactivation of the submersible pump in recovery well 6-DRW01 to allow anaerobic conditions to develop
- Installation and development of six new monitoring wells
- Collection of baseline groundwater samples
- Completion of a field microcosm study
- Injection of substrate for field-scale pilot study
- Performance monitoring
- Report preparation

3.2 Pilot Study Objectives

The primary objective of the pilot study is to determine if reductive dechlorination can be a cost effective approach to remediate cVOCs at Site 82, in lieu of ongoing (and expensive) pump and treat operations. This pilot study is not intended to function as a final remedy, such a determination will be made by the Partnering Team after the pilot study is completed.

Chlorinated VOC concentrations in groundwater exceed applicable North Carolina Groundwater Quality Standards (NCGWQS). Furthermore, data collected during recent

LTM sampling activity indicates cVOCs have reached Wallace Creek, although at concentrations less than North Carolina surface water quality standards. Therefore, compliance is driven by both groundwater and surface water impacts.

The effectiveness of the pilot study will be evaluated according to the following criteria:

1. Reductions in the concentration of parent VOC(s) (e.g., PCE or TCE) and increases in the ratio of daughter products to parent products. Pre- and post-treatment groundwater samples will be used to make this determination.
2. Changes in geochemical parameters that indicate a shift towards a more reducing environment (such as the development of iron-reducing, sulfate-reducing, or methanogenic conditions).

All new monitoring wells will be gauged and sampled prior to initiation of the pilot study. The resulting laboratory analytical data and field geochemical data will be used to establish baseline conditions. Subsequent data will be compared to baseline conditions to evaluate performance during the test.

3.3 Technology Description

This section comprises a brief overview of the methodology associated with the technology to be employed at Site 82.

3.3.1 Reductive Dechlorination Process

Reductive dechlorination is a process in which indigenous microorganisms (e.g., bacteria, and other microbes) degrade (metabolize) chlorinated organic contaminants, converting them to innocuous end products, such as ethene and ethane. Reductive dechlorination involves the transfer of electrons from an electron donor source to the cVOC compound, resulting in the sequential replacement of a chlorine atom with a hydrogen atom. An external electron donor is required for the process to occur. Potential electron donor sources include biodegradable organic co-contaminants, native organic matter, or materials intentionally added to the subsurface. Strongly reducing conditions are favorable for biologically mediated dechlorination of cVOCs. In addition, competing electron acceptors, such as dissolved oxygen, nitrate, ferric iron [Fe(III)] generally must be depleted.

The principal anaerobic biodegradation pathway for reductive dechlorination of chlorinated ethenes is:

$$\text{PCE} \rightarrow \text{TCE} \rightarrow \text{cis-1,2-DCE} \rightarrow \text{vinyl chloride} \rightarrow \text{ethene}$$

The transformation rates for each step vary. The key rate limiting step is often the conversion of cis-1,2-Dichloroethene (cis-1,2-DCE) to vinyl chloride, which can result in accumulation of cis-1,2-DCE. However, if an appropriate bacterial consortium and the right conditions are present, complete dechlorination can occur. The proposed field-scale microcosm study will assist in determining whether an effective native consortium of dechlorinators is present at the Site or whether bioaugmentation is necessary.

Enhanced reductive dechlorination is typically implemented by injection of an electron donor. The electron donor serves two purposes: (a) depleting competing electron acceptors

and creating strongly reducing conditions and (b) providing an electron donor source for reductive dechlorination. Various substrates, including lactate, high fructose corn syrup, other carbohydrates, and emulsified vegetable oil are often used for this purpose.

3.3.2 Selected Substrate

A variety of carbon based substrates have been used to enhance in-situ treatment of chlorinated solvents, including solid carbon sources (mulch, EHC, organic waste, etc.), long-lasting liquids such as emulsified oil, Hydrogen Release Compound (HRC™ – developed by Regenesis), oleate and soluble carbon sources including alcohols (ethanol/methanol), lactate or lactose (cheese whey or off-spec milk), and weak acids such as acetic acid (acetate) or citric acid (citrate).

The two primary substrate categories to be evaluated for the purposes of this study are: 1) soluble, and 2) insoluble (or slightly soluble) liquids, which can be readily injected and distributed in the subsurface via conventional pumping techniques. Soluble substrates, such as lactate, molasses, and ethanol, tend to be "quick burn" liquids that are readily fermented, and persist in the environment for a relatively short period of time (weeks to months, depending on biological and chemical demand). These soluble substrates must be added periodically at either high batch dosages or continuously at low dosages to provide the necessary carbon. Insoluble substrates, such as vegetable oil, slowly degrade to fatty acids, which are subsequently fermented over time, and may persist for several years.

Soluble substrates are readily mixed with water and are relatively easy to distribute in the subsurface. Insoluble substrates, in the form of micro-emulsifications (tiny oil droplets emulsified in water using special blending equipment) have a viscosity similar to that of milk, and can be injected at dilute ratios to achieve efficient subsurface distribution, although generally less so than their soluble carbon donor counterparts, because of sorption and other factors.

A possible solution to the problem of frequent injections vs. efficient subsurface distribution is combining soluble and insoluble substrates during one injection event, as is planned for the subject pilot test. In this manner, strongly reducing conditions favorable for dechlorinators to thrive are rapidly established, while a sustainable source of carbon is also introduced, potentially mitigating the need for periodic re-injection.

The field microcosm study will facilitate evaluation of differing substrates (lactate and emulsified oil) in terms of biological growth. The field injection study will be used to evaluate long term performance of a blend of emulsified oil (50-60%) and ethyl lactate. In the subsurface, ethyl lactate is fermented into acetate and hydrogen, while the emulsified oil degrades to fatty acids, which are then fermented to hydrogen. The hydrogen acts as the primary electron donor. Ethyl lactate also releases ethanol, which acts as an electron donor. One injection of ethyl lactate/oil blend is currently planned, with monitoring for one year.

4. Pilot Study Implementation

The scope of work will include, but is not limited to, the following tasks:

1. Contractor Mobilization and Demobilization
2. Site Preparation
3. Monitoring well installation, development, surveying, and sampling
4. Temporary deactivation of pump and treat operations at recovery well 6-DRW01
5. Gauging and baseline groundwater sampling event
6. Field microcosm studies
7. Injection of substrate blend into 6-DRW01
8. Performance monitoring for six months following injection
9. Waste Management

Each of these tasks is described in the following sections.

Applications will be submitted for any required drilling and underground injection control (UIC) permits. The start of the pilot study test period is considered to be the injection of the ERD substrate. Preparation of the UIC permit application package will be initiated early to insure that the permit to inject the selected substrate emulsion is received prior to the proposed injection date.

4.1 Contractor Mobilization and Demobilization

The subcontractor will mobilize all resources necessary to efficiently and completely perform the scope of work tasks. These resources include, but are not limited to, personnel, equipment, materials, supplies, lower tier Subcontractor, and support facilities.

The subcontractor will be responsible for having all equipment properly decontaminated prior to mobilization to the Site. Personnel and equipment will be satisfactorily decontaminated in accordance with the Subcontractor's site-specific Health and Safety Plan (SHSP) prior to being removed from the site. Any debris or rinsate generated during decontamination will be properly collected and containerized. The subcontractor will furnish all equipment to safely and legally collect and store water encountered during the performance of the SOW for off-site disposal. Containers for and disposal of investigation-derived waste (IDW) will be coordinated with the Base Remedial Action Contractor (RAC).

The subcontractor will stage its equipment and temporary facilities within the areas designated by CH2M HILL and/or the Base.

The Base will provide a source of potable water. The subcontractor will provide CH2M HILL with all appropriate Material Safety Data Sheet (MSDS) documentation of the reagents prior to mobilization.

After completion of the pilot study, all above-grade components will be demobilized.

4.2 Site Preparation

The site preparation task will include the following activities:

- Identification and marking of subsurface utilities
- Establishment of work zones and equipment staging areas
- Establishment of operations area
- Establishment of equipment and personnel decontamination areas

CH2M HILL will coordinate with Base personnel and a professional utility locator to define all subsurface structures that might be impacted by drilling activity in the immediate area of the pilot study. The field engineer will mark the locations of six intermediate-depth monitoring wells. All utilities will be marked by a professional utilities locating service prior to the start of drilling.

Work zones will be delineated at the Site for the different types of project activities. Personnel and equipment access will be controlled during project activities. The establishment of the work zones will accomplish the following:

1. Properly protect personnel against the hazards that are present.
2. Confine work activities and contamination to the designated areas.
3. Locate and evacuate personnel in the event of an emergency.

Three types of work zones will be established during site operation activities: the exclusion zone, the contamination reduction zone, and the support zone. The SHSP will specifically address these zones as well as PPE, ambient air monitoring, and health and safety hazard assessments.

4.3 Monitoring Well Installation

In April 2005, the Partnering Team agreed to install six intermediate-depth monitoring wells around the pilot study area to serve as monitoring points from the injection zone. From December 10 to 13, 2005, the six new intermediate-depth monitoring wells (6-GW47IW through 6-GW52IW) were installed using Rotosonic drilling methods to a depth of 100 feet bgs. The monitoring wells are located around the injection point (6-DRW01) at distances ranging from approximately 20 to 50 feet, as shown on **Figure 2-5**.

The monitoring wells were constructed within the innermost Rotosonic casing using a 10-foot section of two-inch diameter, 0.010-inch machine slotted Schedule 40 polyvinyl chloride (PVC) screen with a bottom cap. The screen was connected to a threaded, flush-joint, PVC riser. Each well was equipped with stainless steel centralizers, attached to the riser pipe and spaced at intervals of 50 feet. The new monitoring wells were completed at grade with flush-mounted 8.5-inch diameter steel protective locking cover set in two foot square concrete aprons.

All monitoring wells were constructed and developed in accordance with the standard operating procedures (SOPs) as described in the Base Master Project Plans (CH2M HILL,

2005b). Generation, characterization, and proper disposal of drilling and development fluids and well cuttings are discussed in Section 4.8.

All new monitoring well installations will be referenced both horizontally and vertically. Each new well will be surveyed relative to permanent land monuments and the Universal Transverse Mercator (UTM) coordinate system and will be referenced to a US Geological Survey (USGS) datum/benchmark. Elevations will be surveyed to the nearest 0.01 foot, while horizontal location will be established to the nearest 0.1 foot.

4.4 Deactivation of Submersible Pump in Recovery Well 6-DRW01

The recovery well pumps currently in operation draw relatively oxygenated water into target area, creating slightly aerobic, oxidizing conditions in the subsurface. The recovery well scheduled for substrate injection (6-DRW01) was temporarily deactivated for the purposes of this study, in order to promote anaerobic conditions.

Recovery well 6-DRW01 contributes only 10 to 15 percent of the total groundwater flow into the existing groundwater pump and treat system. Temporary deactivation of the well is not expected to have a significant impact on the overall effectiveness of the pump and treatment system, in terms of plume containment. All other recovery wells and the current remediation system will remain in operation during the test period.

In January 2006, the submersible pump in recovery well 6-DRW01 was deactivated by Shaw, following approval of the Partnering Team. The well was isolated from the treatment system, and the pump and drop-pipe were removed from the well. Water quality parameters [dissolved oxygen (DO) and oxidation reduction potential (ORP)] were monitored periodically after the recovery well was taken off-line to confirm that anaerobic reducing conditions had returned. After completion of the pilot study, the pump will be re-installed and returned to service, if pump and treat is determined to be the appropriate long term remedy.

4.5 Baseline Groundwater Sampling

The six new monitoring wells (6-GW47IW through 6-GW52IW) and one existing well (6-DRW01) will be gauged and sampled prior to the start of the pilot study. The resulting analytical and geochemical data will be used to establish baseline conditions. Subsequent data will be compared to baseline conditions to evaluate performance during the pilot study.

All groundwater samples will be collected in accordance with the Base Master Project Plans (CH2M HILL, 2005b). Samples will be hand delivered or delivered via an overnight carrier to an off-site laboratory, and analyzed for: VOCs (EPA Method 8260B), bromide, and natural attenuation indicator parameters (NAIPs) including: dissolved gases (RSK-175); nitrate, nitrite, sulfate, and chloride (EPA Method 300.0); sulfide (EPA Method 376.1); alkalinity (EPA Method 310.1); total organic carbon (TOC), total dissolved iron and manganese (SW-846 6010B). Geochemical parameters, including DO, conductivity, pH, temperature, turbidity, and ORP will also be evaluated in the field.

4.6 Field Microcosm Study

The Technical Memorandum (CH2M HILL, 2005b) proposed conducting laboratory and field microcosm studies prior to implementing the full-scale field pilot study. The laboratory microcosm studies were intended to provide information as to the most effective substrate. However, these studies, which require several months to perform, provide results that may not be representative of actual field conditions. The laboratory study has since been removed from the scope of work.

The field microcosm study will be conducted using two existing monitoring wells: 6-GW52IW and 6-GW01D. Three "Bio-Trap" samplers will be suspended in each test well: one control, one baited with 100% ethyl lactate, and one baited with the same emulsified oil/ethyl lactate blend to be injected in 6-DRW-01. The Bio-traps amended with ethyl lactate will be collected and analyzed approximately three months after emplacement; the Bio-traps amended with the oil/lactate blend will be collected and analyzed approximately six months after emplacement. The samplers will be sent to Microbial Insights, who will utilize quantitative polymerase chain reaction (qPCR) analysis to determine the suitability of the naturally occurring microbes in the ERD process. Results of the field microcosm study will then be evaluated to determine whether the native microbial consortium is likely capable of achieving complete dechlorination, or whether bioaugmentation may be necessary.

4.7 Substrate Injection

Concurrently with the field microcosm studies, a field-scale pilot study will be performed, as described in the following sections.

4.7.1 Dosing Parameters

As previously detailed in Section 3.3, a blend of emulsified oil and ethyl lactate has been selected as the preferred amendment solution; emulsified oil (50 to 60%) will be mixed with 100% ethyl lactate to create a blend of approximately 30% lactate in oil solution, by volume. The solution will be blended by the vendor, prior to delivery. Before injection, the mixture will be diluted to approximately 1% in water using potable water, obtained from a fire hydrant. The target injection volume is one pore volume, which, assuming a 20-foot radius of influence (ROI) and an effective ("mobile") porosity of 0.15, is 28,185 gallons. At 1%, the target volume of solution is 282 gallons or 2,283 pounds (approximately 5.5 55-gallon drums).

The expected injection flow rate is 20 gpm at 20 to 30 pounds per square inch (psi), although flow rates of up to 40 gpm and pressures of up to 60 psi may be utilized to accelerate the injection process. Total injection pumping time is predicted to be 23 hours. All electron donor solution will be injected, even if a longer period of time and slower flow rate is necessary. A bromide tracer will be added to the injectate solution at a concentration of approximately 0.1% by volume to assist in evaluation of the radius of influence achieved by the injection.

4.7.2 Injection Procedure

The blended solution will be injected into the subsurface at Site 82 using the existing 6-inch diameter well (6-DRW01). The injection will be completed using a metering pump system (e.g., Dosatron™ or Dosmatic™), which eliminates the need for a mixing tank. The metering pump will draw solution directly from the drum(s) of blended solution. A series of valves, flow meters, and gauges will be used to throttle/monitor solution/water flow rates.

A temporary potable water conveyance line, consisting of low density two-inch diameter polyethylene pipe, will be extended approximately 350 feet from a fire hydrant, located at the east side of the Lot 203 treatment plant building, to the metering pump system at 6-DRW01. The hydrant will be equipped with a backflow prevention (check) valve and a pressure gauge.

To manage system pressure buildups airlock conditions during injection, the fittings for connecting each hose to a wellhead will include an air relief (bleed-off) valve. The valve will serve two purposes; to prevent airlock in the well during injection, and to prevent unsafe residual pressure conditions when connecting or disconnecting hoses in the system.

During the injection event, the six new monitoring wells (6-MW47IW through 6-MW52IW) will be monitored for the presence of bromide tracer using a groundwater probe equipped with an ion selective electrode. Groundwater elevations, pH, DO, ORP, and conductivity will also be monitored in these wells. Monitoring will be conducted at 5,000 gallon injection intervals until 20,000 gallons have been injected; then monitoring will be conducted at 2,500 gallon injection intervals until the entire volume has been injected.

4.8 Post-Injection Monitoring

Following introduction of the injectate, post-injection groundwater samples will be collected at two-month intervals for a period of six months. Post-injection monitoring will consist of gauging and sampling the six new monitoring wells (6-MW47IW through 6-MW52IW) and one existing monitoring well (6-DRW01). The pilot study will conclude with the third and final post-injection groundwater monitoring event.

All groundwater samples will be collected in accordance with the Base Master Project Plans (CH2M HILL, 2005b). Samples will be hand delivered or delivered via an overnight carrier to an off-site laboratory, and analyzed for: VOCs (EPA Method 8260B), bromide, and NAIPs including: dissolved gases (RSK-175); nitrate, nitrite, sulfate, and chloride (EPA Method 300.0); sulfide (EPA Method 376.1); alkalinity (EPA Method 310.1); TOC, and total dissolved iron and manganese (SW-846 6010B). Geochemical parameters, including DO, conductivity, pH, temperature, turbidity, and ORP will also be evaluated in the field.

Appropriate quality assurance/quality control (QA/QC) samples will be submitted in accordance with all normal protocols. This will include trip blanks (one per cooler with samples for VOC analysis), MS/MSDs (5% of samples), duplicates (10% of samples), and equipment blanks (one per day of sampling).

As described in Section 3.2, the effectiveness of the pilot study will be evaluated in part by a measurable reduction in the groundwater contaminant concentrations. This will be

measured in the seven wells in the pilot study area. Results for individual wells and an average of the wells will be examined.

4.9 Waste Management

Wastes generated during the investigation of potentially contaminated sites are classified as investigation-derived waste (IDW) and will be managed to protect the public and the environment, as well as to meet legal requirements. Section 3.17, "Investigation Derived Waste Handling" of the Master Project Plans provides general information for the characterization, disposal, and handling of contaminated wastes expected to be encountered or generated during this work. This Waste Management Plan section describes the waste management requirements and procedures for remediation activities for this pilot study.

Remediation activities at Site 82 are addressed under the provisions of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA). Waste generated from pilot study activities will be managed and disposed of in accordance with North Carolina Department of Environment and Natural Resource (NCDENR) and federal hazardous and solid waste regulations, as specified in Title 40 of the Code of Federal Regulations (CFR) Parts 240 through 258, 260 through 268, and 270. These regulations have been identified in the CERCLA process as applicable or relevant and appropriate requirements (ARARs).

4.9.1 Waste Streams

Project accumulated IDW will consist mostly of waste generated by installation of the monitoring wells. Additional waste will be generated during the pilot study and sampling. Liquid sources of IDW generated during project activities will consist of development water for the monitoring wells and equipment and personnel decontamination water. Other IDW generated during project activities includes discarded PPE, and general construction refuse.

4.9.2 Waste Generation, Containerization, and Staging

The field team leader (FTL) will be responsible for the documentation, generation, containerization, and on-site staging of IDW. Prior to commencing fieldwork, the FTL will contact the RAC and complete an IDW Management Form. A copy of the IDW Management Form will be maintained by the RAC at all times. During fieldwork, IDW will be placed in the containers specified on the IDW Management Form. The containers may be drums, roll-off boxes, poly tanks, or other. The containers will then be labeled (visible marker) corresponding to the appropriate IDW Classification (i.e. media, container type, waste source, etc.) All IDW will be staged at the location specified on the IDW Management Form. The Site 82 staging area will be near Lot 203.

Development water from monitoring wells, equipment and personnel decontamination water, and soil cuttings from installation of monitoring wells will be adequately contained in 55-gallon drums.

In general, wastes will be removed from the Site as soon as possible. At the completion of the field effort, the FTL will contact the RAC to have the IDW containers removed from the Site. The RAC will check to see that all IDW Management Forms are complete and correct and transport the IDW containers to the secondary staging areas. The Investigative

Contractor will also be responsible for providing site-specific data to the RAC if required. All IDW management actions should be documented in the field notes/logbook.

4.9.3 Waste Characterization and Disposal

The RAC will be responsible for the documentation, secondary staging, characterization and disposal of most IDW generated during the Site 82 pilot study. All wastes will be classified according to 40 CFR 261 to determine if they are hazardous using both generator knowledge of the materials and sample results. It is assumed that environmental media generated from these activities may contain listed waste because of the area's history of use.

In accordance with the MCB Camp Lejeune Master Project Plans, the RAC will perform appropriate sampling/analysis of the IDW including development water from monitoring wells, equipment and personnel decontamination water, soil cuttings from installation of monitoring wells, injection borings, and soil sampling borings and/or review site-specific data to characterize the waste for disposal.

Discarded personal protective equipment (PPE), general construction refuse, and general demolition debris will be placed in trash bags and placed in dumpsters temporarily staged on-site. Typically, uncontaminated wastes such as general construction debris will be characterized using process knowledge and generally will be classified as municipal solid waste. All IDW management actions should be documented in the field notes.

5. Health and Safety Considerations

General Health and Safety Considerations are detailed in the comprehensive Master HASP contained in the Master Project Plans (CH2M HILL, 2005b). Development of a comprehensive SHSP will be the combined responsibility of CH2M HILL and Subcontractors. The Master SHSP will address the potential hazards associated with the pilot study, and will be maintained on-site during all field activities.

Addenda to the Master SHSP will be prepared by the CH2M HILL Project Health and Safety Manager (PHSM) to address changes to specific activities and the hazardous control measures associated with the specific projects. The addenda will be submitted to the Partnering Team for review and approval prior to beginning site work. In this manner, the SHSP will be considered a "living document", to be reviewed and updated as necessary.

The Master SHSP does not address hazards associated with specialized remedial implementation tasks and equipment (such as operation of a drill rig). Accordingly, specialty subcontractors are responsible for health and safety procedures specific to their particular work components, and are required to develop and submit a HSP to CH2M HILL for review prior to the start of fieldwork. Subcontractors must comply with the established HSP, and CH2M HILL must monitor and enforce compliance with the established HSP.

Inclement weather conditions may occur without warning and are a concern during drilling activity. It will be the responsibility of the Site Safety Coordinator (SSC) to halt work in the case of eminent danger. In the event that extreme weather conditions caused by high winds, hurricanes, etc. arise, site personnel will secure or removal all site facilities, materials, and equipment; secure temporary utilities where possible; verify equipment tiedowns; and cover all exposed openings in existing facilities to minimize potential wind and water damage. The SSC will also be responsible to commence work once the danger has passed.

Housekeeping and maintaining the cleanliness of the Site will be a priority during well installation and injection activities to minimize the potential of foreign object debris dangers to personnel and equipment during inclement weather conditions.

The hurricane season in the immediate area surrounding Camp Lejeune begins on June 1 and continues through November 30. Storms of non-tropical origins such as frontal passages, local thunderstorms, and tornadoes are much more frequent and can occur year-round. The contractor will review all Navy notification procedures and local readiness plans concerning inclement weather once they are made available.

6. Site Activity Considerations

Several considerations related to the execution of the pilot study at Site 82 include, but are not limited to, the following:

1. Equipment, space, and utility requirements
   - Subcontractors will be solely responsible for their equipment, instrumentation, materials, and supplies.
   - Underground utilities will be identified and labeled by Camp Lejeune staff and/or a professional utility location subcontractor.
   - The Drilling Subcontractors will be responsible for providing an equipment and materials storage area in a designated area of the project during the well installation phase.
2. Site security
   - During working hours, the Drilling Subcontractor will secure the working area.
   - Site access during the project will be limited to authorized personnel only.
3. Waste management
   - Subsurface media excavated during well drilling operations will be placed in drums or roll-off boxes (with water-resistant tarps or other suitable covers maintained in place) provided by the RAC and located in the project work area.
   - The RAC will provide separate drums or roll-offs for collection of normal waste materials, trash and debris generated during injection.
   - Larger water supplies for well installation and/or substrate injection are available at Camp Lejeune but the subcontractor will need to provide the appropriate water tanker or storage system to collect the water and transport it to the work area.

7. Submittal Requests

This section provides an overview of the information to be included in the transmittal memorandum to prospective Subcontractors:

7.1 Project Related Information

- The Subcontractor's technical approach;
- An estimate as to the expected duration to complete the chemical injection phase, including the set-up period and demobilization from this project phase;
- An approximation as to the expected sizing of the equipment and materials storage area related to injection;
- Electrical service requirements for injections (as applicable);
- An estimate as to the prescribed period of time for the injected chemicals to meet performance standards;
- Warranties that may be offered related to the performance of the injected chemicals;
- Identification of any separate utility evaluation measures considered necessary by the subcontractor to implement the remedial system using the prescribed technology.

7.2 Firm Related Information

- A listing of all firms proposed as part of the prime technology subcontractor's team to complete this project (included in the cost proposal form);
- Resumes of all key staff (with their company affiliation) that will have active involvement in executing the expected SOW for this project, and their primary roles in this regard;
- A summary of relevant experience of the subcontractors, and the listed key staff, in completing similar projects under similar conditions;
- A list of at least three references that may be contacted regarding performance of the subcontractor's team in completing similar projects;
- Documentation of the health and safety record of the prime technology subcontractor and each of the proposed companies on his team, including copies of the latest Occupational Safety and Health Administration (OSHA) 200 logs; and
- The experience modification rate (EMR) of the prime technology subcontractor and each of the proposed companies on his team.

8. Reporting

A Pilot Study Report will be prepared to present an overview of the procedures, material quantities, field observations, analytical results, and conclusions of the pilot study. The report will include:

- A summary of the substrate injection process including quantity of material injected;
- Results of the field microcosm study;
- Analytical data from the baseline sampling through the six-month post-injection period;
- Analysis of the effectiveness of the remedial technology in reducing contaminant concentration and the extent of the radius of influence; and
- Recommendations for future site activities.

A draft report will be issued to allow for a comment period. Any comments received will be addressed in the final version.

9. Schedule

9.1 Schedule

The proposed schedule for implementing the pilot study at Site 82 is presented in **Figure 9-1**. The tasks presented in the pilot study schedule correspond to the tasks identified in this work plan.

9.2 Project Organization

The project organization is presented in **Figure 9-2**. The Partnering team includes representatives from CH2M HILL, Naval Facilities Engineering Command (NAVFAC), MCB Camp Lejeune, NCDENR, United States Environmental Protection Agency (USEPA) Region 4, and Shaw Group.

Mr. Tegwyn Williams, L.G. will serve as the Project Manager (PM) for the pilot study and as the primary CH2M HILL contact. The PM is responsible for overall project management and the overall QA/QC of project deliverables.

Mr. Dean Williamson, P.E. will serve as the Senior Reviewer for the pilot study. The Senior Reviewer is responsible for reviewing the technical aspects of the work from project scoping to project completion.

The project team will include: the Engineers, FTL, and SSC. All field and subcontractor activity will be under the direction of the FTL.

10. References

Baker Environmental, Inc., 1993. *Remedial Investigation Report for Operable Unit No. 2 (Sites 6, 9, and 82), MCB Camp Lejeune, North Carolina.* August 1993.

CH2M HILL, 2005a. *Review of Groundwater Remediation Activities, Operable Unit 2 (Site 82), Marine Corps Base Camp Lejeune, North Carolina*. January 2005.

CH2M HILL, 2005b. *Master Project Plans, Marine Corps Base Camp Lejeune, Jacksonville, North Carolina.* August 2005.

CH2M HILL, 2006. *Draft Annual Long-Term Monitoring Report, Operable Unit No. 2 – Sites 6 & 82, Marine Corps Base Camp Lejeune, North Carolina.* June 2006

Figures

\\Ariadne\groups\GIS\USNavFaceNGCom\315007CampLejeune\Projects\Sites6 and 82I\Figure_2_1_Base_Loc_Map.mxd

Duplin
Onslow
Pender
Carteret
Jacksonville
Morehead City
Site 82
MCB Camp Lejeune
Atlantic Ocean
117
258
17
70
241
40
17

WV
VA
NC
SC
Marine Corps Base
Camp Lejeune
Atlantic Ocean

Legend
- Installation Area
- Limited Access Higwhay
- Highway
- Local Roads
- Cities
- Site 82

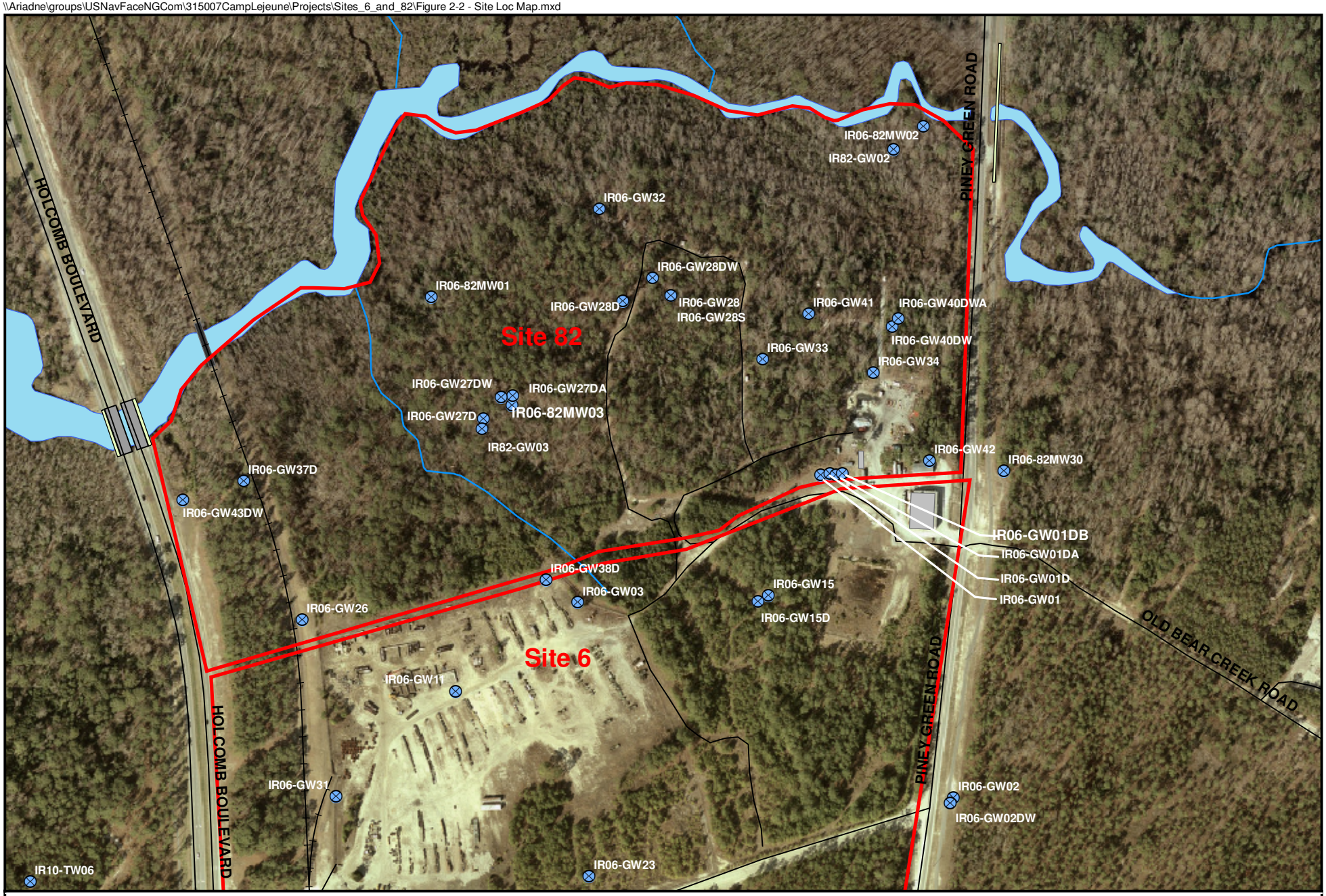
N

0 4,500 9,000 13,500 18,000
Meters

Figure 2-1
Base Location Map
Site 82, Operable Unit No. 2
Pilot Study Work Plan
MCB Camp Lejeune, North Carolina

CH2MHILL

\\Ariadne\groups\USNavFaceNGCom\315007CampLejeune\Projects\Sites_6_and_82\Figure 2-2 - Site Loc Map.mxd



Legend

- Monitoring Well Locations
- Environmental Restoration Area
- Structure Area
- Surface Water Body Area

N
W E
S

130 65 0 130
Meters

Figure 2-2
Site Location Map
Site 82, Operable Unit No. 2
Pilot Study Work Plan
MCB Camp Lejeune, North Carolina

CH2MHILL

\\Ariadne\groups\USNavFaceNGCom\315007CampLejeune\Projects\Sites_6_and_82\Figure 2-3 - Groundwater Contour Map.mxd

IR06-SRMW06
NM

IR06-GW30
9.0

IR82-GW02
2.80

IR06-GW32
5.90

IR06-SRW05
NM

IR06-SRW03
NM

IR06-GW28S
8.10

IR06-SRW04
NM

Site 82

IR06-SRW02
NM

IR06-GW41
18.70

IR06-GW33
14.80

IR06-SRW01
NM

IR06-GW42
24.30

IR82-GW03
12.10

Site 6

IR06-GW03
14.40

IR06-GW01
17.40

IR06-GW31
18.0

IR06-GW23
21.90

Legend

- Sampling Locations
- Environmental Restoration Area
- MCB Camp Lejeune Installation Area
- Water Bodies
- Roads
- GW Contours (Ft above MSL)

NM = Not Measured
NA = Data Not Available

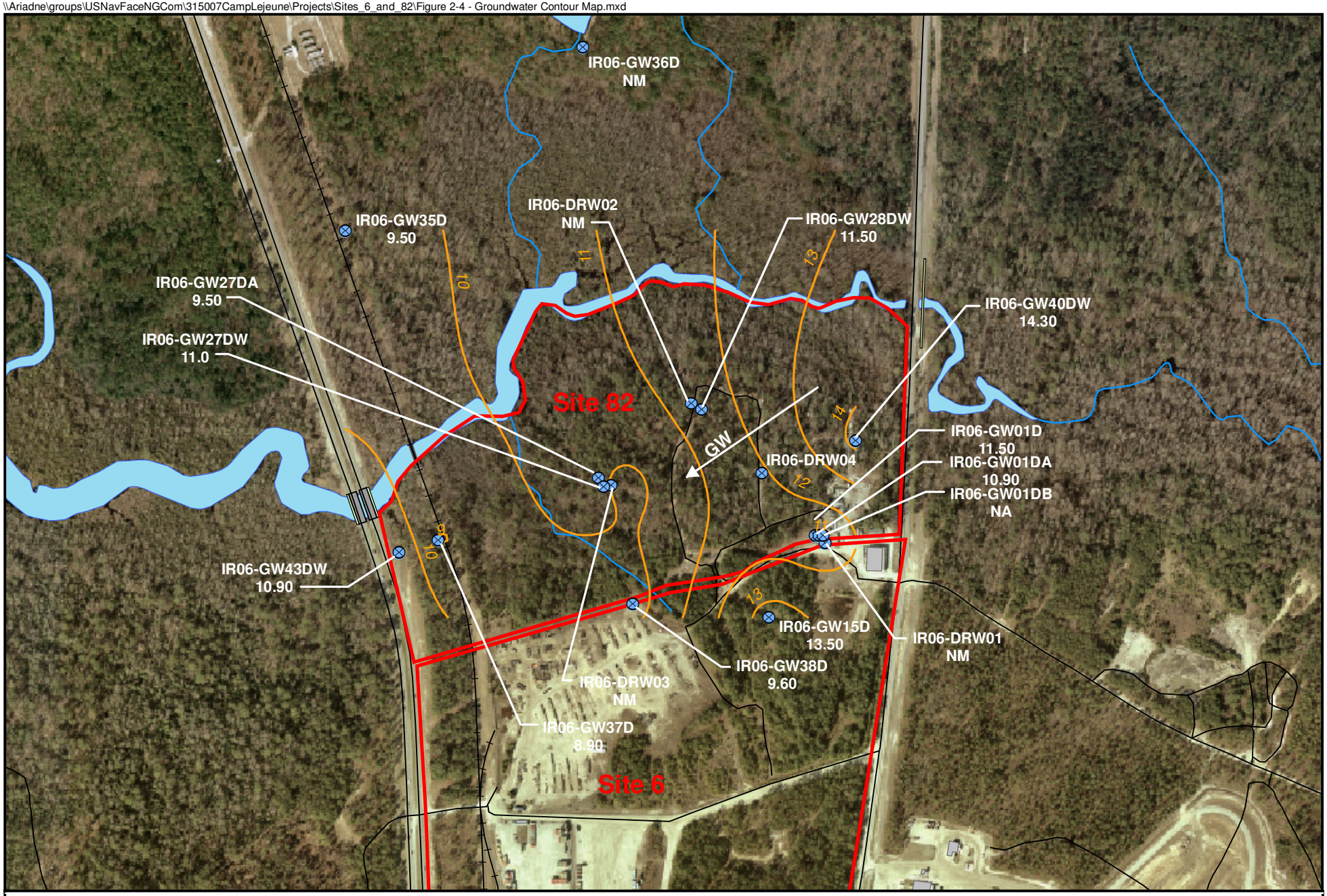
N
W E
S

0 75 150 300
Meters

Figure 2-3
Groundwater Contour Map
Surficial Aquifer (September 2005)
Site 82, Operable Unit No. 2
Pilot Study Work Plan
MCB, Camp Lejeune, North Carolina

AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL JOINT VENTURE

\\Ariadne\groups\USNavFaceNGCom\315007CampLejeune\Projects\Sites_6_and_82\Figure 2-4 - Groundwater Contour Map.mxd



Legend

- Sampling Locations
- Environmental Restoration Area
- Water Bodies
- GW Contours (Ft above MSL)
- Road Centerline

MN = Not Measured
NA = Data Not Available

Groundwater Flow Direction

8.90 Groundwater Elevation (Ft above MSL)

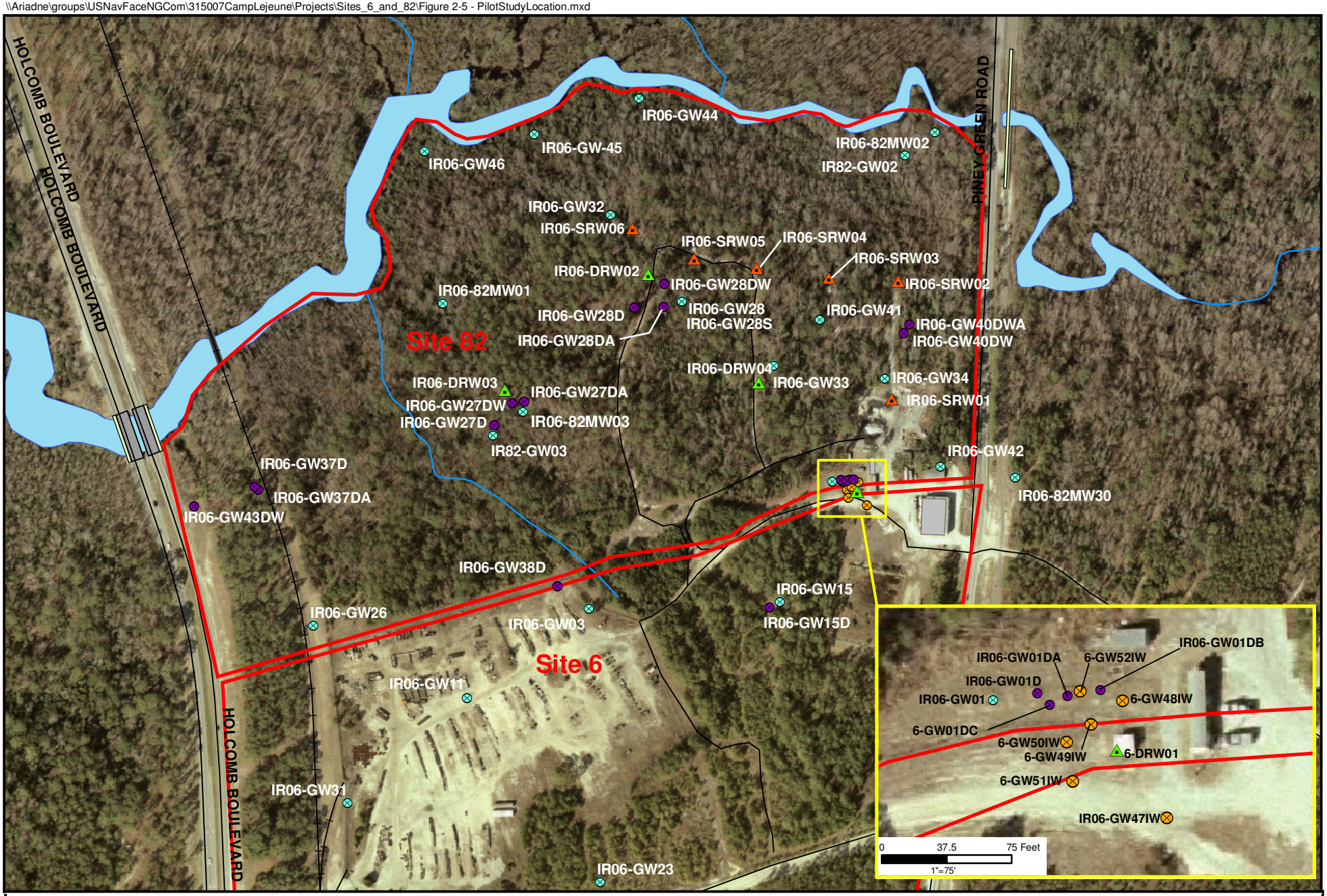
N W E S

0 90 180 360 Meters

Figure 2-4
Groundwater Contour Map
Castle Hayne Aquifer (September 2005)
Site 82, Operable Unit No. 2
Pilot Study Work Plan
MCB Camp Lejeune, North Carolina

AGVIQ ENVIRONMENTAL SERVICES
CH2M HILL JOINT VENTURE

\\Ariadne\groups\USNavFaceNGCom\315007CampLejeune\Projects\Sites_6_and_82\Figure 2-5 - PilotStudyLocation.mxd



Legend

- Environmental Restoration Area
- Deep Monitoring Well
- New Intermediate-Depth Pilot Study Wells
- Shallow Monitoring Well
- Deep Recovery Well
- Shallow Recovery Well
- Approximate location of pilot study

N
W E
S

0 187.5 375 750 Feet

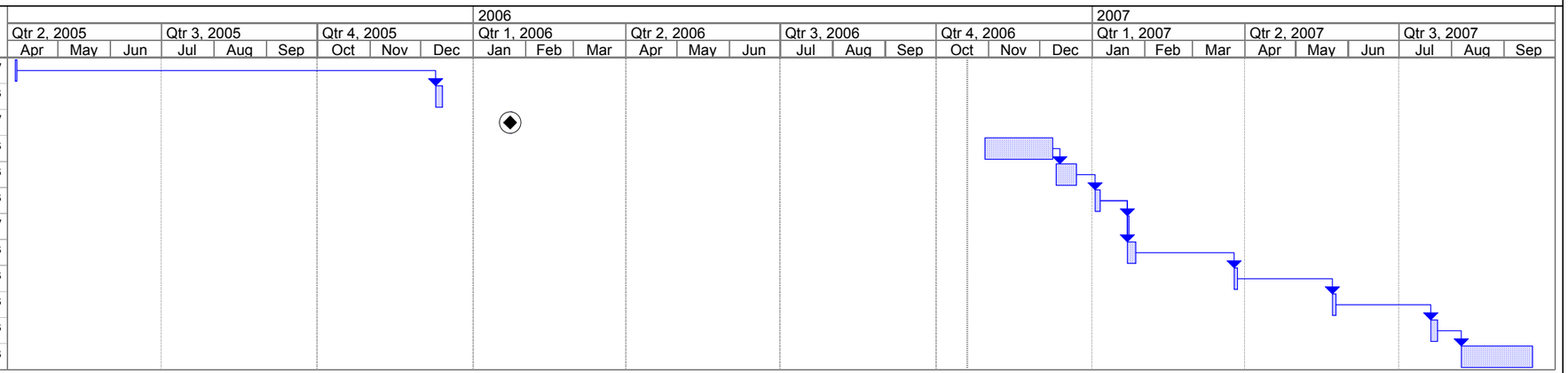
1" = 375 ft

Figure 2-5
Pilot Study Location
Site 82, Operable Unit No. 2
Pilot Study Work Plan
MCB Camp Lejeune, North Carolina

CH2MHILL

Figure 9-1
Project Schedule
Site 82 Pilot Study Work Plan
MCB Camp Lejeune, North Carolina

ID	Task Name	Duration
1	Partnering Team approval for monitoring well install	1 day
2	Monitoring Well Installation (6 wells)	3 days
3	Shut down Recovery Well 6-DRW01	1 day
4	**Draft Pilot Study Work Plan**	30 days
5	**Final Pilot Study Work Plan**	2 wks
6	Baseline Groundwater Sampling	3 days
7	Field Microcosm Study Implementation	1 day
8	Substrate Injection	5 days
9	First Post-Injection Groundwater Monitoring	2 days
10	Second Post-Injection Groundwater Monitoring	2 days
11	Third Post-Injection Groundwater Monitoring	2 days
12	Pilot Study Report (Draft)	30 days



Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline

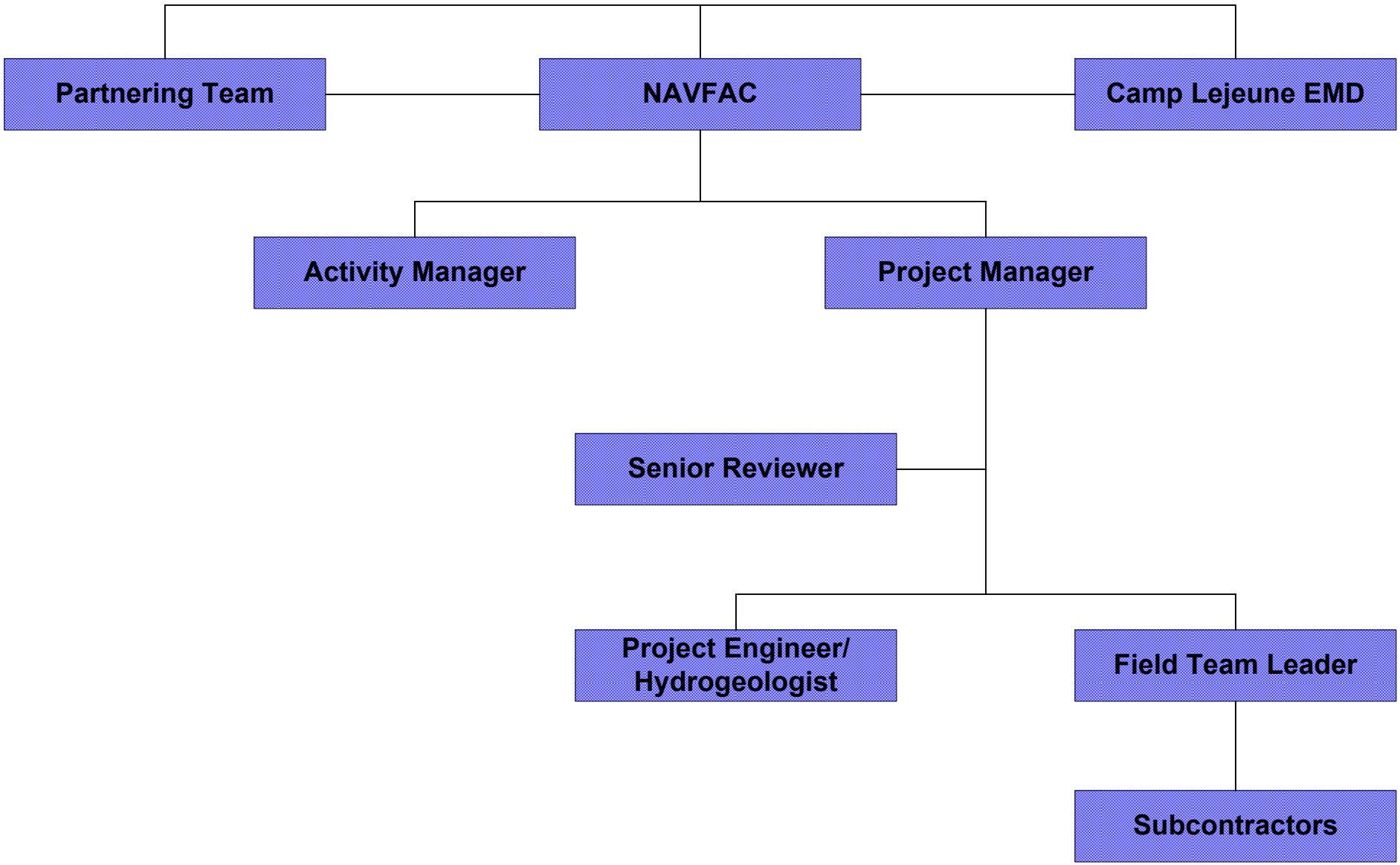


Figure 9-2
Project Organization
Site 82 Pilot Study Work Plan
MCB Camp Lejeune, North Carolina