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GROUNDWATER TREATABILITY STUDY WORK PLAN FOR OPERABLE UNIT 4 (OU 4) WITH TRANSMITTAL LETTER NTC ORLANDO FL

9/30/1997

ABB ENVIRONMENTAL

ABB

02545-009

September 30, 1997

Commanding Officer
Southern Division, Naval Facilities Engineering Command
ATTN: Ms. Barbara Nwokike, Code 187300
P.O. Box 190010
2155 Eagle Drive
North Charleston, SC 29419-9010

SUBJECT: Operable Unit 4, Groundwater Treatability Studies WorkPlan No. 1
Natural Attenuation Assessment
Naval Training Center, Orlando, Florida
Contract No. N62467-D-0317/135

Dear Barbara:

Enclosed please find copies of the Final Treatability Study Workplan No.1, Data Collection Plan for Assessing Natural Attentuation. This Workplan presents the technical approach for evaluating natural attenuation as a potential follow-up remedial alternative for groundwater at OU 4 and includes comment responses on the draft report that were received from the Navy, FDEP, and EPA.

Installation of additional monitoring wells at OU 4 by SBP will occur for performance monitoring of the recirculation wells for the Interim Remedial Action. These monitoring wells will be sampled as part of the natural attenuation assessment to further characterize the extent and water quality of the contaminant plume. The work presented in this plan will be executed following the installation of these monitoring wells.

If you have questions or comments on this document, please contact me at (781) 245-6606, extension 1052.

Very truly yours,
ABB ENVIRONMENTAL SERVICES, INC.

John Kaiser FOR
Mark J. Salvetti, P.E.
Task Order Manager

Enclosures

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TREATABILITY STUDY WORKPLAN NO. 1 DATA COLLECTION PLAN FOR ASSESSING NATURAL ATTENUATION

OPERABLE UNIT 4

NAVAL TRAINING CENTER ORLANDO, FLORIDA

UNIT IDENTIFICATION CODE: N65928
CONTRACT NO. N62467-89-D-0317/135

SEPTEMBER 1997

SOUTHERN DIVISION
NAVAL FACILITIES ENGINEERING COMMAND
NORTH CHARLESTON, SOUTH CAROLINA
29419-9010

TREATABILITY STUDY WORKPLAN NO. 1

DATA COLLECTION PLAN FOR ASSESSING NATURAL ATTENUATION

OPERABLE UNIT 4

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

Unit Identification Code: N65928

Contract No.: N62467-89-D-0317/135

Prepared by:

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Barbara Nwokike, Code 1873, Engineer-in-Charge

September 1997

CERTIFICATION OF TECHNICAL
DATA CONFORMITY (MAY 1987)

The Contractor, ABB Environmental Services, Inc., hereby certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0317/135 are complete and accurate and comply with all requirements of this contract.

DATE: September 26, 1997

NAME AND TITLE OF CERTIFYING OFFICIAL: John Kaiser
Installation Manager

NAME AND TITLE OF CERTIFYING OFFICIAL: Mark Salvetti
Project Technical Lead

(DFAR 252.227-7036)

This Workplan was prepared to present the technical approach for evaluating natural attenuation as a potential follow-up remedial alternative for groundwater at Operable Unit 4 at the Naval Training Center (NTC) in Orlando, Florida. The engineering evaluation and professional opinions rendered in this report were conducted or developed in accordance with commonly accepted procedures consistent with applicable standards of practice.

Willard A. Murray, P.E. 9/26/97

Senior Consulting Engineer
Professional Engineer No. PE0039866
Expires February 28, 1999

FOREWORD

To meet its mission objectives, the U.S. Navy performs a variety of operations, some requiring the use, handling, storage, or disposal of hazardous materials. Through accidental spills and leaks and conventional methods of past disposal, hazardous materials may have entered the environment in ways unacceptable by today's standards. With growing knowledge of the long-term effects of hazardous materials on the environment, the Department of Defense (DOD) initiated various programs to investigate and remediate conditions related to suspected past releases of hazardous materials at their facilities. Two of these programs are the Installation Restoration (IR) program and the Base Realignment and Closure (BRAC) program.

The IR program complies with the Base Closure and Realignment Act of 1988 (Public Law 100-526,102 Statute 2623) and the Defense Base Closure and Realignment Act of 1990 (Public Law 101-510, 104 Statute [1808]), which require the DOD to observe pertinent environmental legal provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), Executive Order 12580, and the statutory provisions of the Defense Environmental Restoration Program (DERP), the National Environmental Policy Act (NEPA), and any other applicable statutes that protect natural and cultural resources.

Originally, the Navy's part of this program was called the Naval Assessment and Control of Installation Pollutants (NACIP) program. Early reports reflect the NACIP process and terminology. The Navy eventually adopted the program structure and terminology of the standard IR program.

The IR program is conducted in several stages as follows:

- Preliminary Assessment (PA),
- A site Inspection (SI) (formerly the PA and SI steps were called the Initial Assessment Study [IAS] under the NACIP program),
- Remedial Investigation and Feasibility Study (RI/FS), and
- Remedial Design and Remedial Action (RD/RA).

The goal of the BRAC program is to expedite and improve environmental response actions to facilitate the disposal and reuse of a BRAC installation while protecting human health and the environment.

The Southern Division, Naval Facilities Engineering Command (SOUTHNAVFACENGCOM), the U.S. Environmental Protection Agency, and the Florida Department of Environmental Protection collectively coordinate the cleanup activities through the BRAC cleanup team, called the Orlando Partnering Team in Orlando. This team approach is intended to foster partnering, accelerate the environmental cleanup process, and expedite timely, cost-effective, and environmentally responsible disposal and reuse decisions.

Questions regarding the BRAC program at Naval Training Center, Orlando should be addressed to the SOUTHNAVFACENGCOM BRAC Environmental Coordinator, Mr. Wayne Hansel, Code 18B7, at (407) 646-5294 or SOUTHNAVFACENGCOM Engineer-in-Charge, Ms. Barbara Nwokike, Code 1873, at (803) 820-5566.

EXECUTIVE SUMMARY

Operable Unit (OU) 4 at the Naval Training Center (NTC), Orlando in Orlando, Florida, is composed of Study Areas (SAs) 12, 13, and 14 at Area C. Building 1100, a laundry and dry-cleaning facility located at Area C, was identified as a site where releases of hazardous materials had occurred, including reports of discharged water contaminated with chlorinated solvents.

A plume of chlorinated solvent-contaminated groundwater migrating from the former base laundry and into the adjacent Lake Druid was identified during site investigations conducted at OU 4. Volatile organic compounds (VOCs) detected in groundwater and surface water from Lake Druid included tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE), trans-1,2-DCE, 1,1-DCE, and vinyl chloride (VC). Source areas appear to be multiple and are likely located adjacent to and beneath the former laundry, Building 1100.

At OU 4, an initial technology screening evaluation was conducted to evaluate remedial options for contaminated groundwater and source area treatment. Remedial technologies were identified for treatability testing for possible future implementation at OU 4, including phytoremediation, air sparging, *in situ* chemical oxidation, and natural attenuation. The treatability study is being conducted in support of the OU 4 feasibility study (FS). This workplan was prepared as part of the treatability study to present the technical approach for evaluating natural attenuation. This document is the first in what is expected to be a series of treatability study documents for potential remedial technologies at OU 4.

Natural attenuation was selected based on the type of contaminants present in the groundwater (PCE and its daughter products) and their ability to biodegrade. Degradation products of PCE, including TCE and cis-1,2-DCE, have been detected at significant concentrations indicating that natural unaided biodegradation is already occurring *in situ*. However, at NTC Orlando OU 4, the concentrations of chlorinated solvents in Lake Druid are an indication that under current conditions, natural attenuation is not effective to reduce concentrations of VOCs to applicable standards before reaching the lake. If concentrations of VOCs in the source area (upgradient of the Lake) can be reduced with an alternative treatment technology, natural attenuation could be a viable followup treatment alternative for groundwater in the future.

The purpose of this plan is to present the technical approach that will be used to assess natural attenuation as a potential followup remedial alternative at OU 4. The approach includes collection of additional site data to determine chemical-specific decay rates and to evaluate the distribution of electron donors and acceptors in the contaminant plume. The distribution of electron donors and acceptors will be used to provide evidence of where and how chlorinated solvent degradation is occurring.

Solute fate and transport modeling will be used once the site-specific biological decay rates are calculated, in conjunction with site-specific water quality parameters, to predict the future extent of the contaminant plume. Because chlorinated solvents have been detected in Lake Druid, one of the goals of modeling will be to determine what source concentration VOCs must be reduced to for natural attenuation to be an effective followup remedial alternative. This concentration will be used as the minimum treatment goal for source remediation.

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Naval Training Center
Orlando, Florida

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GLOSSARY

ABB-ES	ABB Environmental Services, Inc.
AFCEE	Air Force Center for Environmental Excellence
bls	below land surface
BRAC	Base Realignment and Closure (Act)
DCE	dichloroethene
FS	feasibility study
GC	gas chromatograph
IRA	Interim Remedial Action
mg/ℓ	milligrams per liter
mV	millivolt
NTC	Naval Training Center
ORP	oxidation-reduction potential
OU	Operable Unit
PCE	tetrachloroethene
RI	remedial investigation
SA	study area
TCE	trichloroethene
TOC	total organic carbon
USEPA	U.S. Environmental Protection Agency
VC	vinyl chloride
VOC	volatile organic compound

1.0 INTRODUCTION

Remedial technologies that may be effective in treating contaminated groundwater at Operable Unit (OU) 4 have been screened for evaluation prior to the OU 4 feasibility study (FS). Technologies that require additional information regarding performance, implementability, and full-scale cost to adequately perform a feasibility evaluation have been recommended for treatability testing. Ordinarily, screening of remedial technologies and treatability studies would be executed during the FS process following the remedial investigation (RI). However, the site screening and interim remedial action (IRA) activities conducted at OU 4 have provided sufficient site characterization data to allow the technology screening and treatability studies to run concurrent with the RI.

Remedial technologies were identified for treatability testing for possible future implementation at OU 4, including phytoremediation, air sparging, *in situ* chemical oxidation, and natural attenuation. This workplan was prepared as part of the treatability study to present the technical approach for evaluating natural attenuation. This document is the first in what is expected to be a series of treatability study documents for potential remedial technologies at OU 4.

1.1 SITE DESCRIPTION. OU 4 is composed of Study Areas (SAs) 12, 13, and 14 at Area C (Figures 1-1 and 1-2). Building 1100, located in Area C, was constructed in 1943 and was used as a laundry and dry-cleaning facility, serving the entire military base. Prior to construction of the facility in 1943, the land was undeveloped. The laundry was closed in 1994. Building 1100 at Area C (the laundry) was identified as a site where releases of hazardous materials had occurred, including reports of discharged water contaminated with chlorinated solvents.

Several investigations have already occurred at OU 4, either under the Base Realignment and Closure Act (BRAC) site screening program or under subsequent efforts to characterize the contamination discovered during site screening.

These efforts have identified a plume of chlorinated solvent contaminated-groundwater migrating from the former base laundry and into the adjacent Lake Druid. Volatile organic compounds (VOCs) detected in groundwater and surface water from Lake Druid included tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2-dichloroethene (DCE), trans-1,2-DCE, 1,1-DCE, and vinyl chloride (VC). Source areas appear to be multiple and are likely located adjacent to and beneath the former laundry, Building 1100. Results from the investigations conducted at OU 4 are summarized in the OU 4 RI Workplan (ABB Environmental Services, Inc. [ABB-ES, 1997a]). An IRA, consisting of two recirculation wells, is being implemented to intercept the majority of the contaminated groundwater before reaching Lake Druid.

Based on the OU 4 focused field investigation (ABB-ES, 1997b) and the source investigation (ABB-ES, 1997c), the chlorinated solvent groundwater plume ranges from approximately 4 to 45 feet below land surface (bls) with total VOCs up to 30 milligrams per liter (mg/ℓ) in the source area (laundry), and approximately 6 mg/ℓ between the laundry and Lake Druid. The water table between Lake Druid and the laundry varies seasonally from less than 1 foot to 4 feet bls. Cross

FIGURE 1-1
SITE LOCATION MAP

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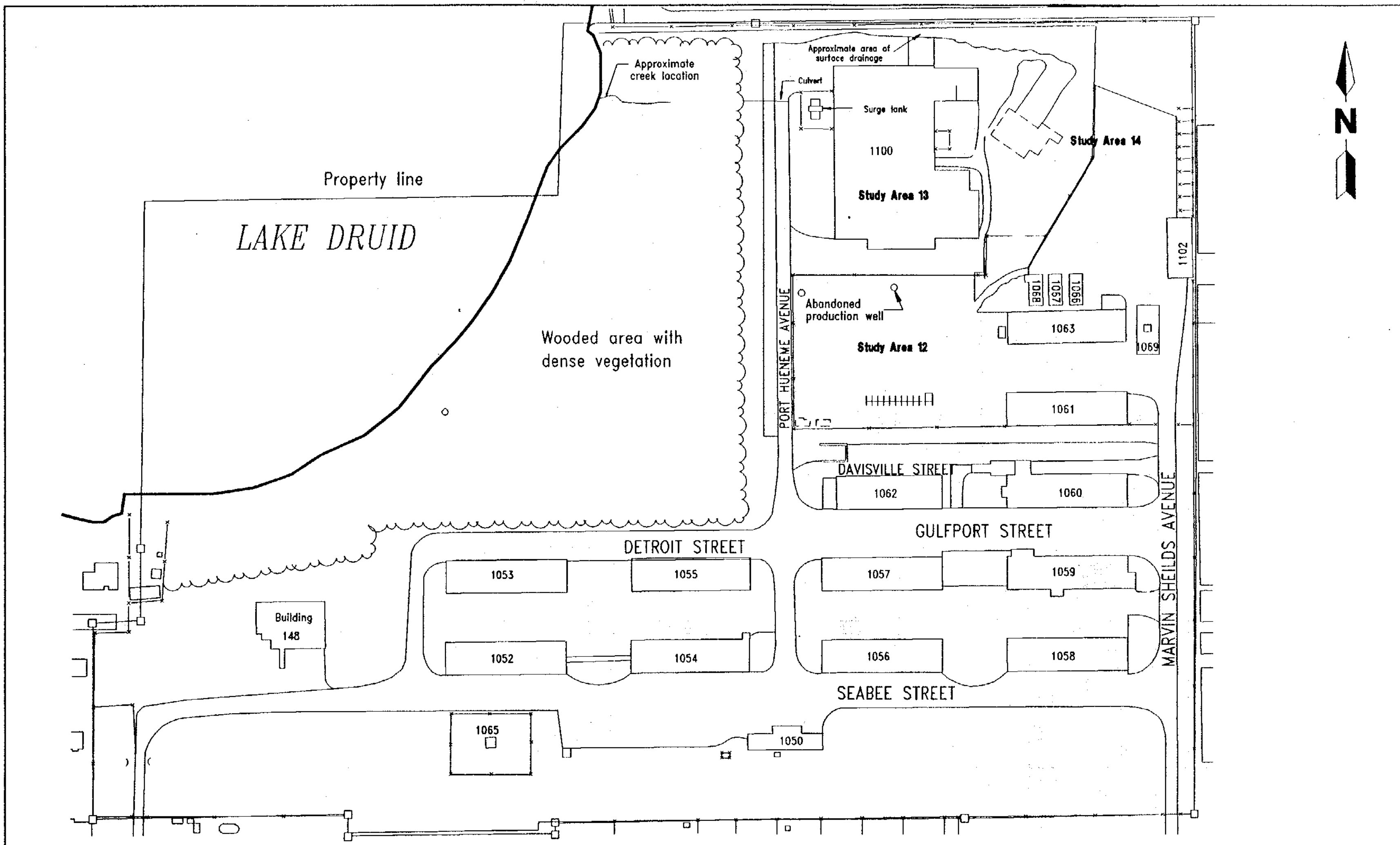

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FIGURE 1-2
MAP OF AREA C

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sections showing the distribution and concentration of VOCs in groundwater at OU 4 have been prepared. Figure 1-3 shows the location of the cross-section lines, and Figures 1-4 and 1-5 show the distribution and concentration of VOCs in groundwater running north-south along the shoreline of Lake Druid and running east-west between Lake Druid and the laundry, respectively. The cross sections are based on samples collected during the focused field investigation with direct-push technology and onsite laboratory gas chromatograph (GC) data.

1.2 EVALUATION OF NATURAL ATTENUATION AS A REMEDIAL ALTERNATIVE. Natural attenuation is being evaluated under the OU 4 FS as a remedial option for groundwater contamination. This assessment is being conducted in accordance with the U.S. Environmental Protection Agency (USEPA) Region IV (USEPA, 1997) and Air Force Center for Environmental Excellence (AFCEE) Natural Attenuation Guidance Documents (AFCEE, 1996).

The USEPA Office of Solid Waste and Emergency Response defines natural attenuation as the following:

> "Naturally-occurring processes in soil and groundwater environments that act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in those media." (USEPA, 1997)

Natural attenuation works through nondestructive mechanisms such as dispersion, adsorption, dilution, volatilization, and/or chemical and biological stabilization of contaminants and destructive mechanisms such as biodegradation. Natural attenuation is recognized as a legitimate and responsible solution for contaminated aquifers and has been shown to be a viable and cost-effective remedial approach.

Natural attenuation was selected based on the type of contaminants present in the groundwater (PCE and its daughter products) and their ability to biodegrade. Degradation products of PCE, including TCE and cis-1,2-DCE, have been detected at significant concentrations indicating that natural unaided biodegradation is already occurring *in situ*. However, at the Naval Training Center (NTC), Orlando OU 4, the concentrations of chlorinated solvents entering Lake Druid are an indication that under current conditions, natural attenuation is not effective enough to be protective of human health and the environment. The remedial action goal for OU 4 is "reducing high VOC concentrations within the surficial aquifer enough to allow natural processes to take over as the remedial alternative for the aquifer and Lake Druid" (ABB-ES, 1997b). If concentrations of VOCs in the source area (upgradient of the lake) can be reduced with an alternative treatment technology, natural attenuation could be a viable followup treatment alternative for groundwater in the future.

The purpose of this plan is to

- present the technical approach that will be used to assess natural attenuation as a viable followup remedial alternative for groundwater at OU 4, and

- identify any data gaps required to assess natural attenuation of groundwater and present a sampling and analysis plan to collect the data.

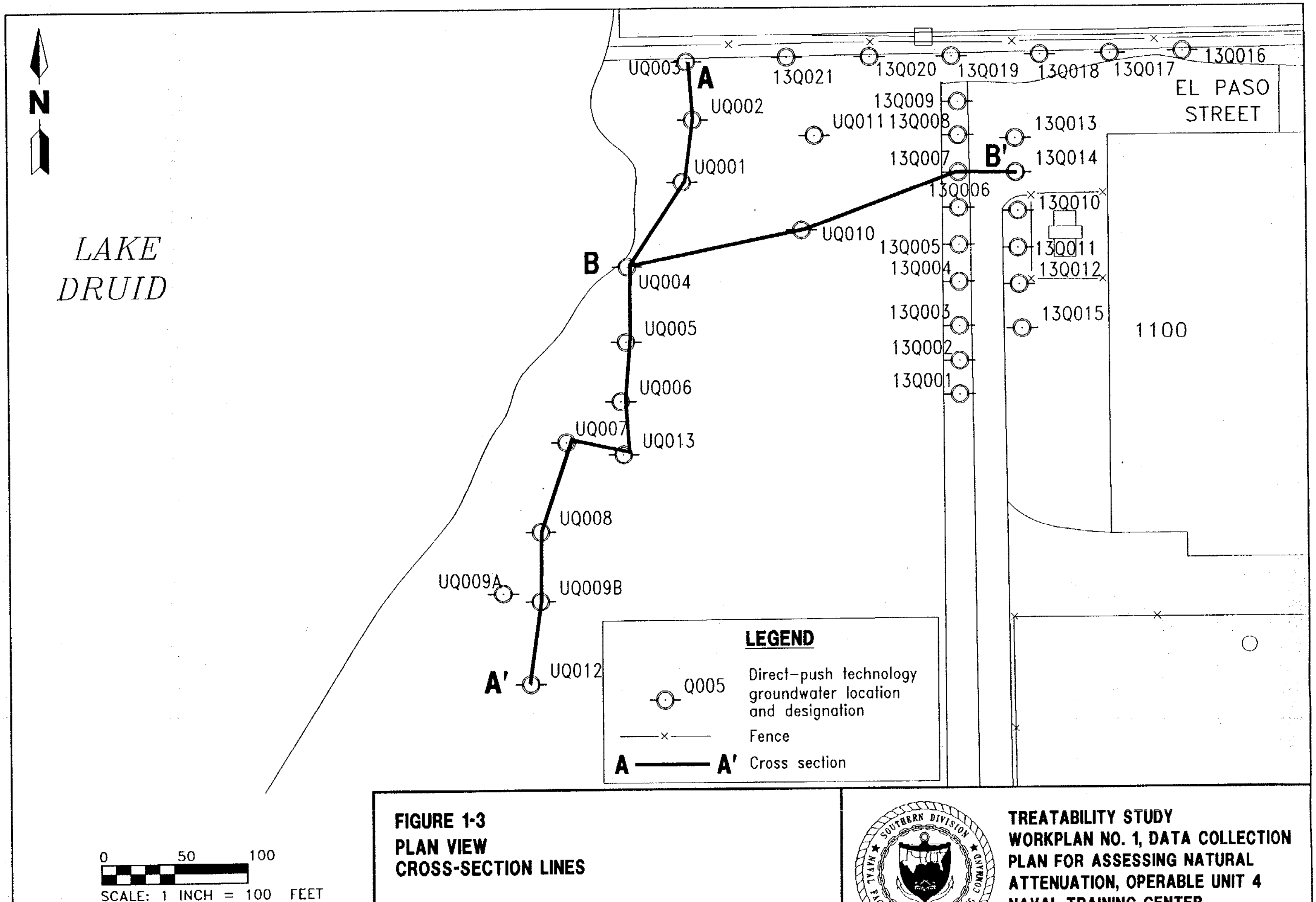

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FIGURE 1-3
PLAN VIEW
CROSS-SECTION LINES

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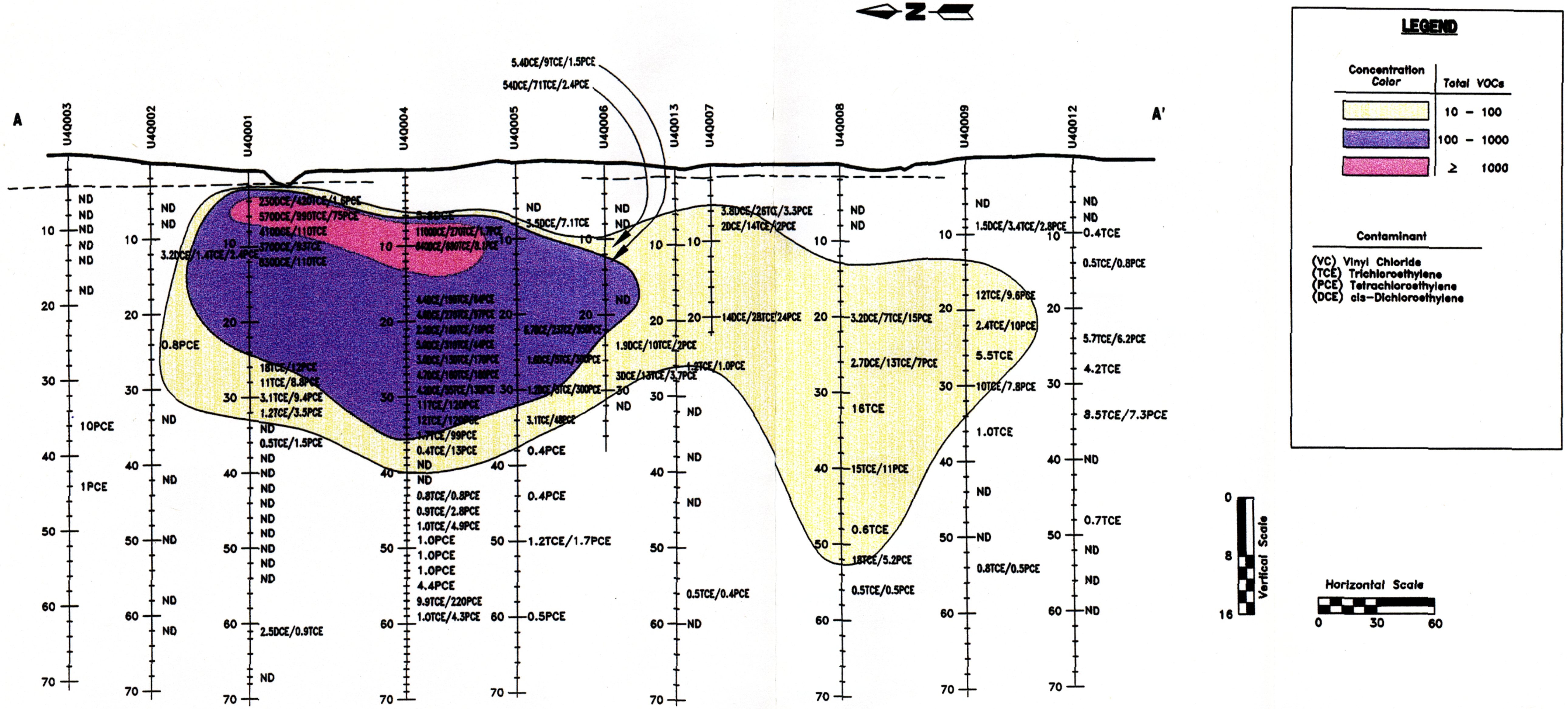

NOTES:
All concentrations in parts per billion (ppb).
VOC=volatile organic compound
ND =not detected

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FIGURE 1-4
NORTH-SOUTH CROSS SECTION A-A' SHOWING GROUNDWATER VOC CONCENTRATIONS

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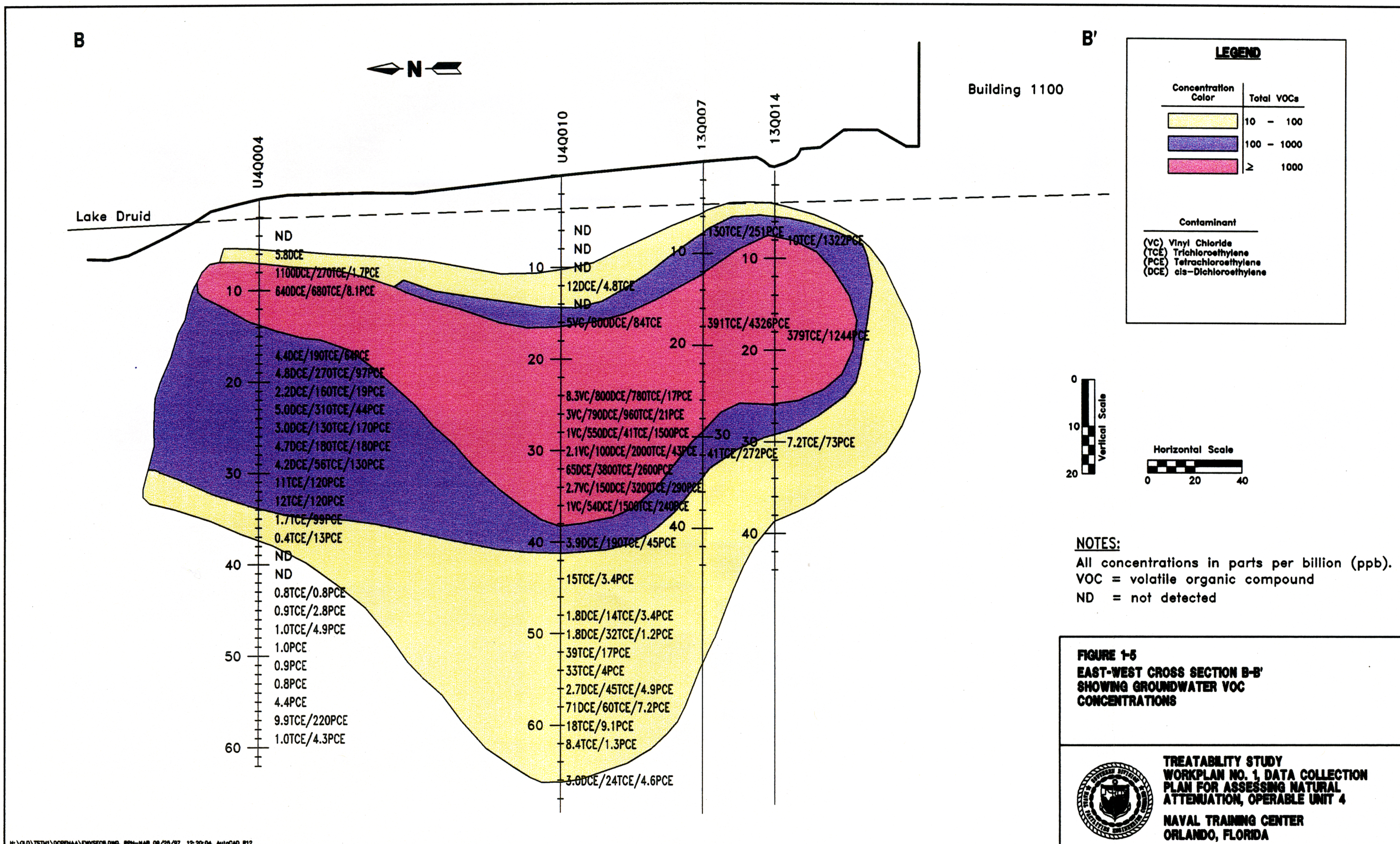

FIGURE 1-5
EAST-WEST CROSS SECTION B-B' SHOWING GROUNDWATER VOC CONCENTRATIONS

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2.0 TECHNICAL APPROACH FOR ASSESSING BIODEGRADATION

To support natural attenuation, it must be demonstrated that attenuation of site contaminants will occur at the rates sufficient to be protective of human health and the environment. This is accomplished by comparing the rate of transport to the rate of attenuation. In other words, to be effective, the rate of attenuation must exceed the rate of transport. To demonstrate this, AFCEE protocol states that the following data can be used:

(1) Observed reductions in contaminant concentrations along the groundwater flowpath downgradient from the source contamination

(2) Documented loss of contaminant mass with field data using chemical data, including
- decreasing parent compound concentrations
- increasing daughter compound concentrations
- depletion of electron acceptors and donors
- increasing metabolic byproduct concentrations

(3) Estimation of future extent of the contaminant plume using models generated with site-specific biological decay rates and groundwater velocity

For OU 4, the observed rates of transport and attenuation will be used to determine the maximum source VOC concentrations allowable for natural attenuation to be an effective followup remedial alternative. These concentrations will be used as the minimum remedial goals for source remediation.

A discussion of the biodegradation calculations, sampling and analysis plans, and analytical models that will be used to address these data needs is presented in Chapters 2.0, 3.0 and 4.0 respectively.

2.1 QUANTIFYING BIODEGRADATION RATES.

Natural attenuation works through non-destructive mechanisms such as dispersion and dilution of contaminants and through destructive mechanisms such as biodegradation. The primary focus of this document is to quantify biodegradation because it is the most important naturally occurring destructive attenuation mechanism.

Site-specific biological decay rates are essential input parameters for solute fate and transport modeling and will be used to simulate natural attenuation of chlorinated solvents. The protocol for quantifying chemical-specific decay rates at OU 4 is based on the USEPA Region IV and AFCEE protocol. According to these guidance documents, measured contaminant concentrations along a particle flowpath can be used to estimate site-specific biological decay rates.

First-order biological decay rates will be estimated for 1,1-DCE, PCE, TCE, cis- and trans-1,2-DCE, and VC, following procedures described in the USEPA Region IV and AFCEE guidance documents. First-order biological decay rates will be calculated according to the following equation:

$$C_t = C_o e^{-kt},\ t = X/V_c,\ and\ t_{1/2} = 0.693/k \qquad (1)$$

where

C_t = concentration in the downgradient monitoring wells (point B),
C_0 = concentration in source area monitoring well (point A),
k = first-order reaction rate (day^{-1}),
t = time of contaminant travel between points A and B,
e = base of natural log,
v_c = retarded contaminant velocity,
x = distance between points A and B, and
$t_{1/2}$ = half-life of the contaminant.

The use of a first-order rate constant may not be appropriate if it is determined that more than one substrate is limiting microbial degradation rates. During data evaluation, if it is determined that the site data does not appear to follow first-order kinetics (nonlinear) a second- or higher-order approximation may be used to estimate biodegradation rates.

Prior to performing the calculation above, measured contaminant concentrations should be normalized for the effects of dispersion, dilution, and sorption, in order to accurately calculate decay rates. This can be accomplished using site-specific data for chloride as a tracer. A detailed description of this procedure can be found in Appendix C of the AFCEE guidance (AFCEE, 1996). Chloride is produced as a result of biodegradation of chlorinated ethenes. Generation of chloride in the aquifer will occur at unknown rates at both the contaminant source as well as downgradient. As a result, chloride is not considered a conservative tracer, and some interpretation will be required to calibrate the model using this approach for normalizing the data.

2.2 BIODEGRADATION MECHANISMS. Biodegradation of organic contaminants occurs through a transfer of electrons from donors to acceptors during bacterial metabolism. Chlorinated solvent plumes attenuate differently depending on the electron donor and electron acceptor mechanism(s) taking place. One of the goals of data collection is to characterize the type and concentration of electron acceptors and donors present in the aquifer.

Hydrogen is the most thermodynamically favored electron donor. The presence of hydrogen in the aquifer can be measured to predict the potential extent of biodegradation. Chlorinated aliphatics can also be utilized by microorganisms as electron donors to derive energy and organic carbon. This process generally occurs under aerobic conditions. However, only the least oxidized chlorinated aliphatic hydrocarbons (cis-1,2-DCE, VC, and to a lesser extent TCE) can be used as electron donors during biodegradation.

Several naturally occurring constituents present in aquifers are utilized as electron acceptors during bacterial metabolism. Oxygen is the most thermodynamically favored electron acceptor for microbial metabolism, so it will be consumed first in the aquifer. As oxygen supply becomes depleted, microorganisms typically use electron acceptors (as available) in the following order of preference: nitrate, iron, sulfate, and finally carbon dioxide. As each electron acceptor class is utilized, the oxidation-reduction potential (ORP) of the aquifer decreases making conditions more favorable for anaerobic reductive dechlorination of chlorinated solvents. (Anaerobic dechlorination occurs in the ORP range of -50 to -240 millivolts [mV]). During anaerobic reductive dechlorination, chlorinated hydrocarbons are used as electron acceptors whereby the chloride atom is removed and replaced with a hydrogen atom. Reductive dechlorination generally occurs by sequential dechlorination of PCE to TCE to cis-1,2-DCE to VC to ethene. The metabolic byproducts generated during this process include methane and chloride.

Contour maps for electron donors (hydrogen) and electron acceptors consumed (oxygen, nitrate, iron, and sulfate) and metabolic byproducts produced (chloride and methane) will be prepared from site data to evaluate the biodegradation mechanisms and predict the future extent of biodegradation. The distribution of VOCs and daughter products will also be used to evaluate natural attenuation of the contaminant plume.

3.0 DATA COLLECTION

Data will be collected to obtain a thorough understanding of the biological processes taking place in order to predict contaminant biodegradation rates, the extent of biodegradation, and future behavior of the plume.

3.1 SELECTION OF MONITORING LOCATIONS. Based on the OU 4 site screening data (ABB-ES, 1996), the chlorinated solvent groundwater plume ranges from approximately 4 to 45 feet bls with total VOCs up to 30 mg/ℓ in the source area (laundry) and approximately 6 mg/ℓ between the laundry and Lake Druid. Several monitoring locations installed during previous investigations (monitoring wells, observation wells, and drive point locations) within the contaminant plume at OU 4 were selected for sampling to assess natural attenuation. A minimum of two sampling points is required to quantify biodegradation rates. However, based on the type and distribution of PCE daughter products in the contaminant plume at OU 4, the rate and extent of PCE decay appears to be greatly varied. For this reason, several locations at OU 4 were selected for sampling to more accurately assess VOC decay rates.

Existing monitoring locations were chosen along a common groundwater flowpath with screens set within three different depth intervals in the contaminant plume: shallow interval from approximately 3 to 12 feet bls, mid-depth interval from approximately 14 to 20 feet bls, and the deepest interval from 25 to 35 feet bls. For the purpose of this assessment, monitoring locations screened within these depth intervals will be referred to as shallow, mid-depth, and deep interval locations. The locations chosen for sampling at these three intervals are shown in plan view in Figures 3-1, 3-2, and 3-3. A mid-depth sampling location (OLD-13-05A, Figure 3-2) outside the contaminant plume was also selected for sampling to establish background water quality conditions.

Installation of additional monitoring wells at OU 4 will be conducted as part of the IRA for performance monitoring of the recirculation wells. These wells will be sampled as part of the natural attenuation assessment to further characterize the horizontal and vertical extent and water quality of the contaminant plume. Three additional downgradient monitoring wells will be installed with screens intercepting the mid and lower depths of the contaminant plume. The locations for these three monitoring wells are shown on Figures 3-2 and 3-3.

One new monitoring well (microwell) was installed in June 1997 for the natural attenuation assessment. The microwell was installed with a TerraProbe℠ at location OLD-13-26A shown on Figure 3-1. The well was positioned in the vicinity of the contaminant source area (laundry) and screened in the shallow interval at 6 to 12 feet bls.

Table 3-1 presents a summary of the selected monitoring points for sampling, showing their respective screen lengths and rationale for selection. An east-west cross section of the contaminant plume showing the sampling location screened intervals and distribution of total VOCs is shown on Figure 3-4.

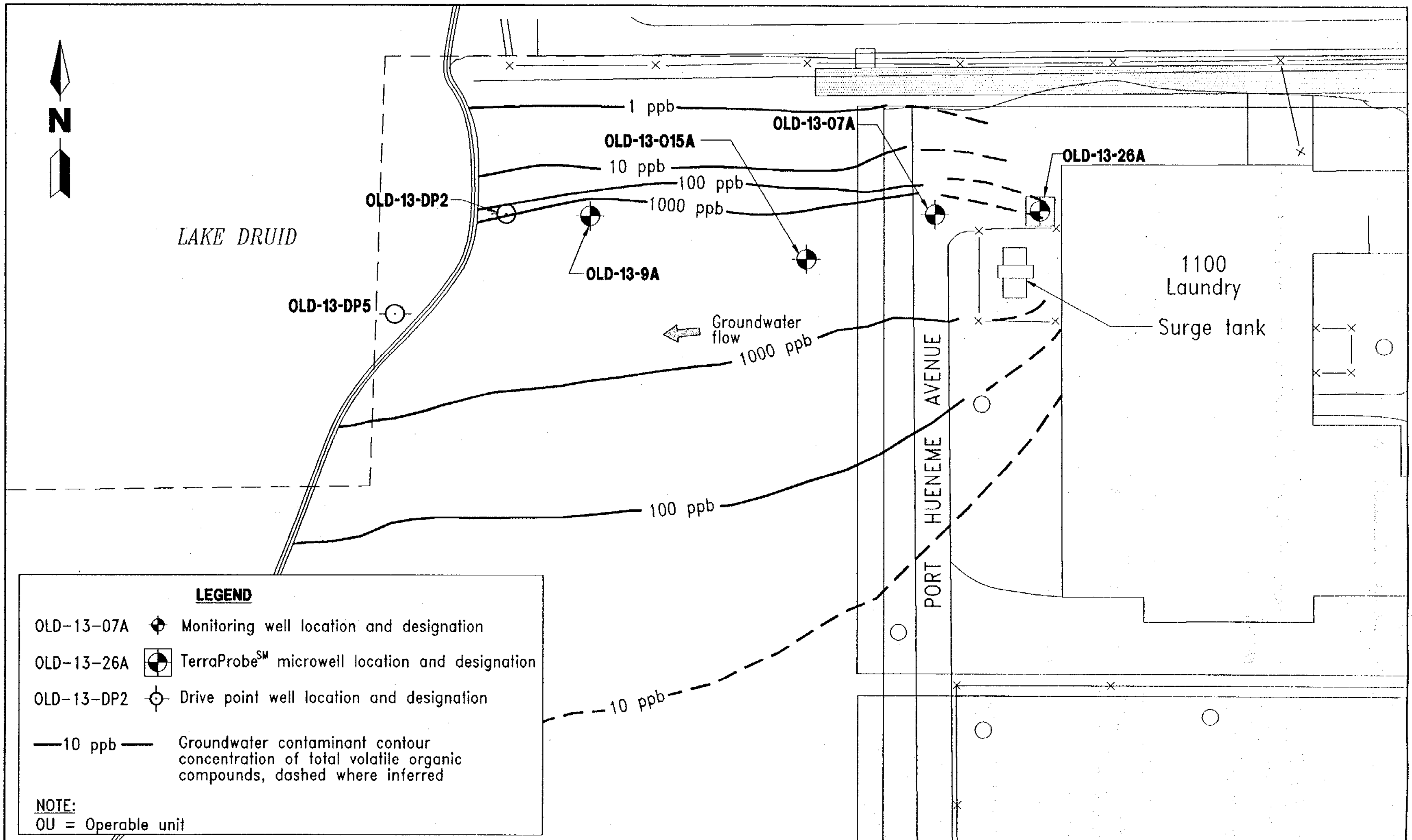

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FIGURE 3-1
SHALLOW INTERVAL WELL SAMPLING LOCATIONS

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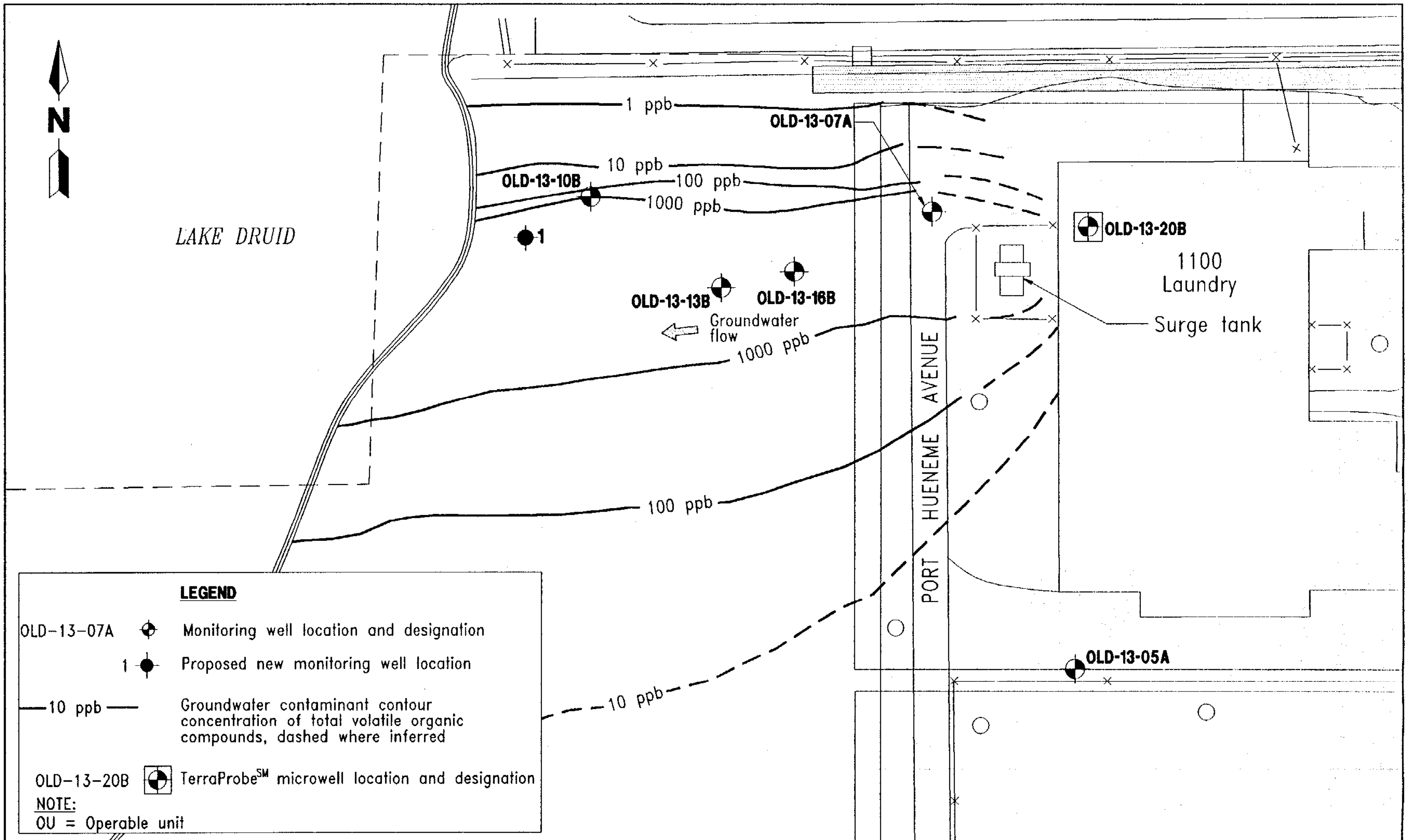

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FIGURE 3-2
MID-DEPTH INTERVAL WELL SAMPLING LOCATIONS

TREATABILTY STUDY
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ORLANDO, FLORIDA

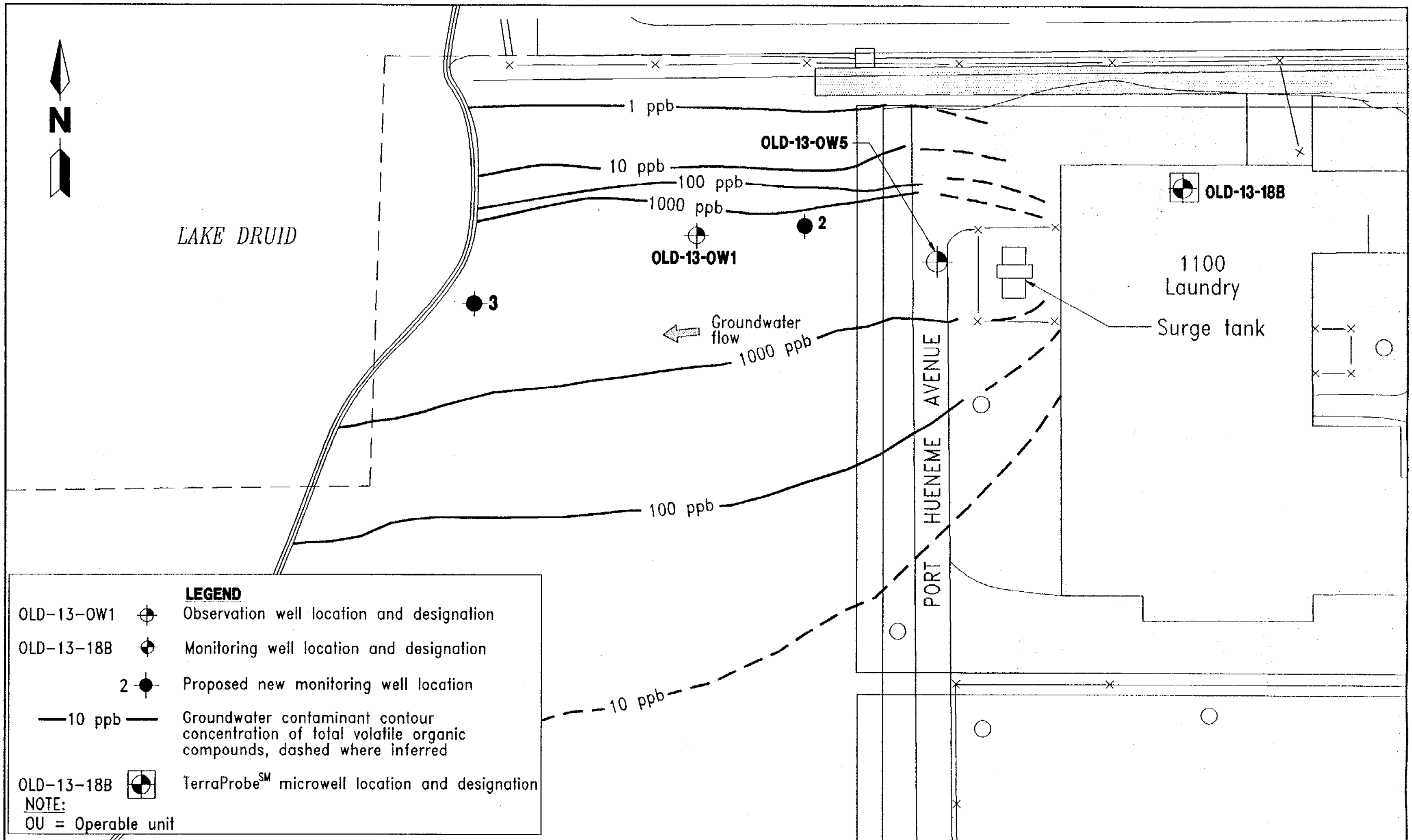

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FIGURE 3-3
DEEP INTERVAL WELL SAMPLING LOCATIONS

SOUTHERN DIVISION NAVAL FACILITIES ENGINEERING COMMAND

TREATABILTY STUDY WORKPLAN NO. 1, DATA COLLECTION PLAN FOR ASSESSING NATURAL ATTENUATION, OPERABLE UNIT 4 NAVAL TRAINING CENTER ORLANDO, FLORIDA

Table 3-1
Sampling Locations for Assessing Natural Attenuation at OU 4

Treatability Study Workplan No. 1
Data Collection Plan for Assessing Natural Attenuation
Operable Unit 4
Naval Training Center
Orlando, Florida

Location	Screen Depth (feet bls)	Pump Intake Position (feet bls)	Rationale for Selection
Shallow Interval Wells			
OLD-13-26A TerraProbe℠ Microwell	6 to 12	7	Location near the contaminant source area.
OLD-13-07A Monitoring Well	3 to 18	7	Downgradient location along the groundwater flow line.
OLD-13-15A Monitoring Well	2.5 to 12.5	7	Downgradient location along the groundwater flow line.
OLD-13-09A Monitoring Well	1 to 11	7	Downgradient location along the groundwater flow line.
OLD-13-DP2 Drive Point Location	5 to 6	6	Downgradient location along the groundwater flow line; located close to Lake Druid.
OLD-13-DP5 Drive Point Location	2 to 3	3	Downgradient location along the groundwater flow line; located at Lake Druid.
Mid-Depth Interval Wells			
OLD-13-20B TerraProbe℠ Microwell	14 to 20	20	Location near the contaminant source area.
OLD-13-07A Monitoring Well	3 to 18	18	Downgradient location along the groundwater flow line.
OLD-13-16B Monitoring Well	18 to 23	20	Downgradient location along the groundwater flow line.
OLD-13-13B Monitoring Well	16 to 21	20	Downgradient location along the groundwater flow line.
OLD-13-10B Monitoring Well	16 to 21	20	Downgradient location along the groundwater flow line.
Westerly Downgradient Monitoring Well Location 1 (to be installed for the IRA)	16 to 21	20	Downgradient location along the groundwater flow line; close vicinity to Lake Druid.
Deep Interval Wells			
OLD-13-18B TerraProbe℠ Microwell	25 to 31	30	Location near the contaminant source area.
OLD-13-OW5 Observation Well	30 to 35	30	Downgradient location along the groundwater flow line.
Westerly Downgradient Monitoring Well Location 2 (to be installed for the IRA)	28 to 33	30	Downgradient location along the groundwater flow line.

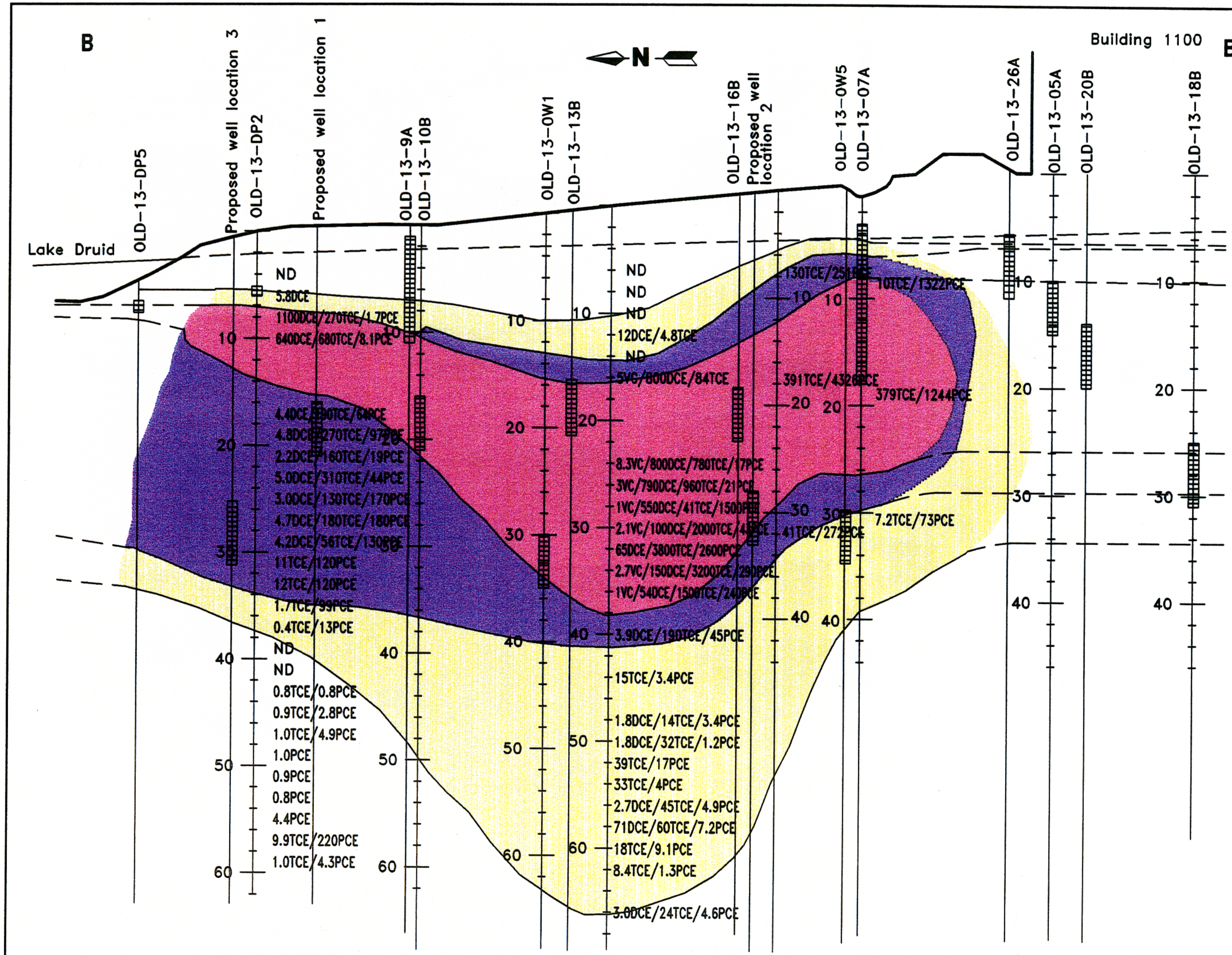
See notes at end of table.

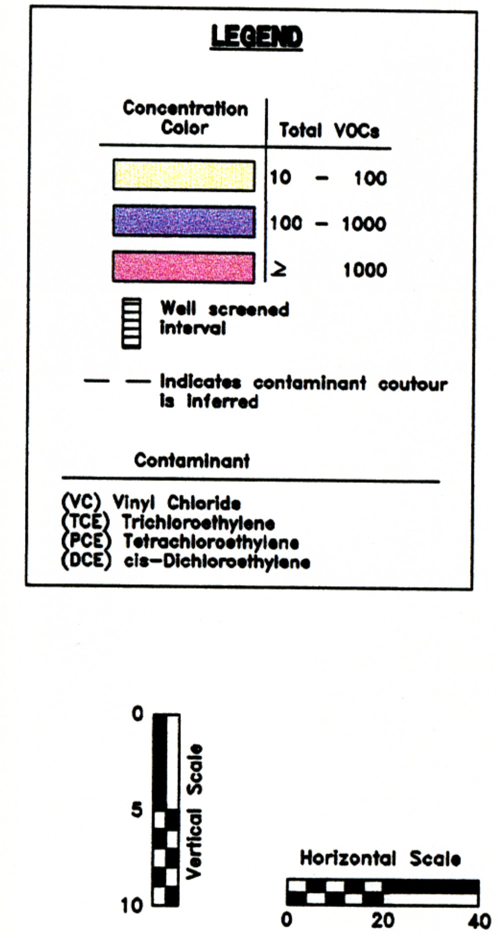
Table 3-1 (Continued)
Sampling Locations for Assessing Natural Attenuation at OU 4

Treatability Study Workplan No. 1
Data Collection Plan for Assessing Natural Attenuation
Operable Unit 4
Naval Training Center
Orlando, Florida

Location	Screen Depth (feet bls)	Pump Intake Position (feet bls)	Rationale for Selection
Deep Interval Wells (Continued)			
OLD-13-OW1 Observation Well	30 to 35	30	Downgradient location along the groundwater flow line.
Westerly Downgradient Monitoring Well Location 3 (to be installed for the IRA)	25 to 30	30	Downgradient location along the groundwater flow line; close vicinity to Lake Druid.
Background Sampling Location (mid-depth sampling location)			
OLD-13-05A Monitoring Well	10 to 15	12	Used to establish background water quality conditions.

Notes: bls = below land surface.
IRA = Interim Remedial Action.
OU = operable unit.
SM = service mark.





NOTES:

All concentrations in parts per billion.
VOC = volatile organic compound
ND = not detected

FIGURE 3-4
EAST-WEST CROSS SECTION B-B' SHOWING GROUNDWATER VOC CONCENTRATIONS AND MONITORING LOCATION SCREENED INTERVALS

TREATABILITY STUDY WORKPLAN NO. 1, DATA COLLECTION PLAN FOR ASSESSING NATURAL ATTENUATION, OPERABLE UNIT 4

NAVAL TRAINING CENTER ORLANDO, FLORIDA

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3.2 ANALYTICAL PROTOCOL. Samples from the contaminant plume will be collected and analyzed for electron donors (hydrogen) and electron acceptors (dissolved oxygen, nitrate, iron, and sulfate) along with VOCs and daughter products, and various other water quality parameters (total organic carbon [TOC], ORP, pH, temperature, chloride, alkalinity, and dissolved gases). Table 3-2 lists the methods that will be utilized to analyze for these parameters.

3.3 SAMPLING PROCEDURES. Several of the water quality parameters required to assess natural attenuation are sensitive to the effects of turbulence and aeration. These parameters include dissolved oxygen, pH, ORP, dissolved gases, and VOCs. Particular care must be taken when sampling to ensure collection of representative groundwater samples.

Low-flow sampling procedures will be used for collection of all groundwater samples in accordance with procedures described in the NTC, Orlando Project Operations Plan (ABB-ES, 1997d). Samples must be collected with a peristaltic pump or a bladder pump at depths shown in Table 3-2. Samples should be collected directly into a sample container of appropriate size, style, and preservation for the desired analysis (see Table 3-2). Groundwater should be directed down the inner walls of the sample container to minimize aeration. All samples to be analyzed for VOCs and dissolved gases (methane, ethene, and ethane) must be filled so that no air space remains in the container for volatilization. Sampling and analysis of hydrogen gas in groundwater samples will be done in the field according to procedures described in Appendix A, Subsection 4.4.2 of the AFCEE guidance document (AFCEE, 1996). The principle used for sampling hydrogen gas is to continuously pump groundwater through a gas sampling bulb containing a nitrogen or air "bubble" so that hydrogen can partition between the gas and liquid phases until equilibrium is reached. The "bubble" is then analyzed for hydrogen and the concentration in groundwater is back-calculated using the Ideal Gas law and Henry's law.

Table 3-2
Analytical Parameters for Assessing Natural Attenuation at OU 4

Treatability Study Workplan No. 1
Data Collection Plan for Assessing Natural Attenuation
Operable Unit 4
Naval Training Center
Orlando, Florida

Analysis	Method Reference	Data Use	Sample Volume, Container and Preservation
VOCs	USEPA SW-846[1] Method 8260	Characterization of target VOCs and degradation products and compare concentrations over time.	Three 40 mℓ glass vials: HCL to pH < 2: cool to 4°C.
Dissolved Oxygen	Modified Winkler procedure (Hach[2] Field Test Kit)	Electron acceptors, used to characterize biodegradation processes.	A flow-through cell is required for sampling to minimize aeration.
Nitrate (NO_3^{-1}) and Nitrite ($NO2^{-2}$) Nitrogen	Ion Chromatography	Electron acceptors, used to indicate anaerobic biological activity.	Collect 250 mℓ in plastic container, cool to 4°C.
Dissolved Iron (II) (Fe^{+2})	Ion Chromatography or Hach[2] Field Test Kit	An electron acceptor, used to indicate anaerobic biological activity.	Follow test kit instructions.
Iron III (Fe^{+3})	Ion Chromatography or Hach[2] Field Test Kit	Oxidized form of Iron II.	Follow test kit instructions.
Sulfide (S^{-2})	Ion Chromatography	Reduced form of sulfate.	Collect 250 mℓ in plastic container, cool to 4°C.
Sulfate (SO_4^{-2})	Ion Chromatography	An electron acceptor, used to indicate anaerobic biological activity.	Collect 250 mℓ in plastic container, cool to 4°C.
Methane, Ethane, Ethene	Kampbell et al.[3] or modified USEPA Method SW-846 3810	Byproduct of anaerobic dechlorination, used to classify biodegradation processes in the aquifer.	Collect 3 @ 40 mℓ in glass containers, cool to 4°C.
Total Organic Carbon	USEPA SW-846 [1] Method 9060	Used to determine potential of anaerobic biodegradation in the absence of anthropogenic carbon (groundwater).	Collect 100 mℓ glass vials with Teflon™-lined cap; H_2SO_4 to pH < 2, cool to 4°C.
Alkalinity	Hach [2] Field Test Kit	Used to determine the buffering capacity of groundwater.	Collect 250 mℓ in glass or plastic container, analyze within 6 hours.
Temperature	Field Instrumentation	Well development.	
pH	Field Instrumentation, meter	Biological processes are pH sensitive.	Collect 250 mℓ in glass or plastic container, analyze immediately.
Chloride	Ion Chromatography	Final product of chlorinated solvent reduction; can be used to estimate dilution in calculation of rate constants.	Collect 100 mℓ in plastic containers, cool to 4°C.

See notes at end of table.

Table 3-2 (Continued)
Analytical Parameters for Assessing Natural Attenuation at OU 4

Treatability Study Workplan No. 1
Data Collection Plan for Assessing Natural Attenuation
Operable Unit 4
Naval Training Center
Orlando, Florida

Analysis	Method Reference	Data Use	Sample Volume, Container and Preservation
Oxidation-Reduction Potential	Field Instrumentation, Electrode and Meter, A2580B	Used as an overall indicator of biodegradation processes. Anaerobic dechlorination occurs in the ORP range of -50 to -240 mV.	Collect 100 mℓ in glass container, filling container from bottom, analyze immediately.
Hydrogen	Bubble strip method (USEPA, 1997) and Gas Chromatography Reducing Gas Detector	Electron donor, predicts the potential for reductive dechlorination.	Collect in glass gas sampling bulb per AFCEE protocol.

[1] USEPA. 1992. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*. SW-846, 3rd Edition.
[2] Hach brand environmental test kits.
[3] Kampbell, D.H., J.T. Wilson, and S.A. Vandegrift. 1989. "Dissolved Oxygen and Methane in Water by a GC Headspace Equilibrium Technique." *Int. J. Environ. Anal Chem.* 36:249-257.

Notes: OU = operable unit.
VOC = volatile organic compound.
USEPA = U.S. Environmental Protection Agency.
mℓ = milliliter.
°C = degrees Celsius.
HCL = hydrochloric acid.
< = less than.
H_2SO_4 = sulfuric acid.
ORP = oxidation-reduction potential.
mV = millivolts.
AFCEE = Air Force Center for Environmental Excellence.

4.0 DATA INTERPRETATION

Once the data are collected, the natural attenuation assessment can proceed. Effective documentation of natural attenuation requires evaluation of site-specific data to quantify groundwater flow, sorption, dilution, and biodegradation. The results of these calculations will be used to document the occurrence and rates of attenuation by modeling the fate and transport of dissolved contaminants.

4.1 CONCEPTUAL MODEL. A preliminary conceptual model was developed for OU 4 groundwater during site screening and the IRA. The new data collected for this assessment will be used to refine the current conceptual model. All available site data will be used to present a three-dimensional representation of the hydrogeologic data and contaminant transport system to assess natural attenuation. Specifically, the following data will be prepared:

- potentiometric maps and contaminant contour (isopleth) maps
- electron acceptor and electron donor distribution maps showing consumption of dissolved oxygen, nitrate, iron, and sulfate
- alkalinity contour map (utilization of electron donors tends to increase total alkalinity)
- metabolic by-product (chloride and methane) maps
- calculation of first-order biodegradation rate constants as described in Chapter 2.0

These data will be used to support the fate and transport modeling described below.

4.2 SOLUTE FATE AND TRANSPORT MODELING. Natural attenuation modeling will be used once the site-specific biological decay rates are calculated, in conjunction with site-specific water quality parameters, to predict the fate and transport of chlorinated solvents and the degradation products. This is accomplished by comparing the rate of transport to the rate of attenuation or decay. The primary purpose of comparing the rate of transport to the rate of attenuation is to estimate if the contaminants are attenuating at a rate sufficient to allow degradation of contaminants to acceptable concentrations before reaching receptors. At OU 4, the first downgradient receptor is Lake Druid. For natural attenuation to be effective, VOC groundwater concentrations must be reduced to acceptable levels prior to reaching the Lake.

Comparison of the rate of solute transport to the rate of attenuation will be accomplished using a numerical flow and transport model such as RT3D. The RT3D model calculates plume migration by including convection, dispersion, adsorption, diffusion, contaminant half-life, and contaminant mass flow rate from the source. The model uses a groundwater velocity flow field and accounts for retardation and microbial processes including sequential degradation involving multiple daughter products. The program calculates the concentration distribution of dissolved contaminants in space and time in mg/ℓ.

The contaminant half-lives determined from field measurements will be used in this equation to estimate site-specific decay rates for each contaminant. The outputs from this model can be presented graphically to show the predicted effect of contaminant attenuation modeled both with and without the effects of decay.

At NTC, Orlando OU 4, the concentrations of chlorinated solvents in Lake Druid are an indication that under current conditions, natural attenuation is not effective enough to prevent VOCs in excess of applicable standards from entering the lake. However, if the concentrations of VOCs in the source areas upgradient of the lake could be decreased with an alternative treatment technology, natural attenuation could be a viable followup remedial alternative for groundwater in the future. This assessment will be used to determine to what concentration VOCs must be reduced at the source for natural attenuation to be an effective followup remedial alternative. This concentration will be used as the minimum treatment goal for source remediation at OU 4.

To evaluate this scenario, the fate and transport model will be run assuming a constant source to reproduce current conditions and with a reduced contaminant source concentration (simulating conditions after source reduction) to predict the effectiveness of natural attenuation as a followup treatment technology. Using this model, a prediction of the maximum constant source concentration that could be remediated by natural attenuation will be made.

The results of this natural attenuation assessment will be presented in a technical memorandum. If natural attenuation is selected as a remedial technology for OU 4, a long-term monitoring plan would be included in the OU 4 remedial design. Long-term monitoring is required to confirm predictions made about the future extent of the contaminant plume. This will provide confirmation that natural attenuation is occurring at rates sufficient to protect potential downgradient receptors.

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