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FINAL CENTRAL GROUNDWATER PLUME FEASIBILITY STUDY OPERABLE UNIT (OU) 1
PART 1 OF 4 MCAS CHERRY POINT NC
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CH2M HILL

Final

Operable Unit 1
Central Groundwater Plume
Feasibility Study

Marine Corps Air Station
Cherry Point, North Carolina

Contract Task Order 0177

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Prepared for

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Mid-Atlantic

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Acronyms and Abbreviations

AFCEE	Air Force Center for Engineering and the Environment
AOC	area of concern
ARAR	applicable or relevant and appropriate requirement
ARS	ARS Technologies, Inc.
AS	air sparge
BERA	Baseline Ecological Risk Assessment
bgs	below ground surface
bls	below land surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	*Code of Federal Regulations*
CLEAN	Comprehensive Long-term Environmental Action—Navy
COC	chemical of concern
COPC	chemical of potential concern
CTE	central tendency exposure
DCA	dichloroethane
DCE	dichloroethene
DNA	deoxyribonucleic acid
DNAPL	dense non-aqueous phase liquid
DRMO	Defense Reutilization and Marketing Office
EAD	Environmental Affairs Department
EE/CA	Engineering Evaluation/Cost Analysis
ERA	Ecological Risk Assessment
ERD	enhanced reductive dechlorination
EVO	emulsified vegetable oil
FFA	Federal Facilities Agreement
FRCE	Fleet Readiness Center-East
FS	Feasibility Study
ft^2	square feet
ft/day	feet per day
ft/ft	feet per foot
GIS	geographic information system
gpm	gallons per minutes
GRA	general response action
HDD	horizontal directional
HDPE	high-density polyethylene
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient

HRC®	Hydrogen Release Compound
HVAC	heat, ventilation, and air conditioning
IAS	Initial Assessment Study
IDW	investigation-derived waste
IR	Installation Restoration
ISCO	in situ chemical oxidation
ISCR	in situ chemical reduction
ISEB	in situ enhanced bioremediation
IWTP	Industrial Wastewater Treatment Plan
LUC	land use control
LUCAP	Land Use Control Assurance Plan
µg/L	microgram per liter
MCAS	Marine Corps Air Station
MCL	maximum contaminant level
mg/L	milligrams per liter
MNA	monitored natural attenuation
mV	millivolt
NACIP	Navy Assessment and Control of Installation Pollutants
NADEP	Naval Aviation Depot
NAPL	non-aqueous phase liquid
NAS	Natural Attenuation Software
Navy	Department of the Navy
NAVFAC	Naval Facilities Engineering Command
NC 2B	North Carolina 2B Surface Water Standards
NC 2L	North Carolina 2L Groundwater Standards
NCAC	North Carolina Administrative Code
NCDENR	North Carolina Department of Natural Resources
NCGS	North Carolina General Statutes
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NFA	no further action
NPL	National Priorities List
O&M	operation and maintenance
ORP	oxidation-reduction potential
OU	operable unit
PAH	polycyclic aromatic hydrocarbon
PCA	tetrachloroethane
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PLFA	phospholipid-derived fatty acids
PRAP	Proposed Remedial Action Plan
PRB	permeable reactive barrier
PRG	preliminary remediation goal

RA	remedial action
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RD	remedial design
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision
ROI	Radius of Influence
SARA	Superfund Amendments and Reauthorization Act
SSL	soil screening level
STP	sewage treatment plant
SVOC	semivolatile organic compound
SWMU	solid waste management unit
TBC	to-be-considered
TCA	trichloroethane
TCE	trichloroethene
TCL	Target Compound List
TOC	total organic carbon
TS	Treatability Study
USEPA	United States Environmental Protection Agency
UST	underground storage tank
VC	vinyl chloride
VOC	volatile organic compound
ZVI	zero-valent iron

SECTION 1

Introduction

This Feasibility Study (FS) report presents an evaluation of remedial alternatives to mitigate chlorinated volatile organic compound (VOC) groundwater contamination at Operable Unit (OU) 1, denoted as the OU1 Central Groundwater Plume, located within Marine Corps Air Station (MCAS) Cherry Point, North Carolina (**Figure 1-1**). OU1 is an industrial area approximately 565 acres in size located in the southern portion of MCAS Cherry Point. Historical activities at OU1 resulted in the release of trichloroethene (TCE) to groundwater.

This report was prepared for Naval Facilities Engineering Command (NAVFAC), Mid-Atlantic Division under the Comprehensive Long-term Environmental Action—Navy (CLEAN) III Contract N62470-02-D-3052, Contract Task Order 0177, for submittal to NAVFAC Mid-Atlantic Division, MCAS Cherry Point Environmental Affairs Department (EAD), United States Environmental Protection Agency (USEPA) Region 4, and North Carolina Department of Environment and Natural Resources (NCDENR). The Department of the Navy (Navy), EAD, USEPA, and NCDENR work jointly as the MCAS Cherry Point Tier I Partnering Team.

The FS was developed in accordance with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 requirements, as amended by the Superfund Amendments and Reauthorization Act (SARA) of 1986 and implemented by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and USEPA's FS guidance (1998a). Consistent with the CERCLA process, this FS will support the selection of a preferred remedy. Subsequent to the selection of the preferred remedy, the Proposed Remedial Action Plan (PRAP) will be prepared followed by the Record of Decision (ROD).

A comprehensive summary of historical activities and environmental investigations conducted at OU1 is provided in the reports titled *Final Remedial Investigation for Operable Unit 1* (TetraTech NUS, 2002) and the *OU1 Remedial Investigation Addendum* (CH2M HILL, 2009). The OU1 Remedial Investigation (RI) Addendum provides a summary of the 2002 RI, and an updated evaluation of the OU1 site conceptual model, nature and extent of contamination, identification of potential sources, an updated assessment of potential risks to human health, and a summary of potential risks to ecological receptors.

This FS report addresses the sites identified as potential sources of contamination to the OU1 Central Groundwater Plume. Other sites within OU1 not related to the Central Groundwater Plume are being addressed and documented separately.

1.1 Objectives and Approach

The OU1 RI Addendum determined that groundwater in the surficial aquifer beneath OU1 contains contaminants at concentrations above regulatory standards established to protect groundwater as a potential source of drinking water, and poses a potential human health risk for future potable use. In addition, the OU1 Central Groundwater Plume may have the potential to impact surface water where groundwater discharge to surface water occurs.

This FS was completed to evaluate remedial alternatives for the OU1 Central Groundwater Plume. The objectives of this FS are:

- Identify applicable or relevant and appropriate requirements (ARARs) and to-be-considered (TBC) criteria that may affect the remediation of the groundwater within OU1.
- Develop remedial action objectives (RAOs), including the identification of cleanup goals for the surficial aquifer that would minimize risks to potential receptors.
- Develop and evaluate remedial alternatives to mitigate risks to potential receptors from exposure to groundwater and for the protection of groundwater and surface water at OU1.

Pursuant to USEPA FS guidance (1998a), the remedial alternatives are evaluated according to their ability to meet the following evaluation criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The information presented herein will be used to select remedial alternative(s) that comply with the requirements of the NCP. This FS Report is not intended to serve as a Decision Document; rather, it gives a conceptual overview of remedial alternatives and an assessment of their feasibility.

A vapor intrusion investigation and evaluation is currently being conducted at OU1. If potential risk is identified as a result of the vapor intrusion evaluation, the risk will be addressed separately.

1.2 Site Background and History

This section provides a descriptive summary of both MCAS Cherry Point and OU1, including a description and environmental history of the Installation, and the history and current setting of OU1. A more-detailed description is provided in the OU1 RI Addendum (CH2M HILL, 2009).

1.2.1 Installation Description

MCAS Cherry Point is a 13,164-acre military reservation located adjacent to the city of Havelock in southeastern Craven County, North Carolina (**Figure 1-1**). MCAS Cherry Point was commissioned in 1942 and provides support facilities and services for the Second Marine Aircraft Wing, the Fleet Readiness Center-East ([FRCE], formerly Naval Aviation Depot [NADEP]), Combat Service Support Detachment 21 of the Second Marine Logistics Group, the Naval Air Maintenance Training Group Detachment, and the Defense

Reutilization and Marketing Office (DRMO). MCAS Cherry Point maintains facilities for training and for supporting the Atlantic Fleet Marine Force aviation units and is designated as a primary aviation supply point.

1.2.2 Environmental History

MCAS Cherry Point has been actively involved with environmental investigations and remediation programs since 1983, beginning with the Navy Assessment and Control of Installation Pollutants (NACIP) Program. The NACIP Program was modeled after the USEPA Superfund Program, authorized by CERCLA in 1980. An Initial Assessment Study (IAS) was the first investigation of potentially hazardous sites at MCAS Cherry Point conducted under NACIP in 1983.

The Navy's Installation Restoration (IR) Program was initiated in 1986, following enactment of the SARA legislation, and replaced the NACIP.

In 1988, a Resource Conservation and Recovery Act (RCRA) Facility Assessment (RFA) was conducted at MCAS Cherry Point. The RFA was the first step under the RCRA corrective action process and consisted of a preliminary review of all available relevant documents, a visual site inspection, and a sampling event (when appropriate) at the 114 solid waste management units (SWMUs) and two areas of concern (AOCs) identified in the RFA (A. T. Kearney, 1998).

In 1989, the Navy entered into a RCRA Administrative Order on Consent (Consent Order) with USEPA to perform RCRA Facility Investigations (RFIs) at 35 of the 114 SWMUs identified in the RFA. On December 16, 1994, MCAS Cherry Point was scored and ranked by USEPA for inclusion on the CERCLA (or Superfund) National Priorities List (NPL). Since the Consent Order was signed, additional sites have been identified. The original RCRA permit modification was issued in 1998 and identified 116 new SWMUs and two new AOCs.

On May 12, 2005, the Navy, USEPA, and NCDENR executed a Federal Facilities Agreement (FFA) for MCAS Cherry Point. Under the FFA, all past and future work at IR Program sites, SWMUs, and AOCs will be reviewed, and a course of action for future work requirements at each site will be developed. The execution of the FFA effectively terminated the RCRA Consent Order.

As part of the requirements established under CERCLA, an administrative record file has been established for the IR Program at MCAS Cherry Point. The administrative record is a compilation of all documents that the Navy uses to select a remedial action or removal action for a site. Regardless of the nature of the site, an administrative record must be maintained. The administrative record will also serve as the basis for any future legal review of decisions made by the Navy concerning remedial action taken at a site. A copy of the MCAS Cherry Point administrative record file is available for review online as part of the MCAS Cherry Point IR Program public Web site at: http://go.usa.gov/2EH.

1.2.3 OU1 Description and History

OU1 is an industrial area approximately 565 acres in size, located in the southwestern portion of MCAS Cherry Point (**Figures 1-2** and **1-3**). OU1 is bounded by C Street and Sandy Branch to the northwest, portions of the MCAS Cherry Point flightline and runway to the northeast and southeast, and East Prong Slocum Creek to the southwest (**Figure 1-3**).

Of the 11 sites identified in the FFA to be investigated as part of the OU1 RI, six sites were identified as contributing to the OU1 Central Groundwater Plume contamination as described in the OU1 RI Addendum (CH2M HILL, 2009). The locations of these sites are shown in **Figure 1-3**. These sites are:

- Site 42—Industrial Wastewater Treatment Plant (IWTP)
- Site 47—Industrial Area Sewer System
- Site 51—Building 137 Former Plating Shop
- Site 52—Building 133 Former Plating Shop and Ditch
- Site 92—VOCs in Groundwater near the Stripper Barn
- Site 98—VOCs in Groundwater near Building 4032

A description of each site is presented below.

Site 42—Industrial Wastewater Treatment Plant

The IWTP is located near the center of OU1, north of A Street. Site 42 specifically consists of the soil and groundwater around the IWTP structure. Waste streams in the Industrial Area Sewer System (Site 47) discharge to the IWTP, which currently discharges treated effluent to the Air Station Sewage Treatment Plant (STP).

Prior to the current connection to the Air Station STP, treated effluent from the IWTP was discharged to Sandy Branch, Tributary #2. Sludge from the IWTP was formerly disposed of by landfilling or lagoon storage (e.g., OU2, Site 10) (WAR, 1983). The RFA indicated that the IWTP was used to treat wastes from industrial sources such as metal plating, painting, aircraft maintenance, vehicle maintenance, and stormwater from bermed containment areas (A. T. Kearney, 1998). A groundwater extraction and treatment system was installed at OU1 in 1998 to remediate the groundwater VOC plume in the vicinity of FRCE, and the treatment component (packed tower air stripper) was located at the IWTP. As a result of decreasing system efficiency and the potential for interference with ongoing attempts to further define the nature and extent of groundwater contamination beneath OU1 by altering local groundwater gradients, the groundwater extraction and treatment system was shut down in February 2005.

Site 47—Industrial Area Sewer System

Site 47 is a system of underground pipes and aboveground drains that transfer industrial wastewater from various parts of FRCE and the surrounding industrial portions of OU1 to the IWTP or STP (A. T. Kearney, 1998). Portions of the sewer system were constructed in 1942; the system has been expanded several times to connect facilities that formerly discharged to the sanitary or storm sewer systems. Site 47 only includes the industrial sewers within OU1 that currently discharge to the IWTP (**Figure 1-3**). Industrial processes that currently or historically created wastewater discharge to the sewer system include metal plating, metal finishing, solvent degreasing, paint stripping, painting, fuel storage, fueling, aircraft washing, and general maintenance. Concentrated wastes are no longer discharged to the industrial sewers, but are containerized and transported to the IWTP. Leaks have been detected at several locations within the sewer system in the past. Inspections and repairs are conducted as part of the facility’s ongoing maintenance process.

An infiltration and leakage study was conducted at Site 47 in 1993 to identify the sewer segments to be repaired or replaced. Soil and groundwater samples were collected to determine if contamination had leaked from the segments (Halliburton NUS, 1993a). Forty-four soil borings were installed and samples were collected along various segments of the industrial area sewer system. A subsurface soil sample was collected from each soil boring at the groundwater table. All soil concentrations were below the industrial soil screening levels and the study concluded that no further action was required. However, as a result of this study, certain segments of the sewer system were repaired.

Site 51—Building 137 Former Plating Shop

Site 51 is a former Plating Shop that was located within Building 137 inside FRCE, in the central portion of OU1. The Plating Shop operated from 1942 to 1990, and consisted of an area of approximately 4,000 square feet (ft^2) that included a 3-foot-deep sump for containment of spillage and tank overflows. The area has been cleaned and renovated, and an autoclave has been constructed over a portion of the former plating shop.

The wastes generated in the plating shop consisted of plating solution overflow and rinse water containing zinc and chromium that were discharged to the sump. The sump was constructed of steel and set into the concrete pit, which was covered with wooden grating. Concrete piers were present in the sump so that tanks and equipment could be mounted above the sump. The sump discharged to the industrial sewer system (Site 47) until 1987, when the sump was plugged and the plating shop converted to a closed-loop system. From then until the Plating Shop was moved in 1990, wastes were transported to the IWTP (Site 42) in containers for batch treatment.

Site 52—Building 133 Former Plating Shop and Ditch

Site 52 is a former Plating Shop that was located within Building 133 in FRCE, in the central portion of OU1. The Plating Shop operated from 1942 to 1990, and consisted of an area of approximately 2,000 ft^2 that included a 2.5-ft-deep sump for containment of spillage and tank overflows. In addition, former employees indicated that a ditch was formerly present behind Building 133 that received stormwater flow as well as industrial wastewater discharge from the Plating Shop and other areas within Building 133. This former ditch was covered in the 1970s by an addition to Building 133. The plating shop area was cleaned and renovated in 1996 and is currently used to process and store non-hazardous parts and supplies.

The wastes generated in the plating shop consisted of plating solution overflow and rinse water that discharged to the sump. The sump was constructed of steel and set into the concrete pit, which was covered with wooden grating. Concrete piers were present in the sump so that tanks and equipment could be mounted above the sump. The sump wastes likely discharged to the former ditch behind Building 133 prior to the installation of the industrial sewer system (Site 47). An addition constructed on the southeastern side of the building subsequently covered this ditch. The sump then discharged to the industrial sewer system (Site 47) until 1987, when the sump was plugged and the plating shop converted to a closed-loop system. From then until the plating shop was moved in 1990, wastes were transported to the IWTP (Site 42) in containers for batch treatment.

Site 92—VOCs in Groundwater near the Stripper Barn

Site 92 is a plume of VOC-contaminated groundwater near the Stripper Barn portion of Building 137, in the central portion of OU1. The area around the site is covered with buildings and concrete, and portions of the industrial sewer system (Site 47) are located beneath and around the Stripper Barn.

The Stripper Barn is the area where paint is removed from aircraft. In the past, large quantities of solvent were used to remove paint; during the paint removal process, spent solvent flowed into the industrial sewer system. The current paint removal method requires approximately 90 percent less solvent, and spent solvent is captured for proper disposal. Any historical spills that occurred outside the building may have flowed toward storm drains located northeast of the Stripper Barn.

Site 98—VOCs in Groundwater near Building 4032

Site 98 is a plume of VOC-contaminated groundwater near Building 4032, located southeast of the IWTP in the central portion of OU1. Site 98 was discovered by MCAS Cherry Point during an investigation of underground storage tanks (USTs) at Building 4032 in 1994, and was identified as a new site for inclusion in the FFA in 1999. The area around the site is paved with some grassy areas.

1.3 Report Organization

This FS report comprises the following sections:

- **Section 1—** Introduction and Background
- **Section 2—** Results of Environmental Investigations
- **Section 3—** Applicable or Relevant and Appropriate Requirements and Remedial Action Objectives
- **Section 4—** Development and Screening of Remedial Alternatives
- **Section 5**—Development and Description of Alternatives
- **Section 6—** Detailed and Comparative Analysis of Alternatives
- **Section 7—** References

Tables and figures are provided at the end of each respective section. Appendixes are provided electronically on the enclosed CD-ROM (that is, compact disk read-only-memory).

\\aphrodite\Proj\USNavFacEngCom\CherryPoint\Projects\OU1\RI_Draft\section1\Figure 1-1 - Base Location Map.mxd

Legend

- Cities
- Rivers and Streams
- Military Installation
- County Boundary

N W E S

0 20,000 40,000 Feet

Figure 1-1
Base Location Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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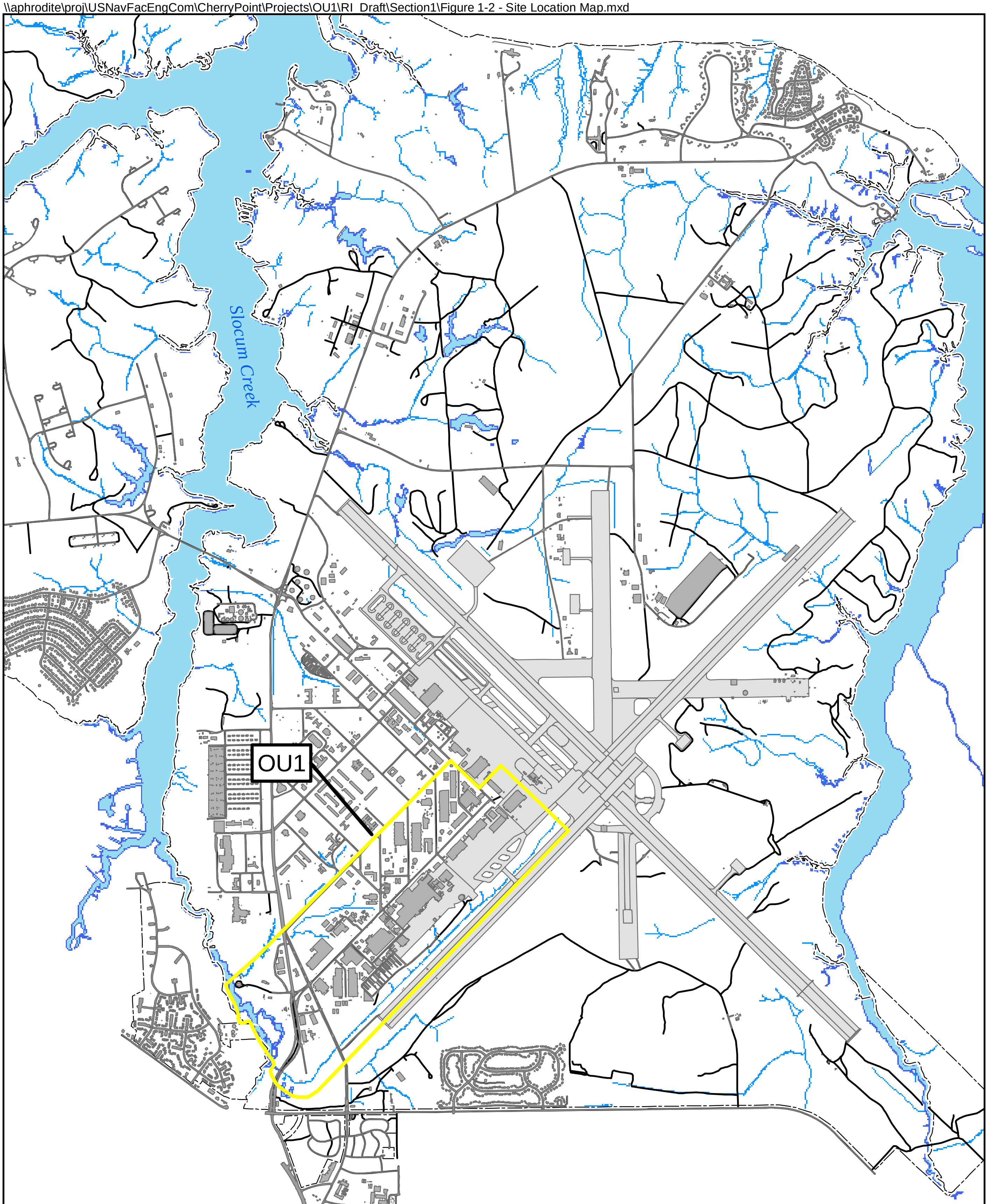

Legend

- OU Boundary
- Surface Water
- Base Boundary
- Buildings
- Runway
- Road

N
W E
S

0 1,500 3,000
Feet

Figure 1-2
OU1 - Site Location Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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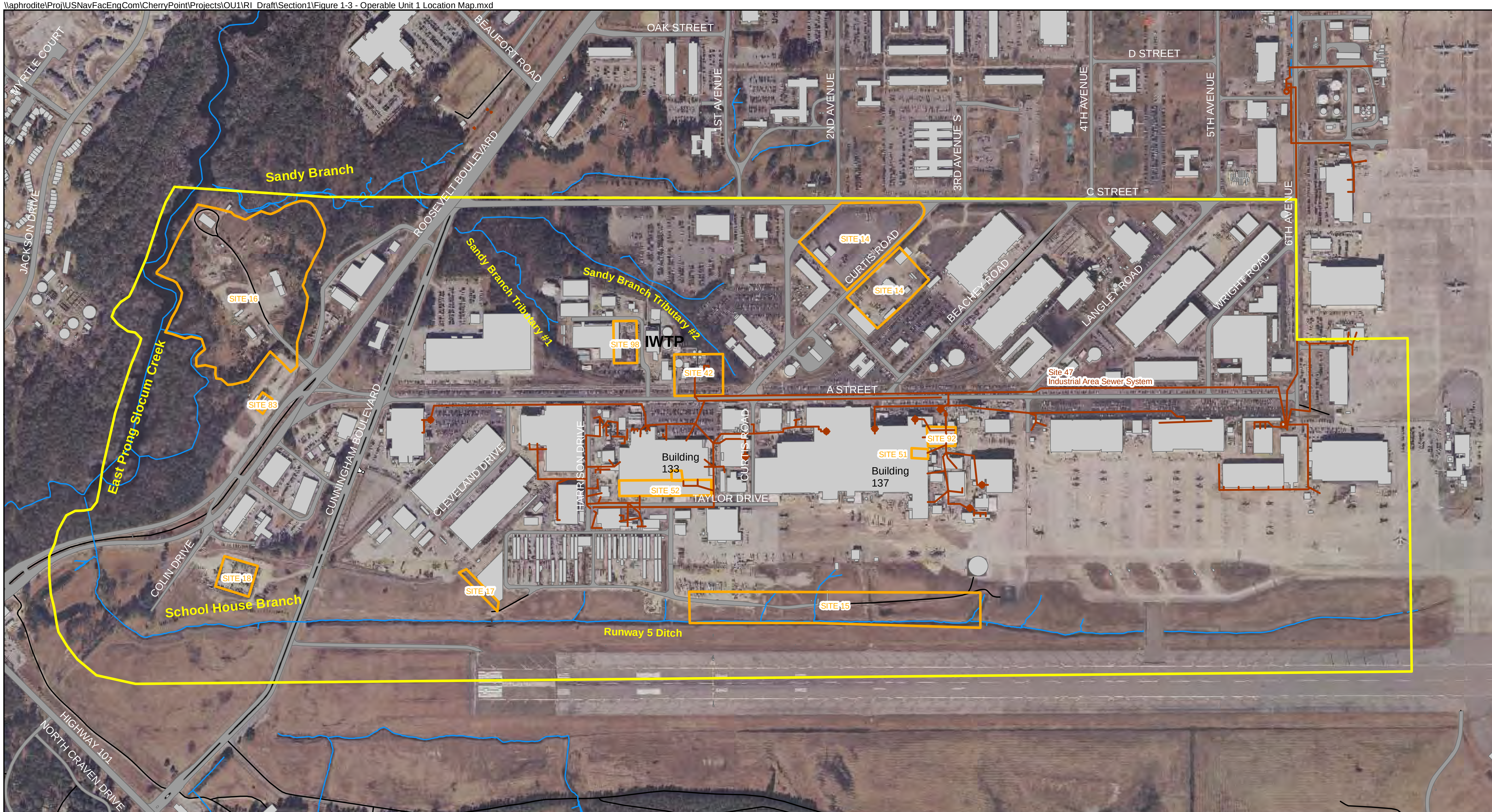
\\aphrodite\Proj\USNavFacEngCom\CherryPoint\Projects\OU1\RI_Draft\Section1\Figure 1-3 - Operable Unit 1 Location Map.mxd



Legend

- Surface Water
- Industrial Area Sewer System
- Site Boundary
- OU1 Boundary
- Existing Buildings

IWTP - Industrial Wastewater Treatment Plant

W N S E

0 500 1,000 Feet

Figure 1-3
Operable Unit 1 Location Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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SECTION 2

Results of Environmental Investigations

This section presents a summary of previous environmental investigations, the site conceptual model, the nature and extent of contamination, and potential human health and ecological risk at OU1. The 2002 RI and OU1 RI Addendum provide more-detailed information.

2.1 Previous Investigations

Site investigation activities at OU1 began in 1983 with the NACIP program. Multiple investigations have been conducted at OU1. The results of site investigations performed at OU1 from 1983 to 2000 were consolidated and presented in the 2002 RI (TetraTech NUS, 2002). The 2002 RI evaluated the nature and extent of contamination in soil, groundwater, sediment, and surface water, and assessed the potential risks by this contamination to human health and the environment.

Treatability studies were conducted at Sites 51 (Building 137) and 52 (Building 133) in 2004. During these studies, the groundwater plume in these areas was found to extend beyond the previously characterized boundaries and also to contain areas of significantly higher VOC concentrations than previously identified in the 2002 RI. The Navy conducted additional site investigations between 2005 and 2008 to further characterize the extent of the OU1 VOC groundwater plume.

The OU1 RI Addendum summarizes the results of the 2002 RI, presents an evaluation of the more recent activities conducted after the 2002 RI, and includes a summary of the ecological risk assessment, which was conducted separately. The OU1 RI Addendum presented an updated evaluation of the site conceptual model, nature and extent of contamination in soil and groundwater, potential risks by this contamination to human health and the environment, and provided the basis for the selection of remedial alternatives for the sites and environmental media within OU1.

Additional field activities were conducted in 2009 based on the proposed future actions described in the OU1 RI Addendum. Additional monitoring wells were installed to further characterize the extent of the plume in the vicinity of Sandy Branch Tributary #2, and to collect another round of samples from existing monitoring wells to update OU1 groundwater conditions. Details of the findings from these activities are provided in **Appendix A** of this FS and are discussed in general below.

2.2 Physical Characteristics

2.2.1 Surface Water

Surface water bodies present within OU1 include East Prong Slocum Creek and its tributaries Schoolhouse Branch and Sandy Branch (**Figure 1-3**). Schoolhouse Branch flows along the southeastern boundary of OU1. Two tributaries of Sandy Branch occur within the western portion of OU1, which flow to Sandy Branch, located along the western boundary of OU1. East Prong Slocum Creek is brackish, is larger than its two tributaries, and occurs along the southwestern boundary of OU1. From East Prong Slocum Creek, surface water flows into Slocum Creek and eventually the Neuse River. East Prong Slocum Creek, Schoolhouse Branch, and Sandy Branch have been classified by NCDENR as Class C fresh water bodies (TetraTech NUS, 2002).

2.2.2 Hydrostratigraphy

The hydrogeologic framework to a depth of approximately 500 feet beneath OU1 consists of nine hydrostratigraphic units: five aquifers and four confining units. From shallowest (youngest) to deepest (oldest), the aquifers with associated confining units include the surficial, Yorktown, Pungo River, Upper Castle Hayne, and Lower Castle Hayne aquifers. Each aquifer is separated by the confining unit except where the units are absent or discontinuous.

The surficial aquifer is the first encountered groundwater beneath OU1 (depth of approximately 4 to 21 feet below ground surface [bgs]) and is unconfined. The saturated thickness ranges from approximately 30 to 45 feet beneath OU1, and is controlled by the fine-grained Yorktown confining unit (generally sandy silt) at the base of the aquifer. The surficial aquifer has been evaluated as two different groundwater zones due to differences in aquifer properties: the upper and lower surficial aquifers. The upper surficial aquifer is defined as the upper 10 to 15 feet of saturated thickness, and is generally monitored by wells installed across or near the water table. The lower surficial aquifer is defined as the lower 20 to 30 feet of the aquifer and is monitored by wells installed typically just above the Yorktown confining unit.

The Yorktown aquifer occurs beneath the Yorktown confining unit and is generally a confined to semi-confined aquifer. The saturated thickness is approximately 40 feet and is controlled by the Yorktown confining unit at the top and the Pungo River confining unit at its base, where present.

A regional, Pleistocene-age paleochannel eroded the Yorktown and Pungo River confining units and deposited younger-aged sediments in the southwestern portion of OU1. As a result, the uppermost aquifers may be in direct hydraulic communication within the paleochannel. Groundwater levels northeast of the paleochannel boundary (outside the paleochannel) show a discontinuity across the Yorktown confining unit (which acts as an aquitard) and a downward vertical gradient from the surficial aquifer to the Yorktown aquifer. Groundwater levels southwest of the paleochannel boundary (within the paleochannel) generally show similar groundwater levels between the surficial and Yorktown aquifers and an upward vertical gradient from the Yorktown aquifer to the surficial aquifer.

The locations of hydrogeologic cross-sections through OU1 are shown in **Figure 2-1**, with the conceptual cross-sections A-A′, B-B′, and C-C′ shown in **Figures 2-2** through **2-4**. VOC isoconcentrations are also shown in these cross sections, illustrating vertical plume distribution.

2.2.3 Aquifer Properties

Aquifer properties of the upper and lower surficial aquifers were estimated from hydraulic conductivity ("slug") testing. The hydraulic conductivity values reported for the upper surficial aquifer were less than those for the lower surficial aquifer. The hydraulic conductivity values were estimated to range between 0.2 and 16.3 feet per day (ft/day) and 1.9 to 78.9 ft/day for the upper and lower surficial aquifers, respectively (CH2M HILL, 2009).

2.2.4 Groundwater Flow

Groundwater flows generally westward in the upper and lower surficial aquifers towards East Prong Slocum Creek and Sandy Branch, with an average horizontal hydraulic gradient of approximately 0.004 feet per foot (ft/ft) (**Figures 2-5** and **2-6**). Groundwater flow appears to have minimal discharge to Sandy Branch Tributaries #1 and #2 and follows along their same general direction. The average linear horizontal groundwater velocity in the upper and lower surficial aquifer is estimated at approximately 0.1 to 0.2 ft/day.

The direction of the vertical hydraulic gradient from the surficial to Yorktown aquifers is downward within the central and northeastern portions of OU1, and upward within the paleochannel located beneath the southwestern portion of OU1.

2.3 Nature and Extent of Contamination

The sampling activities conducted during the RIs for OU1 included soil, groundwater, sediment, and surface water sampling as part of the 2002 RI (TetraTech NUS, 2002), soil and groundwater sampling as part of the OU1 RI Addendum (CH2M HILL, 2009), and groundwater sampling as part of the 2009 additional investigation activities (**Appendix A**).

The sediment and surface water data from the 2002 RI, soil data from both the 2002 RI and OU1 RI Addendum, and updated groundwater data from both the OU1 RI Addendum and 2009 additional investigation activities were used to define the nature and extent of contamination as discussed below.

Figure 2-7 presents a graphical representation of the conceptual site model for the OU1 Central Groundwater Plume and supports the discussion in this section.

2.3.1 Soil

Site-specific soil investigations were conducted at 4 of the 6 sites identified as potential sources of contamination (Sites 42, 47, 51, and 52) during the 2002 RI. Soil samples were also collected at Sites 51 and 52 during treatability studies and later site investigation activities and analyzed for VOCs, as described in the OU1 RI Addendum.

The 2002 RI evaluated the nature and extent of contamination in soil by grouping sites that are located in close proximity to one another (eight soil groupings). Portions of Site 47 were grouped with Site 42 and Site 51 separately. Site 52 was evaluated as an individual site. Soil data was compared to USEPA Region 9 residential and industrial soil Preliminary Remediation Goals (PRGs), USEPA Generic Soil Screening Levels (SSLs) for transfers from soil to air (inhalation), USEPA Region 4 ecological soil screening values, North Carolina SSLs for the protection of groundwater, and the two times average background concentrations established in the MCAS Cherry Point background evaluation report (TetraTech NUS, 2002).

The RI Addendum included an evaluation of soil samples collected at Sites 51 and 52 in areas of suspected contaminant releases. Soil samples were compared to USEPA Region 9 residential and industrial PRGs and North Carolina SSLs (CH2M HILL, 2009).

Site 42 (Industrial Wastewater Treatment Plant)

Table 2-1 summarizes the chemicals of potential concern (COPCs) observed above regulatory standards and the maximum concentrations detected at Site 42 during the 2002 RI. COPCs included VOCs, semivolatile organic compounds (SVOCs), pesticides, polychlorinated biphenyls (PCBs), and inorganic constituents.

The inorganic constituents observed above screening criteria included aluminum, arsenic, cadmium, chromium, iron, mercury, vanadium, and zinc. Aluminum, arsenic, iron, and vanadium maximum concentrations were observed below background concentrations, and chromium and mercury were within the background concentration range; these constituents were determined to be naturally occurring. Cadmium and zinc were observed at only one surface soil sample location, at concentrations slightly exceeding human health or ecological screening criteria and above their respective background concentrations. As a result, the cadmium and zinc occurrence were believed to be localized and not indicative of a past release from a significant source at Site 42 (TetraTech NUS, 2002).

Sites 47 and 51 (Industrial Area Sewer System and Building 137)

Table 2-2 summarizes the COPCs and maximum concentrations observed at Sites 47 and 51. COPCs included VOCs, pesticides, and inorganic constituents.

The pesticides alpha-chlordane, dieldrin, and heptachlor epoxide were only observed within subsurface soil above the industrial PRG at one location within Site 51, beneath the slab of the building. Pesticides were not observed in other soil samples collected in the immediate vicinity of this location. There are no known disposal or discharge sources for pesticides at this site; the concentrations detected in soil were believed to be related to historical applications for termite control (TetraTech NUS, 2002).

The maximum arsenic concentration observed was within the range of the arsenic background concentration and was considered to be naturally occurring (TetraTech NUS, 2002).

Site 52 (Building 133)

Table 2-3 summarizes the COPCs and maximum concentrations observed at Site 52. COPCs included VOCs, pesticides and inorganic constituents.

The pesticides dieldrin and heptachlor epoxide were only observed within subsurface soil above the industrial PRG at one location within Site 52, beneath the slab of the building. Pesticides were not observed above screening criteria at other soil sample locations at the site. Pesticide storage or disposal were not related to the former building operations and the detected concentrations in soil were most likely related to normal pesticide applications at this site (TetraTech NUS, 2002).

The maximum arsenic concentration observed was within the range of the arsenic background concentration and was considered to be naturally occurring (TetraTech NUS, 2002).

Summary

Residual soil contamination detected at these sites was not detected above screening criteria in groundwater, and ultimately, is not contributing to groundwater contamination. Details related to the results of the risk assessments posed by this contamination are summarized in Sections 2.6 and 2.7.

2.3.2 Groundwater

VOCs and SVOCs

The most prevalent VOCs detected above regulatory standards within the Central Groundwater Plume (in order based on the greatest frequency of exceedances) included TCE, vinyl chloride (VC), 1,2-dichloroethene (1,2-DCE), 1,1-dichloroethane (1,1-DCA), and 1,1-DCE. These chemicals generally exceeded the regulatory standards on a frequency of greater than 10 percent. Other VOCs related to chlorinated solvents detected above regulatory standards, but less frequently, included tetrachloroethene (PCE), 1,1,1-trichloroethane (1,1,1-TCA), 1,1,2,2-tetrachloroethane (1,1,2,2-PCA), and 1,2-DCA.

Three distinct plumes of TCE and its degradation products occur within OU1 (**Figures 2-8** through **2-13**). Concentration trends of TCE, 1-2-DCE, and VC within each plume are discussed in **Appendix A**.

The most-elevated TCE concentrations (**Figures 2-8** and **2-9**) occurred beneath Building 133, at concentrations that may be indicative of the presence of dense non-aqueous phase liquid (DNAPL) (maximum concentration of 62,000 micrograms per liter (μg/L), as reported in the RI Addendum [CH2M HILL, 2009]). Beneath Building 133, TCE generally occurs only within the upper surficial aquifer and was not observed in the lower surficial aquifer. TCE extends from the upper surficial aquifer into the lower surficial aquifer at locations downgradient of Building 133, and the plume extends from the western portion of the building over 3,000 feet to East Prong Slocum Creek and Sandy Branch. TCE was not observed on the western side of the creek, as the plume is believed to discharge to the creeks.

Another distinct TCE plume occurs within the upper surficial aquifer beneath Building 137, and extends approximately a few hundred feet in the southwestern direction beneath the building. The plume extends from the upper surficial aquifer to the lower surficial aquifer downgradient of Building 137 and mixes with the plume from beneath the IWTP.

A third TCE groundwater plume within the upper surficial aquifer occurs near the IWTP. The TCE plume from this area migrates within the upper and lower surficial aquifers beneath Tributary #2 to Sandy Branch and also joins the larger plume that extends from Building 133.

Detections of 1,2-DCE (**Figures 2-10** and **2-11**) and VC (**Figures 2-12** and **2-13**) generally occurred at similar monitoring wells with exceedances of the North Carolina 2L Groundwater Standard (NC 2L) for TCE. The most-elevated concentration of cis-1,2-DCE (maximum concentration of 33,000 μg/L, as reported in RI Addendum) was detected within the upper surficial aquifer beneath Building 133. However, the most-elevated concentration of VC (maximum concentration of 8,000 µg/L, as reported in RI Addendum [CH2M HILL, 2009]) was detected beneath the IWTP within the upper surficial aquifer. Similar to TCE, 1,2-DCE and VC contamination extends from the upper surficial aquifer beneath Building 133 to the lower surficial aquifer downgradient of the building, and further to Sandy Branch and East Prong Slocum Creek.

Concentrations of 1,1-DCE generally exceeded the NC 2L standard in a small area within the upper surficial aquifer beneath Building 137, within the lower surficial aquifer downgradient of Building 137 and upgradient of the IWTP, and within the upper surficial aquifer beneath the IWTP. Concentrations of 1,1,1-TCA were only detected above the NC 2L standard at one monitoring well completed within the upper surficial aquifer at Building 137.

Benzene and other petroleum-related hydrocarbons are being investigated under the MCAS Cherry Point UST Program and are not addressed as part of this FS. However, the presence of petroleum compounds as a carbon source can contribute to the degradation of chlorinated VOCs in groundwater. Two separate petroleum plumes occur within the upper surficial aquifer to the northwest and beneath the northwestern portions of Buildings 133 and 137 (**Figures 2-14 and 2-15**) (Catlin, 2008a and 2008b).

Twelve other VOCs and four SVOCs generally exceeded their respective NC 2L standard at a frequency of less than 10 percent. Other chlorinated VOCs with concentrations above the NC 2L standards in descending order of exceedance frequency included PCE, 1,1-DCA, 1,1,2,2-PCA, 1,2-DCA, and bromodichloromethane. PCE generally occurred at locations with elevated concentrations of TCE within the upper surficial aquifer beneath Buildings 133 and 137. Detected concentrations of 1,1-DCA occurred primarily beneath Buildings 133 and 137, whereas 1,2-DCA concentrations consisted only of localized detections at individual monitoring wells. Concentrations of 1,1,2,2-PCA were only detected above the NC 2L standard within the upper surficial aquifer at multiple monitoring wells in Site 16. Bromodichloromethane was detected inconsistently and infrequently (CH2M HILL, 2009).

Pesticides and PCBs

Pesticides were only observed at nine monitoring wells during the 2002 RI. Seven of these monitoring wells occur at Sites 16, 17, or 83. Pesticide and PCB contamination at these sites is being addressed separately from this FS. Sites 16 and 83 are currently being evaluated as part of a Supplemental RI. A no further action Record of Decision (ROD) was completed for Site 17 in 2010 (CH2M HILL, 2010). Outside of Sites 16, 17, and 83, heptachlor epoxide was observed at a concentration of 0.81 µg/L at MW-04, and 4,4-DDT was observed at a concentration of 0.26 µg/L at MW-06. Monitoring wells located adjacent to these wells did not have pesticide exceedances (TetraTech NUS, 2002), so the contamination is believed to be very localized and likely related to normal pesticide applications.

PCBs were not observed in groundwater (TetraTech NUS, 2002).

Inorganic Constituents

Of the inorganic data available, arsenic, cadmium, iron, lead, manganese, and thallium were detected at more than two monitoring wells above the regulatory standards during the 2002 RI and/or RI Addendum. Other inorganic constituents observed at less than two monitoring wells above regulatory standards included aluminum, beryllium, cyanide, nickel, and vanadium. These constituents were not carried further in the evaluation due to their infrequent detection at concentrations exceeding the regulatory standards.

Lead detections in groundwater were located in the area of the Building 3996 UST site in the northeastern portion of OU1 and at Site 14 in the north-central area of OU1. The lead is believed to be related to leaded gasoline petroleum releases, and is being addressed by the UST Program at these locations.

The detections of thallium in groundwater at OU1 were determined to be due to false positives reported by the laboratory method. As a result, thallium is not a site-related constituent (TetraTech NUS, 2002).

Arsenic, iron, and manganese concentrations were determined to be consistent with naturally-occurring concentrations in groundwater due to their concentrations in relation to established background concentrations and their widespread occurrence (TetraTech NUS, 2002). Concentrations observed during the RI Addendum were similar to those found during the 2002 RI.

Total cadmium was observed during the RI Addendum at four monitoring wells (N4GW22, MW61, MW62, and 74GW11) within OU1 (locations shown in **Figure 2-1**), with a maximum concentration of 3.7 J μg/L, which is above the NC 2L of 1.75 μg/L (CH2M HILL, 2009). Dissolved cadmium was below the NC 2L, which suggests that the cadmium occurrence is most likely related to the sediments of the aquifer and not dissolved groundwater concentrations. In addition, where total cadmium exceeded the NC 2L standard, adjacent monitoring wells did not contain elevated concentrations of cadmium. Therefore, the total cadmium concentrations are not believed to be site-related and are most likely naturally-occurring.

2.3.3 Surface Water and Sediment

Surface water and sediment samples were collected from East Prong Slocum Creek, Sandy Branch, and Schoolhouse Branch as part of the 2002 RI. Surface water results were compared to North Carolina Water Quality Standards and ecological screening levels. Sediment results were compared to USEPA Region 9 Soil PRGs and ecological screening levels.

VOCs, SVOCs, PCBs, pesticides, and inorganic constituents were observed in surface water and sediment at each surface water body in OU1. However, only manganese at Sandy Branch; PCBs, arsenic, and mercury at Schoolhouse Branch; and chlordane, arsenic, manganese, and thallium at East Prong Slocum Creek, were observed in surface water above the North Carolina Water Quality Standards. However, detected thallium concentrations are a result of false positive detections from the laboratory analytical technique previously used. Arsenic, manganese, and mercury were determined to be likely associated with background conditions. PCB exceedances of surface water standards were associated with drainage ditches and the Runway 5 ditch, and are also likely a result of the elevated turbidity during sampling. Chlordane was detected at a concentration of 0.0057 μg/L, slightly above the NCWQS criteria (0.004 μg/L) in only one of seven surface water samples (TetraTech NUS, 2002).

Polycyclic aromatic hydrocarbons (PAHs), pesticides, arsenic, antimony, cadmium, copper, chromium, lead, iron, mercury, nickel, silver, and zinc were observed at concentrations in sediment exceeding screening criteria within Sandy Branch. PAHs, a SVOC, and PCBs were observed above screening criteria within sediment of Schoolhouse Branch. PAHs, PCBs, arsenic, cadmium, copper, iron, manganese, aluminum, and cyanide were observed above screening criteria within sediment of East Prong Slocum Creek (TetraTech NUS, 2002).

2.4 Natural Attenuation Evaluation Summary

Natural attenuation evaluations were conducted as part of the OU1 RI Addendum (CH2M HILL, 2009), as well as the 2009 additional groundwater investigation, findings of which are described in detail in **Appendix A**. This section provides a brief summary of the 2009 additional groundwater investigation findings.

During the March and May 2009 sampling events, field measurements and groundwater samples were collected in order to evaluate the geochemical characteristics of the upper surficial and lower surficial aquifers. Field measurements included DO, ORP, pH, temperature, conductivity, and turbidity. In addition, groundwater samples were collected and analyzed for a suite of monitored natural attenuation (MNA) indicator parameters, including nitrate, nitrite, sulfide, chloride, total organic carbon (TOC), methane, ethane, and ethene.

Analytical results indicated conditions were generally favorable to biologically-mediated reductive dechlorination. Oxidation-reduction potential (ORP) ranged from -99 to 112 millivolts (mV) and from -143 to 57 mV in the upper and lower surficial aquifers, respectively. Dissolved oxygen was depressed over the majority of the plume area (<0.5 milligrams per liter [mg/L]). Temperature and pH were within acceptable ranges, although pH was slightly acidic (as low as 5.0), especially in source areas. “Daughter” compounds, including cis-1,2-DCE, VC, chloride, and ethene, were present throughout the plume, indicating that biologically mediated natural attenuation is occurring. Highest concentrations of VC, chloride, and ethene were present in source and near source areas, where the most strongly reducing conditions are present, based on dissolved oxygen and ORP levels. Concentrations of methane were also elevated in source areas, with concentrations as high as 33,000 μg/L in the upper surficial aquifer. TOC appears to be a key parameter limiting progress of natural attenuation, with concentrations ranging from 5 to 10 mg/L or less in most areas of the site (>20 mg/L is considered optimal).

2.5 Fate and Transport Modeling

Fate and transport modeling was conducted as part of the OU1 RI Addendum using the screening-level models BIOCHLOR and Natural Attenuation Software (NAS) to predict source area concentration reductions required to prevent impacts to surface water above regulatory standards. Flow paths within the upper and lower surficial aquifers were modeled beginning beneath Building 133, and included both the Sandy Branch and East Prong Slocum Creek flow paths (CH2M HILL, 2009).

The upgradient portion of the Sandy Branch BIOCHLOR and NAS models predicted that no concentration reductions of PCE, TCE, cis-1,2-DCE, or VC were required to prevent plume discharge to Sandy Branch above surface water standards. However, the downgradient portion of the Sandy Branch BIOCHLOR model predicted that VC concentration reductions of up to 50 percent to 75 percent near monitoring well 16GW06 would be required.

The East Prong Slocum Creek BIOCHLOR model predicted that reduction of TCE groundwater concentrations within the lower surficial aquifer beneath Building 133 and within the upper surficial aquifer beneath Site 16 was required to meet surface water standards at the point of discharge to East Prong Slocum Creek. However, the NAS model predicted that no TCE concentration reductions would be required.

2.6 Human Health Risk Assessment

A baseline Human Health Risk Assessment (HHRA) was performed as part of the 2002 RI to evaluate the potential human health risks for soil, groundwater, sediment, surface water, and air at OU1. Potential receptors that were evaluated included industrial workers, maintenance workers, full-time employee/military personnel, adolescent trespassers, adult recreational users under both current and hypothetical future land use conditions, and adult and child residents under the hypothetical future land use conditions (TetraTech NUS, 2002).

An updated HHRA was also conducted as part of the OU1 RI Addendum, which included a summary of risks associated with exposure to soil at Sites 47 and 52, and an evaluation of the magnitude and probability of actual or potential health risks associated with exposure to OU1 groundwater. Exposure to soil at Sites 47 and 52 was evaluated for current/future construction and maintenance workers and potential future residents and industrial workers. Exposure to groundwater from the surficial aquifer was evaluated for current industrial workers and hypothetical future construction workers and adult and child residents (CH2M HILL, 2009).

The updated HHRA did not evaluate potential human health risks associated with current and future receptors for inhalation of indoor air, since a vapor intrusion investigation is currently being conducted to further assess this exposure pathway. If risks are identified as a result of the vapor intrusion evaluation, the risk will be addressed separately.

A general summary of the baseline HHRA and the updated HHRA are discussed below by media type.

2.6.1 Soil

Estimated cancer risks were below or within the USEPA target risk range of 10^{-4} and 10^{-6} and hazard indices (HIs) were below the acceptability threshold of 1.0 for exposure to soil by each receptor at Site 42 (TetraTech NUS, 2002).

The results of the initial HHRA indicated that exposure to soil by construction workers exceeded USEPA's target hazard level at Sites 51 and 52, due to alpha-chlordane, dieldrin, and/or heptachlor epoxide (TetraTech NUS, 2002). The occurrence of these pesticides was within subsurface soil at one location beneath the slabs of Buildings 133 and 137. The presence of pesticides at these sites was attributed to historic, routine applications of pesticides, as discussed in **Section 2.3.1**.

The updated HHRA determined that exposure to VOCs in soil at Sites 47 and 52 would not result in any unacceptable risks (CH2M HILL, 2009).

Therefore, the results of the HHRA indicate that no potential unacceptable human health hazards or risks associated with exposure to soil are present within OU1.

2.6.2 Groundwater

The 2002 RI HHRA calculated HIs and cancer risk for potential future potable use of the surficial aquifer that exceeded USEPA's target levels. VOCs (1,1,1-TCA, benzene, 1,2-DCE, cis-1,2-DCE, TCE, and VC), carcinogenic PAHs, arsenic, iron, and thallium were the major risk contributors for the surficial aquifer. The carcinogenic PAHs were mainly detected in one sample from monitoring well 51GW14. Only one of the PAHs, chrysene, was detected in more than one sample (detected in three samples). Arsenic and iron were determined to be associated with background conditions and the occurrence of thallium was attributed to false-positive detections related to the laboratory analytical method. No risk was identified for the Yorktown and Castle Hayne aquifers (Tetra Tech NUS, 2002).

The updated HHRA evaluation presented in the OU1 RI Addendum determined that potable use of the surficial aquifer groundwater by future residents may result in unacceptable risk. The noncarcinogenic hazard to both a child and adult resident and carcinogenic risk to the lifetime resident using the surficial aquifer groundwater as a potable water supply exceeded USEPA acceptable levels for both reasonable maximum exposure (RME) and central tendency exposure (CTE) point evaluations. These hazards and risks were primarily associated with chlorinated VOCs (with PCE, TCE, and VC contributing the greatest risk and hazard), with additional contributions from benzene and arsenic.

The updated HHRA also determined that exposure to surficial aquifer groundwater by a construction worker would result in a hazard index (HI) of 1.7. However, no individual constituents or target organs had HIs above USEPA's target level of 1.0. The carcinogenic risk to a future construction worker from exposure to surficial aquifer groundwater was within USEPA's target risk range. Therefore, there were no calculated hazards or risks to a future construction worker above USEPA's target levels.

2.6.3 Sediment

The estimated cancer risk for exposure to OU1 sediments by child residents and lifetime residents exceeded USEPA's target levels. The risk was associated with PAHs observed in one sediment sample within Schoolhouse Branch (TetraTech NUS, 2002). All other receptors potentially exposed to sediment were below or within the USEPA target risk range of 10^{-4} and 10^{-6} and HIs were below the acceptability threshold of 1.0.

2.6.4 Surface Water

All receptors potentially exposed to surface water were below or within the USEPA target risk range of 10^{-4} and 10^{-6} and HIs were below the acceptability threshold of 1.0 (TetraTech NUS, 2002).

2.7 Ecological Risk Assessment

Steps 1 through 3a of the Ecological Risk Assessment (ERA) process were summarized in the 2002 RI (TetraTech NUS, 2002). Maximum concentrations from soil and sediment data collected during field investigations from 1985 through 2000 and surface water data from

2000 were compared to ecological screening values. Several inorganics, PAHs, pesticides, and PCBs were identified as COPCs with risk to upper-trophic-level receptors.

Potential impacts from groundwater to surface water were also estimated in the 2002 RI by comparing maximum groundwater concentrations to surface water screening values. Fourteen VOCs, eight SVOCs, nine pesticides, and 15 inorganics in the surficial aquifer had maximum concentrations that exceeded surface water screening levels. However, the locations of the maximum concentrations were at significant distances from East Prong Slocum Creek and Sandy Branch, and not representative of the concentrations in groundwater discharging to the creeks.

The Step 3a Addendum identified portions of Soil Grouping 3 (Sites 16, 83, and BRAC Site 5), Sandy Branch, Tributary #2, and Site 17 (discharge to the School House Branch Aquatic System) as primary areas posing potential ecological risk.

The Baseline Ecological Risk Assessment (BERA) identified a small portion of risk in Soil Grouping 3 to soil invertebrates only, with the trees the most valuable ecological aspect. However, the risk was not considered significant for soil invertebrates, since the quality of soil in the area is sandy with little retention of moisture and organic material and not ideal for soil invertebrates. Trees in the area provide nesting and roosting areas for birds and help to stabilize the soil, reducing erosion and subsequent deposition of soils into East Prong Slocum Creek.

The BERA also identified potential ecological risks at Sandy Branch Tributary #2 related to COPCs in sediment (several inorganics, pesticides, PAHs, and other SVOCs). Based on these identified risks, supplemental sampling and analysis were recommended.

The Post-BERA Work Plan proposed supplemental sampling and wetland delineation at Sandy Branch Tributary #2, presented key concepts and strategies for addressing risk associated with Tributary #2, and finalized the risk management decision for Soil Grouping 3. This document recommended no further action (NFA) for Soil Grouping 3 and the Navy, EAD, USEPA, and NCDENR concurred.

An Engineering Evaluation/Cost Analysis (EE/CA) was prepared for Sandy Branch Tributary #2 and adjacent floodplain/wetland habitat to remove COPC-contaminated media to levels protective of at-risk ecological receptors (i.e., benthic macroinvertebrates). The EE/CA was ultimately used to select a sediment and soil removal technique to facilitate the removal action from a comparison of three alternatives. The sediment and soil removal was completed in 2008.

2.8 Chemicals of Concern

A chemical of concern (COC) is defined as any COPC that contributes significant risks to a pathway in a use scenario for a receptor. USEPA classifies any COPC with a cancer risk greater than 10^{-6} and/or a non-cancer hazard quotient (HQ) greater than 0.1 (where the cumulative cancer risk is greater than 10^{-4} and/or HI is greater than 1) as a COC.

Potential unacceptable risks were identified for exposure to groundwater from the surficial aquifer by a future adult resident, future child resident, and future lifetime resident. No unacceptable human health risks were determined for exposure to soil, sediment, surface water, and groundwater from the Yorktown and Castle Hayne aquifers. Potential unacceptable ecological risks were identified only within soil and sediment of Sandy Branch Tributary #2. However, a soil and sediment removal action to address these risks was completed in 2008 as part of a separate remedial action.

In addition, COCs were also identified where concentrations exceeded ARARs, such as NC 2L standards and Federal Maximum Contaminant Level (MCL). The ARARs are discussed in more detail in **Section 3**.

Petroleum-related compounds (investigated and managed by the UST Program) and naturally-occurring inorganic constituents were specifically excluded as COCs, since they are not related to historical CERCLA releases at OU1.

A summary of the OU1 Central Groundwater Plume COCs is provided in **Table 2-4**. This table also provides the groundwater quality standards, sample exceedance frequencies from the OU1 RI Addendum and 2009 Additional Groundwater Investigation, and whether the COC is addressed by this FS. NC 2L standards have been revised since the completion of the OU1 RI Addendum. This COC list includes an updated comparison of the OU1 RI Addendum and 2009 Additional Groundwater Investigation analytical results to the NC 2L standards revised on January 1, 2010.

2.9 Previous Treatability Studies

In November 2001, a treatability study (TS) was conducted on the Building 137 plume using a one-time substrate injection of Hydrogen Release Compound (HRC®). The treatability study appears to have left the overall size of the plume beneath Building 137 relatively unchanged. Initially, the results of the treatability study were positive; TCE concentrations decreased from 5,150 µg/L (baseline event) to 320 µg/L (final performance monitoring event in December 2002). However, the May 2004 sampling event results showed a rebound of TCE concentrations to 3,000 µg/L. Chlorinated VOC concentrations also increased once during the fourth round of performance monitoring, conducted in the spring of 2002.

In January 2005, a treatability study was conducted at both Buildings 133 and 137. Liquid EHC™, a controlled-release carbon plus zero-valent iron (ZVI) compound, was injected into the relatively highest chlorinated-VOC-contaminated subsurface zones located from 10 to 20 feet bgs. The focus of the treatability study was to evaluate the effectiveness of enhanced anaerobic bioremediation on the Buildings 133 and 137 shallow chlorinated VOC plumes. The EHC™ compound has a combined potential effect of stimulated biological oxygen consumption (via fermentation of added organic carbon substrate), direct chemical reduction with reduced metals, and the corresponding enhanced thermodynamic decomposition reactions that are realized at lowered ORP conditions.

A chronology of events associated with the 2005 TS is as follows:

Activity	Date	Time* [days]
Tracer test and baseline monitoring [Phases 1 and 2]	November 30-December 21, 2004	21
EHC™ injection [Phase 3]	January 8-12, 2005	0
Post-injection performance monitoring [Phase 4]	-	-
Round 1	March 9-10, 2005	56
Round 2	May 3-5, 2005	111
Round 3	July 26-27, 2005	195
Round 4	November 15-16, 2005	307

* Elapsed time after completion of EHC™ injection (January 12, 2005)

Primary conclusions of the 2005 treatability study were as follows (CH2M HILL, 2007):

- EHC™ injection was effective in initially reducing chlorinated VOC concentrations in wells located near the injection points. Mass reduction of chlorinated VOCs was achieved.
- The increase in concentrations of 1,1-DCA, cis-1,2-DCE, and VC, with reduction of nitrate and sulfate in several wells, following the EHC™ injections, indicated that anaerobic degradation was a factor in reducing chlorinated VOCs in the plumes beneath Buildings 137 and 133.
- The geochemical data indicate that abiotic reduction was a secondary process in chlorinated VOC reduction. An increase in pH and a sharp decline in ORP at two wells, combined with sharp decreases in TCE and TCA, indicated that abiotic reduction took place. A decrease in dissolved TCE and TCA, without significant formation of daughter products was also observed, providing further evidence of the abiotic treatment.
- Microbial analyses (*Dehalococcoides,* deoxyribonucleic acid [DNA], and phospholipid-derived fatty acids [PLFA]) indicated that the composition, health, and diversity of the biomass in the aquifer could support anaerobic reductive dechlorination.
- Concentrations initially decreased, but some rebounded with time, in a similar manner as the previous (2001) HRC® treatability study at Building 137. Rebound was likely associated with the following factors:
  - Under-dosing for the mass of chlorinated VOC present
  - Continuing sources (residual DNAPL beneath Building 133)

It is important to note that the treatability studies implemented at the buildings were small scale in size relative to a full scale remedy. The one-time installation of monitoring wells and several rounds of sampling required significantly lower disruption to building activities than installation and operation of an extensive treatment system would require. Based on the results of the treatability studies, a significant number of injection wells would be required to inject and distribute enough substrate to completely treat the source area. Such an extensive network of wells would be difficult to implement in Building 133 due to building operations, small size of the workshop areas, low ceilings, and abundance of equipment. It is estimated that given the site hydrogeology, a radius of influence of approximately 12.5 ft could be achieved. Therefore, the estimated number of well pairs required would be on the order of 30 to 40 if vertical injection wells are used (60 to 89 individual wells) or 4 to 6 horizontal wells, with injection occurring approximately every 2 years. Installation of this number of wells would require an approximately 2 to 3 month period of near-continuous drilling (assuming no issues with clearance and utilities are encountered) and IDW management. Injection of the substrate would likely require an additional 2 to 3 months for each injection, every 2 years, for a period of approximately 10 to 20 years. Additionally, injection beneath Building 133 is likely to be high-risk from an operations standpoint, because the exact area of suspected DNAPL is not well-defined, and degradation products (i.e., vinyl chloride) could generate potential vapor intrusion risks.

TABLE 2-1
COPC Exceedances, Site 42
Marine Corps Air Station Cherry Point, North Carolina

Media	COPCs		Maximum Concentration	Applicable Regulatory Standard
Surface Soil (0 – 2 ft bgs)	SVOCs (μg/kg)	benzo(a)pyrene	80	62
		benzo(g,h,i)perylene	110	100
		bis(2-ethylhexyl)phthalate	200	100
	Pesticides / PCBs (μg/kg)	4,4'-DDE	4.9	2.5
		Aroclor 1254	150	20
		Aroclor 1260	130	20
	Inorganics (mg/kg)	aluminum	5,620	50
		arsenic	2.6	0.39
		cadmium	4	1.6
		chromium	19.5	0.4
		iron	5,830	200
		mercury	0.17	0.1
		vanadium	11.6	2
		zinc	54.4	50
Subsurface Soil (2 – 20 ft bgs)	VOCs (μg/kg)	1,1,1-trichloroethane	38,000	1,670
		methylene chloride	760 J	20.2
		tetrachloroethene	20,000	19,000
		trichloroethene	7,100	6,100
	SVOCs (μg/kg)	2-methylnaphthalene	30,000	19,000
		naphthalene	34,000	19,000
	Inorganics (mg/kg)	arsenic	8.9	2.7

Notes:
COPC – Chemical of Potential Concern
μg/kg – microgram per kilogram
mg/kg – milligram per kilogram
μg/L – microgram per liter
J – analyte positively identified; the reported concentration is approximate
Applicable regulatory standards are generally the Region 4 surface soil screening value or Region 9 PRG for residential soil for shallow soil, and the Region 9 PRG for industrial soil for subsurface soil (2002 RI).

TABLE 2-2
COPC Exceedances, Sites 47 and 51
Marine Corps Air Station Cherry Point, North Carolina

Media	COPCs		Maximum Concentration	Applicable Regulatory Standard
Surface Soil (0 – 2 ft bgs)	VOCs (µg/kg)	trichloroethene	6,400	2,800
	Inorganics (mg/kg)	arsenic	3.88	0.39
		cyanide	76	1.1
Subsurface Soil (2 – 12 ft bgs)	VOCs µg/kg)	1,1-dichloroethene	15,000	120
		1,2-dichloroethene (total)	18,000	15,000
		trichloroethene	20,000	6,100
	Pesticides (µg/kg)	alpha-chlordane	18,000	11,000
		dieldrin	27,000	150
		heptachlor epoxide	9,800	270
	Inorganics (mg/kg)	arsenic	10.5	2.7
		cadmium	136	81
		chromium	2,630	450
		cyanide	37.6	3.5

Notes:
COPC – Chemical of Potential Concern
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
µg/L – microgram per liter
Applicable regulatory standard are generally the Region 4 surface soil screening value or Region 9 PRG for residential soil for shallow soil, and the Region 9 PRG for industrial soil for subsurface soil (2002 RI).

TABLE 2-3
COPC Exceedances, Site 52
Marine Corps Air Station Cherry Point, North Carolina

Media	COPCs		Maximum Concentration	Applicable Regulatory Standard
Surface Soil (0 – 2 ft bgs)	Inorganics (mg/kg)	cyanide	4.6	1.1
Subsurface Soil (2 – 9 ft bgs) from 2002 RI	Pesticides (µg/kg)	dieldrin	9,100	150
		heptachlor epoxide	4,600	270
	Inorganics (mg/kg)	arsenic	4.8	2.7
		cyanide	8.2	3.5
Subsurface Soil (2 – 16 ft bgs) from RI Addendum	VOCs (µg/kg)	TCE	280	18.3
		1,2,4-trichlorobenzene	5,100	2,610
		1,2-dichlorobenzene	65,000	24
		1,4-dichlorobenzene	8,200	23
		xylenes	6,900	4,960
		isopropylbenzene	1,900	70

Notes:
COPC – Chemical of Potential Concern
µg/kg – microgram per kilogram
mg/kg – milligram per kilogram
µg/L – microgram per liter
Applicable regulatory standard are generally the Region 4 surface soil screening value or Region 9 PRG for residential soil for shallow soil, and the Region 9 PRG for industrial soil for subsurface soil (2002 RI) and the North Carolina soil screening levels (RI Addendum)

TABLE 2-4
List of OU1 Central Groundwater Plume COCs
Marine Corps Air Station Cherry Point, North Carolina

Constituent	Screening Criteria: MCL	Screening Criteria: NC2LGW	Screening Criteria: Background	Sample Exceedances: Samples Analyzed	Sample Exceedances: NC2LGW	Sample Exceedances: Frequency above NC2L (above background)	Maximum Detection: Maximum Concentration	Maximum Detection: Location	COC to be Addressed by Central Groundwater Plume FS? / Comments
NC2L Exceedance and Risk-Based COC									
Volatile Organic Compounds (µg/L)									
Trichloroethene (TCE)	5	3	--	876	393	45%	62,000	52GW53	**Yes:** Cancer risk $>10^{-4}$ and HI>1
Vinyl Chloride	2	0.03	--	876	294	34%	8,000	42GW05	**Yes:** Cancer risk $>10^{-4}$ and HI>1
cis-1,2-Dichloroethene (cis-1,2-DCE)	70	70	--	765	230	30%	33,000	52GW08	**Yes:** HI>1
1,2-Dichloroethene (1,2-DCE) (total)	70	--	--	235	--	--	16,000	42GW05	**Yes:** HI>1
1,1-Dichloroethane (1,1-DCA)	--	6	--	876	143	16%	8,800	47GW07	**Yes**: Cumulative HI>1; however, individually has HI>0.1 and <1
Tetrachloroethene (PCE)	5	0.7	--	877	83	9%	71	52GW53	**Yes**: Cancer risk $>10^{-4}$
1,1,2,2-Tetrachloroethane (1,1,2,2-PCA)	--	0.2	--	877	38	4%	6	16GW02	**Yes**: Cumulative cancer risk $>10^{-4}$; however, individually has cancer risk $>10^{-6}$ and $<10^{-5}$
1,2-Dichloroethane (1,2-DCA)	5	0.4	--	877	21	2%	14	47GW07	**Yes**: Cumulative cancer risk $>10^{-4}$; however, individually has cancer risk $>10^{-5}$ and $<10^{-4}$
Benzene	5	1	--	876	116	13%	7,700	74GW23	**No**: Petroleum-related compound that will be addressed as part of the UST Program
1,4-Dichlorobenzene	75	6	--	561	20	4%	98	N2GW27	**No**: Petroleum-related compound that will be addressed as part of the UST Program
1,2-Dichloropropane	5	0.6	--	877	2	0.2%	4	51EX15	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Semi-Volatile Organic Compounds (µg/L)									
4-Methylphenol	--	40	--	61	2	3%	470	52GW44	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Inorganic Constituents (µg/L)									
Iron	--	300	4,740	75	75	100%	268,000	52GW01	**No**: Presence in groundwater not related to a CERCLA release; 2002 RI determined to be naturally occurring constituent
Manganese	--	50	93	61	50	82%	3,180	47GW19	**No**: Presence in groundwater not related to a CERCLA release; 2002 RI determined to be naturally occurring constituent
Arsenic	10	10	6	113	3	3%	56	N4GW22	**No**: Presence in groundwater not related to a CERCLA release; 2002 RI determined to be naturally occurring constituent
NC2L Exceedance Only COC									
Volatile Organic Compounds (µg/L)									
1,1-Dichloroethene (1,1-DCE)	7	7	--	877	96	11%	2,900	47GW07	**Yes**
trans-1,2-Dichloroethene (trans-1,2-DCE	100	100	--	764	27	4%	1,100	MW73	**Yes**
1,1,1-Trichloroethane (1,1,1-TCA)	200	200	--	877	13	1%	49,000	47GW07	**Yes**

TABLE 2-4
List of OU1 Central Groundwater Plume COCs
Marine Corps Air Station Cherry Point, North Carolina

Constituent	Screening Criteria			Sample Exceedances			Maximum Detection		COC to be Addressed by Central Groundwater Plume FS? / Comments
	MCL	NC2LGW	Background	Samples Analyzed	NC2LGW	Frequency above NC2L (above background)	Maximum Concentration	Location	
2-Methylnaphthalene	--	30	--	62	7	11%	78	74GW16	**No**: Petroleum-related compound that will be addressed as part of the UST Program
1,2-Dichlorobenzene	600	20	--	561	7	1%	470	MW65	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Isopropylbenzene	--	70	--	388	8	2%	1,100	74GW15	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Chlorobenzene	100	50	--	876	12	1%	930	MW65	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Bromodichloromethane	80	0.06	--	876	6	0.7%	9	52GW07	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Xylene, total	10000	500	--	697	4	0.6%	5,200	14GW34	**No**: Petroleum-related compound that will be addressed as part of the UST Program
m- and p-Xylene	--	500	--	336	2	0.6%	1,100	74GW23	**No**: Petroleum-related compound that will be addressed as part of the UST Program
o-Xylene	--	500	--	337	1	0.3%	980	74GW23	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Acetone	--	6000	--	860	3	0.3%	1,300	52GW10	**No**: Not believed to be a site-related constituent; detected in field blank samples and likely a laboratory artifact
Ethylbenzene	700	600	--	877	2	0.2%	1,770	14GW34	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Chloromethane	--	3	--	877	3	0.3%	100	16GW06	**No**: Not believed to be a site-related constituent; detected in field blank samples and likely a laboratory artifact
Methylene chloride	5	5	--	877	9	1.0%	170	52GW35/ 52GW51	**No**: Not believed to be a site-related constituent; detected in field blank samples and likely a laboratory artifact
Toluene	1000	600	--	877	2	0.2%	7,100	74GW23	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Bromoform	80	4	--	877	1	0.1%	5	52GW01	**No**: Not believed to be a site-related constituent; detected in field blank samples and likely a laboratory artifact
Dibromochloromethane	80	0.4	--	877	1	0.1%	1	N2GW41	**No**: Petroleum-related compound that will be addressed as part of the UST Program
1,1-Dichloropropene		0.19	--	196	0	0.0%	2	74GW24	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program

TABLE 2-4
List of OU1 Central Groundwater Plume COCs
Marine Corps Air Station Cherry Point, North Carolina

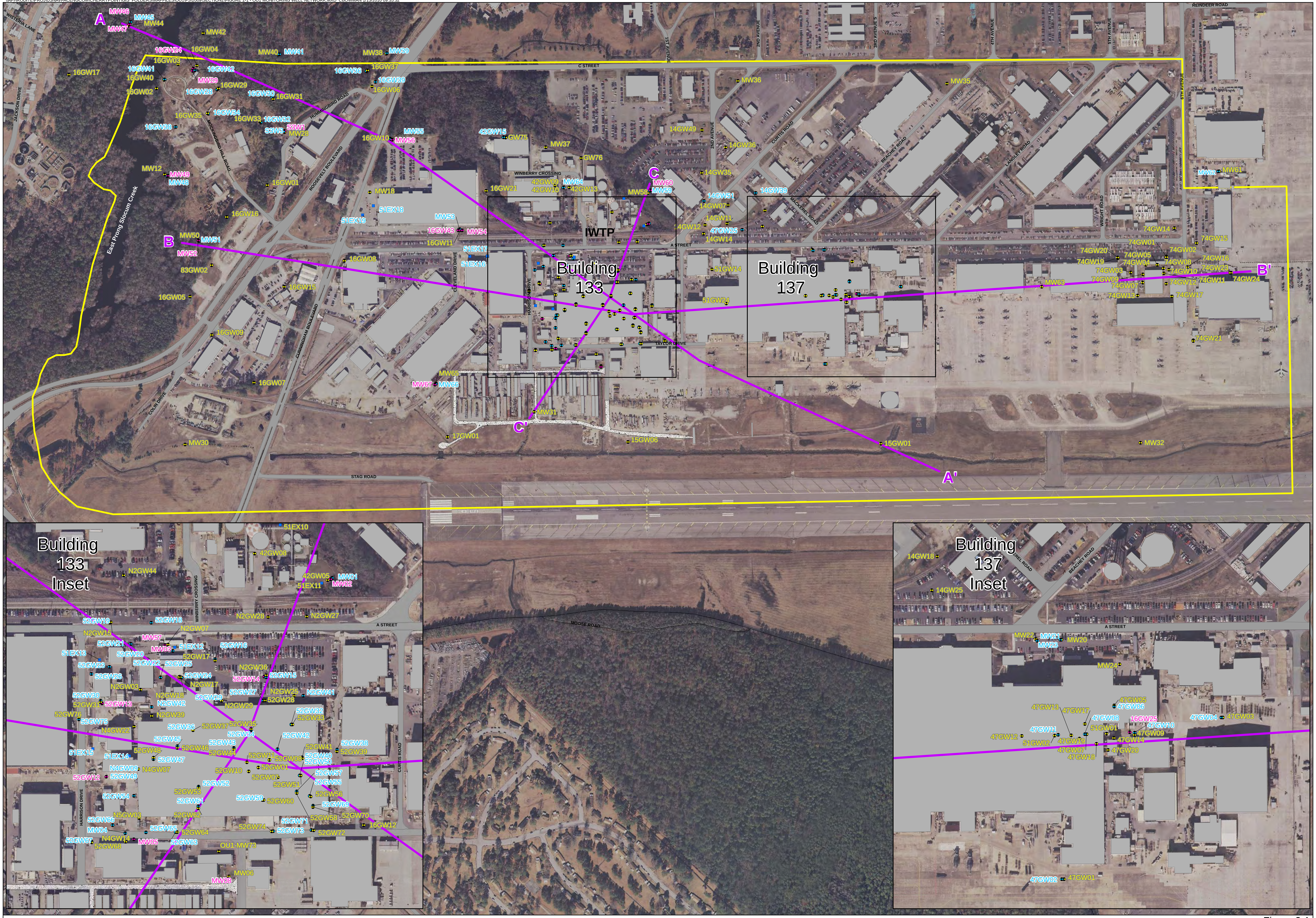
Constituent	Screening Criteria			Sample Exceedances			Maximum Detection		COC to be Addressed by Central Groundwater Plume FS? / Comments
	MCL	NC2LGW	Background	Samples Analyzed	NC2LGW	Frequency above NC2L (above background)	Maximum Concentration	Location	
1,2,4-Trimethylbenzene	--	400	--	197	1	0.5%	2,000	N2GW18	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
Methyl Tert-Butyl Ether (MTBE)	--	20	--	230	1	0.4%	471	14GW22	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
N-Butylbenzene	--	70	--	197	1	0.5%	117	74GW16	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
Semi-volatile Organic Compounds (µg/L)									
Naphthalene	--	6	--	234	12	5%	680	N2GW18	**No**: Petroleum-related compound that will be addressed as part of the UST Program
Chrysene	--	5	--	62	1	2%	38	52GW70	**No**: Petroleum-related compound that will be addressed as part of the UST Program
1-Methylnaphthalene		30		31	1	3%	615	74GW10	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
Benzo(a)anthracene	--	0.05		114	1	0.9%	2	51GW14	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
Benzo(a)pyrene	0.2	0.005		114	1	0.9%	2	51GW03	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
Benzo(b)fluoranthene	--	0.05		114	1	0.9%	1	51GW14	**No**: Identified from 2002 RI, Petroleum-related compound that will be addressed as part of the UST Program
Pesticide/Polychlorinated Biphenyls (µg/L)									
Dieldrin	--	0.002	--	15	1	7%	0	17GW01	**No**: Presence in groundwater not related to a CERCLA release; from normal basewide pesticide application (associated with Site 17 investigations conducted separately)
Heptachlor epoxide	0.2	0.004	--	15	1	7%	0	16GW15	**No**: Presence in groundwater not related to a CERCLA release; from normal basewide pesticide application (investigated as part of Site 16 investigations conducted separately)

TABLE 2-4
List of OU1 Central Groundwater Plume COCs
Marine Corps Air Station Cherry Point, North Carolina

	Screening Criteria			Sample Exceedances			Maximum Detection		
Constituent	MCL	NC2LGW	Background	Samples Analyzed	NC2LGW	Frequency above NC2L (above background)	Maximum Concentration	Location	COC to be Addressed by Central Groundwater Plume FS? / Comments
Inorganic Constituents (µg/L)									
Cadmium	5	2	--	113	4	4%	4	MW62	**No**: Presence in groundwater is likely naturally occurring, since only total cadmium concentrations were observed above the regulatory standards and in localized areas.
Risk Based Only COC									
Volatile Organic Compounds (µg/L)									
1,1,2-Trichloroethane (1,1,2-TCA)	5	--		877	1	0.1%	39	52GW08	**Yes**: Cumulative cancer risk >10^{-4} and HI>1; however, individually has cancer risk >10^{-6} and <10^{-5} and HI>0.1 and <1
Chloroform	80	70		877	1	0.1%	40	52GW14	**Yes**: Cumulative cancer risk >10^{-4}; however, individually has cancer risk >10^{-6} and <10^{-5}
1,3-Dichlorobenzene	--	200		561	1	0.2%	34	MW65	**No**: Petroleum-related compound that will be addressed as part of the UST Program

Notes:
-- Not available
µg/L - micrograms per liter
NC2LGW - North Carolina 2L Standards for Groundwater (January 2010)
Includes results from the OU1 RI Addendum and 2009 Additional Groundwater Investigation

\\APHRODITE\PROJ\NAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-1 - OU1 MONITORING WELL NETWORK.MXD CBOWMAN 1/15/2010 09:35:32



Legend

- Extraction Well
- Upper Surficial Monitoring Well
- Lower Surficial Monitoring Well
- Yorktown Monitoring Well
- Cross Section Transects
- Existing Buildings
- OU1 Boundary
- Paved Road

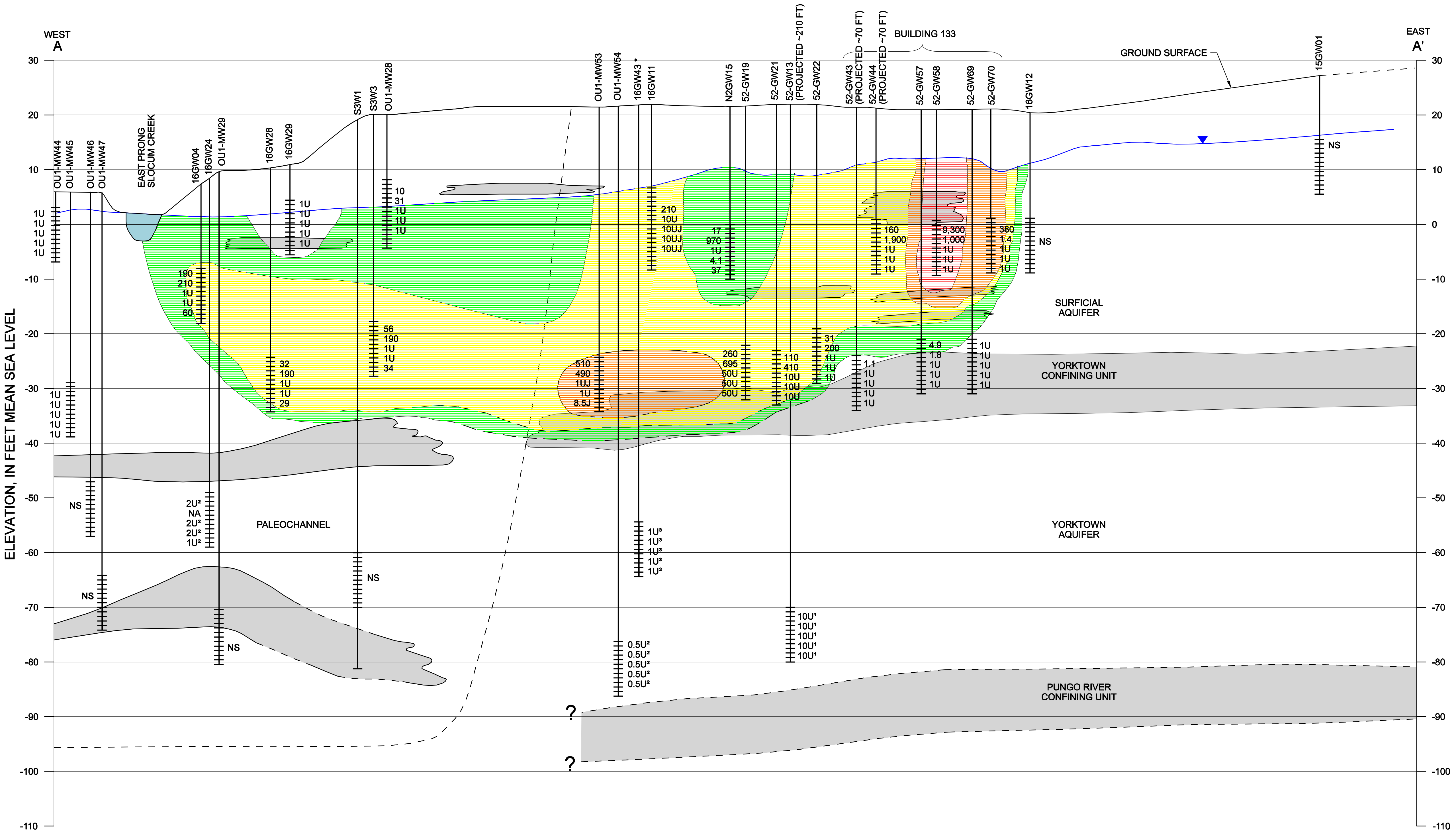
IWTP - Industrial Wastewater Treatment Plant

0 210 420 630 Feet

0 100 200 300 Feet

Figure 2-1
OU1 Monitoring Well Network and
Location of Hydrogeologic Cross-Sections
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL



LEGEND

WELL SCREEN INTERVAL

LINE OF APPROXIMATELY EQUAL TCE ISOCONCENTRATION IN ug/L

PREDOMINANTLY COARSE-GRAINED MATERIAL

PREDOMINANTLY FINE-GRAINED MATERIAL

TCE ISOCONCENTRATION CONTOURS

- 3 – 30 µg/L
- 30 – 300 µg/L
- 300 – 3,000 µg/L
- 3,000 – 11,000 µg/L
- >11,000 µg/L

NOTES:

ALL ANALYTICAL DATA IS FROM THE SPRING 2009 SAMPLING EVENT UNLESS OTHERWISE NOTED.

1. ANALYTICAL DATA IS FROM THE APRIL AND MAY 2006 SAMPLING EVENT.
2. ANALYTICAL DATA IS FROM EITHER THE MARCH OR MAY 2005 SAMPLING EVENT.
3. ANALYTICAL DATA IS FROM THE AUGUST 2008 SAMPLING EVENT.

CONCENTRATIONS ARE PRESENTED IN THE FOLLOWING ORDER:

TRICHLOROETHENE (TCE)
1,2 - DICHLOROETHENE (1,2 - DCE)
1,1,1 - TRICHLOROETHANE (1,1,1 - TCA)
1,1 - DICHLOROETHENE (1,1 - DCE)
VINYL CHLORIDE

ALL CONCENTRATIONS ARE IN ug/L

NA = NOT ANALYZED
ug/L = MICROGRAMS PER LITER
NS = NOT SAMPLED
J = ESTIMATED VALUE
NC2L FOR TCE = 3 ug/L

VERTICAL SCALE 0 – 10

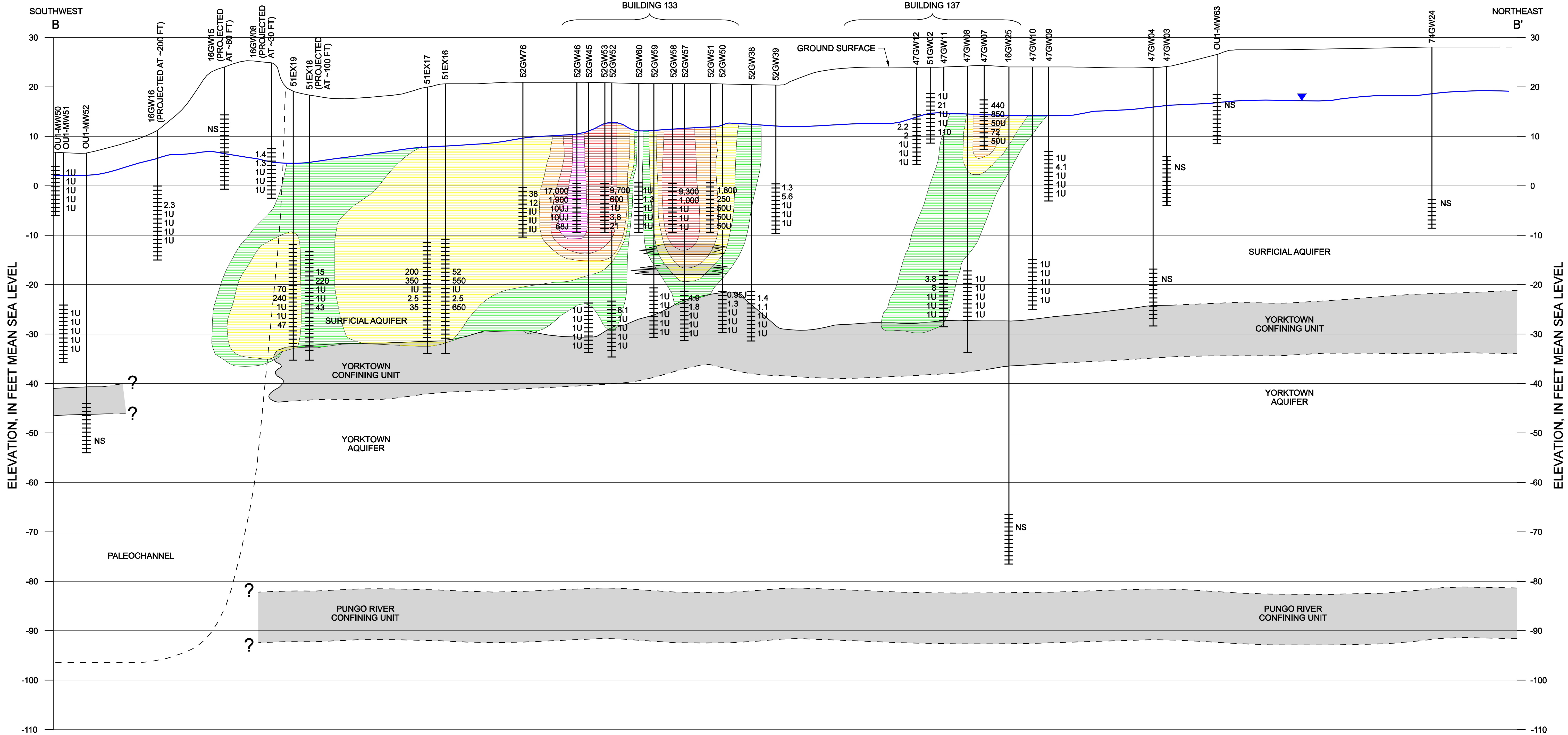
APPROXIMATE HORIZONTAL SCALE (SCALE IN FEET) 0 – 300

VERTICAL EXAGGERATION = 30

FIGURE 2-2
VOC ISOCONCENTRATIONS
CROSS SECTION A-A'
MARINE CORPS AIR STATION CHERRY POINT
CHERRY POINT, NC

CH2MHILL

FILENAME: fn01g004_358454.dgn PLOT DATE: 12/28/2009



LEGEND

WELL SCREEN INTERVAL

LINE OF APPROXIMATELY EQUAL TCE ISOCONCENTRATION IN ug/L

PREDOMINANTLY COARSE-GRAINED MATERIAL

PREDOMINANTLY FINE-GRAINED MATERIAL

TCE ISOCONCENTRATION CONTOURS

- 3 – 30 µg/L
- 30 – 300 µg/L
- 300 – 3,000 µg/L
- 3,000 – 11,000 µg/L
- >11,000 µg/L

NOTES:

ALL ANALYTICAL DATA IS FROM THE APRIL AND MAY 2006 SAMPLING EVENT UNLESS OTHERWISE NOTED.

1. ANALYTICAL DATA IS FROM THE MAY 2005 SAMPLING EVENT.
2. ANALYTICAL DATA IS FROM THE NOVEMBER 2005 SAMPLING EVENT.
3. ANALYTICAL DATA IS FROM THE MARCH 2000 SAMPLING EVENT.

CONCENTRATIONS ARE PRESENTED IN THE FOLLOWING ORDER:

TRICHLOROETHENE (TCE)
1,2 - DICHLOROETHENE (1,2 - DCE)
1,1,1 - TRICHLOROETHANE (1,1,1 - TCA)
1,1 - DICHLOROETHENE (1,1 - DCE)
VINYL CHLORIDE

ALL CONCENTRATIONS ARE IN ug/L

NA = NOT ANALYZED
ug/L = MICROGRAMS PER LITER
NS = NOT SAMPLED
J = ESTIMATED VALUE
NC2L FOR TCE = 3 ug/L

VERTICAL SCALE 10 / 0 / 300

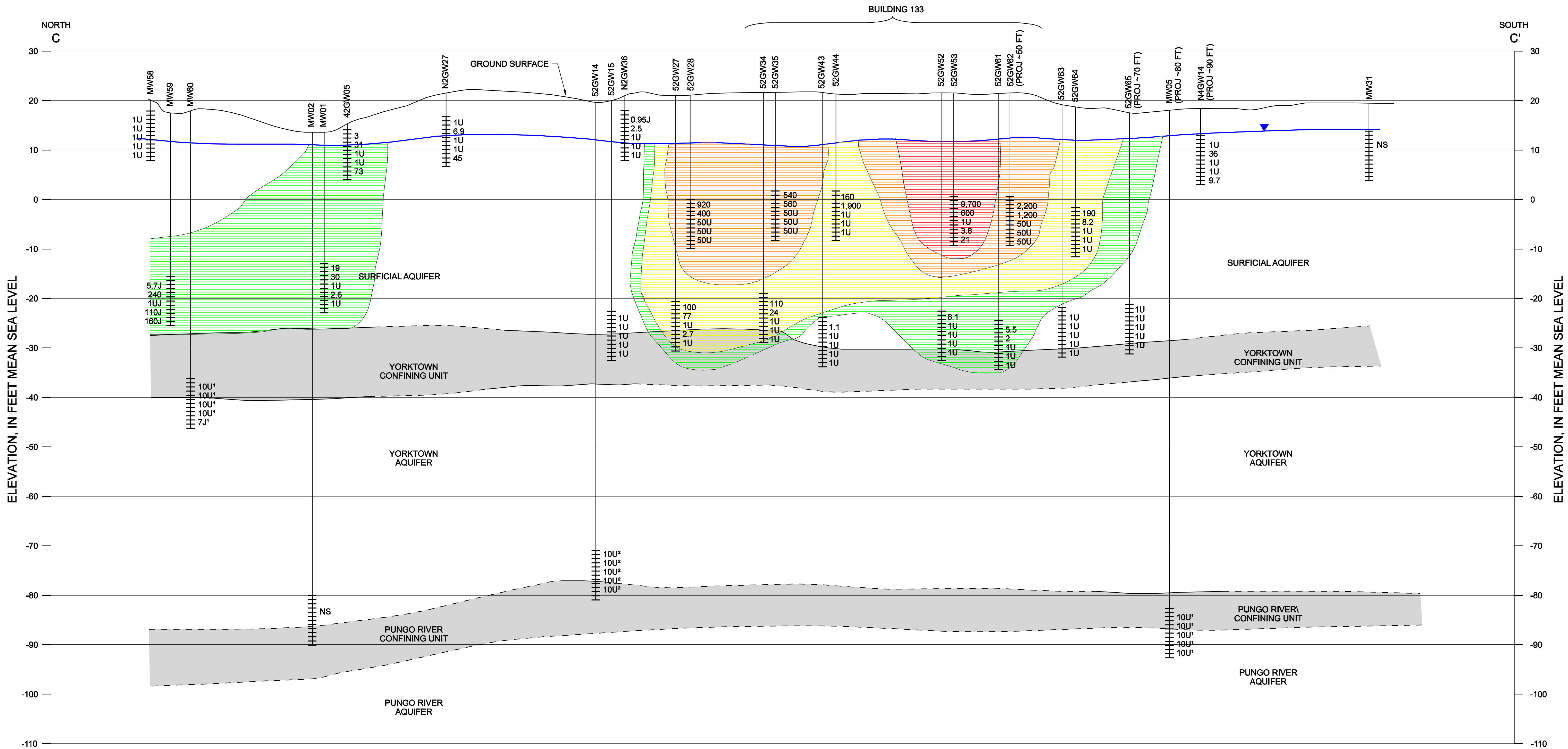
APPROXIMATE HORIZONTAL SCALE (SCALE IN FEET)

VERTICAL EXAGGERATION = 30

FIGURE 2-3
VOC ISOCONCENTRATIONS
CROSS SECTION B-B'
MARINE CORPS AIR STATION CHERRY POINT
CHERRY POINT, NC

CH2MHILL

FILENAME: fn01g005_358454.dgn PLOT DATE: 12/28/2009



LEGEND

WELL SCREEN INTERVAL

LINE OF APPROXIMATELY EQUAL TCE ISOCONCENTRATION IN ug/L

PREDOMINANTLY COARSE-GRAINED MATERIAL

PREDOMINANTLY FINE-GRAINED MATERIAL

TCE ISOCONCENTRATION CONTOURS

3 – 30 µg/L

30 – 300 µg/L

300 – 3,000 µg/L

3,000 – 11,000 µg/L

>11,000 µg/L

NOTES:

ALL ANALYTICAL DATA IS FROM THE SPRING 2009 SAMPLING EVENT UNLESS OTHERWISE NOTED.

1. ANALYTICAL DATA IS FROM THE APRIL AND MAY 2006 SAMPLING EVENT.
2. ANALYTICAL DATA IS FROM THE JUNE 2007 SAMPLING EVENT.

CONCENTRATIONS ARE PRESENTED IN THE FOLLOWING ORDER:

TRICHLOROETHENE (TCE)
1,2 - DICHLOROETHENE (1,2 - DCE)
1,1,1 - TRICHLOROETHANE (1,1,1 - TCA)
1,1 - DICHLOROETHENE (1,1 - DCE)
VINYL CHLORIDE

ALL CONCENTRATIONS ARE IN ug/L

NA = NOT ANALYZED
ug/L = MICROGRAMS PER LITER
NS = NOT SAMPLED
J = ESTIMATED VALUE
NC2L FOR TCE = 3 ug/L

VERTICAL SCALE 0 – 10

APPROXIMATE HORIZONTAL SCALE (SCALE IN FEET) 0 – 150

VERTICAL EXAGGERATION = 15

FIGURE 2-4
VOC ISOCONCENTRATIONS
CROSS SECTION C-C'
MARINE CORPS AIR STATION CHERRY POINT
CHERRY POINT, NC

CH2MHILL

FILENAME: fn01g006_358454.dgn PLOT DATE: 12/28/2009

\\APHRODITE\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-5 - GW CONTOUR UPPER SURFICIAL.MXD CBOWMAN 12/18/2009 14:04:20

Legend

- Extraction Well
- Monitoring Well
- Groundwater Elevation Contour (ft msl)
- Surface Water
- Operable Unit (OU) Boundary
- Existing Buildings
- Paved

Notes:
1. ft msl - feet (relative to) mean sea level
2. NU - Not used in contouring

W N S E

0 200 400

Feet

Figure 2-5
2009 Groundwater Elevation Map
Upper Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\APHRODITE\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-6 - GW CONTOUR LOWER SURFICIAL.MXD CBOWMAN 12/18/2009 14:05:04

Legend

- Extraction Well
- Monitoring Well
- Groundwater Elevation Contour (ft msl)
- Surface Water
- Operable Unit (OU) Boundary
- Existing Buildings
- Paved

Notes:
1. ft msl - feet (relative to) mean sea level
2. NU - Not used in contouring

0 200 400 Feet

Figure 2-6
2009 Groundwater Elevation Map
Lower Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

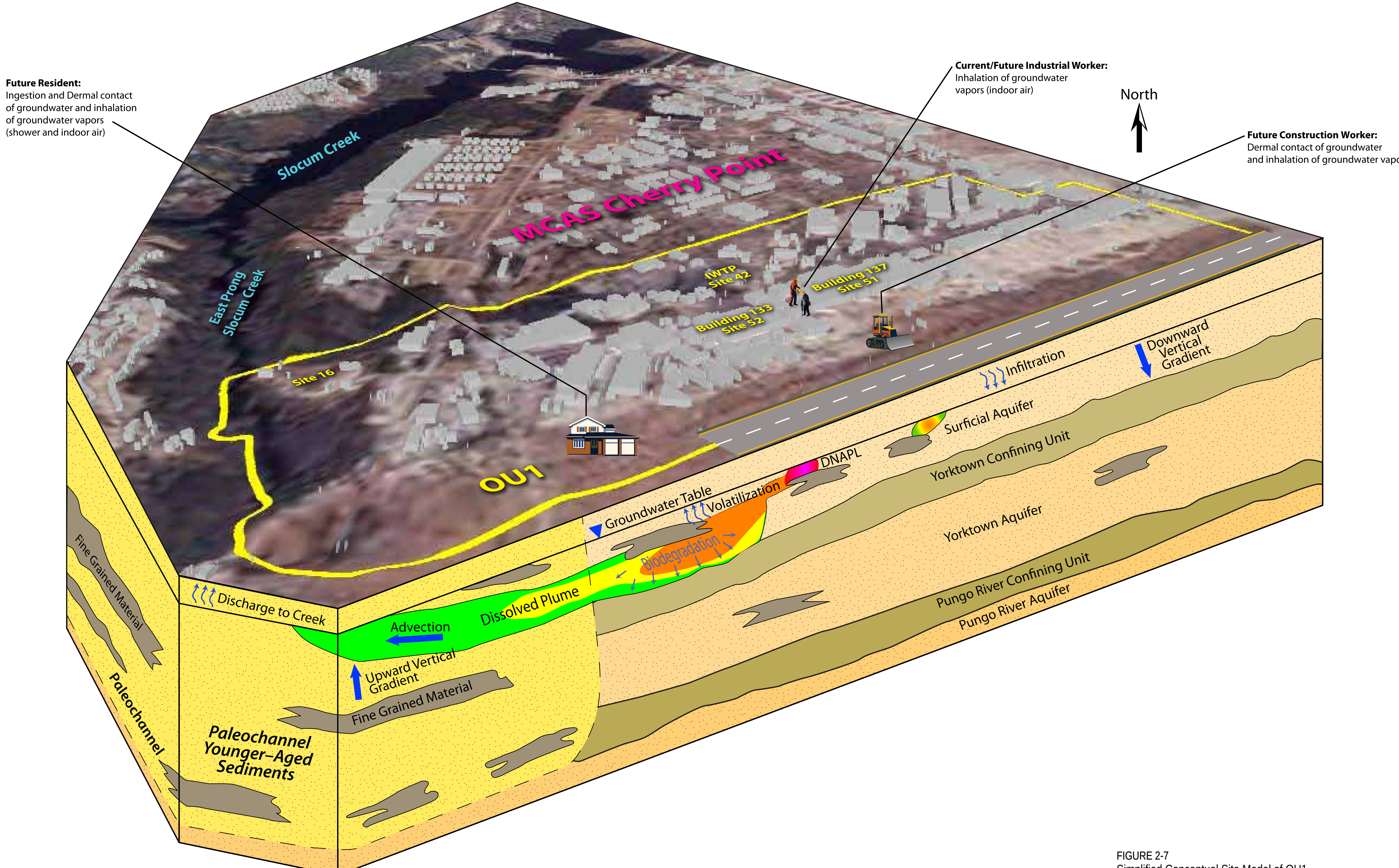
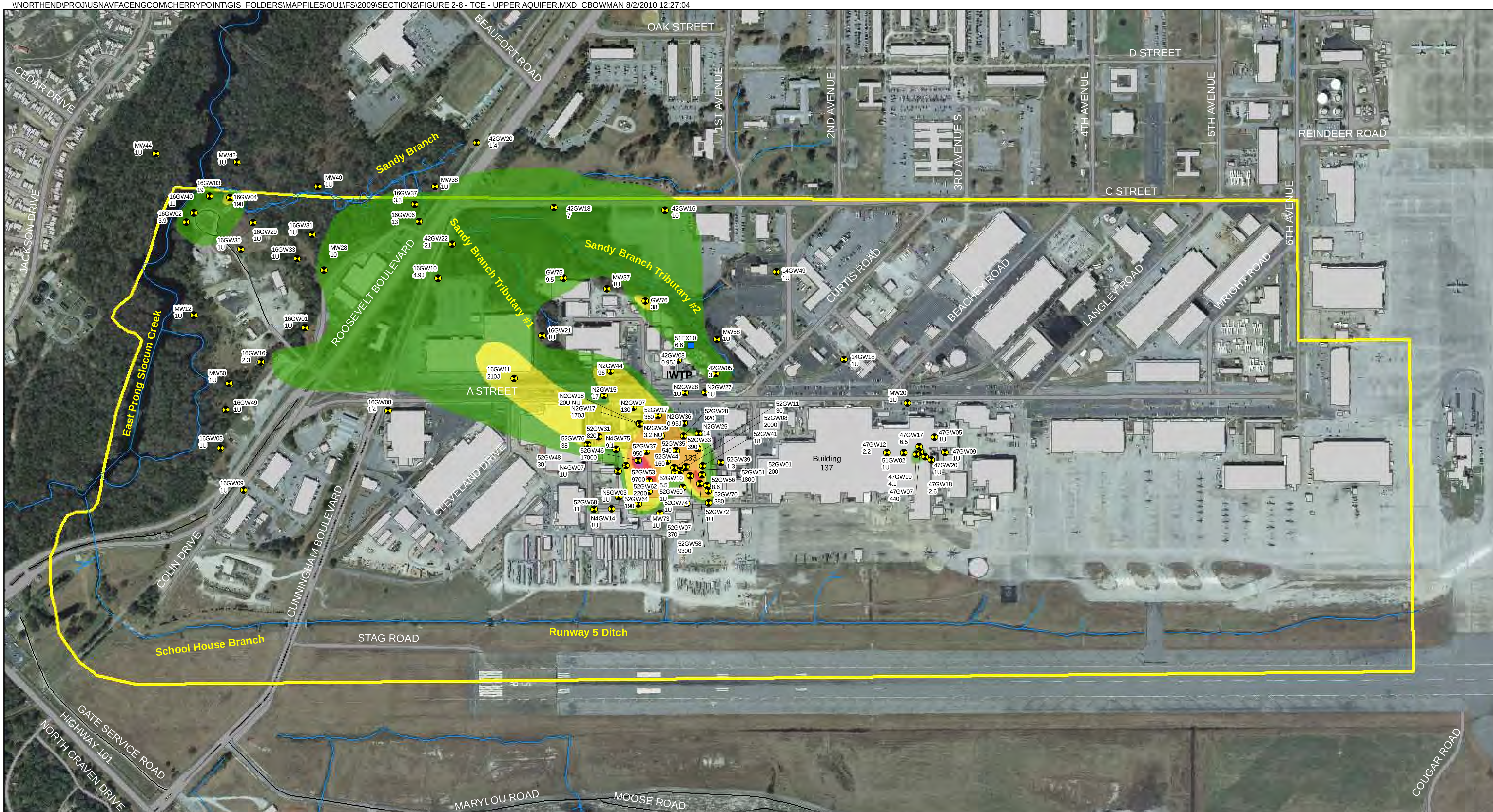


FIGURE 2-7
Simplified Conceptual Site Model of OU1
Marine Corps Air Station Cherry Point
Cherry Point, NC

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-8 - TCE - UPPER AQUIFER.MXD CBOWMAN 8/2/2010 12:27:04



Legend

- Extraction Well
- Monitoring Well - Upper Aquifer
- Surface Water
- OU1 Boundary
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L
- 3,000 - 11,000 µg/L
- > 11,000 µg/L

IWTP - Industrial Wastewater Treatment Plant

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
NU = Not Used
Concentrations are from the Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

0 600 1,200 Feet

Figure 2-8
Trichloroethene (TCE) Isoconcentration Map
Upper Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-9 - TCE - LOWER AQUIFER.MXD CBOWMAN 8/2/2010 12:41:55

Legend

- Extraction Well
- Monitoring Well - Lower Aquifer
- Surface Water
- OU1 Boundary
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

IWTP - Industrial Wastewater Treatment Plant

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
NU = Not Used
Concentrations are from Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

0 600 1,200 Feet

Figure 2-9
Trichloroethene (TCE) Isoconcentration Map
Lower Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-10 - 1_2_DCE - UPPER AQUIFER.MXD CBOWMAN 8/2/2010 12:44:55

Legend

- Extraction Well
- Monitoring Well
- Surface Water
- OU1 Boundary
- Existing Buildings
- 70 - 700 µg/L
- 700 - 7,000 µg/L

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 70 µg/L (Jan 2010)
NU = Not Used
Concentrations are from the Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

0 600 1,200 Feet

IWTP - Industrial Wastewater Treatment Plant

Figure 2-10
1,2-Dichloroethene (1,2 DCE) Isoconcentration Map
Upper Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-11 - 1_2_DCE - LOWER AQUIFER.MXD_CBOWMAN 8/2/2010 12:46:21

Legend

- Extraction Well
- Monitoring Well
- Surface Water
- OU1 Boundary
- Existing Buildings
- 70 - 700 µg/L
- 700 - 7,000 µg/L

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 70 µg/L (Jan 2010)
NU = Not Used
Concentrations are from the Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

0 600 1,200 Feet

Figure 2-11
1,2-Dichloroethene (1,2 DCE) Isoconcentration Map
Lower Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

IWTP - Industrial Wastewater Treatment Plant

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-12 - VC - UPPER AQUIFER.MXD CBOWMAN 8/2/2010 12:52:29

Legend

- Extraction Well
- Monitoring Well - Upper Aquifer
- Surface Water
- OU1 Boundary
- Existing Buildings
- 0.03 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

IWTP - Industrial Wastewater Treatment Plant

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 0.03 µg/L (Jan 2010)
NU = Not Used
Concentrations are from the Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

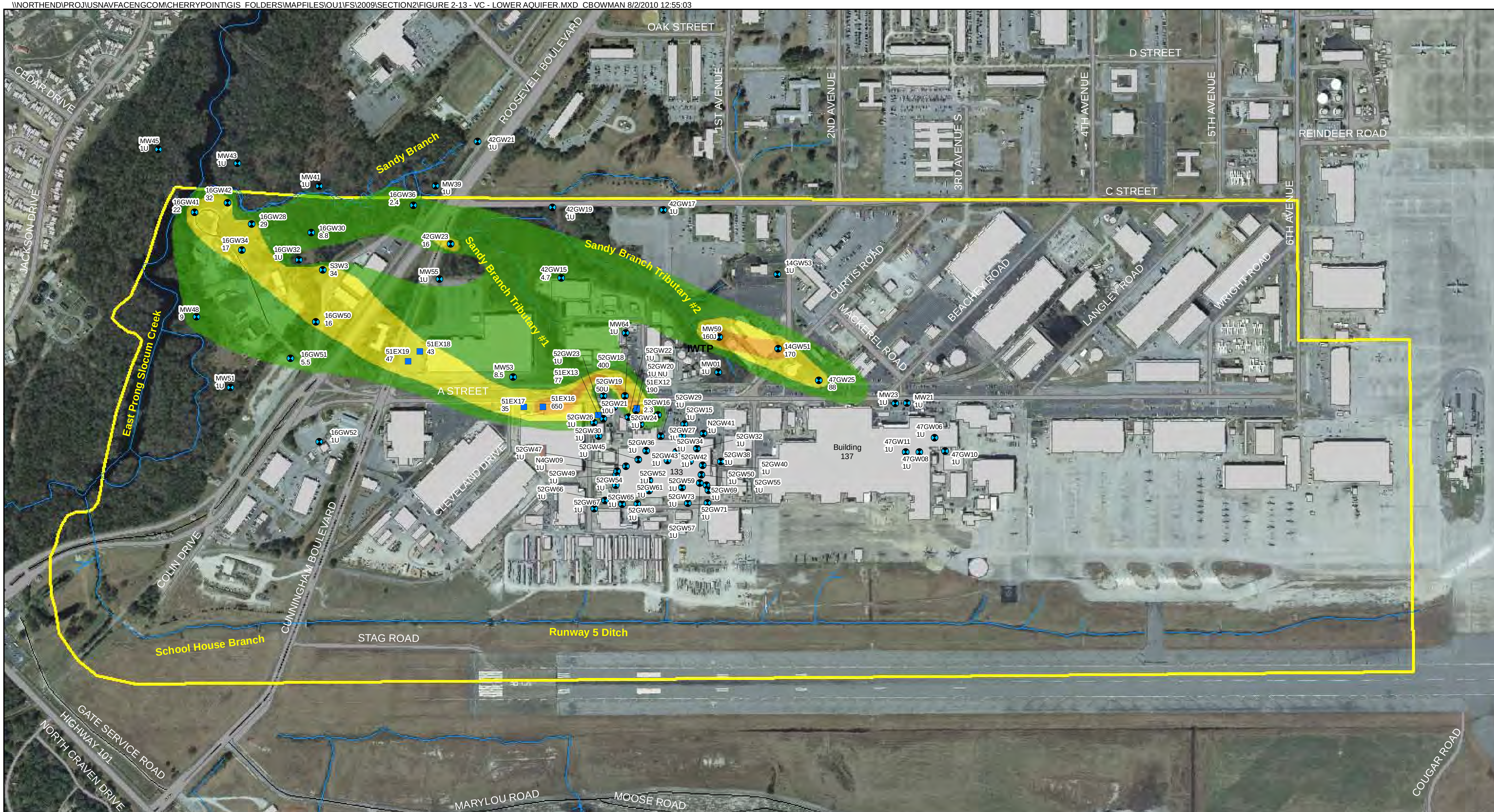
W N S E

0 600 1,200 Feet

Figure 2-12
Vinyl Chloride Isoconcentration Map
Upper Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-13 - VC - LOWER AQUIFER.MXD CBOWMAN 8/2/2010 12:55:03



Legend

- Extraction Well
- Monitoring Well - Lower Aquifer
- Surface Water
- OU1 Boundary
- Existing Buildings
- 0.03 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

IWTP - Industrial Wastewater Treatment Plant

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 0.03 µg/L (Jan 2010)
NU = Not Used
Concentrations are from the Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

W N S E

0 600 1,200 Feet

Figure 2-13
Vinyl Chloride Isoconcentration Map
Lower Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-14 - VOC PLUMES - LOWER BENZENE_ZOOM_BOX_ROUND_2.MXD CBOWMAN 8/2/2010 12:57:40

Legend

- Monitoring Wells
- Monitoring Wells in the UST program
- Surface Water
- Inferred
- > 1 µg/L
- Existing Buildings

Data and interpretations are from Catlin Engineers and Scientists
References:
Catlin Engineers and Scientists, 2008a
Catlin Engineers and Scientists, 2008b

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 1 µg/L
NU = Not Used
µg/L = micrograms per liter
U - analyte not detected above detection limit

W N S E

0 200 400 Feet

Figure 2-14
Benzene Isoconcentration Map
Lower Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\SECTION2\FIGURE 2-15 - VOC PLUMES - UPPER BENZENE_ZOOM_BOX_ROUND_2.MXD CBOWMAN 8/2/2010 13:26:39

Legend
- Monitoring Wells
- Monitoring Wells in the UST program
- Surface Water
- > 1 µg/L
- Free Product
- Existing Buildings

0.10 Free Product Thickness (ft)
1.5 Benzene Concentrations (µg/L)

Data and interpretations are from Catlin Engineers and Scientists
References:
Catlin Engineers and Scientists, 2008a
Catlin Engineers and Scientists, 2008b

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 1 µg/L
NU = Not Used
ft = feet
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

W N S E

0 200 400 Feet

Figure 2-15
Benzene Isoconcentration Map
Upper Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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SECTION 3

Applicable or Relevant and Appropriate Requirements and Remedial Action Objectives

This section discusses the ARARs and RAOs for the remedial alternatives considered in this FS.

3.1 Applicable or Relevant and Appropriate Regulations

As required by Section 121 of CERCLA, remedial actions carried out under Section 104 or secured under Section 106 must attain the levels of standards of control for hazardous substances, pollutants, or contaminants specified by the ARARs of Federal and State environmental laws and State facility-siting laws, unless waivers are obtained. Only promulgated Federal and State laws and regulations can be considered ARARs. If the ARARs do not address a particular situation, remedial actions may be based on the TBC criteria or guidelines. ARARs are distinguished by the USEPA as either being applicable to a situation or relevant and appropriate to it. These distinctions are critical to understanding the constraints imposed on RAs by environmental regulations other than CERCLA. The definitions of ARARs and TBCs below are from the NCP (40 CFR 300.5) and USEPA (1991).

- **Applicable requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site.
- **Relevant and appropriate requirements** are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under Federal or State law that, while not "applicable," address problems or situations sufficiently similar (relevant) to those encountered at a CERCLA site, that their use is well-suited (appropriate) to the particular site.
- **TBC information** are non-promulgated criteria, advisories, guidance, and proposed standards that have been issued by the Federal or State government that are not legally binding and do not have the status of potential ARARs. However, the TBC information may be useful for developing an interim remedial action or for determining the necessary level of cleanup for the protection of human health and/or the environment. Examples of TBC information include USEPA Drinking Water Health Advisories, Reference Doses, and Cancer Slope Factors.

Another factor in determining which response or remedial requirements must be met is whether the requirement is substantive or administrative. CERCLA response actions must meet substantive requirements but not administrative requirements. Substantive requirements are those dealing directly with actions or with conditions in the environment. Administrative requirements implement the substantive requirements by prescribing procedures such as fees, permitting, and inspection that make substantive requirements effective. This distinction applies to onsite actions only; offsite response actions are subject to all applicable standards and regulations, including administrative requirements such as permits.

3.2 Determination of ARARs and TBCs

Federal and North Carolina ARARs are summarized in **Appendix B**. The tables summarize the ARARs by classification (and TBC criteria as appropriate for each classification): chemical-specific, location-specific, and action-specific (see below).

The remedial action alternatives developed in this FS report were analyzed for compliance with Federal and North Carolina ARARs. The analyses involved identifying potential requirements for each of the alternatives, evaluating their applicability or relevance, and determining if the alternative(s) can achieve the ARARs. Results of these analyses are presented in **Section 4**.

Chemical-specific ARARs

Chemical-specific ARARs set health-based concentration limits or discharge limits in various environmental media for specific hazardous substances, pollutants, or contaminants. Examples of chemical-specific ARARs for OU1 are

- Federal Safe Drinking Water Act MCLs and MCL goals that are enforceable standards for drinking water sources
- NC 2L Groundwater Standards that are enforceable for drinking water sources and as an antidegradation/beneficial use standard
- State of North Carolina 2B Surface Water Standards (NC 2B)

Chemical-specific ARARs and TBCs for OU1 are presented in **Table B-1** in **Appendix B**.

The primary chemical-specific ARAR for establishing groundwater cleanup levels at OU1 is the NC 2Ls. The NC 2Ls are generally equal to or are more conservative than Federal MCLs.

Location-specific ARARs

Location-specific ARARs are design requirements or activity restrictions that are based on the geographical position of a site. An example is RCRA location requirements that set USEPA policy for carrying out provisions of Executive Order 11988 (Flood Plain Management) and Executive Order 11990 (Protection of Wetlands). Location-specific ARARs for OU1 are presented in **Appendix B**, **Table B-2**.

Action-specific ARARs

Action-specific ARARs set performance, design, or other standards for particular activities in managing hazardous substances or pollutants. For example, the design requirements for landfilling hazardous waste, established in RCRA 40 CFR Section 264.301, are action-specific. RCRA contains the greatest number of action-specific ARARs because it regulates hazardous waste management. Action-specific ARARs for OU1 are presented in **Appendix B**, **Table B-3**. Depending on the selected remedy, injection wells may be employed, which would need to comply with Well Construction and Injection Standards (15A North Carolina Administrative Code [NCAC] 2C .0100 and .0200).

3.3 Remedial Action Objectives

The RAOs consist of medium-specific goals for protecting human health and the environment. The RAOs reflect the COCs, exposure routes and receptors, and acceptable contaminant concentrations (or range of acceptable contaminant concentrations) for each medium of concern at OU1.

The RAOs for OU1 are as follows:

- Restore groundwater quality at OU1 to the NC 2L and MCL standards, based on the classification of the aquifer as a potential source of drinking water (Class GA or Class GSA) under 15A NCAC 02L.0201
- Prevent human exposure to groundwater above levels that would cause unacceptable risks
- Prevent migration or discharge of COCs in groundwater to sediment and surface water in East Prong Slocum Creek and Sandy Branch at levels that would cause unacceptable risks to human or ecological receptors

3.4 Performance Criteria

Performance criteria are established in this section for purposes of evaluating remedial alternatives and for use in the conceptual design and cost estimates. Performance criteria provide a basis for delineating the extent and volume of contaminated media that require remediation and provide the design performance of the remedial alternatives. The performance criteria described here represent the levels of performance necessary to meet the RAOs.

3.4.1 Groundwater

PRGs were developed for the COCs in groundwater at OU1. The PRG for each COC was determined by selecting the most conservative of either the NC 2L, MCL, and/or calculated risk-based performance standard using the methodology presented in the NCAC, Title 15A, Subchapter 2L, Section .0202 (d)(1), but no lower than the most conservative (lowest) chemical-specific ARAR. **Table 3-1** summarizes the PRGs for the COCs in groundwater.

3.4.2 Surface Water and Sediment

The HHRA and ERA for OU1 concluded that there are no unacceptable risks from exposure to surface water or sediment, and no COC exceedances of the chemical-specific ARARs or TBCs for these media within OU1. Therefore, no remedial alternatives directly addressing surface water and sediment were evaluated in this FS. The remedial alternatives for groundwater will address any potential surface water and sediment issues related to the COCs. The cleanup levels for groundwater are more stringent than NC regulatory standards for surface water.

TABLE 3-1
List of OU1 Central Groundwater Plume PRGs
Marine Corps Air Station Cherry Point, North Carolina

COC	Groundwater PRG (µg/L)	Basis
Cadmium	1.75	NC2L
Chloroform	70	NC2L
1,1-Dichloroethane (1,1-DCA)	70	NC2L
1,1-Dichloroethene (1,1-DCE)	7	NC2L
1,2-Dichloroethane (1,2-DCA)	0.38	NC2L
cis-1,2-Dichloroethene (cis-1,2-DCE)	70	NC2L
trans-1,2-Dichloroethene (trans-1,2-DCE)	100	NC2L
1,2-Dichloroethene (1,2-DCE) (total)	70	NC2L (cis-1,2-DCE)
1,1,2,2-Tetrachloroethane (1,1,2,2-PCA)	0.17	NC2L
Tetrachloroethene (PCE)	0.7	NC2L
1,1,1-Trichloroethane (1,1,1-TCA)	200	NC2L
1,1,2-Trichloroethane (1,1,2-TCA)	5	MCL[1]
Trichloroethene (TCE)	2.8	NC2L
Vinyl Chloride	0.015	NC2L

Notes:

µg/L - micrograms per liter
MCL - Maximum Contaminant Level

NCAC - North Carolina Administrative Code

NCDENR - North Carolina Department of Environment and Natural Resources
NC2L - North Carolina 2L Standards for Groundwater
[1]A performance standard was also calculated using the methodology presented in the NCAC, Title 15A, Subchapter 2L, Section .0202 (d) (1); however, the calculated value was less conservative than the MCL

1,1,2-TCA additional groundwater PRG was calculated by [4 x 10^{-3} mg/kg/day (reference dose) x 70 kg (adult body weight) x 0.20 (relative source contribution for organics)] /[2 L/day (avg. water consumption)] = 28 µg/L

SECTION 4

Development and Screening of General Response Actions and Potential Technologies

This section describes the initial steps to develop alternatives for the remediation of groundwater at OU1, including the identification of general response actions (GRAs), and the initial identification and screening of potential technologies.

4.1 General Response Actions

The GRAs describe the broad range of actions that will satisfy the RAOs at the site. The GRAs may include no action, institutional controls, monitoring, containment, removal, treatment, disposal or any combination of these. Consideration of the No Action GRA is required by CERCLA.

With the exception of the No Action alternative, each GRA can be achieved through the implementation of site-specific remedial technologies. In this context, the following definitions apply:

- Remedial technologies are defined as the general categories of remedies under a GRA. For example, in situ chemical treatment is one of the remedial technologies under the GRA of treatment.
- Process options are specific categories of remedies within each remedial technology. The process options are used to implement each remedial technology. For example, the chemical treatment remedial technology could be implemented using one of several types of treatment options (e.g., in situ chemical oxidation [ISCO] or in situ chemical reduction [ISCR]).-

Table 4-1 lists the GRAs for groundwater contamination and their effectiveness for meeting the RAOs. GRAs to be considered to satisfy RAOs for the remediation of groundwater at OU1 include no action, institutional controls, monitoring, containment, removal, treatment, and disposal.

4.2 Screening of Remedial Technologies and Process Options

A screening of remedial technologies was conducted to evaluate groundwater remediation alternatives at OU1. **Table 4-2** summarizes the results of the screening process. Certain technologies and/or process options are not appropriate for implementation at OU1, because of impracticality, site conditions, economics, access, or COC characteristics, and were excluded from further consideration.

4.2.1 Summary of Retained Technologies

Technologies and process options retained following screening for effectiveness, implementability, and cost are summarized in **Table 4-3**, in accordance with USEPA (1998a). The selected technologies were combined into remedial alternatives summarized in

Section 5, with a detailed comparative review and expanded set of evaluation criteria included in Section 6.

4.2.2 Development of Remedial Target Areas

Remedial action target areas were defined to support the development of the remedial alternatives. The target areas were divided into two separate zones to allow for a focused review and selection of remedial alternatives. Zone 1 (Source Zone) corresponds to areas where the highest dissolved phase concentrations (COC concentrations generally greater than 1,000 µg/L) were detected and includes Building 133 (Site 52). Zone 2 (Downgradient Zone) corresponds to all other areas where lower dissolved phase concentrations (COC concentrations generally less than 1,000 µg/L) were detected. The target areas are depicted on **Figure 4-1**.

4.2.3 Feasibility of Source Zone Treatment—Building 133 (Site 52)

The major source of the groundwater contamination is the DNAPL area located beneath Building 133. To effectively remediate the DNAPL area, an aggressive source treatment would be required and would need to encompass the entire DNAPL area. Treatment of the entire DNAPL area would require a dense network of treatment points. To implement such a design, unrestrictive placement and uninterrupted system operation would be needed.

Due to the current industrial use of Building 133, extensive subsurface infrastructure, low overhead clearance, dense spacing of equipment and workspaces, and a round-the-clock operational schedule, it would be difficult or impossible to properly implement an in situ treatment technology throughout the source area. The dense network of known utilities adjacent to Building 133 is shown in **Figure 4-2**. The only viable option would be to conduct a partial source area treatment which would result in reduced effectiveness (as discussed in the results of the previous treatability studies in Section 2.9).

To further complicate the situation, FRCE is the only source of repair within the continental United States for many jet engines, rotary wing engines, and turbofan vectored thrust engines and provides services for the Navy and Marine Corps, Air Force, Army, other federal agencies, and multiple other foreign nations. Operations at Building 133 are considered mission critical for these services during both peacetime and current wartime efforts. Disruption of operations to implement a source treatment remedy is not practicable. Also, current military plans to migrate to newly-developed aircraft types (e.g., the V-22 Osprey and the Joint Strike Fighter) mean that extensive modifications to the buildings within FRCE are already underway, in the planning stages, or projected to occur within the next decade to prepare for FRCE to maintain these aircraft. Future building modifications and construction activities are likely to impact any installed treatment system, possibly requiring it to be moved or reinstalled, or to potentially delay or interfere with making the needed building modifications.

As discussed in Section 2.6.2, the only exposure scenario from the OU1 Central Groundwater Plume with potentially unacceptable human health risk is for potable use by the hypothetical future resident (vapor intrusion is currently being investigated and will be addressed separately). Therefore, due to the absence of and ability to control exposure, a source zone treatment would not result in a reduction of the human health risk. Conversely, a source zone treatment has the potential to generate increased vapor intrusion risks to the current workers at Building 133. Thus, implementation of a source treatment based remedy would likely result in a greater overall risk to human health. Therefore, it has been determined that source zone treatment is not feasible in this location and will not be discussed further in this FS.

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TABLE 4-1
General Response Actions
Operable Unit 1 Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

General Response Action (GRA)	Effect Associated with Remedial Actions Objectives (RAOs)
No Action	None. Serves as a baseline to compare other response actions.
Institutional Controls	Prevents human exposure to groundwater by placing restrictions on aquifer use and activities that may result in exposure.
Monitoring	Performed in conjunction with other alternatives to determine if RAOs are being met or if/when cleanup goals are met. *Monitored Natural Attenuation (MNA)* is a technology option for the *Monitoring* GRA and the [In Situ] *Treatment* GRA. *MNA* alone is an intrinsic process to reduce contaminant concentrations (and, thus, toxicity and volume) without performing any other measures (Table 4-2) .
Containment	Minimizes or prevents the migration of contaminants in the groundwater to receptors.
Removal	Removes contaminants from the saturated zone by physical extraction of groundwater and/or removal of impacted saturated soil.
Treatment (In situ or Ex situ)	Reduces the mobility, toxicity, or volume of contaminated groundwater.
Disposal	Minimizes the likelihood of exposure to contaminants by extracting them from groundwater and placing them in a controlled environment.

TABLE 4-2
Technology Screening
Operable Unit 1, Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

General Response Action	Remedial Technology	Process Options	Description	Effectiveness	Implementability	Relative Cost	Primary Screening	
							Retain	Reject
No Action	None	None	No action provided. This process option is retained to provide the basis for comparing active process options and technologies.	None	Not applicable	Not applicable	X	
Institutional Control	Administrative Restrictions	Land-Use Controls (LUCs) / Deed Notices	LUCs issued for property within potentially contaminated areas to restrict property use and well installation. The Navy uses a Web-based management tool, LUC Tracker, as part of the Naval Installation Restoration Information System (NIRIS).	Effective in protecting human health given consistent implementation (i.e., enforcement of no drinking water well installations or no construction prior to vapor intrusion evaluations until cleanup levels are met).	Easy to implement. No current drinking water wells at OU1. Use of *Navy LUC Tracker* tool.	Very low	X	
	Access Restrictions	Fences	Security at active military installation already established. Source areas and downgradient areas are not fenced in.	Cannot meet RAOs by itself. Effective at limiting site access, but does not physically prevent exposure to groundwater or surface water.	Easy to implement. Security already implemented at facility.	Low		X
Monitoring	Sampling	Performance and Compliance Monitoring	Sample media containing COCs and/or media at points of compliance.	Provides performance and compliance monitoring data.	Easily implemented. Generate monitoring plan and sample on established schedule.	Low, but long-term cost until cleanup levels are met.	X	
	Monitored Natural Attenuation (MNA)¹	Intrinsic process and Performance Monitoring	Natural attenuation (all mechanisms including biodegradation, advection-dispersion, dilution, etc.) coupled with regular monitoring for the COCs as well as for other indicators of biodegradation.	Effective for sites such as this where there are no unacceptable current risks (no exposure) and future risks are minimal.	Easily implemented, only monitoring well installation and sampling would be required to monitor the progress.	Low, but long-term cost until cleanup levels are met.	X	
Containment	Vertical Barriers	Slurry wall, sheet piling, vibrating barrier wall, etc.	Physically or chemically or combination of the two to create subsurface barriers to contain/prevent contaminated groundwater flow to downgradient. Isolates and/or contains contamination, therefore effective for most contaminants.	Containment of the plume will not achieve all RAOs. Can be effective for isolating source areas, but not effective for dissolved-phase contaminants.	Can be implemented in fine porous media to depths of 30 to 60 feet bgs using conventional construction, deeper using injection methods. However, walls cannot be considered in the source area because of site operations and utility density. Only implementable in downgradient plumes.	Moderate to high depending on area and volume requirements.		X
		Air sparging (AS) "Curtain"	Air is injected into groundwater through a system of vertical wells or directionally drilled slotted pipes to remove or treat volatile compounds in-situ.	Sparging produces a large area of influence (generally 40 to 50 feet on each side of a directionally drilled well) for removal of VOCs via in-situ mass transfer (stripping). Unlike enhanced reductive dechlorination, "daughter" products such as VC are not generated by the process.	Easily implemented using vertical or horizontal wells. Horizontal wells would limit disruption to occupied buildings and underground utilities. The high water table at OU1 would make soil vapor extraction difficult. An above ground compressed air system with associated long term O&M would be required. Air sparging has the potential to generate vapor intrusion risks and should not be conducted adjacent or beneath occupied buildings.	Moderate to High. Because of the size of the plumes, increased capital expense for equipment, as well as long-term O&M costs, would be expected.	X	
		Permeable Reactive Barrier (PRB)	Treats groundwater plume as it passes through a permeable reactive zone. Reactive zone may be a combination of physical, chemical, and biological processes. Chemical reductants such as ZVI, lime, organic mulches, phosphate materials are typical PRB applications to treat CVOCs. No O&M is required (other than periodic replacement or recharge of spent material). Maximum depth attainable is variable, depending on subsurface lithology and excavation methodology.	Highly effective in treating CVOCs, especially using ZVI. ZVI reactivity can be expected to persist for 30+ years, while other media, such as mulch or adsorbent materials, would need to be replenished or "recharged" periodically.	Installation will prove difficult in source and near-source areas because of utility density. The plume extends to the Yorktown Confining Unit, requiring an approximately 50 ft deep wall. If placed downgradient near Slocum Creek, a PRB would be easier to implement, with a wall approximately 35 feet deep.	High cost. Costs include wall construction, iron material purchase, trench soils disposal. For a bio/mulch wall approach, fresh electron donor would need to be injected every 3-5 years.	X	
Treatment (Ex-Situ)	Groundwater Extraction (Pump and Treat)2	Vertical or horizontal extraction wells	Series of wells to extract contaminated groundwater. Drilling techniques are used to position wells vertical or horizontally, or at an angle, to reach contaminants not accessible (beneath buildings) by direct vertical drilling. This process would only be used to supplement In-Situ treatment alternatives.	Extraction wells may serve two purposes: containment by hydraulic control and removal of contaminated groundwater. Extraction from horizontal wells are not recommended beneath source area buildings due to structural concerns.	Easily implemented in area with moderate to high permeability. Well installations will be difficult considering utilities and active installation logistics. Long-term O&M and water treatment or disposal.	High. O&M costs are typically high.		X
		Collection trenches	Perforated pipe in trenches backfilled with porous media to collect water. Same as vertical or horizontal extraction wells; Structures, property access, and utility conflicts can make continuous barriers difficult. Downgradient locations are more acceptable to collection trenches. This process would only be used to supplement In-Situ treatment alternatives.	Collection trenches may serve two purposes: containment by hydraulic control and removal of contaminated groundwater.	Not possible to implement in area of concentrated underground utilities, i.e. source and near-source areas. Site utility density and aircraft maintenance activities in source areas preclude trenching technologies at OU1 source areas.	High. O&M costs are typically high.		X

TABLE 4-2
Technology Screening
Operable Unit 1, Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

General Response Action	Remedial Technology	Process Options	Description	Effectiveness	Implementability	Relative Cost	Primary Screening	
							Retain	Reject
Treatment (In-situ)	Physical Treatment	Hot Water or Steam Flushing/Stripping (i.e., Hydrous Pyrolysis/ Oxidation (HPO))	Steam (and possibly oxygen) is forced into an aquifer through either vertical or horizontal injection wells. Vaporized components rise to the unsaturated zone, where they are removed by vacuum extraction and treated. Heating options include hot water injection, steam injection, in situ heating via six phase heating, radio frequency, etc.	Generally effective in removing contamination. Subsurface steam injection may mobilize the contaminant vapor plume which can aggravate indoor air vapor intrusion issues, especially in the source areas beneath the buildings.	Implementation expected to be difficult considering current site operations at OU1. Steam flushing would introduce potential risks to the building occupants, including vapor intrusion.	Moderate to high		X
		Hydraulic or Pneumatic Fracturing	High-pressure injection of fluids, followed by granular slurry or *proppant* , to create subsurface fracture patterns that enhance injection material distribution, increase probability of COC contact and increase contact time.	This technology can enhance effectiveness of injection of reactive materials (ISCO, ERD, etc.), especially in uniform, low permeability materials.	Readily implemented, limited risk to buried utilities and foundations. Hydraulic fracturing/injection is too slow to be considered for widespread use at OU1. Pneumatic injections are rapid, and this approach was retained for near source injections only, in order to improve contact with the formation.	Moderate to high, balanced by the increase in effective contact.	X	
		Groundwater Recirculation Wells and In-well Air Stripping	Air is injected into the well casing where it strips VOCs as water is extracted through the well. Off gas is captured and treated. A circulation cell is setup in aquifer as water is drawn in the bottom and exits the top.	Systems have a small radius of influence in lower permeability materials, are prone to fouling, and require long term routine O&M.	Readily implemented with standard well construction. Ambient air is the only amendment introduced to the subsurface. Has the potential to generate vapor intrusion risks and should not be conducted adjacent or beneath occupied buildings.	Low to moderate.		X
	Chemical	Chemical Oxidation (ISCO)	Oxidant such as permanganate, persulfate, Fenton's reagent, or ozone is injected, which chemically oxidizes organic contaminants to less harmful or totally harmless compounds.	Aquifer heterogeneity would make uniform distribution difficult and limit contact efficiency. Source areas are generally characterized by reducing conditions, rendering oxidation less efficient. Plumes may reestablish later due to incomplete destruction of source mass. Multiple injection events are likely to be required because of the inferred high natural oxidant demand of the subsurface (based on previous bench scale and field pilot testing at nearby Camp Lejeune). The groundwater velocity of 0.2 ft/day would reduce the effectiveness of the lateral distribution and potential treatment by injecting upgradient.	Readily implemented, with health and safety precautions. Surfacing of reagents can be dangerous and may corrode buried utilities. Higher risk/cost than bioremediation, with questionable relative benefit. Building structure and operations would prohibit the installation of a dense network of treatment points since the effectiveness of ISCO is driven by contact with contaminants. A partial network of injections would limit the effectiveness of the technology. Has the potential to generate vapor intrusion risks dependent on the type of oxidant selected.	Moderate to high. Costs increase if multiple injections are needed.		X
		In Situ Chemical Reduction (ISCR)	Reduction agents (ZVI, polysulfide, dithionate, ferrous sulfate, etc.) to chemically treat CVOCs. ISCR technology is similar to in situ bioremediation where reagents are injected into the subsurface using horizontal or vertical wells to treat CVOCs.	Can be effective, depending on contact between the contaminant and reagent. Solid reagents are more difficult to distribute, and generally require fracturing. Micro-scale iron generally persists 3-5 years on average in the environment before it must be reinjected. The groundwater velocity of 0.2 ft/day would reduce the effectiveness of the lateral distribution and potential treatment by injecting upgradient.	Readily implemented using vertical injection borings. Considered relatively safe, although "daylighting" of iron powder can occur at shallower injection depths. Has the potential to generate vapor intrusion risks when applied adjacent to or beneath occupied buildings.	Moderate to high. Costs increase if multiple injections are required.	X	
Treatment (In-Situ)	Biological Treatment	In Situ Enhanced Bioremediation (ISEB)	Use of an organic substrate such as lactate, molasses, or vegetable oil to promote anaerobic biodegradation of CVOCs via reductive dechlorination pathway. Injected using vertical or horizontal wells.	Based on previous pilot studies in the source zone, dechlorination was effective, although significant rebound occurred, indicating high concentrations and/or insufficient dosing. Bioaugmentation may improve results. The groundwater velocity of 0.2 ft/day would reduce the effectiveness of the lateral distribution and potential treatment by injecting upgradient.	Readily implemented. Presence of utilities/structures limit source/near source options. Amendments are relatively innocuous. Building structure and operations would prohibit the installation of a dense network of treatment points since the effectiveness of ISCO is driven by contact with contaminants. A partial network of injections would limit the effectiveness of the technology. Has the potential to generate vapor intrusion risks when applied adjacent to or beneath occupied buildings.	Moderate to high. Costs increase if multiple injections are required.	X	
		Phytoremediation	Use of plants, grasses, and trees to remove and transform or evapotranspire contaminants. Also for hydraulic control.	Not applicable at OU1 due to depth to groundwater and presence of aboveground structures.	Not applicable at OU1 due to depth to groundwater and presence of aboveground structures.	Not applicable		X

Note:
Retained alternatives are shaded

1 - As part of the long-term ground water monitoring program for MNA, geochemical parameters including DO, ORP, pH, specific conductivity, temperature, and turbidity can be measured. In addition, natural attenuation parameters, including but not limited to methane/ethane/ethene, sulfate, and ferrous iron, can be analyzed during monitoring events to evaluate geochemical conditions. The changes in geochemistry and target constituent concentrations will provide evidence of a shift from anaerobic to aerobic conditions.

2 - Alternatives utilizing Groundwater Extraction were not further evaluated due to high costs and logistical issues. In addition, pump and treat is an undesirable alternative per Navy policy and has a low sustainability ranking. Treatment processes that were evaluated include chemical oxidation and reduction, hydrolysis, reverse osmosis, air stripping, steam stripping, critical fluid extraction, carbon adsorption, separation, activated sludge, anaerobic reactor, fluidized bed biological treatment and wetlands treatment (phytoremediation).

TABLE 4-3
Summary of Technologies and Process Options Retained for Development and Evaluation
Operable Unit 1, Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

General Response Action (GRA)	Remedial Technology Type	Process Option	Description	Area of Consideration
No Action	None	Not Applicable.	No action provided. This process option is retained to provide the basis for comparing active process options and technologies.	N/A.
Institutional Control	Administrative Restrictions	Land-Use Controls (LUCs) (or Deed Notices)	LUCs issued for property within potentially contaminated areas to restrict property use and well installation. DOD does not deed-restrict Federal property; however, if property is transferred to non-Federal entity in the future before cleanup levels are met, a deed restriction would be necessary. The Navy developed and deployed a Web-based management tool, *LUC Tracker* , as part of the Naval Installation Restoration Information System (NIRIS).	Groundwater PRG Attainment Area boundaries. Applies to exposure to chlorinated VOCs in groundwater and potential indoor air vapor in any new or modified buildings resulting from chlorinated VOCs in groundwater.
Monitoring	Sampling	Performance and Compliance Monitoring	Sample media containing chlorinated COCs and/or media at points of compliance.	Groundwater PRG Attainment Area boundaries (performance groundwater monitoring). Possible monitoring in Sandy Branch, Tributaries #1 and #2 and Slocum Creek (sediment and surface water) during remedy. Performed with any process option until RAOs are achieved.
	Monitored Natural Attenuation (MNA)	Intrinsic Process and Performance Monitoring	Natural attenuation (all mechanisms, including biodegradation, advection-dispersion, dilution, etc.) coupled with regular monitoring for the COCs and other indicators of biodegradation.	Sample network throughout the Groundwater PRG Attainment Area boundaries, upgradient, and downgradient. Standalone alternative or in combination with another technology. Also can be considered a process option of the Biological Treatment technology type.
Containment	Vertical Barriers	Air Sparge "Curtain"	Air is injected into groundwater through a system of vertical wells or directioanlly drilled slotted pipes to remove or treat volatile compounds in-situ.	Downgradient plume at Site 16 near the confluence of Sandy Branch and Slocum Creek. Two directionally drilled wells would be installed, each with 450 feet of slotted pipe, installed at a depth of approximately 50 feet bgs.
		Permeable Reactive Barrier (PRB)	Treats groundwater plume as it passes through a permeable reactive zone. Reactive zone may be a combination of physical, chemical, and biological processes. May also include measures such as low-permeability barriers to channel groundwater towards the treatment zone. Chemical reductants such as ZVI, lime, organic mulches, phosphate materials are typical PRB applications to treat CVOCs. No O&M is required (other than periodic replacement/recharge of spent material). One pass trench method is limited to ~ 35 feet nbgs. Deeper barriers may be logistically difficult/impossible to install in deep sands using bioploymer slurry methods, because of formation collapse.	Downgradient plume at Site 16 near the confluence of Sandy Branch and Slocum Creek. Estimated dimensions of a PRB installed using the one-pass trench method would be approximately 950 feet in length and 35 feet deep.
Treatment (In-Situ)	Physical Treatment	Pneumatic Fracturing	High-pressure injection of fluids, followed by granular slurry or *proppant* , to create subsurface fracture patterns that enhance injection material distribution, increase probability of COC contact and increase contact time.	Near source areas. Pneumatic fracturing would be used to improve distribution of reagents in the dense silty materials of the Upper Surficial Aquifer.
	Chemical Treatment	In-Situ Chemical Reduction (ISCR)	Reduction agents (ZVI, polysulfide, dithionate, ferrous sulfate, etc.) to alter state, promote precipitate or form less soluble, more stable compounds. ISCR technology is similar to in situ bioremediation where reagents are injected into the subsurface using wells to treat CVOCs.	Downgradient plume at Site 42 near the confluence of Sandy Branch Tributary #1 and Tributary #2. Two rows of ISCR injection wells will be screened to create a barrier wall-like configuration throughout dissolved-phase plumes in the upper and lower aquifers.
	Biological Treatment	In Situ Enhanced Bioremdaition (ISEB)	Use of an organic substrate such as lactate, molasses, or vegetable oil to promote anaerobic biodegradation of CVOCs via reductive dechlorination pathway.	Injection wells in the near-source plume along A Street. The ERD injection wells will be paired wells with each well screened at different intervals to create a barrier wall-like configuration throughout dissolved-phase plumes in the upper and lower aquifers.

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\UPDATE_04202011\FIGURE 4-1 - TCE - REMEDIAL TARGET ZONES.MXD CBOWMAN 4/25/2011 09:44:06

Legend

- Extraction Well
- Monitoring Well - Lower Aquifer
- Surface Water
- OU1 Boundary
- Remedial Target Zone
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

IWTP - Industrial Wastewater Treatment Plant

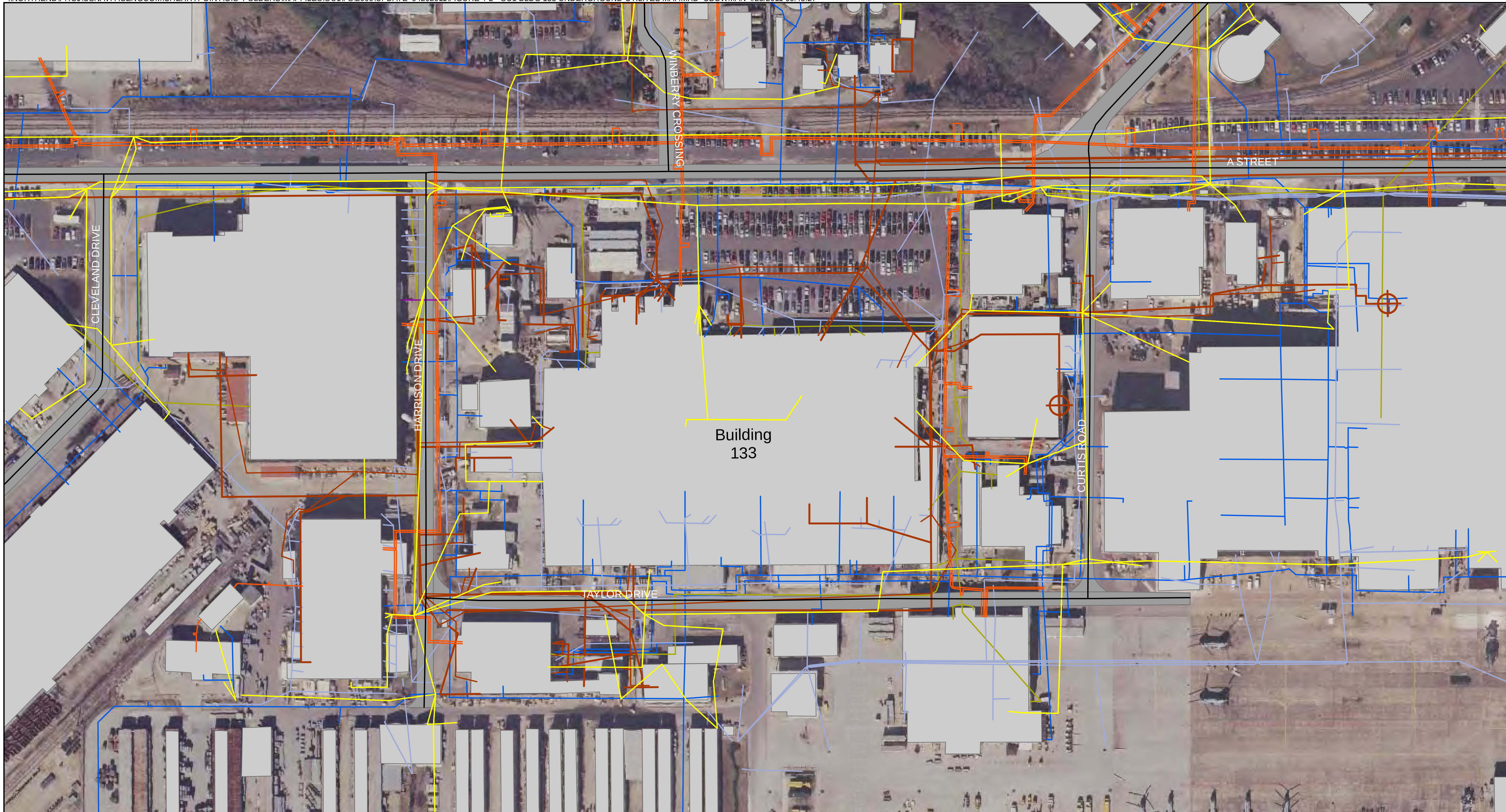
Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
NU = Not Used
Concentrations are from Spring 2009 sampling event
µg/L = micrograms per liter
U - analyte not detected above detection limit
J - concentration is estimated

0 600 1,200 Feet

Figure 4-1
Remedial Target Zones
Lower Surficial Aquifer
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\UPDATE_04202011\FIGURE 4-2 - OU1 BLDG 133 UNDERGROUND UTILITES MAP.MXD CBOWMAN 4/25/2011 09:45:27



Legend

- OU1 Boundary
- Electrical Cable Line
- Fuel Line
- Heating and Cooling Line
- Industrial Waste Line
- Industrial Area Sewer System
- Storm Sewer Line
- Wastewater Line
- Water Line
- Existing Buildings

W N S E

0 150 300 Feet

Figure 4-2
Operable Unit 1 Building 133
Underground Utilities Map
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

CH2MHILL

SECTION 5

Development and Description of Alternatives

This section presents a description of remedial alternatives developed for management or treatment of COCs in groundwater of the surficial aquifer at OU1. In accordance with USEPA (1988), remedial alternatives were developed by assembling remedial technologies and representative process options after the initial screening process (**Section 4**). Remedial alternatives were developed based on site-specific considerations primarily related to the nature of the COCs and their concentration, and site hydrogeologic conditions.

Based on initial screening of technologies (**Table 4-3**), in accordance with RAOs specified in Section 3.4, the following remedial alternatives were selected for further evaluation and analysis.

Zone 1 (Source Zone)

- Alternative 1—No Action
- Alternative 2—MNA and LUCs
- Alternative 3 – In-Situ Enhanced Bioremediation (ISEB)

Zone 2 (Downgradient Zone)

- Alternative 1—No Action
- Alternative 2—MNA and LUCs
- Alternative 3 – Permeable Reactive Barrier (PRB), MNA, and LUCs
- Alternative 4 – ISEB Barrier, MNA, and LUCs
- Alternative 5 – Air Sparge Curtain, MNA, and LUCs

In accordance with RAOs summarized in Section 3.4, the objective of the Zone 1 remedial alternative is to reduce near source COC concentrations within treatment zones by at least 70 percent in 10 years or less (average of before and after concentrations within the treatment zone), significantly reducing mass flux into the central portion of the plume to be managed by MNA, and to prevent discharge of groundwater exceeding NC 2B standards to surface water. The objective of the Zone 2 remedial alternative is to treat the downgradient plume and prevent the discharge of groundwater exceeding NC 2B standards to surface water.

5.1 Common Components of Various Alternatives

This section describes those components that are common to select groups of alternatives. These common remedial components include groundwater sampling to collect additional site data for the Remedial Design (RD), a multi-media monitoring program, construction-derived materials and investigation-derived waste (IDW) handling, LUCs, and Five-Year Reviews.

5.1.1 Performance Monitoring Wells

Implementation of Alternatives 1 and 2 (both Zones) would not require the installation of additional performance monitoring wells in either the upper or lower surficial aquifer. A baseline sampling event from the existing monitoring well network was performed in 2009.

Implementation of Zone 1 – Alternative 3 and Zone 2 - Alternatives 3, 4, and 5 would require the installation of additional performance monitoring wells and baseline sampling from the newly-installed monitoring wells. The additional monitoring wells would be installed in both the upper and lower surficial aquifers to collect data to further refine the design aspects of the selected alternative (e.g., injection dosage and depth; temporal data to determine biodegradation rates for MNA) by confirming contaminant distribution and aquifer geochemistry conditions, establishing baseline conditions, and adding to the performance monitoring dataset.

5.1.2 Performance Monitoring Program

Periodic sampling would be required as part of any remedial action until cleanup goals are met. Varying periods and frequencies of monitoring are appropriate for each alternative. The performance monitoring program for the selected remedy would be fully developed during the RD phase after the ROD is finalized, and would include an exit strategy for discontinuing the monitoring program when the cleanup levels are met. The assumptions regarding the details of performance monitoring that were made in order to calculate the costs for each alternative are provided in **Appendix C**.

5.1.3 Construction- and Investigation-derived Waste

All soil cuttings, purged groundwater, and decontamination fluids generated during remedial construction, implementation, and sampling are assumed (based on the characterization data) to be:

- Nonhazardous
- Below State and Federal regulatory standards for chlorinated VOCs
- Below other related special handling or disposal criteria.

Full waste characterization would be performed prior to disposal. Aqueous material or waste would be characterized and disposed at the Base IWTP or offsite as determined by MCAS Cherry Point. Soil material or waste would be characterized and appropriately disposed offsite.

5.1.4 Five-Year Reviews

Five-Year Reviews would be required at OU1 (along with other operable units at MCAS Cherry Point) until cleanup levels are met in the groundwater of the surficial aquifer. For the purposes of this FS, it was assumed that other operable units at MCAS Cherry Point would also be included in the 5-year reviews (costs pro-rated between OUs). Cost assumptions and details are provided in **Appendix C** for each alternative.

5.1.5 Land-Use Controls

LUCs are included as part of the remedial actions for all alternatives other than No Action. LUCs are used to support and enhance the remedial alternatives as appropriate. The same objectives, implementation, and maintenance activities associated with LUCs are applicable to all alternatives (with the exception of the No Action alternative). Cost assumptions and details are provided in **Appendix C** for each alternative.

5.1.6 Monitored Natural Attenuation

As summarized previously in Section 2.4, subsurface conditions are generally favorable for natural attenuation at OU1. Therefore, MNA is a critical component of all alternatives presented in this FS (aside from No Action), particularly for areas of the plume not directly addressed by active remedies (i.e., between source zones and potential receptors).

5.2 Description of Selected Remedial Alternatives

5.2.1 Zone 1 (Source Zone)

Alternative 1—No Action

The 'No Action' alternative is required under CERCLA. No Action means no remedial actions or process options are implemented, and no attempt is made to meet RAOs. The No Action alternative is evaluated to determine the risks to human health and the environment if no additional actions were taken, and is used as a baseline for comparison to other options/alternatives. The retention of the No Action alternative satisfies CERCLA requirements, but will not mitigate risk from contaminated groundwater.

The "No Action" alternative does not meet the OU1 RAOs. It would allow natural attenuation to reduce the contaminant plume in groundwater, but the lack of monitoring could potentially expose future receptors to contaminants in groundwater.

Alternative 2—Monitored Natural Attenuation and Land Use Controls

MNA Description

MNA includes tracking the process of natural attenuation via groundwater performance monitoring. TCE is the most widespread COC in groundwater within OU1 and the most frequently-detected COC above the NC 2L standards. The maximum concentration observed within the upper surficial aquifer was 62,000 µg/L (52GW46). TCE concentrations above 11,000 µg/L (1 percent of the solubility of TCE) indicate that TCE may be present as a non-aqueous phase liquid (NAPL) beneath Building 133.

The eight USEPA (1999 and 2004) objectives for performance monitoring of a MNA remedy are as follows:

1. Demonstrate that natural attenuation is occurring according to expectations.
2. Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, microbiological, or other changes) that may reduce the efficacy of any of the natural attenuation processes.
3. Identify any potentially toxic and/or mobile transformation products.
4. Verify that the plume(s) is (are) not expanding downgradient, laterally or vertically.
5. Verify no unacceptable impact to downgradient receptors.
6. Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy.

7. Demonstrate the efficacy of institutional controls put in place to protect potential receptors.
8. Verify attainment of remediation objectives.

MNA is being considered more frequently as part of remedial actions at various CERCLA sites. USEPA does not consider MNA to be a "presumptive" or "default" remedy—it is one option that should be evaluated with other applicable remedies (USEPA, 1999). USEPA does not view MNA to be a "no action" or "walk-away" approach, but rather considers it to be an alternative means of achieving remediation objectives that may be appropriate for specific, well-documented site circumstances where its use meets the applicable statutory and regulatory requirements.

Source control and long-term performance monitoring are fundamental components of any MNA remedy (USEPA, 1999). The use of MNA differs from the No Action alternative because performance monitoring continues until the RAOs have been achieved, and longer if necessary to verify that the site no longer poses a threat to human health and/or the environment.

The benefits of MNA include the following:

- Generation of a lesser volume of remediation-derived wastes. No waste stream other than purge water is generated during sampling events (and soil cuttings if additional monitoring wells are installed).
- Does not require the installation of infrastructure other than a network of monitoring points.
- Does not rely on the application of any amendments or natural attenuation enhancements to the subsurface.
- There is no operation and maintenance (O&M) associated with MNA other than monitoring well maintenance and routine sampling.

The disadvantages of MNA include the following:

- MNA has limited ability to attenuate DNAPL.
- MNA often takes a much longer time to achieve cleanup levels compared to other, more-aggressive remedies.
- MNA is limited by naturally existing physical, biological, and geochemical processes. Native geochemical and biological conditions may not sustain complete reduction of TCE in all areas of the site without the addition of engineered amendments. In such cases, MNA relies solely on the slower physical processes, such as diffusion and dispersion.

Although a MNA performance monitoring program has not yet been implemented at OU1, the eight USEPA MNA performance monitoring objectives have already been partially met, based on data and conclusions presented in the 2009 Additional Investigation Memorandum Technical Memorandum (**Appendix A**) (CH2M HILL, 2009) as detailed in **Table 5-1**. The chlorinated VOC plumes in the upper and lower surficial aquifers have likely stabilized due to natural attenuation processes (**Appendix A**).

Concentrations of the chlorinated COCs in groundwater presently attenuate to concentrations below NC 2B standards before the groundwater reaches Sandy Branch Tributaries #1 and #2, Sandy Branch, and East Prong Slocum Creek (note: transformation products of chlorinated VOCs are included as COCs in this FS). Surface water and sediment data from the stream indicate no unacceptable human health or ecological risk and no ARAR non-compliance.

The greatest uncertainty for this alternative is the estimated timeframe to meet cleanup levels. One hundred years was assumed for the purposes of the cost estimate. A more accurate estimation can be made following the collection of temporal COC and geochemical data from baseline and performance sampling. For purposes of this FS, Zone 1 MNA costs are assumed to be included in the selected Zone 2 alternative.

LUCs Description

LUCs have been evaluated in this FS in conjunction with all alternatives. The objectives, implementation, and maintenance activities associated with the LUCs are essentially to the same for each alternative, since LUCs will be required until cleanup levels are achieved. The LUCs to be implemented include, but are not limited to, land use restrictions in the Base Master Plan process and the filing of a Notice of Contaminated Site per North Carolina General Statutes 143B-279.9 and 143B-279.10. LUCs will be implemented and maintained by the Navy and MCAS Cherry Point until the concentrations of hazardous substances in the groundwater are at such levels to allow for unrestricted use and unlimited exposure. The specific objectives of the LUCs include the following:

- Prohibit all uses of groundwater from the surficial aquifer in areas where COC concentrations exceed cleanup levels, including but not limited to, human consumption, dewatering, irrigation, heating/cooling and industrial processes, unless prior written approval is obtained from USEPA and NCDENR.
- Prohibit intrusive activities below the water table in areas with contaminated groundwater, unless prior written approval is obtained from USEPA and NCDENR.
- Limit activities that would interfere with operation of the selected remedy or cause uncontrolled exposures to COCs.
- Maintain the integrity of any existing or future monitoring or remediation system at the site.

Successful implementation of LUCs, including adequate documentation and communication, would be required for the protection of human health and the environment. For this FS, the following supplemental implementation measures are proposed where applicable:

- Incorporate groundwater use restrictions into the ROD for OU1.
- Define land use controls (LUCs) in the RD or prepare a separate LUC RD that will provide implementation and maintenance instructions.
- Incorporate the LUC boundaries into the Air Station's master planning process and geographic information system (GIS).

The following maintenance measures are proposed for successful implementation of LUCs:

- Update the LUC Assurance Plan (LUCAP) to incorporate OU1 LUCs.
- Conduct quarterly site inspections to ensure that groundwater use restrictions are maintained.
- Review the integrity and effectiveness of the LUCs during the Five-Year Reviews.

For purposes of this FS, Zone 1 LUC costs are assumed to be included in the selected Zone 2 alternative.

Alternative 3—In Situ Enhanced Bioremediation

Alternative 3 represents a combined approach of in-situ enhanced bioremediation with MNA and LUCs. The MNA and LUCs components are similar to Alternative 2. Source zone ISEB would target VOC impacts in the surficial aquifer and upper portion of the lower surficial aquifer, immediately downgradient of Building 133. By treating near the source area, concentrations of VOCs migrating downgradient would be reduced over time, potentially increasing the longevity, time between potential injection events, or negating the need to continue downgradient treatment.

Total organic carbon at the site is known to be low (generally 5-10 mg/L or less), and may be limiting to progress of natural bio-attenuation. By adding fermentable organic carbon, natural anaerobic biodegradation via reductive dechlorination is enhanced. A variety of different organic substrates have been used to stimulate reductive dechlorination, broadly categorized into four types (AFCEE, 2007): soluble substrates (e.g., sodium lactate and molasses), slow-release substrates (e.g., food-grade vegetable oil), solid substrates (e.g., mulch) and miscellaneous experimental substrates (e.g., hydrogen gas).

The appropriate type of electron donor substrate for a given site involves the ability to effectively distribute the substrate throughout the treatment zone and the ability to sustain the reactive zone with that substrate over the treatment timeframe in a cost-effective manner (AFCEE, 2007). In general, the more soluble the substrate the easier it is to mix and distribute throughout the aquifer matrix. However, many soluble substrates (e.g., lactate) are consumed too quickly, and the need for frequent reinjections reduces cost-effectiveness. Emulsified vegetable oils (EVO) are frequently used for ERD applications due to the ease of injection and distribution (the emulsions are miscible during injection) in conjunction with their decreased solubility, providing a slow-release carbon source. During previous ISEB treatability studies (Section 2.9), COC concentrations were reduced initially, followed by rebound. To reduce the frequency of applications required, use of a slow-release electron donor is preferable (and assumed for the purpose of the cost estimate). However, because of high concentrations in the near source area, it was assumed that injections would be conducted every two years for a total duration of 10 years.

The source zone ISEB conceptual layout is shown in **Figure 5-1**. As shown in the figure, a conceptual layout of 50 pairs of clustered wells would be installed, spaced at 25 foot intervals, on both sides of A Street. Fifty shallow injection wells would be screened from 20 to 35 feet bgs, and 50 deep injection wells would be screened from 35 to 50 feet bgs. The preferred substrate for this application would be a commercially available EVO product.

Dosage calculations for the EVO product are provided in **Appendix C**. A single well injection rate of 10 gallons per minute (gpm) was assumed.

Alternative 3 cost estimates were evaluated for a duration of 30 years. However, the estimated time to reach cleanup levels may exceed 30 years dependant on site conditions, and considering that the source zone is not treated, residual DNAPL beneath Building 133 would be expected to serve as a long term source to groundwater. Areas of the plume between the injection wells and downgradient treatment would be addressed by MNA. Implementation, O&M, monitoring, reporting, and other alternative cost assumptions are provided in **Appendix C**. For purposes of this FS, costs for MNA (beyond the performance monitoring discussed in the first bullet below) and LUCs for Zone 1 are assumed to be captured in the selected Zone 2 remedy.

Other general assumptions include the following:

- Monitoring will be conducted in 30 monitoring wells on a quarterly basis for the first year and on an annual basis thereafter. Groundwater samples will be analyzed for TCL VOCs. Field parameters (such as water level, pH, specific conductance, temperature, ORP, and dissolved oxygen) will be measured during sample collection.
- LUCs would need to be maintained until RAOs are achieved (See Alternative 2 description for LUC details).
- MNA is a significant component of this alternative, and monitoring data would be evaluated to determine system performance and site progress toward meeting cleanup levels.
- The remedy also would be reviewed for protectiveness during each 5-year review.

The uncertainties for this alternative include the following:

- The estimated timeframe to meet cleanup levels.
- The achievable ROI for the electron donor/substrate
- The required frequency of substrate reinjection.

5.2.2 Zone 2 (Downgradient Zone)

In this attainment area, Alternatives 3 through 5 include a downgradient treatment technology installed perpendicular to the flow path of the contaminated groundwater plume, producing treatment zones that allow the passage of groundwater as contaminants are treated and/or removed. By utilizing various groundwater treatment technologies, contaminant treatment can occur through physical, chemical, or biological processes.

Ideally, the base of the downgradient treatment zone would connect to a low permeability zone or aquitard, in order to prevent contaminated groundwater from flowing under the treatment zone. In the case of OU1, where the downgradient plume is discharging to Slocum Creek and/or Sandy Branch, contaminant underflow is considered to be low risk, provided that backfill sand of appropriate permeability (not excessively high) is used.

Alternative 1 – No Action

See Section 5.2.1 (Zone 1, Alternative 1 – No Action) for a description of this alternative. The No Action alternative is evaluated to determine the risks to human health and the environment if no additional actions were taken, and is used as a baseline for comparison to other options/alternatives.

Alternative 2 – Monitored Natural Attenuation and Land Use Controls

See Section 5.2.1 (Zone 1, Alternative 2 – MNA and LUCs) for a description of this alternative.

Alternative 3—Permeable Reactive Barrier, Monitored Natural Attenuation, and Land Use Controls

Alternative 3 would use a permeable reactive barrier (PRB) as the downgradient groundwater treatment method. A variety of reactive materials could conceptually be used in the PRB.

ZVI is commonly used as a reactive agent for PRBs. Oxidation of ZVI under anaerobic conditions yields hydrogen ions, which are reducing agents for chlorinated solvents. If properly designed and installed, ZVI PRBs have been shown to be effective in reducing a wide range of dissolved chlorinated solvents in groundwater for up to 20 years or longer, without generation of toxic daughter products. Removal efficiencies of 90% or more are common.

Compost or mulch has become an increasingly common medium for use in PRBs because it provides a low-cost, slow-release electron donor for anaerobic reductive dechlorination. Primary limitations associated with using a mulch PRB at OU1 are:

- Possible generation of TCE daughter products, such as VC, close to Slocum Creek
- Carbon source (substrate) needs to be replenished at regular intervals, at least every 3 to 5 years
- Uniform replenishment of the electron donor in a long barrier is expected to be logistically difficult.

For these reasons, a mulch PRB was not evaluated further.

A conceptual layout of two ZVI PRBs is illustrated in **Figure 5-2**: one cutting off the southern lobe of the plume between Slocum Creek and Sandy Branch (Site 16 area), and a second barrier cutting off the northern lobe of the plume, near Roosevelt Boulevard. The first PRB would be constructed using the DeWind one-pass trench system, successfully used at nearby Camp Lejeune. Target depth would be 35 feet, with a thickness of 2 feet and total length of 950 feet. A conceptual design for this PRB includes a target iron loading of 20 percent, or 422 cubic yards (855 tons) of granular ZVI. The remainder of backfill material would consist of clean sand, trucked in from an off-site source. It was assumed for costing purposes that the upper five feet of native vadose zone soil would be ”clean” and could therefore be re-used as backfill.

It is assumed the second (smaller) PRB would consist of a series of closely spaced (25 feet) soil borings, with micro-scale ZVI injected at 3.5 foot vertical intervals from 20 to 50 feet below land surface (bls) using the ARS Technologies, Inc. (ARS) “Ferox” process. A conceptual design for this PRB includes a target iron dosage of 0.7 percent (iron to soil ratio). A total of 155 tons of iron would be injected into 30 borings, arranged in a double row of staggered injection points (15 borings per row). It's important to note that the mass and associated reaction longevity for micro-scale iron is significantly less than that of the pelletized iron used in continuous trenches. Therefore, it was assumed that micro-scale iron would need to be re-injected every six years for 30 years, which greatly increases projected long term O&M expenditures.

Ideally, a second one-pass trench would be constructed to cut-off the northern plume, in lieu of "Ferox" injections. DeWind has recently developed a larger one-pass trenching machine, which they claim is capable of installing PRBs to a depth of up to 45 feet bgs. However, this machine has not been field tested, and DeWind will not commit to projects deeper than 40 feet bgs at this time. The base of the TCE plume in the area of 42GW23 and MW-55 is inferred to be approximately 50 to 55 feet bgs. If the shallow soil could be "benched" to approximately 10 feet bgs (depth to groundwater is approximately 15 feet bgs at this location), it may be possible to construct a second continuous trench to cut-off the northern lobe of the plume near Roosevelt Boulevard. A budgetary cost estimate for this scenario (Appendix C - "3A Option") was prepared, although a conceptual layout diagram is not included in the Figures. Use of one-pass trenching technology > 40 feet bgs would require further evaluation beyond the scope of this FS.

As an alternative to the one-pass excavator, the 50-foot deep trench could be constructed using a long-stick track-mounted excavator and biopolymer slurry to support the sidewalls during implementation. The sidewalls of the PRB excavation would be supported by the differential hydrostatic head of the slurry and the slurry shear strength while the reactive medium was placed into the trench with a tremie pipe. The biodegradable slurry, which includes water, guar gum, and preservatives that prevent premature degradation while the slurry is in use, would be prepared in a batch mixing plant and pumped directly into the open excavation. It would be constantly circulated between the excavation and the slurry storage tanks (or fractionation tanks) to maintain uniform slurry properties throughout the excavation. Slotted PVC pipes would also be installed in the excavation during the backfilling process to develop the PRB after it was completely backfilled. Finally, clean backfill would then be placed atop the reactive medium and then the site would be restored. Installation of the PRB using this method would be more expensive and higher risk. O&M costs would be similar to the traditional one pass trenching method described in the paragraphs above.

Alternative 4—In Situ Enhanced Bioremediation Barrier, Monitored Natural Attenuation, and Land Use Controls

Injection of biological substrate to stimulate enhanced reductive dechlorination (ERD) of the VOCs, combined with a bioaugmentation culture is considered to be a feasible option, since bioaugmentation would be expected to ensure that complete transformation of VOCs to non-toxic end products (such as ethene and ethane) would be accomplished before the groundwater migrated into the creek. In this alternative, biological substrate to enhance ERD would be injected into a row of injection wells, installed perpendicular to groundwater flow, creating a barrier-style treatment zone.

The biological substrate promotes natural degradation of chlorinated solvents by anaerobic microorganisms in the aquifer through the addition of organic substrates/electron donors such as EVO, EHC®, molasses, lactate, etc. The organic substrate is fermented to hydrogen and low molecular weight organic acids (i.e., electron donors) to support anaerobic reductive dechlorination (Air Force Center for Engineering and the Environment [AFCEE], 2007).

A conceptual layout of downgradient injection wells is shown in **Figure 5-3** and includes 38 wells, screened from 10-30 feet bgs, cutting off the southern lobe of the plume between Slocum Creek and Sandy Branch (Site 16 area), and a second row of 15 pairs of nested wells (30 wells total) screened from 20 to 35 feet bgs and 35 to 50 feet bgs. All wells would be spaced at up to 25 foot intervals, assuming a 12.5 foot radius of influence, which is considered reasonable based on CH2M HILL's previous experience with injection scenarios at similar sites. It is assumed these wells would be used to inject a combination of emulsified vegetable oil (EVO) and bioaugmentation culture. Dosing calculations and volumes are summarized in **Appendix C**. It is assumed that EVO would be re-injected every two years to replenish electron donor.

Alternative 5—Air Sparge Curtain, Monitored Natural Attenuation, and Land Use Controls

The other feasible option is an air sparge (AS) barrier, or "curtain". A long directional-drilled sparging well(s) would be installed perpendicular to the direction of groundwater flow across the plume to treat impacted groundwater before it reaches the creek, via mass transfer ("stripping") of TCE and aerobic biodegradation of less highly-oxidized daughter products such as cis-1,2 DCE and VC to concentrations less than applicable NC 2B standards. Many AS systems are operated simultaneously with soil vapor extraction (SVE) systems, especially at sites where there is the potential risk of exposure of receptors to COCs in off-gas from the AS system. However, at the proposed location for the OU 1 "curtain" no potential vapor receptors are present. In addition, SVE would be difficult to implement at OU1 because of the shallow water table and relatively low-permeability vadose zone. A previous AS curtain installed near the Site 16 area of the plume had multiple operation and maintenance problems and the system ultimately became ineffective and was shut down. Similar problems may be encountered with installation of a new system.

As shown in **Figure 5-4**, the conceptual "curtain" system would consist of two horizontal directionally drilled AS wells. The first well, Well "A", would be positioned near Site 16, bridging Slocum Creek and Sandy Branch, and installed to a depth of 50 feet bgs. Well A would be designed to contain the southwestern finger of the chlorinated VOC plume, approximately 50 ft bgs, with 500 feet of slotted pipe and a total length of 1,100 feet. The second horizontal sparge well, Well "B", would be located along Roosevelt Boulevard, and installed to a depth of approximately 70 feet bgs. Well B would be designed to contain the northwestern finger of the chlorinated VOC plume, with 400 feet of slotted pipe and a total length of 1,100 feet. A single header/manifold would connect the horizontal directional (HDD) wells to aboveground process equipment, consisting primarily of a rotary screw air compressor and a small enclosure. Well construction materials were assumed to be four-inch diameter, DR 11 high-density polyethylene (HDPE).

The assumed effective timeframe of the downgradient treatment alternative is 30 years, although it is possible that any one of the three options presented could continue to be used beyond 30 years.

Implementation, O&M (including amendment re-injections), monitoring, reporting, and other alternative cost assumptions and details are provided in **Appendix C**.

Other general assumptions for each option include the following:

- Monitoring will be conducted in 60 monitoring wells on a quarterly basis for the first year and on an annual basis thereafter. Groundwater samples will be analyzed for Target Compound List (TCL) VOCs. Field parameters (such as water level, pH, specific conductance, temperature, ORP, and dissolved oxygen) will be measured during sample collection.
- LUCs would need to be maintained until RAOs are achieved (See Alternative 2 description for LUC details).
- MNA is a significant component of this alternative, and monitoring data would need to be evaluated to determine system performance and site progress toward meeting cleanup levels.
- Monitoring of the ASD systems would be required to ensure continued effectiveness.
- The remedy also would be reviewed for protectiveness during each 5-year review.

Uncertainties for this alternative include the following:

- The estimated timeframe to meet cleanup levels.
- The achievable radius of influence (ROI) for the electron donor/bioaugmentation culture and air sparge curtain.
- The required frequency of substrate reinjection.

Baseline and performance sampling would provide the temporal COC and geochemical data needed to make a more accurate estimation of remedial timeframe, and also provide more data to determine the effective distribution of the substrate and the rate of substrate consumption.

TABLE 5-1
USEPA Monitored Natural Attenuation Performance Monitoring Objectives
Operable Unit 1, Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

MNA Objective (USEPA, 2004)		Evaluation for OU1
1	Demonstrate that natural attenuation is occurring according to expectations.	The OU1 RI Addendum and the 2009 Sampling Event concluded that Natural Attenuation Indicator Parameters in the upper and lower Surficial aquifer indicate favorable to ideal conditions for chlorinated VOC natural attenuation processes.
2	Detect changes in environmental conditions (e.g., hydrogeologic, geochemical, or microbiological) that may reduce the efficacy of any of the natural attenuation processes.	None detected during the OU1 RI Addendum or the 2009 Sampling Event. Additional spatial and temporal data will be collected during baseline sampling and performance monitoring.
3	Identify any potentially toxic and/or mobile transformation products.	Chlorinated VOC breakdown products were identified during the OU1 RI Addendum and the 2009 Sampling Event. Breakdown products of the chlorinated COCs will be monitored as part of the COCs (some of the COCs are breakdown products of PCE/TCE) during remedy implementation.
4	Verify that the plume(s) is(are) not expanding downgradient, laterally or vertically.	The OU1 RI Addendum and the 2009 Sampling Event concluded that the CVOC plumes throughout OU1 have stabilized due to natural attenuation processes (Section 2.2.4 and 2.2.5). Further spatial and temporal data will be collected and evaluated during baseline sampling and performance monitoring.
5	Verify no unacceptable impact to downgradient receptors.	The OU1 RI Addendum and the 2009 Sampling Event concluded that the CVOC plumes throughout OU1 have stabilized due to natural attenuation processes. The concentrations of chlorinated VOCs in groundwater in wells adjacent to Sandy Branch and Slocum Creek are above NC2L groundwater standards. Most likely, natural attenuation processes will not have reduced chlorinated VOCs by the time groundwater has reached and discharges into Sandy Branch and Slocum Creek.
6	Detect new releases of contaminants to the environment that could impact the effectiveness of the natural attenuation remedy.	There are no known continuing chlorinated VOC source areas (i.e. ongoing releases) at OU1.
7	Demonstrate the efficacy of institutional controls that were put in place to protect potential receptors.	LUCs will be implemented and enforced as they are at other current post-ROD operable units at MCAS Cherry Point as part of remedy implementation.
8	Verify attainment of remediation objectives.	Attainment of RAOs will be evaluated throughout MNA. The remedy will be considered complete when the data show cleanup levels have been met within the Attainment Areas.

Notes:

The eight USEPA (1999 and 2004) objectives for performance monitoring of the Monitored Natural Attenuation (MNA) portion of Alternative 3 are discussed in Section 5.2.3.

USEPA. 1999. *Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites* . Office of Solid Waste and Emergency Response (OSWER) Directive 9200.4-17P. April 21.

USEPA. 2004. *Performance Monitoring of MNA Remedies for VOCs in Ground Water* . EPA/600/R-04/027. April.

\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\UPDATE_04202011\FIGURE 5-4 - ALT 3 ZONE 1 IN-SITU ENHANCED BIOREMEDIATION.MXD CBOWMAN 4/20/2011 16:11:35

Legend

- Biological Amendment Injection Wells
- Monitoring Well - Lower Aquifer
- Former Extraction Well
- Surface Water
- OU1 Boundary
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
Concentrations are from Spring 2009 sampling event
Concentrations are in µg/L (micrograms per liter)
IWTP - Industrial Wastewater Treatment Plant
PRB - Permeable Reactive Barrier

W N S E

0 600 1,200 Feet

Figure 5-1
Zone 1 Alternative 3 - In-Situ Enhanced Bioremediation
Lower Surficial Aquifer
Operable Unit 1
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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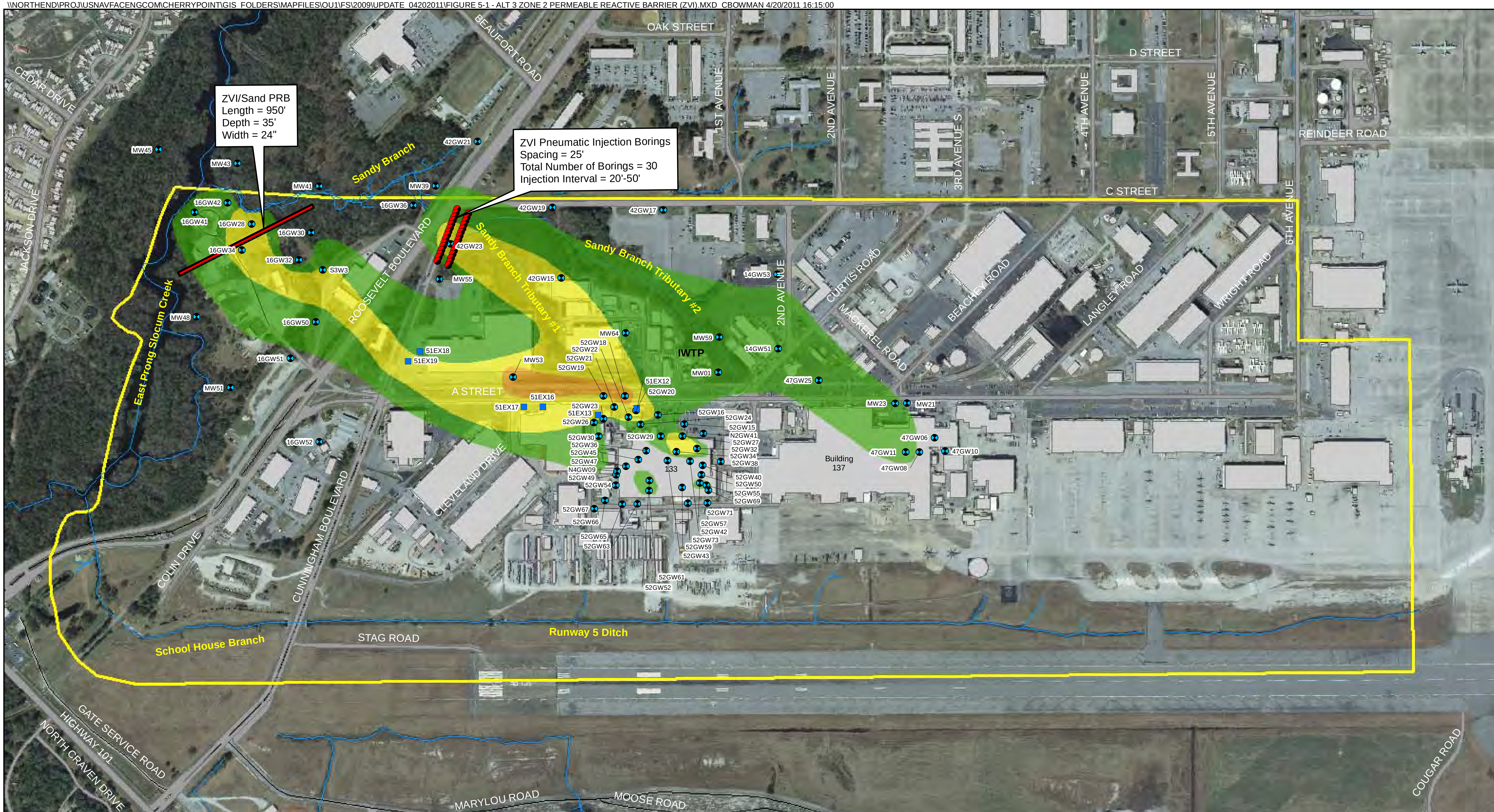
\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\UPDATE_04202011\FIGURE 5-1 - ALT 3 ZONE 2 PERMEABLE REACTIVE BARRIER (ZVI).MXD CBOWMAN 4/20/2011 16:15:00



Legend

- Pneumatic Injection Borings
- Monitoring Well - Lower Aquifer
- Former Extraction Well
- Surface Water
- ZVI/Sand PRB
- OU1 Boundary
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
Concentrations are from Spring 2009 sampling event
Concentrations are in µg/L (micrograms per liter)
IWTP - Industrial Wastewater Treatment Plant
PRB - Permeable Reactive Barrier

W N S E

0 600 1,200 Feet

Figure 5-2
Zone 2 Alternative 3 - Permeable Reactive Barrier (ZVI)
Lower Surficial Aquifer
Operable Unit 1
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\UPDATE_04202011\FIGURE 5-2 - ALT 4 ZONE 2 INJECTION WELLS.MXD CBOWMAN 4/20/2011 16:16:35

Legend

- Former Extraction Well
- Monitoring Well - Lower Aquifer
- Biological Amendment Injection Wells
- Surface Water
- OU1 Boundary
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
Concentrations are from Spring 2009 sampling event
Concentrations are in µg/L (micrograms per liter)
IWTP - Industrial Wastewater Treatment Plant

W N S E

0 600 1,200 Feet

Figure 5-3
Zone 2 Alternative 4 - Injection Wells
Lower Surficial Aquifer
Operable Unit 1
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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\\NORTHEND\PROJ\USNAVFACENGCOM\CHERRYPOINT\GIS_FOLDERS\MAPFILES\OU1\FS\2009\UPDATE_04202011\FIGURE 5-3 - ALT 5 ZONE 2 AIR SPARGE CURTAIN.MXD CBOWMAN 4/20/2011 16:18:04

Legend

- Monitoring Well - Lower Aquifer
- Former Extraction Well
- Casing
- Slotted Pipe
- Surface Water
- OU1 Boundary
- Existing Buildings
- 3 - 30 µg/L
- 30 - 300 µg/L
- 300 - 3,000 µg/L

Notes:
NC2L - North Carolina Groundwater Standard
NC2L = 3 µg/L (Jan 2010)
Concentrations are from Spring 2009 sampling event
Concentrations are in µg/L (micrograms per liter)
IWTP - Industrial Wastewater Treatment Plant
Estimated HDD Air Sparge Well Depth = 50-70 ft bgs

W N S E

0 600 1,200 Feet

Figure 5-4
Zone 2 Alternative 5 - Air Sparge Curtain
Lower Surficial Aquifer
Operable Unit 1
Marine Corps Air Station Cherry Point
Cherry Point, North Carolina

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SECTION 6

Detailed and Comparative Analysis of Alternatives

In this section, detailed analysis is performed on the developed alternatives using the standard NCP criteria specified in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (USEPA, 1988). The alternatives were evaluated individually against each criterion, and then the different alternatives were compared to determine various tradeoffs that must be balanced. The results of the detailed analysis can be used to support the selection of a Preferred Alternative and provide the foundation for the ROD.

The nine NCP evaluation criteria are as follows:

1. Overall protection of human health and the environment
2. Compliance with ARARs
3. Long-term effectiveness and permanence
4. Reduction of toxicity, mobility, or volume through treatment
5. Short-term effectiveness
6. Implementability
7. Cost
8. State acceptance
9. Community acceptance

The NCP categorizes these nine criteria into the following three groups. Each type of criteria has its own weight when it is evaluated.

- **Threshold criteria** are requirements that each alternative must meet to be eligible for selection as the preferred alternative, and include overall protection of human health and the environment and compliance with ARARs (unless a waiver is obtained).

- **Primary balancing criteria** are used to weigh effectiveness and cost tradeoffs among alternatives. The primary balancing criteria include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The primary balancing criteria represent the main technical criteria upon which the alternative evaluation is based.

- **Modifying criteria** include State acceptance and community acceptance, and may be used to modify aspects of the preferred alternative when preparing the ROD. Modifying criteria are generally evaluated after public comment on the PRAP. Accordingly, only the seven threshold and primary balancing criteria are part of the detailed analysis phase presented in this FS.

6.1 NCP Overview of Evaluation Criteria

The nine evaluation criteria developed by the USEPA are described in the following subsections. **Table 6-1** provides details on the analysis factors and considerations utilized during the analysis of each alternative for NCP Criteria 1 through 6.

6.1.1 Criterion 1—Protection of Human Health and the Environment

The assessment against this criterion evaluates how each alternative, as a whole, achieves and maintains protection of human health and the environment and describes how site risks are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This assessment also allows for consideration of whether the alternative poses unacceptable short-term or cross-media impacts.

6.1.2 Criterion 2—Compliance with ARARs

This evaluation criterion is used to determine whether each alternative will meet all of its Federal, State, and local ARARs, as identified in **Section 3.1**. The analysis summarizes which requirements are applicable or relevant and appropriate for each alternative, and describes how the alternative meets these requirements. If a waiver is required because an ARAR is not met, the basis for justification should be discussed.

6.1.3 Criterion 3—Long-term Effectiveness and Permanence

Long-term effectiveness and permanence are measured in terms of the risk remaining at the site after response objectives have been met. Alternatives providing the highest degree of long-term effectiveness and permanence are those that leave little or no waste at the site, do not require long-term maintenance and monitoring, and minimize the need for institutional controls. The evaluation of this criterion includes consideration of the following factors:

- The magnitude of residual risk to human and environmental receptors posed by any untreated waste or treatment residues remaining at the conclusion of remedial activities.
- The type, degree, and adequacy of long-term controls required to manage untreated waste or treatment residues at the conclusion of remedial activities.
- The long-term reliability of engineering and/or institutional actions to provide continued protection from residuals.
- The potential need to replace technical components of the alternative and the potential exposure pathway and risks posed should the remedial action need replacement.

6.1.4 Criterion 4—Reduction of Toxicity, Mobility, or Volume through Treatment

This evaluation criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of hazardous substances. This evaluation focuses on the following factors for each remedial alternative:

- The treatment process(es) the alternative will employ, and the materials it will treat.
- The amount of hazardous substances that will be destroyed or treated, including how the principal risk(s) will be addressed.

- The degree of expected reduction in toxicity, mobility, or volume measured as a percentage of reduction.
- The degree to which the treatment will be irreversible.
- The type and quantity of residuals that will remain following treatment.
- Whether the alternative would satisfy the statutory preference for treatment as a principal element.

6.1.5 Criterion 5—Short-term Effectiveness

This evaluation criterion addresses the effects of the alternative during the construction and implementation phase until remedial response objectives are met. The following factors are addressed for each alternative:

- Short-term risks that may be posed to the community during construction and implementation of an alternative.
- Potential adverse impacts to workers that may result during construction and implementation, including an evaluation of the effectiveness and reliability of any protective measures that would be taken.
- Potential adverse environmental impacts that may result from the construction and implementation of an alternative, including an evaluation of the reliability of available mitigation measures in preventing or reducing the potential impacts.
- Estimate of the time required to achieve remedial response objectives.

6.1.6 Criterion 6—Implementability

This criterion addresses the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required during its implementation. The following factors are considered during analysis of this criterion:

- Technical Feasibility
  - Ability to construct and operate
  - Reliability of a technology
  - Ease of undertaking additional remedial action, if needed
  - Ability to monitor effectiveness
- Administrative Feasibility
  - Ability to obtain approvals and coordinate with other agencies
- Availability of services and materials
  - Availability of adequate offsite treatment, storage capacity, and disposal services
  - Availability of necessary equipment, specialists, and provisions
  - Availability of services and materials, including the potential for obtaining competitive bids
  - Availability of prospective technologies

6.1.7 Criterion 7—Cost

Preliminary cost estimates were developed for each remedial alternative. These cost estimates are used to compare the alternatives, not to bid the work. These estimates were made from available information, (i.e., they have an expected accuracy of -30 percent to +50 percent for the scope of action described for each alternative). The estimates are divided into capital costs and O&M costs, and are based on information provided by vendors, regulators, and experience on similar projects. The present worth of the capital cost and O&M are included. Details of these cost estimates are included in **Appendix C**. Significant uncertainties that may affect cost are discussed with each alternative.

6.1.8 Criterion 8—State Acceptance

This assessment evaluates the technical and administrative issues and concerns the State may have regarding each of the alternatives. NCDENR will review and comment on this FS.

6.1.9 Criterion 9—Community Acceptance

This assessment evaluates the issues and concerns the public may have regarding each of the alternatives. As with State acceptance, community concerns will be used to evaluate each remedy in this FS. Consistent with the NCP, public comments will be solicited on the selected alternative presented in the PRAP. Any comments will be addressed in the ROD, and will be considered by the USEPA in selection of the remedy.

6.2 Evaluation and Comparison of Alternatives against NCP Criteria

Table 6-2 presents a detailed summary and comparison of the alternatives based on the NCP evaluation criteria. Zones 1 and 2 - Alternative 2, MNA and LUCs, is overall not effective in the short term and do not reduce concentrations of contaminants until an extended period of time has passed. Zone 1 – Alternative 3, ISEB, MNA, and LUCs, reduces contaminant mobility, toxicity, and volume in high concentration zones immediately downgradient of the source. Zone 2 – Alternatives 3 through 5, reduce toxicity mobility, and (to a lesser extent) volume by cutting off the contaminated plume near Slocum Creek and Sandy Branch and preventing discharge of low level VOCs to surface water. Therefore, a combination of Zone 1 and Zone 2 remedial alternatives provides the most effective remedy for the OU1 Central Groundwater Plume (based on current conditions). A cost summary, including present worth estimates, is presented in **Table 6-3**.

6.3 Conclusions and Path Forward

The OU1 Central Groundwater Plume presents technical and logistical challenges because of its size, site infrastructure, dense network of buried utilities near contaminated areas, and suspected DNAPL beneath Building 133. The remediation alternatives presented in this FS, intend to provide cost-effective options to achieve RAOs, as outlined in Section 3.4 (restated below):

1. Restore groundwater quality at OU1 to the NC 2L and MCL standards based on the classification of the aquifer as a potential source of drinking water (Class GA or Class GSA) under 15A NCAC 02L.0201.

2. Prevent human exposure to groundwater above levels that would cause unacceptable risk.
3. Prevent migration or discharge of COCs in groundwater to sediment and surface water in East Prong Slocum Creek and Sandy Branch at levels that would cause unacceptable risks to human or ecological receptors.

The components of Zones 1 and 2 are intended to treat near source zones to the extent practical in order to efficiently reduce COC mass and prevent future discharges to Slocum Creek and Sandy Branch. A Zone 1 active remedy would be expected to improve performance of a Zone 2 remedial alternative over time. The Zone 1 option would serve to cut the source area off from the downgradient dissolved plume. Biodegradation in the dissolved portion of the plume would then be expected to accelerate since the suspected DNAPL source area would no longer be contributing mass to the downgradient portion of the plume. After a few years, a Zone 1 active remedy may be effective enough to discontinue or reduce operation/maintenance of the Zone 2 remedy and should be considered during the 5-year reviews.

Of the Zone 2 remedial alternatives, Alternative 5 (Air Sparge Curtain) using directional wells is less expensive to implement compared to the other alternatives, with the disadvantages of 30-year O&M costs. However, past experience with a similar system in the same vicinity presented numerous operating challenges. Alternative 3 (Permeable Reactive Barrier) is a robust treatment method, capable of reducing TCE (and other chlorinated VOCs) to NC 2L and MCL water quality standards; however, they have the disadvantages of high capital cost, and a construction approach which requires large machinery. The pneumatic iron injection PRB approach described for the deeper portion of the plume near Sandy Branch is not as robust as the one-pass trench technique, but achieves greater target depths. Alternative 4 (ISEB Barrier) represents an intermediate alternative (in terms of cost) between continuous trench PRBs and air sparging. Like air sparging, downgradient injection wells would require ongoing maintenance (reinjection of substrate and bioaugmentation culture) to maintain performance.

This FS provides the Navy and other stakeholders with the information needed to select the most appropriate remedial action for OU1. The Partnering Team will select the preferred alternative(s) for OU1 and document the selection in a PRAP. The PRAP will be subject to public review and comment. Following consideration of public comments on the PRAP, the final remedy for the site will be documented in a ROD. The RD and remedial action for OU1 will be performed in accordance with the requirements contained in the ROD.

TABLE 6-1
NCP Criteria Analysis Factors and Considerations
Operable Unit 1, Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

Analysis Factors	Considerations
Criterion 1 – Overall Protection of Human Health and the Environment	
Human Health Protection	Likelihood that the alternative reduces risk to human health through exposure to contaminants in soil by direct contact, ingestion, or inhalation.
Environmental Protection	Likelihood that the alternative reduces the threat to unaffected groundwater, soil, surface water by minimizing migration of contaminants.
	Likelihood that the alternative reduces risk to ecological receptors.
Criterion 2 – Compliance with ARARs	
Chemical-specific ARARs	Likelihood that the alternative will achieve compliance with chemical-specific ARARs within a reasonable time.
	If it appears that compliance with chemical-specific ARARs will not be achieved, then evaluation of whether a waiver is appropriate must be completed.
Location-specific ARARs	Determination of whether any location-specific ARARs (e.g., preservation of wetlands) apply to the alternative.
	Likelihood that the alternative will achieve compliance with the location-specific ARAR.
	If the location-specific ARAR cannot be met, evaluation of whether a waiver is appropriate must be completed.
Action-specific ARARs	Likelihood that the alternative will achieve compliance with action-specific ARARs (e.g., hazardous waste treatment regulations).
Other Criteria and Guidance	Likelihood that the alternative will achieve compliance with other criteria, such as risk-based criteria.
Criterion 3 – Long-term Effectiveness and Permanence	
Magnitude of Residual Risks	Identity of remaining risks (risks from treatment residuals) as well as risks from untreated residual contamination.
	Magnitude of the remaining risks.
Adequacy and Reliability of Controls	Likelihood that the technologies will meet required process efficiencies or performance specifications.
	Type and degree of long-term management required.
	Long-term monitoring requirements.
	O&M functions that must be performed.
	Difficulties and uncertainties associated with LTO & M functions.
	Potential need for technical components replacement.
	Magnitude of threats or risks should the remedial action need replacement.
	Degree of confidence that controls can adequately handle potential problems.
	Uncertainties associated with land disposal of residuals and untreated wastes.
Criterion 4 – Reduction of Toxicity, Mobility, or Volume through Treatment	
Treatment Process and Remedy	Likelihood that the treatment process addresses the principal threat.
	Special requirements for the treatment process.
Amount of Hazardous Material Destroyed or Treated	Portion (mass) of contaminant that is destroyed.
	Portion (mass) of contaminant that is treated.
Reduction in Toxicity, Mobility, or Volume	Extent that the total mass of contaminants is reduced.
	Extent that the mobility of contaminants is reduced.
	Extent that the volume of contaminants is reduced.
Irreversibility of Treatment	Extent that the effects of the treatment are irreversible.
Type and Quantity of Treatment Residual	Residuals that will remain.
	Quantities and characteristics of the residuals.
	Risk posed by the treatment.
Statutory Preference for Treatment as a Principal Element	Extent to which the scope of the action covers the principal threats.
	Extent to which the scope of the action reduces the inherent hazards posed by the principal threats at the site.

TABLE 6-1
NCP Criteria Analysis Factors and Considerations
Operable Unit 1, Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

Analysis Factors	Considerations
Criterion 5 – Short-term Effectiveness	
Protection of the Community during the Remedial Action	Risks to the community that must be addressed.
	How the risks will be addressed and mitigated.
	Remaining risks that cannot be readily controlled.
Protection of Workers during Remedial Actions	Risks to the workers that must be addressed.
	How the risks will be addressed and mitigated.
	Remaining risks that cannot be readily controlled.
Environmental Impacts	Environmental impacts that are expected with the construction and implementation of the alternative.
	Mitigation measures that are available and their reliability to minimize potential impacts.
	Impacts that cannot be avoided, should the alternative be implemented.
Time until RAOs Are Achieved	Time to achieve protection against the threats being addressed.
	Time until any remaining threats are addressed.
	Time until RAOs are achieved.
Criterion 6 – Implementability	
Technical Feasibility	
Ability to Construct and Operate the Technology	Difficulties associated with source area treatment.
	Uncertainties associated with the construction.
Reliability of the Technology	Likelihood that technical problems will lead to schedule delays.
Ease of Undertaking Additional Remedial Action	Likely future remedial actions that might be anticipated.
	Difficulty implementing additional remedial actions.
Monitoring Considerations	Migration or exposure pathways that cannot be monitored adequately.
	Risks of exposure, should the monitoring be insufficient to detect failure.
Administrative Feasibility	
Coordination with Other Agencies	Steps required to coordinate with regulatory agencies.
	Steps required to establish long-term or future coordination among agencies.
	Ease of obtaining permits for offsite activities, if required.
Availability of Services and Materials	
Availability of Treatment, Storage Capacity, and Disposal Services	Availability of adequate treatment, storage capacity, and disposal services.
	Additional capacity that is necessary.
	Whether lack of capacity prevents implementation.
	Additional provisions required to ensure that additional capacity is available.
Availability of Necessary Equipment and Specialists	Availability of adequate equipment and specialists.
	Additional equipment or specialists that are required.
	Whether there is a lack of equipment or specialists.
	Additional provisions required to ensure that equipment and specialists are available.
Availability of Prospective Technologies	Whether technologies under consideration are generally available and sufficiently demonstrated.
	Further field applications needed to demonstrate that the technologies could be used full scale to treat the waste at the site.
	When technology should be available for full-scale use.
	Whether more than one vendor will be available to provide a competitive bid.

TABLE 6-2
Comparative NCP Criteria Analysis Matrix
Operable Unit 1, Central Groundwater Plume
Feasibility Study
MCAS Cherry Point, North Carolina

NCP Evaluation Criteria	Zones 1 and 2 Alternative 1 No Action	Zones 1 and 2 Alternative 2 Monitored Natural Attenuation (MNA) and LUCs	Zone 1 Alternative 3 Near-Source In-Situ Enhanced Bioremediation	Zone 2 Alternative 3 Permeable Reactive Barrier, MNA, and LUCs	Zone 2 Alternative 4 ISEB, MNA, and LUCs	Zone 2 Alternative 5 Air Sparge Curtain, MNA, and LUCs
Overall Protection of Human Health and the Environment	Will not meet RAOs. Human health risks associated with potential receptors and the potential future use of groundwater as a potable water source.	This alternative will meet RAOs over time via natural attenuation mechanisms, which are effective, but slower than more-aggressive treatment options.	Will meet RAOs immediately downgradient of the Building 133 source area by injecting an organic substrate such as lactate, molasses, or vegetable oil to promote anaerobic biodegradation of chlorinated VOCs via reductive dechlorination pathway.	Downgradient RAOs at Slocum Creek will be met by ZVI the PRB adjacent to Slocum Creek. Protects the creek by treating CVOC as they pass through the PRB.	Downgradient RAOs at Slocum Creek will be met by the ISEB barrier adjacent to Slocum Creek. Protects the creek by treating CVOC as they pass through the biobarrier.	Downgradient RAOs at Slocum Creek will be met by the air sparge curtain, adjacent to Slocum Creek. Protects the creek by treating CVOC as they pass through the curtain.
Compliance with ARARs [a]	Does not comply with chemical-specific or location-specific ARARs.	Complies with ARARs. RI data showed no exceedances in surface water or sediment in the stream and RI concluded that the plumes have stabilized and attenuate (biodegrade, disperse, dilute, etc.) to below NC2B standards before discharging into the stream.	Complies with ARARs. ISEB barriers have been implemented at other DOD facilities in NC (e.g., MCB Camp Lejeune). Near source COC concentrations would meet NC2L standards via anaerobic biodegradation processes and MNA mechanisms.	Complies with ARARs. ZVI PRBs have been implemented at other DOD facilities in NC (e.g., MCB Camp Lejeune).	Complies with ARARs. ISEB barriers have been implemented at other DOD facilities in NC (e.g., MCB Camp Lejeune).	Complies with ARARs. Directional air sparge wells have been implemented at other DOD facilities in NC (e.g., MCB Camp Lejeune).
Long-term Effectiveness and Permanence	As this is not a treatment or institutional control, it will technically not reduce risk; therefore, it is not effective in the long-term. However, risk will be reduced over a longer period of time via natural attenuation, but there will be no mechanism to monitor COC concentrations and to assess remedial progress.	Expected to be an effective and permanent remedy for treatment of groundwater contaminated with CVOCs over a longer period of time. Permanent risk reduction is probable - contaminants must attenuate below the appropriate standards. O&M includes maintaining LUCs, periodic monitoring well repairs, and performance monitoring.	Expected to be an effective remedy for treatment of groundwater contaminated with chlorinated VOCs to below cleanup goals downgradient of the treatment area. O&M for near source zone includes maintenance of injection wells, as well as reinjection of electron donor every two years, for 10 years.	Expected to be an effective remedy for treatment of groundwater contaminated with chlorinated VOCs to below cleanup goals downgradient of the treatment area. Because source areas are not being addressed, a significant period of O&M is required. Common O&M for Zone 2 Alternative 3 options includes maintaining LUCs, periodic monitoring well repairs and performance monitoring. May require ZVI reinjection every 6 years for northern lobe.	Expected to be an effective remedy for treatment of groundwater contaminated with chlorinated VOCs to below cleanup goals downgradient of the treatment area. Because source areas are not being addressed, a significant period of O&M is required. O&M includes maintaining LUCs, periodic monitoring well repairs, and performance monitoring. Requires re-injection of ISEB substrate every 2 years	Expected to be an effective remedy for treatment of groundwater contaminated with chlorinated VOCs to below cleanup goals downgradient of the treatment area. Because source areas are not being addressed, a significant period of O&M is required. Common O&M for includes maintaining LUCs, periodic monitoring well repairs, and performance monitoring. Also includes compressor maintenance and electrical costs.
Reduction of Toxicity, Mobility or Volume Through Treatment	As this is not a treatment, it will technically not reduce toxicity, mobility, and volume. However, reductions will occur over a longer period of time via natural attenuation processes, but there will be no mechanism to monitor the progress of these reductions.	Reduces toxicity, mobility, and volume over a prolonged period of time by naturally degrading, dispersing, volatilizing, and diluting contaminants.	Reduces toxicity, mobility, or volume through promotion of anaerobic biodegradation, followed by other natural attenuation mechanisms. Will generate more drilling fluids and cuttings for characterization and disposal than Alternative 3.	Reduces toxicity, mobility, or volume through promotion of chemical reduction followed by other natural attenuation mechanisms. Will generate more drilling fluids and cuttings for characterization and disposal than Alternative 2.	Reduces toxicity, mobility, or volume through promotion of chemical reduction followed by other natural attenuation mechanisms. Will generate more drilling fluids and cuttings for characterization and disposal than Alternative 2.	Reduces toxicity, mobility, or volume through promotion of mass transfer to the vadose zone/atmosphere. Will generate more drilling fluids and cuttings for characterization and disposal than Alternative 2.
Short-term Effectiveness	No short-term impacts because nothing is implemented.	Requires standard engineering and safety controls during well installations and monitoring to protect the environment and site workers.	Requires engineering and safety controls during drilling and injection to protect the environment and site workers. Multiple injections and increased monitoring would be required during the duration of remediation.	Requires engineering and safety controls during drilling, injection and/or PRB construction to protect the environment and site workers. Multiple injections would be required. Increased monitoring would be required during the duration of remediation.	Requires engineering and safety controls during drilling and injection to protect the environment and site workers. Multiple injections would be required. Increased monitoring would be required during the duration of remediation.	Requires engineering and safety controls during drillingto protect the environment and site workers. Increased monitoring would be required during the duration of remediation.
Implementability	No construction or operation.	Services and materials are available and the technology is easily implementable. Additional monitoring well installations will be required, primarily in downgradient locations. Minor disruption to site operations during groundwater monitoring events and VI mitigation system installation. This alternative is administratively feasible.	Installation of numerous monitoring and injection wells in the near source zone is expected to be logistically challenging because of ongoing site operations, infrastructure, and utilities. Disruption of site activities may occur during well installation and injections. Minor disruption to site operations during groundwater monitoring events. ISEB substrate injection is readily implementable and has been used at several DoD sites in the area.	Disruption of site activities may occur during well installation and injections. Minor disruption to site operations during groundwater monitoring events. One pass trench technology can only be implemented by two vendors at this time, requires large machinery, and may be intrusive to site operations. However, the proposed location of the PRB is downgradient of areas with dense infrastructure. This alternative is administratively feasible, but will require more coordination with various parties throughout the remedy implementation.	Disruption of site activities may occur during well installation and injections. Minor disruption to site operations during groundwater monitoring events. ISEB substrate injection is readily implementable and has been used at several DoD sites in the area.	Disruption of site activities may occur during well installation. Minor disruption to site operations during groundwater monitoring events. Directional drilling (sparge curtain) is readily implemented, and has been used at several DoD sites in the area.
Cost [b] *2009 Present Value (-30% to +50%)*	$0	$6,245,000 *($4,372,000 - $9,368,000)* ●Evaluated over 100-year timeframe.	$6,456,000 ($4,519,000 - $9,684,000) ●Evaluated over 30-year timeframe. ●Assumes MNA and LUC costs will be covered by the selected alternative for Zone 2.	$10,462,000 *($7,323,000 - $15,693,000)* Option (second one-pass trench) - $7,190,000 *($5,033,000 - $10,785,000)* ●Evaluated over 30-year timeframe.	$5,405,000 *($3,784,000 - $8,107,000)* ●Evaluated over 30-year timeframe.	$6,816,000 ($4,771,000 - $10,225,000) ●Evaluated over 30-year timeframe.
State Acceptance	This alternative is not likely to be accepted by NCDENR.	This alternative alone is not likely to be accepted by NCDENR.	Despite the high cost, this alternative is likely to be accepted by NCDENR.	This alternative is likely to be accepted by NCDENR.	This alternative is likely to be accepted by NCDENR.	This alternative is likely to be accepted by NCDENR.
Community Acceptance	This alternative is not likely to be accepted by the community.	This alternative alone is not likely to be accepted by the community.	Despite the high cost, this alternative is likely to be accepted by the community.	This alternative is likely to be accepted by the community.	This alternative is likely to be accepted by the community.	This alternative is likely to be accepted by the community.

TABLE 6-3
Summary of Cost Analysis
Operational Unit 1 Central Groundwater Plume Feasibility Study
MCAS Cherry Point, North Carolina

Zone 1 Alternatives		Alternative 1 No Action	Alternative 2 MNA and LUCs[1]			Alternative 3 Near Source Enhanced Bioremediation		
Alternative Evaluation Timeframe[2]		0 years	100 years			30 years		
			-30%	**Estimate**	*+50%*	*-30%*	**Estimate**	*+50%*
Total Implementation Costs		**$0**	*$0*	$0	*$0*	*$1,077,000*	$1,539,120	*$2,309,000*
Present Value of Future Costs	Discount Rate of 2.7% (OMB, 2009)	**$0**	*$0*	$0	*$0*	*$3,442,000*	$4,916,669	*$7,375,000*
Grand Total Present Value	**Discount Rate of 2.7% (OMB, 2009)**	**$0**	***$0***	**$0**	***$0***	***$4,519,000***	**$6,456,000**	***$9,684,000***

Zone 2 Alternatives		Alternative 1 No Action	Alternative 2 MNA and LUCs			Alternative 3 Downgradient ZVI PRB (w/ Ferox Injections), MNA, and LUCs			Alternative 3 (Option) Downgradient ZVI PRB (Dual Continuous Trench), MNA, and LUCs			Alternative 4 Downgradient Bioamendment Injections, MNA, and LUCs			Alternative 5 Downgradient Air Sparge Curtain, MNA, and LUCs		
Alternative Evaluation Timeframe[2]		0 years	100 years			30 years			30 years			30 years			30 years		
			-30%	**Estimate**	*+50%*	*-30%*	**Estimate**	*+50%*	*-30%*	**Estimate**	*+50%*	*-30%*	**Estimate**	*+50%*	*-30%*	**Estimate**	*+50%*
Total Implementation Costs		**$0**	*$255,000*	$364,000	*$546,000*	*$2,417,000*	$3,452,788	*$5,179,000*	*$3,001,000*	$4,286,558	*$6,430,000*	*$1,154,000*	$1,647,878	*$2,472,000*	*$1,040,000*	$1,485,703	*$2,229,000*
Present Value of Future Costs	Discount Rate of 2.7% (OMB, 2009)	**$0**	*$4,117,000*	$5,881,000	*$8,822,000*	*$4,906,000*	$7,009,223	*$10,514,000*	*$2,393,000*	$3,418,341	*$5,128,000*	*$5,684,000*	$8,119,422	*$12,179,000*	*$3,731,000*	$5,330,630	*$7,996,000*
Grand Total Present Value	**Discount Rate of 2.7% (OMB, 2009)**	**$0**	***$4,372,000***	**$6,245,000**	***$9,368,000***	***$7,323,000***	**$10,462,000**	***$15,693,000***	***$5,394,000***	**$7,705,000**	***$11,558,000***	***$6,838,000***	**$9,767,000**	***$14,651,000***	***$4,771,000***	**$6,816,000**	***$10,225,000***

Notes and References:

[1] Assumes MNA and LUC costs will be covered under the implemented Zone 2 alternative

[2] The 100-year timeframe evaluated for Alternative 2-LUCs is for reference. The cost of LUCs are built into each of Alternatives 3, 4, and 5 for each alternative's respective timeframe (100 years, 40 years, and 60 years,

- The "Real" Discount Rate used to calculate the Present Value cost is 2.7% for a timeframe greater than 30 years per the Office of Management and Budget (OMB), Circular A-94, Appendix C, Revised December 2009, "Discount Rates for Cost Effectiveness, Lease Purchase, and Related Analysis" for Calendar Year 2010, http://www.whitehouse.gov/omb/circulars_a094_a94_appx-c/.

  The Real Discount Rates are a forecast of real interest rates from which the inflation premium has been removed and based on the economic assumptions from the December 2010 Budget Baseline. These real rates are to be used for discounting constant-dollar flows, as is often required in cost-effectiveness analysis.

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- The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternative. Changes in the cost elements are likely to occur as a result of new information and data collected during Baseline Sampling and the Remedial Design phase. This is an order-of-magnitude engineering cost estimate that is expected to be within –30 to +50 percent of the actual project cost (per USEPA, 1988 and 2000).

SECTION 7
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