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TECHNICAL MEMORANDUM ENHANCED BIOREMEDIATION SUMMARY AT STUDY AREA
36 AND STUDY AREA 39 NTC ORLANDO FL
6/15/2001
CH2M HILL



07.04.36, 2001
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June 20, 2001

Ms. Barbara Nwokike
Remedial Project Manager
Southern Division
Naval Facilities Engineering Command
2155 Eagle Drive
Charleston, SC 29406

Subject: Enhanced Bioremediation Summary for Study Areas 36 and 39
Naval Training Center, Orlando, Florida
CTO 0017, Contract No. N62467-98-D-0995

Dear Ms. Nwokike:

Enclosed please find 2 copies of the above referenced document. The enclosed memorandum discusses the progress of the enhanced bioremediation projects at Study Areas 36 and 39. Copies are also being distributed to members of the Orlando Partnering Team.

If you have any questions regarding this document, please call.

Sincerely,

CH2M HILL CONSTRUCTORS, Inc.

Steven N. Tsangaris, P.E.
Project Manager

xc: Wayne Hansel, Southern Division (2 copies)
Nancy Rodriguez, USEPA Region IV (2 copies)
David Grabka, FDEP (2 copies)
Rick Allen, HLA
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TECHNICAL MEMORANDUM

Enhanced Bioremediation Summary for Study Area 36 and Study Area 39, Naval Training Center, Orlando

PREPARED FOR: Orlando Partnering Team:

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CONTRACT: Navy Contract # N62467-98-D-0995

CTO: CTO 0017, Naval Training Center (NTC) Orlando

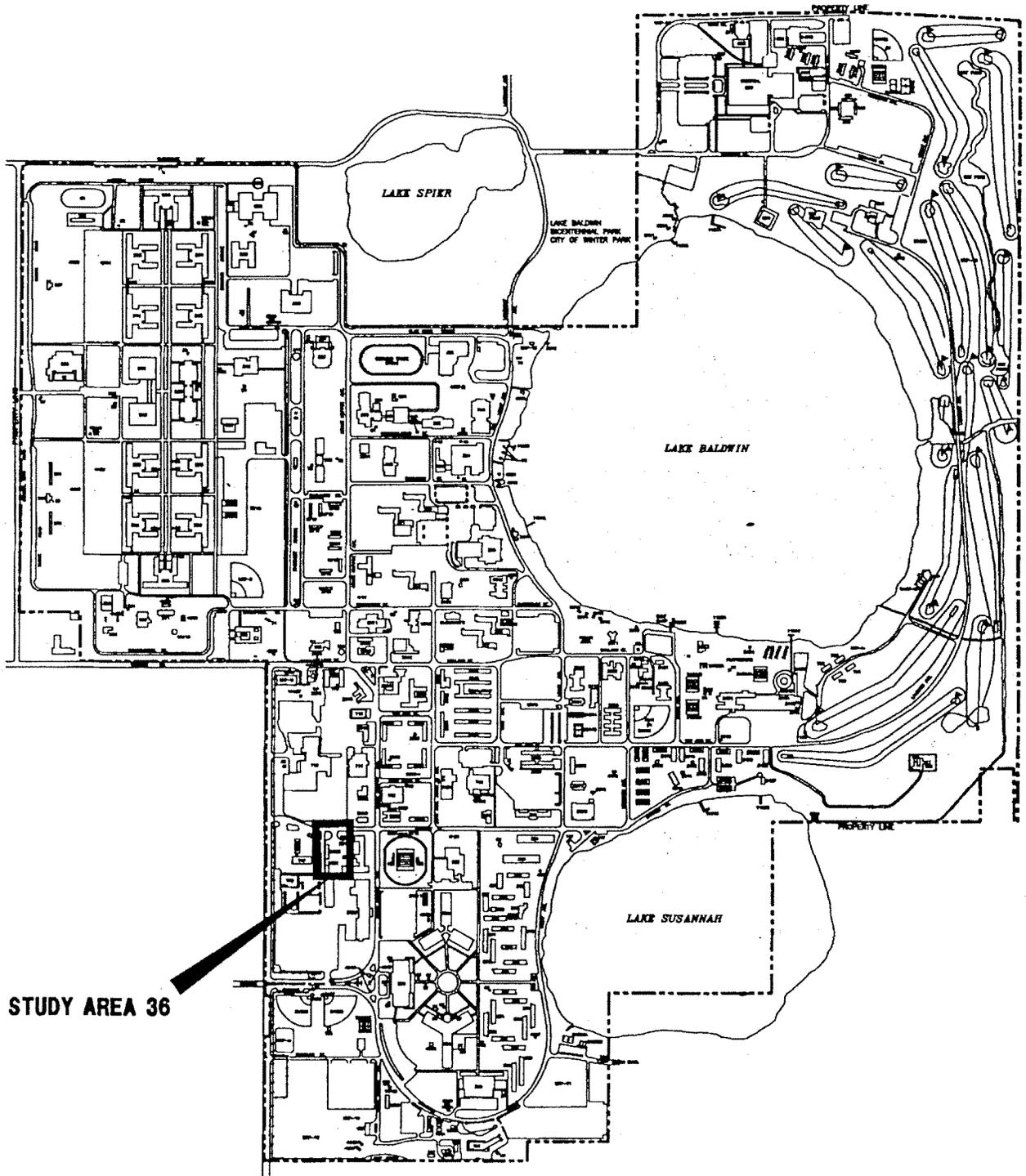
DATE: June 15, 2001

The purpose of this memorandum is to provide the results of the enhanced bioremediation effort performed at the Naval Training Center Orlando, Florida at Study Areas 36 and 39.

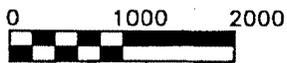
Site Descriptions

Study Area 36 (SA-36) is located south of Langley Street and west of Grace Hopper Avenue on the Main Base, as shown on Figure 1. The Main Base has been modified by Orlando NTC Partners to develop the land for residential use. Thus, the site used to contain Buildings 2121, 2122, and the western half of the Public Works Yard. The areas to the east and south of Building 2121 were used to store a variety of items including pipes, fire hydrants, bricks, and hazardous materials such as waste oil drums, transformers and batteries. Building 2122 was the Paint Shop. Paints and paint thinner were stored inside the building. A flammable materials storage cabinet was located at the north end of the building. Since the land development activities at the Main Base, the site area has been cleared of any buildings or roadways.

Study Area 39 (SA-39) is located in the southwest corner of the Main Base at the Naval Training Center in Orlando, Florida, as shown in Figure 2. SA-39 encompasses approximately 10 acres of land bounded on the south and west by the Main Base's property line, on the east by Grace Hopper Avenue, and on the north by Nautilus Street. The Main Base has been modified by Orlando NTC Partners to develop the land for residential use. Thus, the site used to contain two parking lots, a grassy area and a retention pond. Surface runoff drained into the retention pond and then into Lake Gear, located south of the Base.



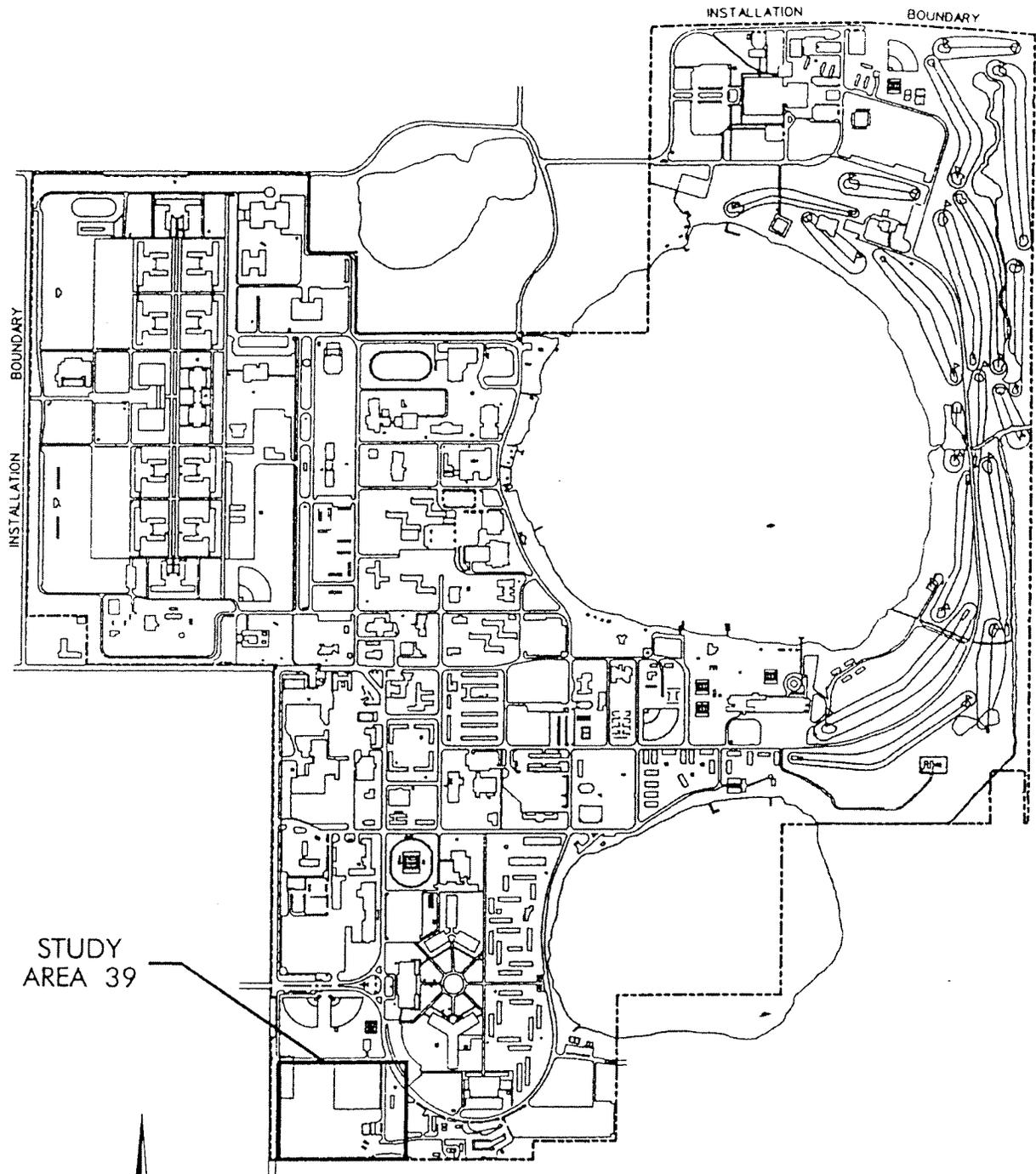
STUDY AREA 36



SCALE: 1 INCH = 2000 FEET



FIGURE 1
SITE LOCATION MAP
STUDY AREA 36
NAVAL TRAINING CENTER
ORLANDO, FLORIDA



STUDY
AREA 39

MAIN BASE

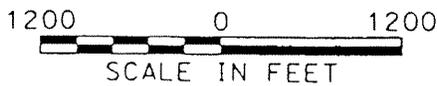
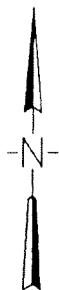


FIGURE 2
SITE LOCATION MAP
STUDY AREA 39

NAVAL TRAINING CENTER
ORLANDO, FLORIDA

nd-5x11v.dgn

R4705001

CAD FILE NO./DATE: 7457M044.dgn/4-28-00

Since the land development activities, the site area has been cleared of any buildings, roadways or retention ponds.

Groundwater Contamination Descriptions

During 1997 through 1998, the groundwater beneath SA-36 was investigated in order to evaluate the perchloroethene (PCE) and trichloroethene (TCE) contamination reported in the groundwater. The results of the study indicated that concentrations of TCE and PCE were detected exceeding the Groundwater Cleanup Target Levels (GCTLs), as shown on Figure 3. The maximum TCE concentration detected in a monitoring well at the site was 300 µg/L. The results of the groundwater investigation at the site indicate that TCE and PCE concentrations in groundwater exceed the GCTL in an area of approximately 5,000 sq. ft. in the North Storage Area (HLA, 1999). Chlorinated solvent detections exceeded screening criteria to a depth of 35 ft below land surface (bls).

Data collected during the *Environmental Site Screening Report (ESSR)* (HLA 1999) during the groundwater investigation at SA-39 indicated tetrachloroethene (PCE) is present at concentrations exceeding the Florida Groundwater Cleanup Target Level (GCTL). Tetra Tech NUS then performed an additional investigation to delineate the lateral and vertical extent of PCE in groundwater at the site. Their *Site Investigation Report for Study Area 39 (SI)* (Tetra Tech NUS 2000) also indicates PCE groundwater contamination in the shallow aquifer zone (A zone wells screened from 6 – 20 ft bls), the intermediate aquifer zone (B zone wells screened from 23 – 30 ft bls), and the deep aquifer zone (C zone wells screened from 34 – 45 ft bls). Specifically, PCE was detected in concentrations above the Florida GCTL in wells 03A, 08A, 09A, 04A and 11A (23 µg/L max. conc.) for the shallow zone, wells 07B, 15B, 33B, 35B, and 38B (94 µg/L max. conc.) for the intermediate zone, and wells 16C, 32C, and 37C (26 µg/L max. conc.) in the deep zone. The data and locations of these wells are shown on Figure 4. The Florida GCTL for PCE is 3 µg/L. According to the *SI Report for SA-39* (Tetra Tech NUS 2000), the intermediate component of the plume (aquifer zone B) is located slightly downgradient of the shallow zone (aquifer zone A), and the deeper component (aquifer zone C) further downgradient. This suggests that the plume is migrating downward as it nears Lake Gear. There was no PCE detected in the two wells screened at the base of the surficial aquifer.

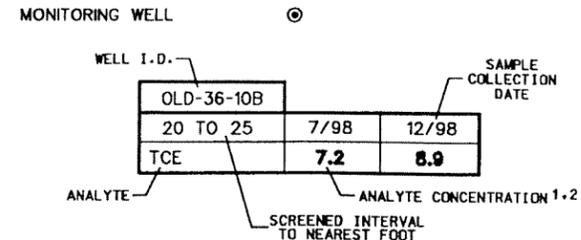
As a result of the PCE and TCE contamination detected at Study Areas 36 and 39, the Orlando Partnering Team (OPT) requested that CCI implement an IRA at the site consisting of enhanced bioremediation using vegetable oil.

Enhanced Bioremediation Study

The first task conducted for the enhanced bioremediation study was to install additional monitoring wells and injections points at each of the study areas. In total 15 injection points and seven downgradient monitoring wells were installed at SA-36. Likewise, 16 injection points and seven downgradient monitoring wells were installed at SA-39. In order to evaluate the permeability of the three groundwater zones beneath both study areas, slug testing was performed to calculate the hydraulic conductivity of the aquifers. Upon completion of the aquifer testing, a round of baseline samples were collected from the

SOURCE:
 BUILDINGS, CURBS, SIDEWALKS, EDGE OF PAVEMENT, AND WELLS 36-MW-16A THROUGH 36-MW-25C ARE TAKEN FROM DRAWING NO. 2267-00-B.dwg, DATED 8-31-00, BY DONALDSON, GARRETT & ASSC. OF MACON, GEORGIA. OTHER WELLS AND SITE FEATURES TAKEN FROM HLA DRAWING DATED 1999.

LEGEND

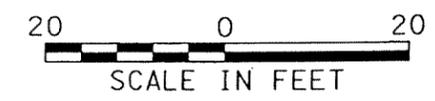
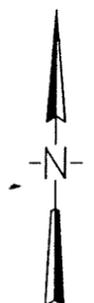


SCREENING CRITERIA

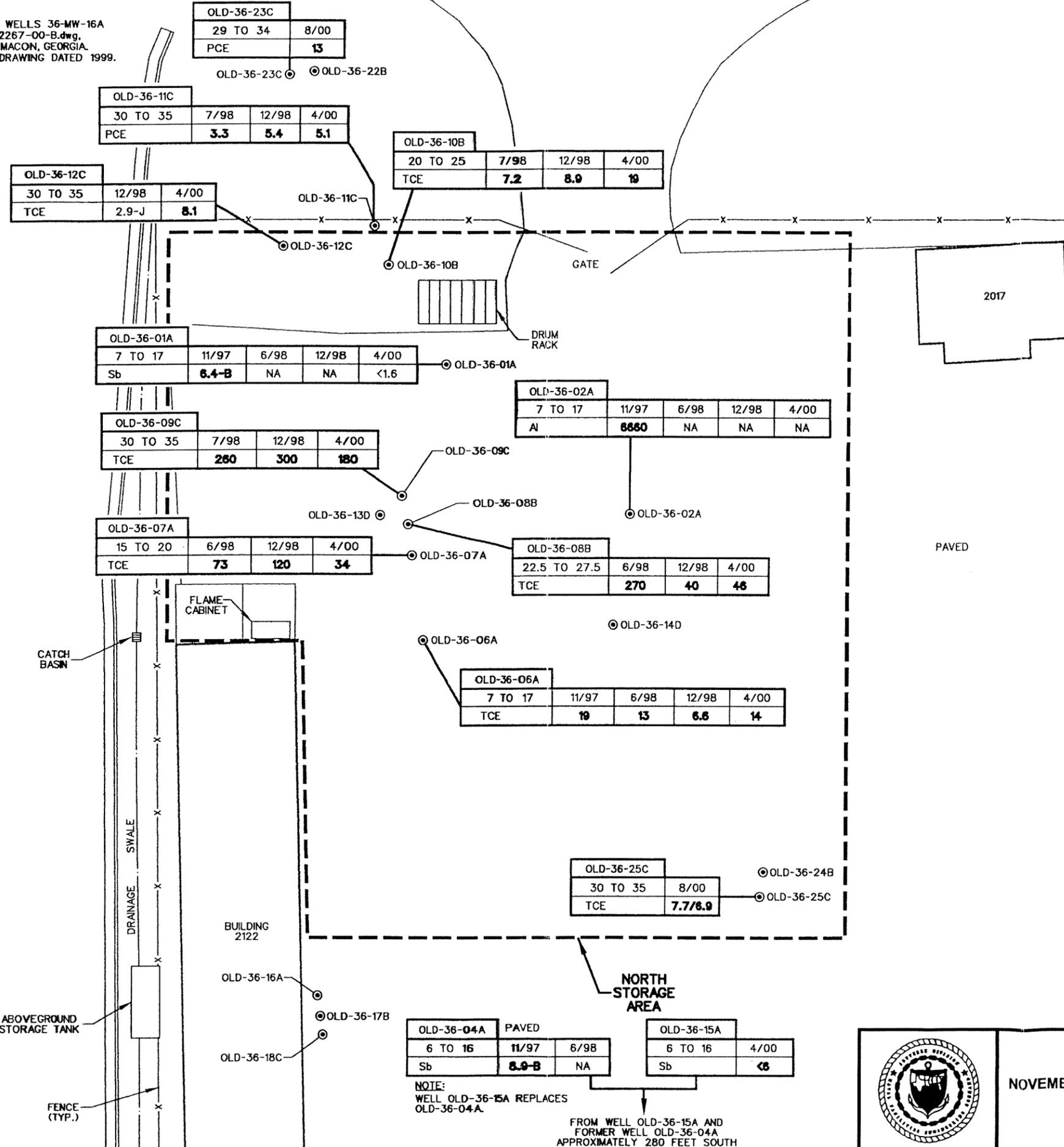
ABBREVIATION	ANALYTE	GCTL ¹	BGSV ¹
Al	Aluminum	200	4067
PCE	Tetrachloroethene	3	-
Sb	Antimony	6	4.1
TCE	Trichloroethene	3	-

GCTL-GROUNDWATER CLEANUP TARGET LEVEL
 BGSV-BACKGROUND SCREENING VALUE

NOTE:
 ONLY ANALYTES EXCEEDING SCREENING CRITERIA IN AT LEAST ONE SAMPLE ARE PRESENTED.



Source: TETRATECH NUS



OLD-36-23C	29 TO 34	8/00
PCE	13	

OLD-36-11C	30 TO 35	7/98	12/98	4/00
PCE	3.3	5.4	5.1	

OLD-36-10B	20 TO 25	7/98	12/98	4/00
TCE	7.2	8.9	19	

OLD-36-12C	30 TO 35	12/98	4/00
TCE	2.9-J	8.1	

OLD-36-01A	7 TO 17	11/97	6/98	12/98	4/00
Sb	6.4-B	NA	NA	<1.6	

OLD-36-02A	7 TO 17	11/97	6/98	12/98	4/00
Al	6660	NA	NA	NA	

OLD-36-09C	30 TO 35	7/98	12/98	4/00
TCE	280	300	180	

OLD-36-08B	22.5 TO 27.5	6/98	12/98	4/00
TCE	270	40	46	

OLD-36-07A	15 TO 20	6/98	12/98	4/00
TCE	73	120	34	

OLD-36-06A	7 TO 17	11/97	6/98	12/98	4/00
TCE	19	13	6.6	14	

OLD-36-25C	30 TO 35	8/00
TCE	7.7/6.9	

OLD-36-04A	PAVED	6 TO 16	11/97	6/98
Sb	8.0-B	NA		

OLD-36-15A	6 TO 16	4/00
Sb	6	

NOTE:
 WELL OLD-36-15A REPLACES OLD-36-04A.
 FROM WELL OLD-36-15A AND FORMER WELL OLD-36-04A APPROXIMATELY 280 FEET SOUTH



FIGURE 3
MONITORING WELL EXCEEDANCES
 NOVEMBER 1997, JUNE/DECEMBER 1998, AND APRIL 2000
 STUDY AREA 36
 NAVAL TRAINING CENTER
 ORLANDO, FLORIDA

LEGEND

MONITORING WELL ⊙
DESTROYED MONITORING WELL ⊗

WELL ID: OLD-39-04A

SCREEN INTERVAL TO NEAREST FOOT	5 TO 15	4/3/96	5/22/97	9/9/99
BDCM	<1	<0.5	1	5.7
PCE	<1	15/14		

ANALYTE: BDCM, PCE

SAMPLE COLLECTION DATE: 4/3/96, 5/22/97, 9/9/99

ESTIMATED CONCENTRATION: 1, 5.7

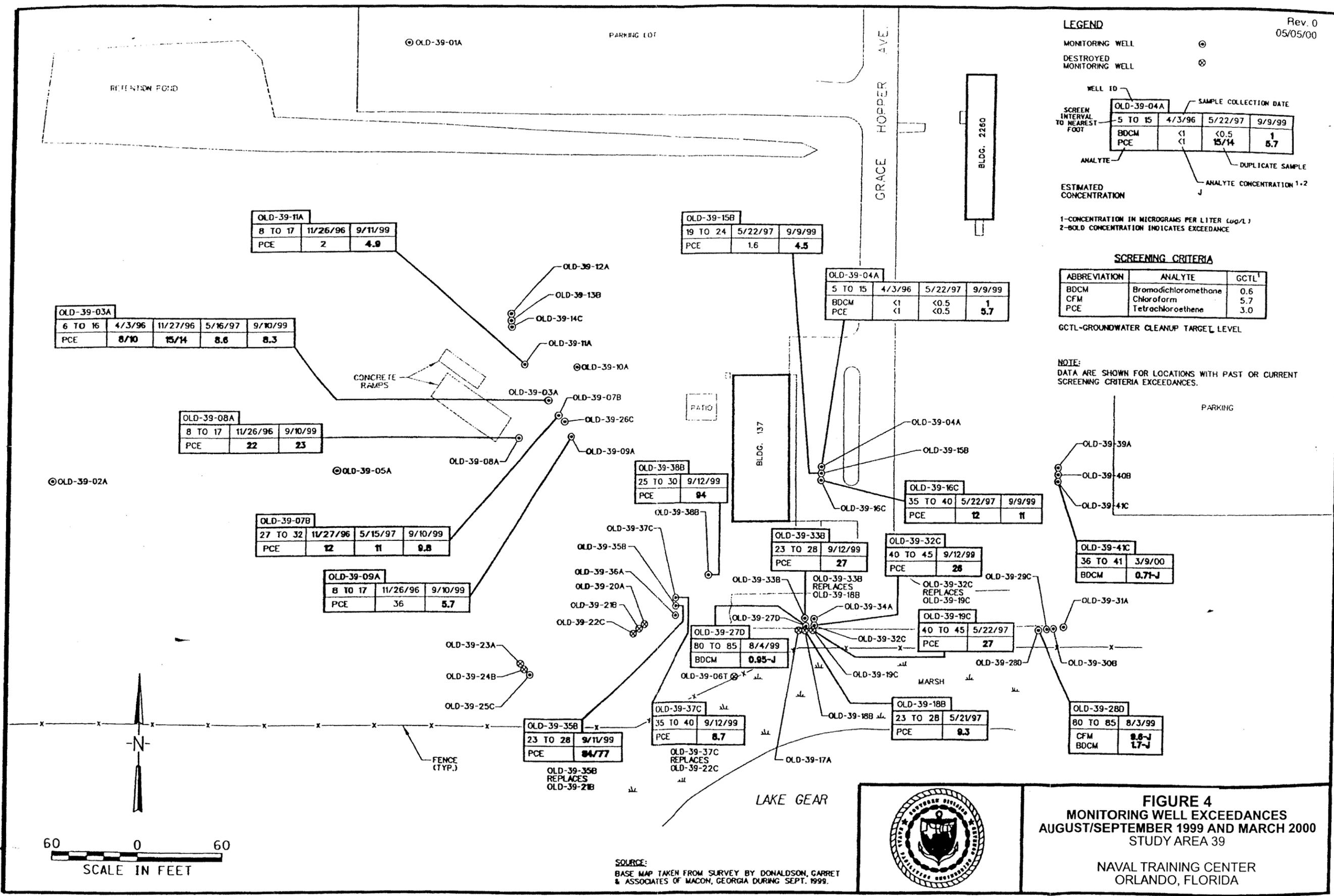
1-CONCENTRATION IN MICROGRAMS PER LITER (ug/L)
2-BOLD CONCENTRATION INDICATES EXCEEDANCE

SCREENING CRITERIA

ABBREVIATION	ANALYTE	GCTL ¹
BDCM	Bromodichloromethane	0.6
CFM	Chloroform	5.7
PCE	Tetrachloroethene	3.0

GCTL-GROUNDWATER CLEANUP TARGET LEVEL

NOTE:
DATA ARE SHOWN FOR LOCATIONS WITH PAST OR CURRENT SCREENING CRITERIA EXCEEDANCES.



SOURCE:
BASE MAP TAKEN FROM SURVEY BY DONALDSON, GARRET & ASSOCIATES OF MACON, GEORGIA DURING SEPT. 1999.



FIGURE 4
MONITORING WELL EXCEEDANCES
AUGUST/SEPTEMBER 1999 AND MARCH 2000
STUDY AREA 39
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

monitoring wells at both study areas. The parameters for which the groundwater was analyzed included:

- VOCs by EPA Method 8260B.
- Nitrate, Nitrite, Chloride, and Bromide by EPA Methods 352, 354, 325, 320.1, respectively
- Alkalinity by EPA Method 310.1
- Total organic carbon (TOC) by EPA Method 9060 Modified
- Total petroleum hydrocarbons (TPH) by FDEP Florida Petroleum Residual Organic Methods (FL-PRO)
- Volatile fatty acids
- Methane, ethane and ethene (MEE) by AM19GA

Food-grade vegetable oil was injected into the aquifers at both study areas once the baseline sampling was completed. In total, 60 gallons of vegetable oil was injected into each of the 15 locations at SA-36 during January 2001. In addition, 60 gallons of vegetable oil was injected into each of the 16 locations at SA-39 during December 2000. Details of the above activities can be found in *Construction Documentation Report Enhanced Biodegradation IRA at Study Area 36* (CH2M HILL, 2001) and *Construction Documentation Report Enhanced Biodegradation IRA at Study Area 39* (CH2M HILL, 2001).

Natural Attenuation Overview

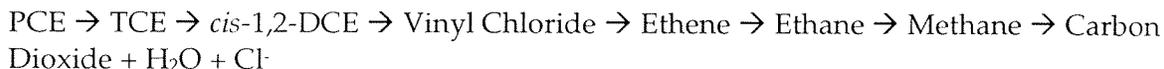
Monitored Natural Attenuation (MNA) relies upon natural attenuation processes to reduce the contaminant concentrations in groundwater. The EPA defines MNA as:

“The biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem.”

The biodegradation component of MNA is usually the dominant factor that dictates the ultimate fate and transport of groundwater contamination because it is most often the component of MNA that has the potential for the reducing the most contamination over a given time period. An understanding of the degree of biological activity present beneath the site, primarily in the contaminant “hot spot,” is required in order to predict the rate of contamination reduction and which natural attenuation component is the dominant mechanism for reducing contamination levels in the subsurface. General guidelines established by the EPA require the contamination levels meet the GCTL established for the site within “a reasonable time-frame” which in practice is considered to be 10 to 15 years after initiating MNA as the remediation remedy. A tool that is used to predict the rate of contamination reduction that is widely used is BIOSCREEN. Site specific data about the groundwater aquifer can be entered into BIOSCREEN and the program can predict the length of time required for contamination levels to reach site specific GCTLs.

Monitoring contaminated groundwater to assess the effectiveness of the reductive dechlorination process is necessary to evaluate the progress towards meeting the GCTLs established for a site. The biodegradation process for chlorinated solvents is a complicated

process and numerous parameters must be analyzed in the site groundwater to evaluate the stages of reductive dechlorination. The reductive dechlorination process for PCE and TCE is shown below:



A series of oxidation reduction reactions are facilitated by microorganisms that allow the above process to take first. A series of electron acceptors will take an electron from two primary electron donors which are dissolved hydrogen and total organic carbon (TOC) sources. The dissolved hydrogen concentrations in groundwater also provide information on the terminal electron accepting process of the aquifer as listed in Table 1.

TABLE 1
Dissolved Hydrogen Concentrations and the Terminal Electron Accepting Process
Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Terminal Electron Accepting Process	Dissolved Hydrogen Concentration
Denitrification	<0.1 nm/L
Iron III Reduction	0.2 – 0.8 nm/L
Sulfate Reduction	1- 4 nm/L
Methanogenesis	>5 nm/L

nm/L– nanomoles per liter

The electron acceptors present in groundwater are listed below:

- Dissolved Oxygen (DO)
- Nitrogen, Nitrate (as N)
- Manganese (total)
- Ferric Iron (Fe III)
- Sulfate (as SO₄)
- Carbon Dioxide

The above electron acceptors are consumed in the groundwater aquifer in the above order due to the thermodynamic nature of each electron accepting process. Therefore, the dissolved oxygen is utilized first, then the nitrogen, and so on and so forth until the terminal electron accepting condition is either sulfate reducing or methanogenic. Once the above electron acceptors are consumed, the reductive dechlorination process will begin and the PCE and TCE become the electron acceptors. Additional groundwater parameters and some parameters previously discussed and their role in the reductive dechlorination process are listed in Table 2.

TABLE 2
Parameters to Measure for Assessment of Natural Attenuation

Parameter	Comments
Dissolved Oxygen	DO is the electron acceptor most thermodynamically favored by microbes for the biodegradation of organic carbon, whether natural or anthropogenic. Reductive dechlorination will not occur, however, if DO concentrations are above approximately 0.5 mg/L.
Nitrate	After DO depletion, anaerobic microbes will use nitrate-containing compounds as an electron acceptor (denitrification).
Iron (III) (II)	After nitrate-compound depletion, anaerobic microbes will use iron (III)-containing compounds as an electron acceptor (bioavailable form). Iron (III) will be reduced to a more soluble form, iron (II), which is indicative of anaerobic degradation of fuel compounds or other hydrocarbons.
Sulfate	After iron (III)-compound depletion, anaerobic microbes will use sulfate-containing compounds as an electron acceptor (sulfate reduction). This will result in the production of sulfide-containing compounds such as hydrogen sulfide.
Carbon dioxide	After sulfate-compound depletion, anaerobic microbes will use carbon dioxide-containing compounds as an electron acceptor (methanogenesis). This will result in the production of methane. Carbon dioxide also will be produced by the oxidation of organic substrates.
Alkalinity	Total alkalinity is indicative of a water's capacity to neutralize acid. Alkalinity results from the presence of hydroxides, carbonates, and bicarbonates of elements (Ca, Mg, Na, K, or ammonia). Alkalinity helps to buffer the pH of the groundwater system from the acids generated during both aerobic and anaerobic degradation. Alkalinity may increase in areas with significant biological activity.
ORP	Oxidation-reduction potential is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons.
PH	pH has an effect on the presence and activity of microbial populations in the groundwater system (especially for methanogens). Microbes capable of degrading chlorinated aliphatic hydrocarbons and petroleum hydrocarbon compounds generally prefer pH values varying from 6 to 8 standard units.
Conductivity	Conductivity is a measure of the ability of a solution to conduct electricity (the direct correlation to the number of ions in solution). Conductivity measurements are used to ensure that collected groundwater samples representing the water in the saturated zone containing the dissolved contamination. If conductivities are radically different, the sample waters may be from different hydrogeologic zones.
Temperature	Temperature directly affects the solubility of oxygen and other geochemical species and will affect the metabolic activity of bacteria.
Chloride	When compared with background levels, chloride is an effective conservative tracer of groundwater contaminant plume migration, due to the release of chloride during degradation of chlorinated hydrocarbons in groundwater. Chloride ions generally do not enter into ORP reactions, form no important solute complexes with other ions, do not form salts of low solubility, are not significantly adsorbed on mineral surfaces, and play few vital biochemical roles.
Methane	Methane is generated as a result of methanogenic bacteria during anaerobic fermentation processes. Its presence indicates a strongly reducing environment.
Ethene	Vinyl chloride can be reduced to ethene in an anaerobic environment. Its presence indicates that vinyl chloride is being degraded via anaerobic processes.
Ethane	Ethene can be further reduced to ethane. Its presence indicates that reductive anaerobic processes are occurring.
TOC	Total organic carbon provides an indication of the amount of potentially degradable organic carbon available to act as an electron donor and a supply of organic carbon for biomass synthesis.

A system has been developed by AFCEE to evaluate the degree to which natural attenuation is occurring in a groundwater plume. The evaluation consists of "scoring" the previously discussed groundwater parameters by applying a numeric value to each parameter in the contamination source well of each plume on the basis of its role in the reductive dechlorination process. The score of each parameter is then summed up to give a final value or "score" to the plume's contamination source well. This process is described in detail in the *Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents* (EPA 1997). The parameters that are scored and their respective values are shown in Table 3.

TABLE 3
Analytical Parameters and Their Respective Values for Screening the Reductive Dechlorination Process
Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Contaminated Zone Concentration	Description	Points Awarded
Dissolved Oxygen	<0.5 mg/L	Suppresses reductive dechlorination at higher concentrations.	3
	>1 mg/L	Vinyl chloride may be oxidized, but reductive dechlorination will not occur	-3
Nitrate	<1 mg/L	May complete the reductive dechlorination process at higher concentrations	2
Iron II	>1 mg/L	Reductive pathway possible, vinyl chloride may be oxidized under Iron III reducing conditions	3
Sulfate	<20 mg/L	May complete the reductive dechlorination process at higher concentrations	2
Sulfide	>1 mg/L	Reductive pathway possible	3
Methane	<0.5 mg/L	Vinyl chloride oxidizes	0
	>0.5 mg/L	Ultimate reductive daughter product, vinyl chloride accumulates	3
ORP	<50 mV	Reductive pathway possible	1
	<-100 mV	Reductive pathway likely	2
pH	5<pH<9	Optimal Range for reductive pathway	0
	5>pH>9	Outside Optimal range for reductive pathway	-2
TOC	>20 mg/L	Carbon and energy source	2
Temperature	>20 °C	Biological process is accelerated	1
CO ₂	>2 times background	Ultimate oxidative daughter product	1
Alkalinity	> 2 times background	Results from interaction of carbon dioxide with aquifer materials	1
Chloride	>2 times background	Daughter product of organic chlorine	1

TABLE 3
Analytical Parameters and Their Respective Values for Screening the Reductive Dechlorination Process
Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Contaminated Zone Concentration	Description	Points Awarded
Dissolved Hydrogen	>1 nm/L	Reductive pathway possible	3
	<1 nm/L	Vinyl chloride oxidized	0
Volatile fatty acids	>0.1 mg/L	Intermediates resulting from biodegradation of aromatic compounds; carbon and energy source	2
BTEX	>0.1 mg/L	Carbon and energy source	2
PCE		Material released	0
TCE		Material released	0
		Daughter product of PCE	2
Cis-1,2-DCE		Material released	0
		Daughter product of TCE and is greater than 80% of the total 1,2-DCE concentration	2
Vinyl Chloride		Material released	0
		Daughter product of DCE	2
Ethene/Ethane	>0.01 mg/L	Daughter product of vinyl chloride/ethene	2
	>0.1 mg/L		3

Notes: The total score for the above parameters are interpreted as follows:
 0 to 5 Inadequate evidence for biodegradation of chlorinated organics
 6 to 14 Limited evidence for biodegradation of chlorinated organics
 15 to 20 Adequate evidence for biodegradation of chlorinated organics
 >20 Strong evidence for biodegradation of chlorinated organics

The score for a plume is only one indicator for determining the degree to which natural attenuation is occurring. The amount of contamination reduction over time also needs to be considered when evaluating natural attenuation processes. Contamination concentrations should meet remediation goals for the site within a “reasonable time frame”.

Enhanced Bioremediation Results

The results of the first round of enhanced bioremediation samples were collected at SA-36 and SA-39 during March 2001 and February 2001, respectively. Therefore, the samples were collected approximately two months after completing the vegetable oil injections. The data from the groundwater sampling event was evaluated using the process described below:

Step 1 – Tabulate the baseline and first round of groundwater sampling results

Step 2 – Evaluate the change in electron acceptor and donator concentrations

Step 3 – Plot the electron acceptor and donator values through the flow path of the plume (i.e., Upgradient → Source → Ingradient → Downgradient).

Step 4 – Evaluate the change in contamination (TCE, PCE) concentrations along with daughter product (*cis*-1,2-DCE, Vinyl Chloride, and MEE) and chloride formation.

Step 5 – Score the contamination source well according to the AFCEE protocol outlined in *Draft EPA Region 4 Suggested Practices for Evaluation of a Site for Natural Attenuation (Biological Degradation) of Chlorinated Solvents* (EPA 1997).

Study Area 36 Groundwater Sampling Results

Groundwater samples were collected from each of the three aquifer zones beneath SA-36. The groundwater samples were collected from the wells in each zone as listed in Table 4 and the analytical results for the baseline and March 2001 samples are listed in Table 5.

TABLE 4
Wells Sampled at Study Area 36
Enhanced Bioremediation Study, Naval Training Center Orlando, Florida

Zone A	Zone B	Zone C
OLD-36-06A	OLD-36-08B	OLD-36-09C
OLD-36-07A	OLD-36-10B	OLD-36-11C
OLD-36-26A	OLD-36-28B	OLD-36-30C
OLD-36-27A	OLD-36-29B	OLD-36-31C
--	--	OLD-36-32C

Study Area 36 Zone A Groundwater Results

The groundwater data for Zone A at SA-36 shows a change in a few parameters between the baseline and March 2001 results. The significant findings which indicate that natural attenuation may be occurring are as follows:

- The dissolved oxygen was depleted by ½ to less than 0.5 mg/L in wells OLD-36-26A and OLD-36-27A which is an indication of microbial activity.
- Nitrate concentrations in every well except OLD-37-27A have decreased which is an indication of nitrate reducing conditions.
- The ORP in all four wells decreased to a negative value, two of which (OLD-36-07A and OLD-36-26A), reported ORP values less than -50 mV which indicates the potential for electron transfer has increased.
- The chloride, methane, ethane, and ethene concentrations increased in all four wells which indicates that the reductive dechlorination process may be occurring.
- The TOC concentrations, in every well except OLD-36-06A, have decreased which is an indication of microbial activity.
- The TCE concentrations decreased in every well except OLD-36-27A; however, the formation of *cis*-1,2-DCE or vinyl chloride did not occur.

TABLE 5
Natural Attenuation Parameters
SA-36, NTC Orlando

Field Test Kit Parameters (mg/L)								Analytical Laboratory Data										
Station ID	Date	Ferrous		Hydrogen		Dissolved	Oxidation	Alkalinity	Chloride	Nitrate/Nitrite	TOC	Methane	Ethane	Ethene	Volatile			cis-1,2-
		Iron	Manganese	Sulfide	Sulfate										Oxygen	Potential	Fatty	
OLD-36-06A	12/04/2000	0.5	0	0.0	90	0.79	151.6	1.5	4.2	0.33	10.70	ND	ND	ND	ND	ND	14	ND
OLD-36-06A	03/14/2001	0.4	0	0.0	125	2.35	-6.6	6.0	8.4	0.09	12	1.7	17	13	ND	ND	9.5	ND
OLD-36-07A	12/01/2000	0.2	0	0.1	<50	0.54	63.0	16	6.2	0.2	12.50	ND	ND	ND	ND	ND	59	ND
OLD-36-07A	03/14/2001	0.2	0	0.0	>200	1.06	-83.4	16	7.7	0.09	11	4.7	24	21	ND	ND	35	ND
OLD-36-26A	12/01/2000	1	0.2	0.3	>200	0.96	207.1	26	6.5	1.2	46.60	ND	ND	ND	ND	ND	15	ND
OLD-36-26A	03/14/2001	0.4	0	0.0	>200	0.43	-125.0	18	9.9	0.02	25	8.5	64	120	ND	ND	10	ND
OLD-36-27A	12/01/2000	0.1	0	0.0	<50	0.98	136.1	160	6.7	ND	8.36	ND	ND	ND	ND	ND	79	1.1 J
OLD-36-27A	03/13/2001	0.1	0	0.0	<50	0.27	-13.2	62	7.7	ND	3	1.7	14	57	ND	ND	97	ND
OLD-36-08B	12/04/2000	0.5	0.1	1.0	80	0.98	-81.8	24	7.0	ND	3.55	90	ND	ND	ND	ND	97	ND
OLD-36-08B	03/15/2001	6	0	0.5	<50	0.44	-134.1	22	6.1	ND	3	80	18	110	ND	ND	35	ND
OLD-36-10B	12/04/2000	0.2	0	0.3	>200	1.08	16.9	25	6.4	ND	15.70	ND	ND	ND	ND	1.7 J	4.5 J	2.3 J
OLD-36-10B	03/15/2001	0.8	0.3	0.1	>200	0.45	-105.7	32	3.3	ND	17	9.9	35	63	ND	1.6 J	12	11
OLD-36-28B	12/01/2000	2.5	0	0.3	>200	0.59	-51.6	300	8.7	ND	90.50	0.012	ND	ND	ND	ND	85	0.54J
OLD-36-28B	03/14/2001	1.1	0	0.7	150	0.38	-40.7	37	7.0	0.01	6	3.6	50	110	ND	ND	66	ND
OLD-36-29B	12/04/2000	2	0.1	NM	70.5	0.65	40.9	27	14	ND	5.18	ND	ND	ND	ND	ND	190	1.9 J
OLD-36-29B	03/13/2001	1	0	0.1	70	0.11	10.9	11	9.6	ND	12	5	70	70	ND	ND	150	ND
OLD-36-09C	12/05/2000	0.3	0.3	5.0	<50	0.71	-178.1	280	8.9	ND	19.80	ND	ND	ND	ND	ND	300	24
OLD-36-09C	03/15/2001	0.2	0	0.5	>200	0.41	-283.7	330	9.5	ND	14	51	210	670	ND	ND	180	20 J
OLD-36-11C	12/06/2000	0.1	0	0.7	100	0.79	18.1	14	6.3	ND	8.77	ND	ND	ND	ND	1.3 J	6.4	3.5 J
OLD-36-11C	03/15/2001	0.1	0.3	0.1	75	0.28	-63.1	16	5.7	ND	11	4.8	18	57	ND	2.5 J	10	5.3 J
OLD-36-12C	12/05/2000	0.2	0	0.0	>200	1.11	78.9	17	5.7	ND	22.70	ND	ND	ND	ND	ND	9	3.2 J
OLD-36-23C	12/06/2000	1.2	0.1	0.5	>200	0.75	-40.9	25	3.7	ND	15.00	37	ND	ND	ND	14	3.2 J	0.81 J
OLD-36-30C	11/29/2000	0.6	0	1.0	70	0.90	-32.0	41	9.4	ND	6.21	ND	ND	ND	ND	ND	37	ND
OLD-36-30C	03/14/2001	0.4	0.1	0.1	<50	0.27	-48.6	25	8.0	0.02	1	5.1	37	78	ND	ND	57	1.3 J
OLD-36-31C	12/05/2000	1.2	0.3	0.0	60	0.79	48.0	18	8.9	ND	6.41	ND	ND	ND	ND	ND	14	ND
OLD-36-31C	03/14/2001	0	0.15	5.0	<50	0.31	-112.9	26	6.9	ND	49	400	84	270	ND	ND	13	ND
OLD-36-32C	12/06/2000	0.1	0.1	0.2	>200	0.78	-26.1	83	7.9	ND	18.50	ND	ND	ND	ND	ND	17	ND
OLD-36-32C	03/13/2001	0.1	0	0.0	80	0.18	-5.8	26	7.8	ND	7	1.8	19	31	ND	ND	13	ND

NM = Not measured due to color of sample.

Reductive dechlorination brings about measurable changes in the chemistry of the groundwater in the affected area. By measuring these changes, one can document and quantitatively evaluate the reductive dechlorination process. Some of the common analytes measured during natural attenuation are discussed below:

Dissolved Oxygen - DO levels should be below 1.0 mg/L for anaerobic degradation

Nitrate - After oxygen is depleted during the degradation process, nitrate may be used as an electron acceptor for anaerobic degradation. Conc's should be low <1.

Ferrous Iron - Also used as an electron acceptor during anaerobic biodegradation. Conc's should be >1 mg/L for reductive pathway.

Sulfate - After oxygen, nitrate, and iron have been depleted, sulfate may be used as the electron acceptor. Sulfate reduction produces sulfide. Conc's should be low (<20)

Sulfide - Concentrations should increase if the sulfate reduction process is occurring. Conc's should be >1 mg/L.

Methane - After oxygen, nitrate, iron and sulfate have been depleted, methanogenesis occurs where carbon dioxide is used as the electron acceptor and methane is produced. The presence of methane in gw is indicative of strongly reducing conditions.

Ethane and Ethene - Are produced during reductive dechlorination. Conc's should increase.

TOC - Total Organic Carbon is used to determine whether anaerobic metabolism of chlorinated solvents is possible in the absence of anthropogenic carbon.

Alkalinity - The total alkalinity of the gw is indicative of a water's capacity to neutralize acid which is generated during aerobic and anaerobic biodegradation. Conc's should increase.

Oxidation Reduction Potential - The redox potential of gw is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox conc's should be <50 and even better if negative which shows iron, sulfate or methanogenesis reducing conditions.

Chloride - Chloride and conductivity data is used to ensure that water is being collected or measured in the correct hydrogeologic zone.

Volatile Fatty Acids - VFAs are produced as metabolic byproducts during the biodegradation of BTEX compounds. Conc's should be >0.1 mg/L

The groundwater analytical and field parameters also can be evaluated through the flow path of the plume to evaluate the reductive dechlorination process. For the purposes of this evaluation, well OLD-36-06A was considered the upgradient well location on the basis of the potentiometric map shown in Figure 5. The remaining wells were considered source wells due to the elevated TCE concentrations in OLD-36-27A, the most downgradient well sampled.

The DO, ORP, and Cl concentrations are plotted along the flow path of the groundwater in Zone A in Figure 6. The plot shows a potential zone of reduction around well OLD-36-26A which is evidenced by a reduction in ORP and DO along with an associated spike in chloride level. In addition, this reductive zone shows an elevation in dissolved gas concentrations (Figure 7) and TOC (Figure 8) with an associated decrease in TCE concentration (Figure 8). However, there is no DCE or vinyl chloride reported in the reductive zone around OLD-36-26A or the remainder of the groundwater plume. On the basis of the groundwater parameters measured for Zone A at SA-36, the associated score for the reductive zone is 10 which is indicative of limited evidence for the reductive dechlorination of chlorinated solvents. The tabulation of this score is shown in Table 6.

Study Area 36 Zone B Groundwater Results

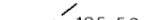
The groundwater data for Zone B at SA-36 shows a change in a few parameters between the baseline and March 2001 results. The parameter changes that are indicative of reductive dechlorination are listed below:

- The dissolved oxygen concentrations have decreased in each monitoring well from the baseline concentrations
- The dissolved gas, MEE, concentrations have increased in each of the monitoring wells from the baseline levels.
- The ORP values have decreased in every well except OLD-36-28B from the baseline measurements.
- Ferrous iron and hydrogen sulfide are reported in the groundwater which are indicative of a reductive environment.
- Sulfate concentrations have reduced in every well except OLD-36-10B.
- The TOC concentrations have either remained relatively constant, or decreased in Zone B after the addition of vegetable oil which indicates it is being consumed in the subsurface.
- TCE concentrations have decreased in every well except OLD-36-10B, and the 1,2-DCE concentration has increased in one the monitoring well.

OLD-36-37C

FORMER LANGLEY STREET

LEGEND

- EXISTING MONITORING WELL 
- NEW MONITORING WELL 
- DESTROYED MONITORING WELL 
- GROUNDWATER ELEVATION (4-5-01) (FT.) 
- GROUNDWATER CONTOUR ELEVATION (FT.) 
- FLOW DIRECTION 

OLD-36-19A (104.24)

OLD-36-23C
OLD-36-22B

OLD-36-34B
OLD-36-35C

104.50

OLD-36-11C
OLD-36-12C
OLD-36-10B

FORMER DRUM RACK

FORMER BUILDING 2017

OLD-36-01A (104.72)

105.00

104.50

OLD-36-32C
PAVED
OLD-36-27A (104.53)

105.50

OLD-36-29B

OLD-36-28B

OLD-36-31C

OLD-36-02A (105.83)

FORMER PAVED AREA

FORMER FLAME CABINET

OLD-36-30C

OLD-36-07A (104.97)

OLD-36-26A (105.00)

OLD-36-06A (105.18)

105.00

FORMER BUILDING 2122

105.50

OLD-36-33A (105.82)

OLD-36-16A (105.59)

FORMER NORTH STORAGE AREA

FORMER PAVED AREA

OLD-36-36C

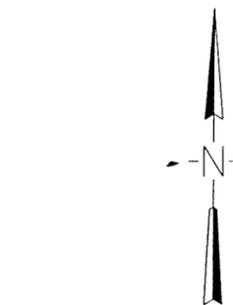


FIGURE 5
SHALLOW (A) ZONE
GROUNDWATER CONTOUR MAP
SA-36
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

SOURCE:
BUILDINGS AND STREETS TAKEN FROM HLA, 1999
AND ARE SHOWN IN THEIR APPROXIMATE LOCATIONS.

n11x17b.dgn

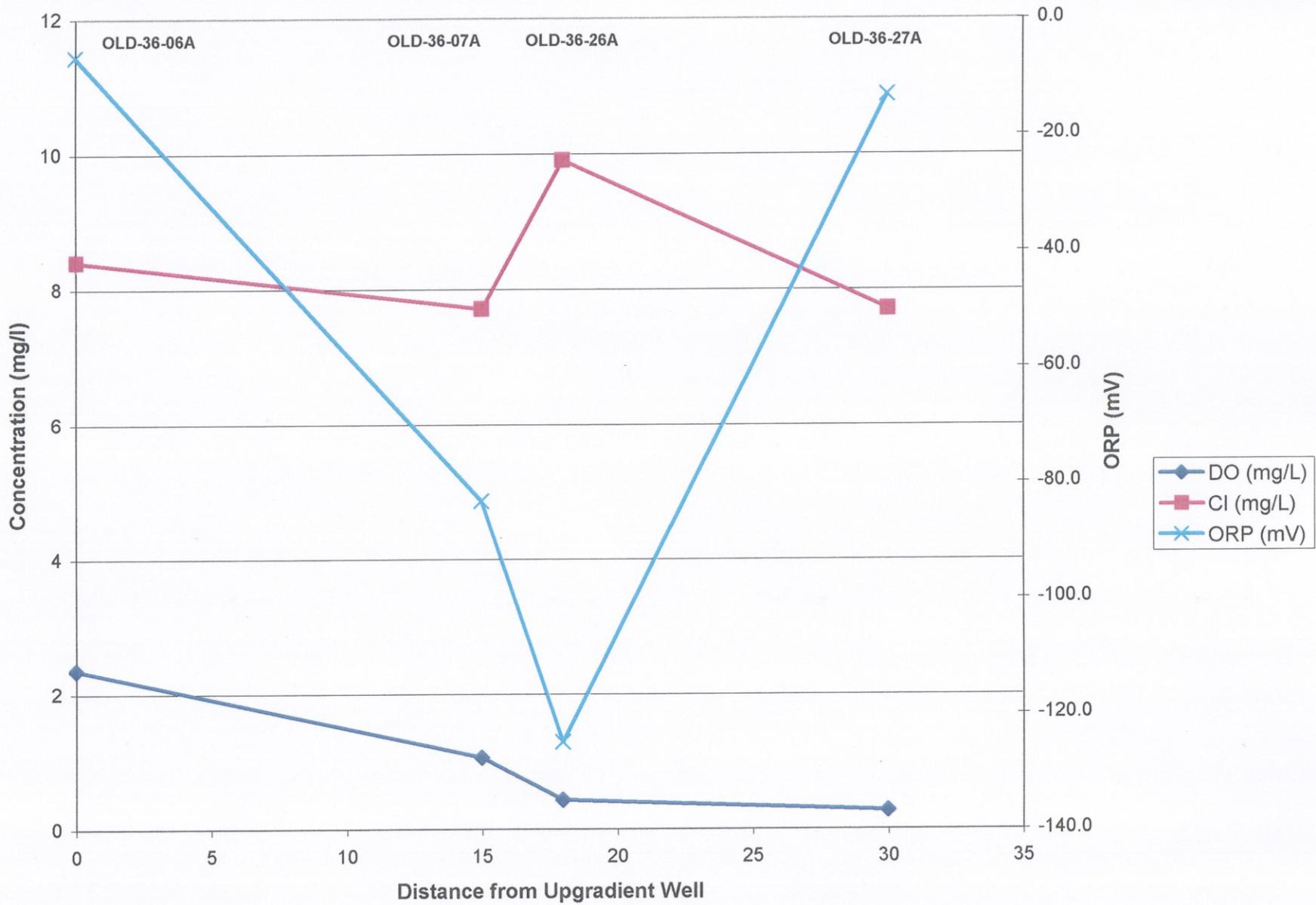


Figure 6
DO, Cl, and ORP Concentrations in Zone A
Study Area 36 Enhanced Bioremediation Study

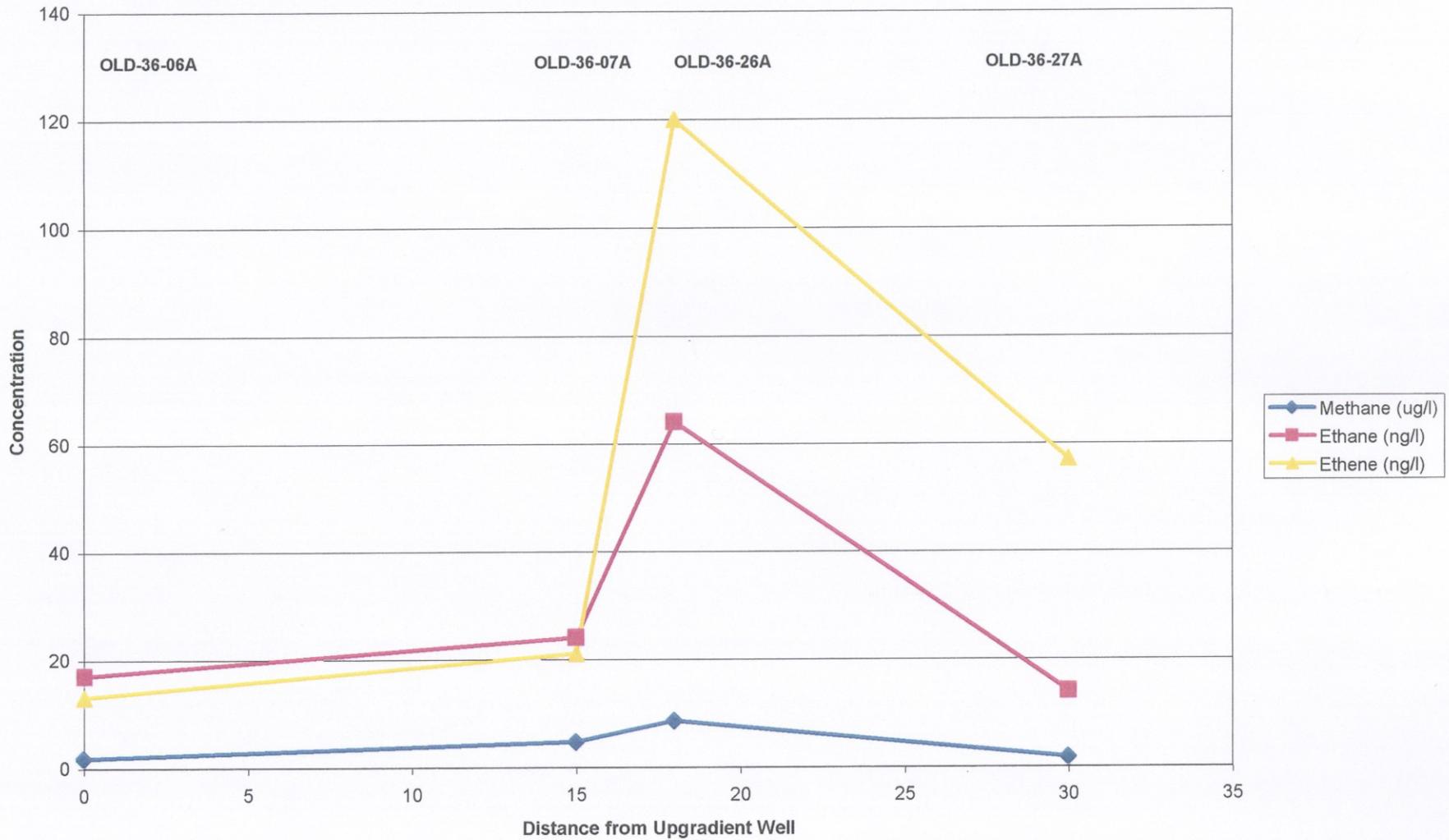


Figure 7
 Ethene, Ethane, and Methane Concentrations in Zone A
 Study Area 36 Enhanced Bioremediation Study

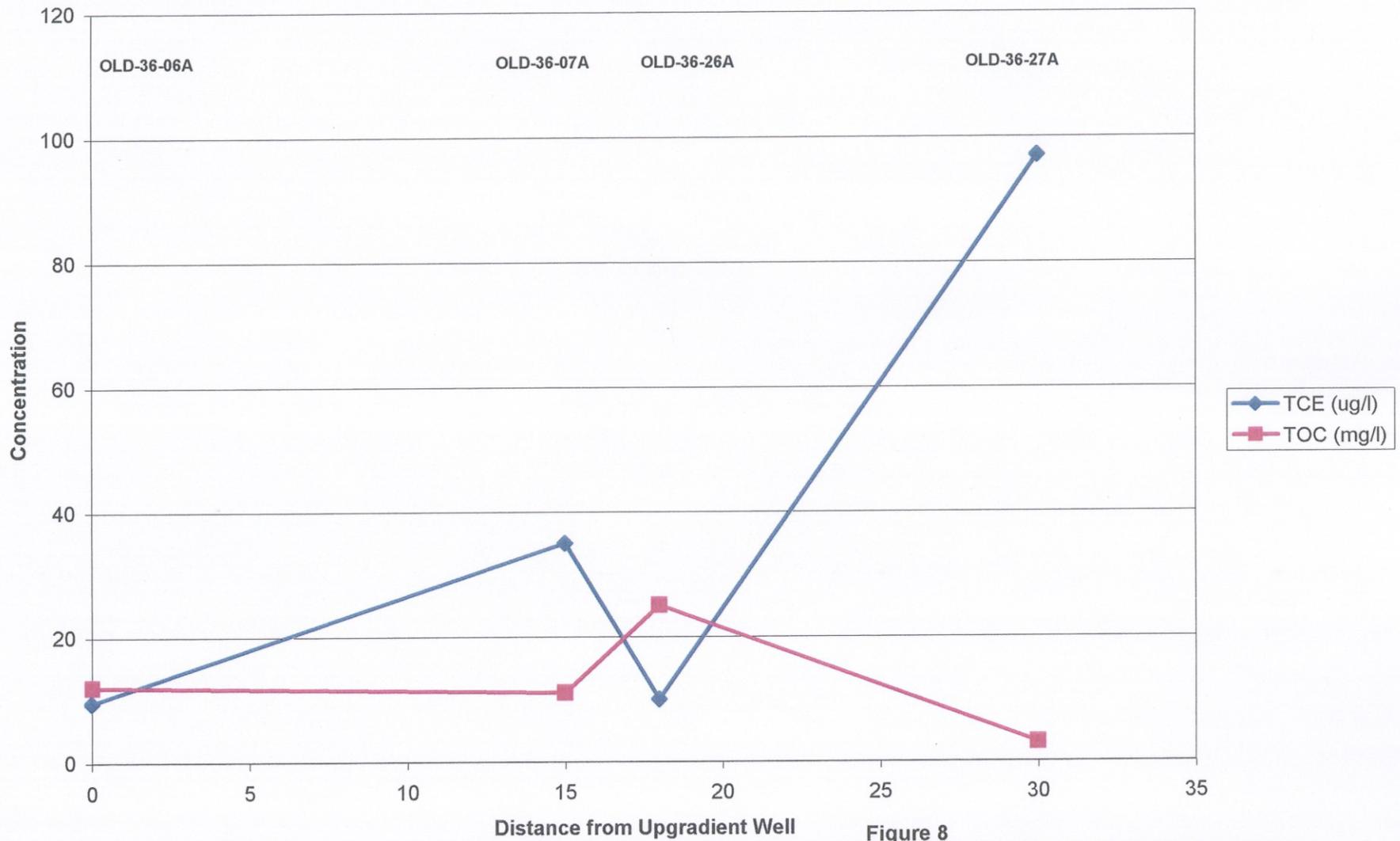


Figure 8
 TCE and TOC Concentrations in Zone A
 Study Area 36 Enhanced Bioremediation Study

TABLE 6

Values for Screening the Reductive Dechlorination Process in Groundwater Zone A at SA-36
 Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Reductive Zone Concentration OLD- 36-26A	Description	Points Awarded
Dissolved Oxygen	0.43 mg/L	Indicative of reductive dechlorination	3
Nitrate	0.02 mg/L	Indicative of Nitrate reducing conditions	2
Iron II	0.4 mg/L	Indicative of reductive dechlorination, concentration above 1 mg/L receives points	0
Sulfate	>200 mg/L	May complete the reductive dechlorination process	0
Sulfide	ND	No hydrogen sulfide reported	0
Methane	0.0085 mg/L	Concentration low to be indicative of reductive dechlorination, has increased from not being detected in previous sampling round	0
ORP	-125 mV	Reductive pathway likely	2
PH	5<pH<9	Optimal Range for reductive pathway	0
TOC	25 mg/L	Carbon and energy source	2
Temperature	>20 °C	Biological process is accelerated	1
CO ₂	Not Measured	Ultimate oxidative daughter product	0
Alkalinity	3 times background	Indicative of reductive dechlorination	1
Chloride	1.2 times background	Concentration too low to be indicative of reductive dechlorination	0
Dissolved Hydrogen	Not Measured	High concentrations indicative of reductive dechlorination process	0
Volatile fatty acids	Not Detected	Concentration too low to be indicative of reductive dechlorination	0
BTEX	Not Detected	Carbon and energy source	0
PCE	Not Detected		0
TCE	10 µg/L	Material released	0
Cis-1,2-DCE	Not Detected		0
Vinyl Chloride	Not Detected		0
Ethene/Ethane	0.000120 / 0.000064 mg/L	Concentration too low to be indicative of reductive dechlorination	0
Total			11

Notes: The total score for the above parameters are interpreted as follows:
 0 to 5 Inadequate evidence for biodegradation of chlorinated organics
 6 to 14 Limited evidence for biodegradation of chlorinated organics
 15 to 20 Adequate evidence for biodegradation of chlorinated organics
 >20 Strong evidence for biodegradation of chlorinated organics

Study Area 36 Zone B Groundwater Results

The groundwater data for Zone B at SA-36 shows a change in a few parameters between the baseline and March 2001 results. The parameter changes that are indicative of reductive dechlorination are listed below:

- The dissolved oxygen concentrations have decreased in each monitoring well from the baseline concentrations
- The dissolved gas, MEE, concentrations have increased in each of the monitoring wells from the baseline levels.
- The ORP values have decreased in every well except OLD-36-28B from the baseline measurements.
- Ferrous iron and hydrogen sulfide are reported in the groundwater which are indicative of a reductive environment.
- Sulfate concentrations have reduced in every well except OLD-36-10B.
- The TOC concentrations have either remained relatively constant or decreased in Zone B after the addition of vegetable oil which indicates it is being consumed in the subsurface.
- TCE concentrations have decreased in every well except OLD-36-10B, and the 1,2-DCE concentration has increased in one the monitoring well.

The groundwater analytical and field parameters also can be evaluated through the flow path of the plume to evaluate the reductive dechlorination process. For the purposes of this evaluation, well OLD-36-08B and OLD-36-10B were considered the upgradient and downgradient well locations, respectively, on the basis of the potentiometric map shown in Figure 9. The remaining two wells were considered source wells due to the elevated TCE concentrations.

The DO, ORP, and Cl concentrations are plotted along the flow path of the groundwater in Zone B in Figure 10. The plot shows a potential zone of reduction around well OLD-36-29B which is evidenced by a reduction in DO along with an associated spike in chloride level. However, the ORP is elevated at that location which indicates a strongly reducing environment may not exist.

The groundwater conditions in the area of OLD-36-08B (upgradient) shows the dissolved gas concentrations, MEE, (Figure 11) are elevated upgradient of Zone B and decrease within the source zone, except for ethane. However, the dissolved gas concentrations are elevated in Zone A at location OLD-36-26A which is upgradient of OLD-36-08B. It is possible that the groundwater from Zone A is migrating to Zone B in the vicinity of OLD-36-26A and OLD-36-08B.

The TOC (Figure 12) in Zone B is below 20 mg/L which indicates it is being consumed by the microbes. The TCE concentrations (Figure 12) do spike at OLD-36-29B and then reduce along the flow path. In addition, the formation of 1,2-DCE is apparent in OLD-36-10B which is indicative of the reductive dechlorination process. On the basis of the groundwater parameters measured for Zone B at SA-36, the associated score for the reductive zone is 6 which is indicative of limited evidence for the reductive dechlorination of chlorinated solvents. The tabulation of this score is shown in Table 7.

OLD-36-37C

FORMER LANGLEY STREET

LEGEND

- EXISTING MONITORING WELL 
- NEW MONITORING WELL 
- DESTROYED MONITORING WELL 
- GROUNDWATER ELEVATION (4-5-01) (FT.)  (106.25)
- GROUNDWATER CONTOUR ELEVATION (FT.)  106.00

FLOW DIRECTION 

OLD-36-20B
(104.32)

OLD-36-23C
OLD-36-22B
(103.97)

OLD-36-34B
OLD-36-35C

OLD-36-11C

OLD-36-12C

OLD-36-10B
(104.37)

FORMER DRUM RACK

OLD-36-01A

OLD-36-32C
PAVED

OLD-36-29B
(104.15)

OLD-36-27A

OLD-36-28B
(103.80)

OLD-36-08B
(104.13)

OLD-36-31C

OLD-36-30C

FORMER FLAME CABINET

OLD-36-26A

105.00

FORMER BUILDING 2017

FORMER PAVED AREA

106.00

105.00

OLD-36-24B
(106.25)

OLD-36-33A
(105.80)

FORMER BUILDING 2122

FORMER NORTH STORAGE AREA

OLD-36-36C

OLD-36-17B
(105.18)

106.00

FORMER PAVED AREA

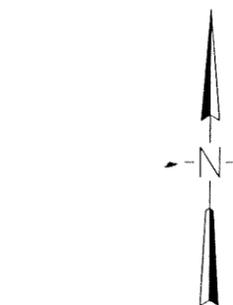


FIGURE 9
INTERMEDIATE (B) ZONE
GROUNDWATER CONTOUR MAP
SA-36
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

SOURCE:
BUILDINGS AND STREETS TAKEN FROM HLA, 1999
AND ARE SHOWN IN THEIR APPROXIMATE LOCATIONS.

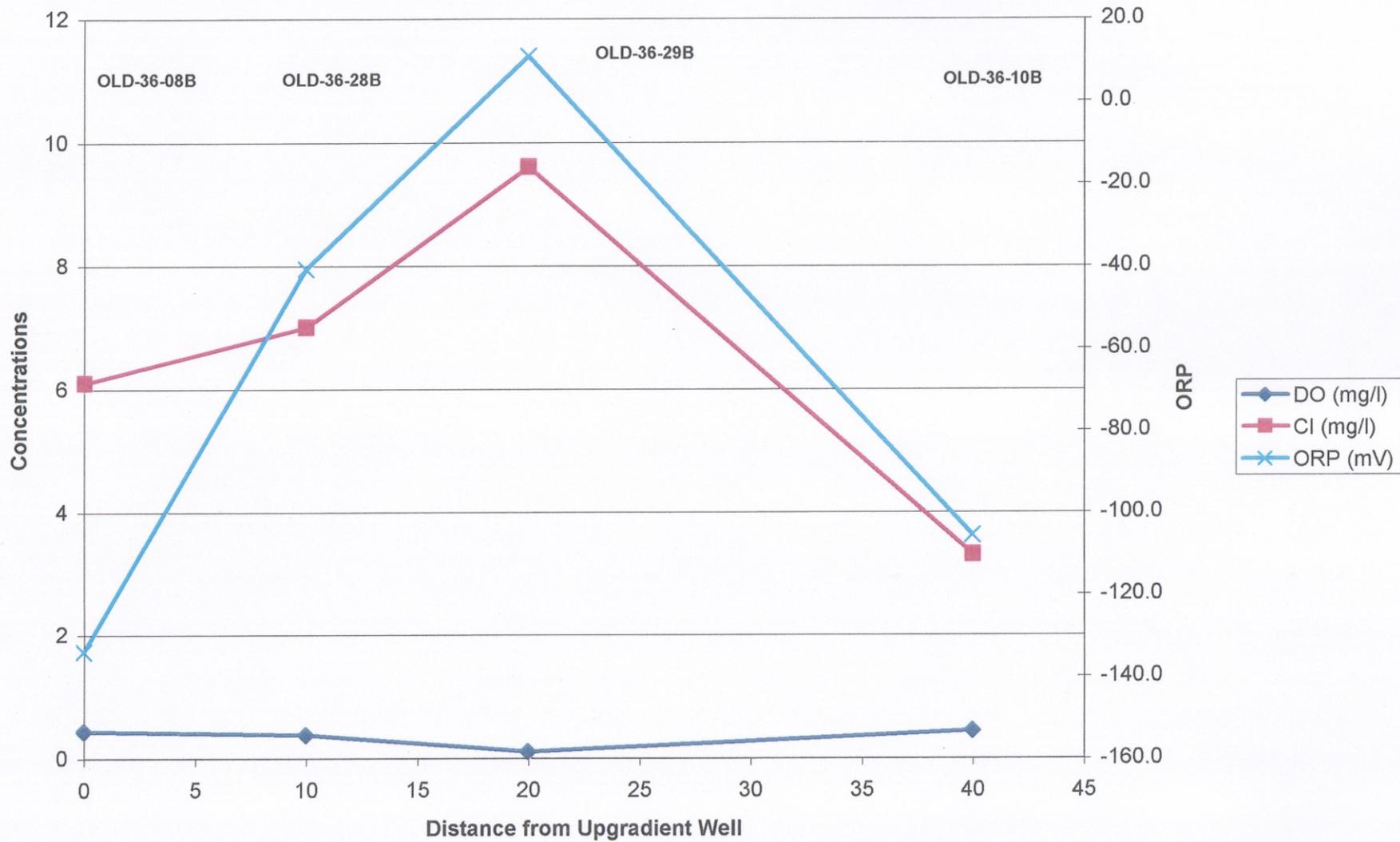


Figure 10
DO, Cl, and ORP Concentrations in Zone B
Study Area 36 Enhanced Bioremediation Study

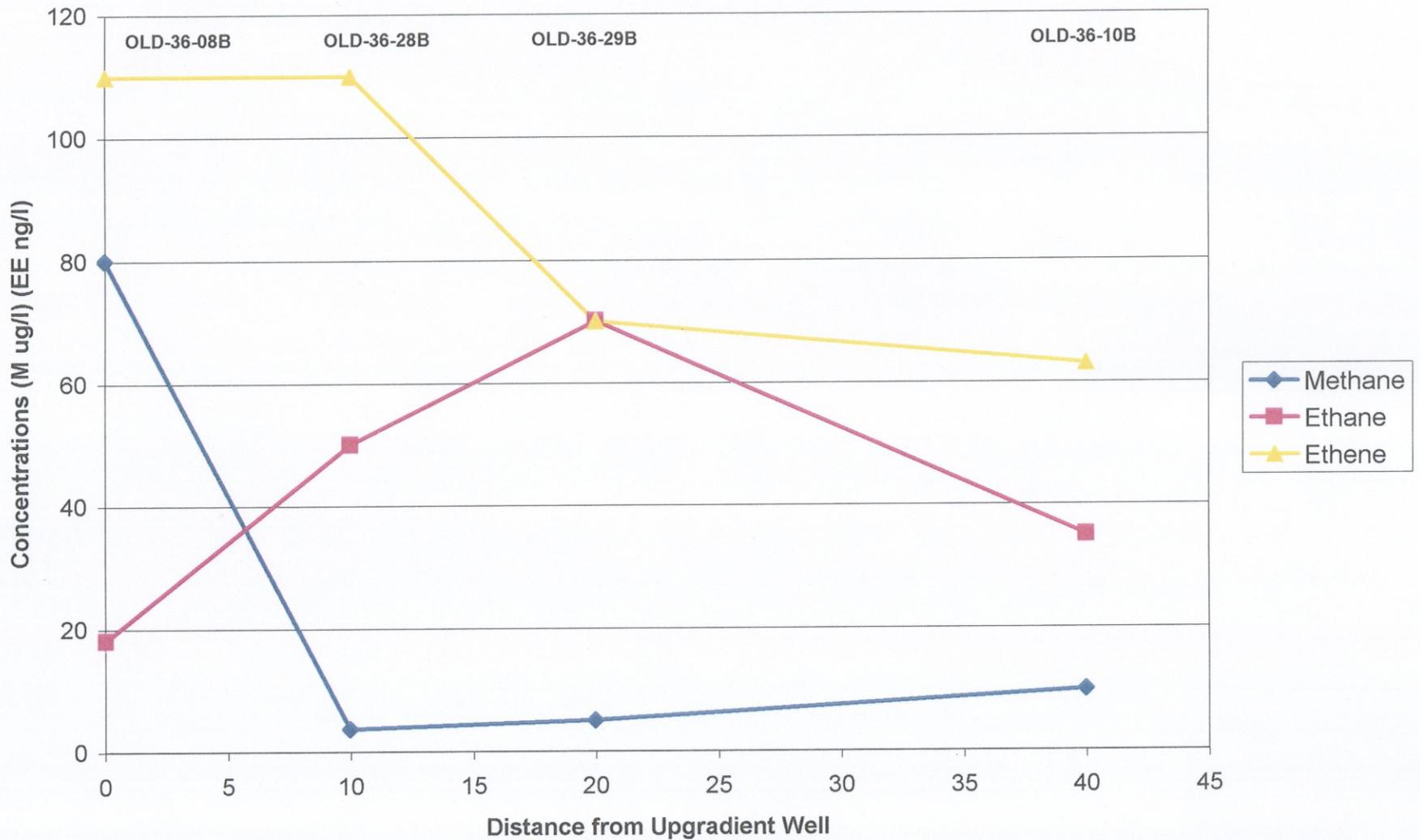


Figure 11
 Methane, Ethene and Ethane Concentrations in Zone B
 Study Area 36 Enhanced Bioremediation Study

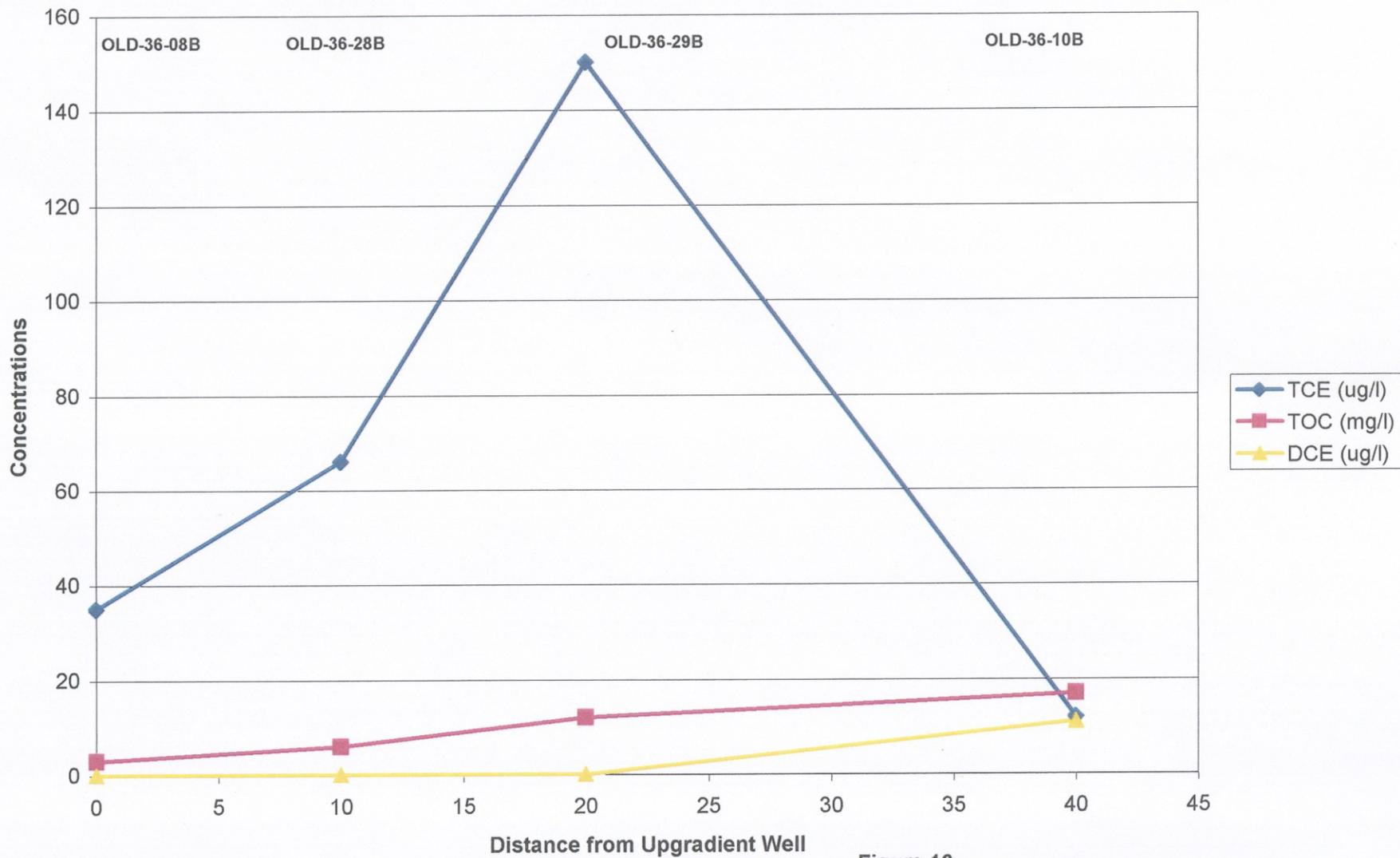


Figure 12
 TCE, DCE, and TOC Concentrations in Zone B
 Study Area 36 Enhanced Bioremediation Study

TABLE 7

Values for Screening the Reductive Dechlorination Process in Groundwater Zone B at SA-36
 Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Reductive Zone Concentration OLD-36-29B	Description	Points Awarded
Dissolved Oxygen	0.11 mg/L	Indicative of reductive dechlorination	3
Nitrate	Not Detected	Nitrate reduction pathway does not exist	2
Iron II	1.0 mg/L	Indicative of reductive dechlorination, however, concentration above 1 mg/L receives points	0
Sulfate	70 mg/L	May complete the reductive dechlorination process	0
Sulfide	0.1 mg/L	Indicative of reductive dechlorination, however, concentration above 1 mg/L receives points	0
Methane	0.005 mg/L	Concentration low to be indicative of reductive dechlorination, has increased from not being detected in previous sampling round	0
ORP	10.9 mV	Reductive pathway possible	1
pH	5<pH<9	Optimal Range for reductive pathway	0
TOC	12 mg/L	Carbon and energy source	0
Temperature	>20 °C	Biological process is accelerated	1
CO ₂	Not Measured	Ultimate oxidative daughter product	0
Alkalinity	0.5 times background	Indicative of reductive dechlorination	0
Chloride	1.6 times background	Concentration too low to be indicative of reductive dechlorination	0
Dissolved Hydrogen	Not Measured	High concentrations indicative of reductive dechlorination process	0
Volatile fatty acids	Not Detected	Concentration too low to be indicative of reductive dechlorination	0
BTEX	Not Detected	Carbon and energy source	0
PCE	Not Detected		0
TCE	150 µg/L	Material released	0
<i>Cis</i> -1,2-DCE	Not Detected		0
Vinyl Chloride	Not Detected		0
Ethene/Ethane	0.000070 / 0.000070 mg/L	Concentration too low to be indicative of reductive dechlorination	0
Total			7

Notes: The total score for the above parameters are interpreted as follows:
 0 to 5 Inadequate evidence for biodegradation of chlorinated organics
 6 to 14 Limited evidence for biodegradation of chlorinated organics
 15 to 20 Adequate evidence for biodegradation of chlorinated organics
 >20 Strong evidence for biodegradation of chlorinated organics

Study Area 36 Zone C Groundwater Results

The groundwater data for Zone C at SA-36 shows a change in a few parameters between the baseline and March 2001 results. The parameter changes that are indicative of reductive dechlorination are listed below:

- The dissolved oxygen concentrations have decreased in each monitoring well from the baseline concentrations
- The dissolved gas, MEE, concentrations have increased in each of the monitoring wells from the baseline levels.
- The ORP values have decreased in every well except OLD-36-32C from the baseline measurements.
- Ferrous iron and hydrogen sulfide are reported in the groundwater which are indicative of a reductive environment.
- Sulfate concentrations have reduced in every well except OLD-36-09C.
- The TOC concentrations have either remained relatively constant or decreased in Zone C, except for well OLD-36-31C, after the addition of vegetable oil which indicates it is being consumed in the subsurface.
- TCE concentrations have decreased or remained relatively constant in Zone C and the 1,2-DCE is present in three monitoring wells.

The groundwater analytical and field parameters also can be evaluated through the flow path of the plume to evaluate the reductive dechlorination process. For the purposes of this evaluation, well OLD-36-11C and OLD-36-30C were considered the upgradient and downgradient well locations, respectively, on the basis of the potentiometric map shown in Figure 13. The remaining two wells were considered source wells due to the elevated TCE concentrations.

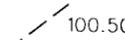
The DO, ORP, and Cl concentrations are plotted along the flow path of the groundwater in Zone B in Figure 14. The plot shows a potential zone of reduction around well OLD-36-09C that is evidenced by a reduction in ORP along with an associated spike in chloride level. In addition, the DO concentrations in Zone C are below 1 mg/L that indicates a reducing environment potentially exists. The groundwater conditions in the area of OLD-36-09C shows the dissolved gas concentrations, MEE, (Figure 15) spike, except for methane. Methane spikes in the next well along the flow path OLD-36-31C.

The TOC (Figure 16) in Zone C is below 20 mg/L, except OLD-36-31C, which indicates it is being consumed by the microbes. The TCE concentration (Figure 16) does spike at OLD-36-09C and then reduces along the flow path. In addition, the formation of 1,2-DCE is apparent in OLD-36-09C which is indicative of the reductive dechlorination process. On the basis of the groundwater parameters measured for Zone C at SA-36, the associated score for the reductive zone is 6 which is indicative of limited evidence for the reductive dechlorination of chlorinated solvents. The tabulation of this score is shown in Table 8.

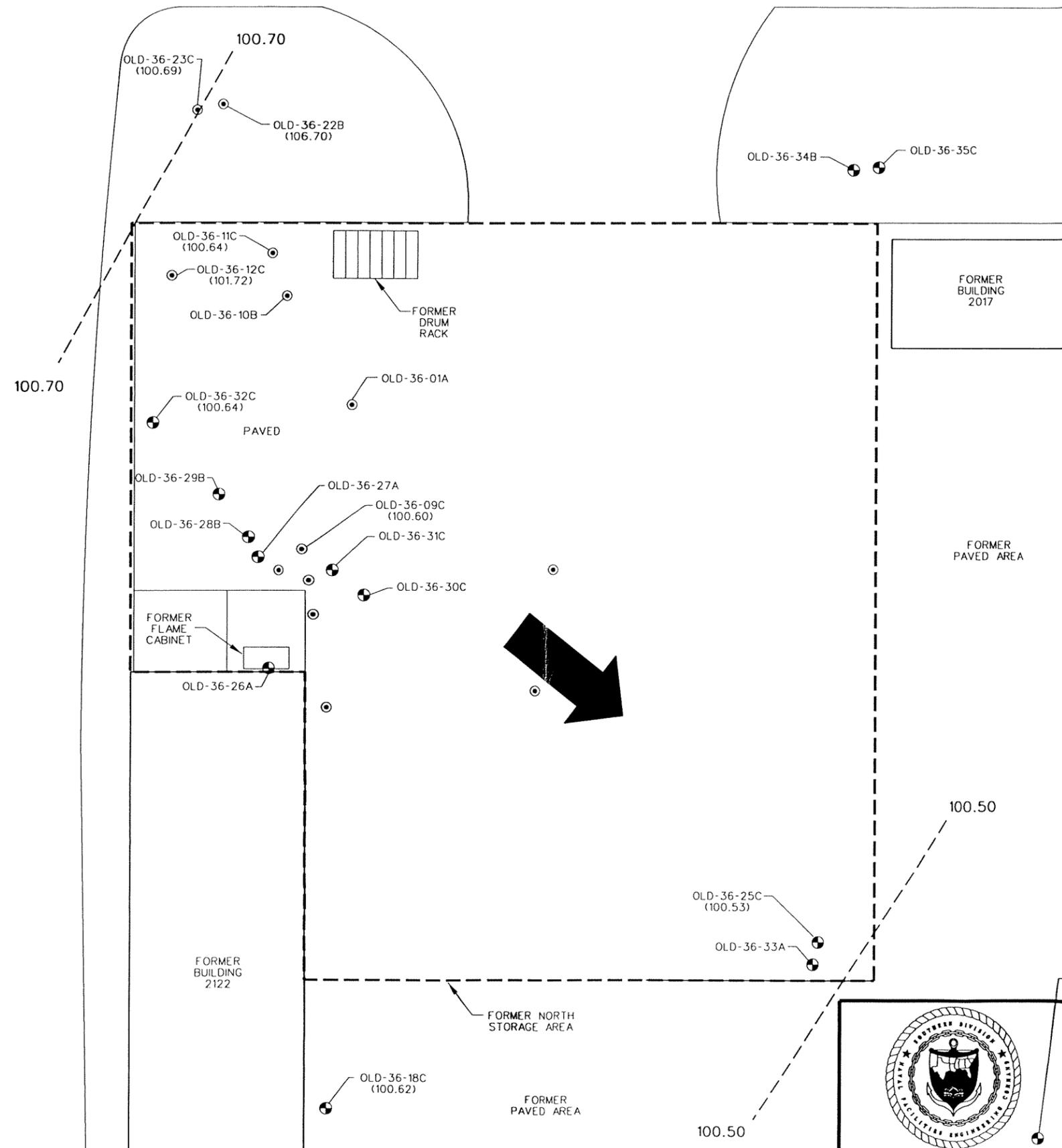
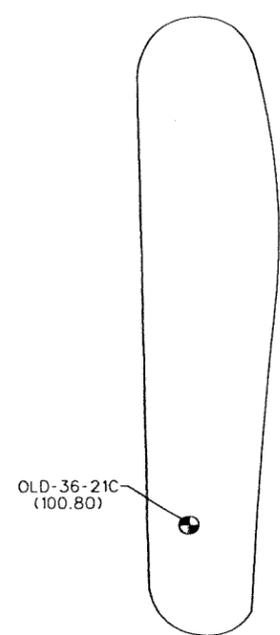
OLD-36-37C
(98.77)

FORMER LANGLEY STREET

LEGEND

- EXISTING MONITORING WELL 
- NEW MONITORING WELL 
- DESTROYED MONITORING WELL 
- GROUNDWATER ELEVATION (4-5-01) (FT.)  (100.69)
- GROUNDWATER CONTOUR ELEVATION (FT.)  100.50

GROUNDWATER FLOW DIRECTION 



FORMER BUILDING 2017

FORMER PAVED AREA

FORMER FLAME CABINET

FORMER BUILDING 2122

FORMER NORTH STORAGE AREA

FORMER PAVED AREA

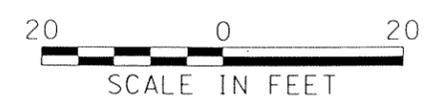
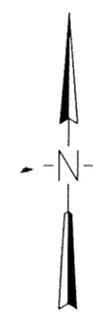


FIGURE 13
DEEP (C) ZONE
GROUNDWATER CONTOUR MAP
SA-36
 NAVAL TRAINING CENTER
 ORLANDO, FLORIDA

SOURCE:
 BUILDINGS AND STREETS TAKEN FROM H.A. 1999
 AND ARE SHOWN IN THEIR APPROXIMATE LOCATIONS.

n11x17b.dgn

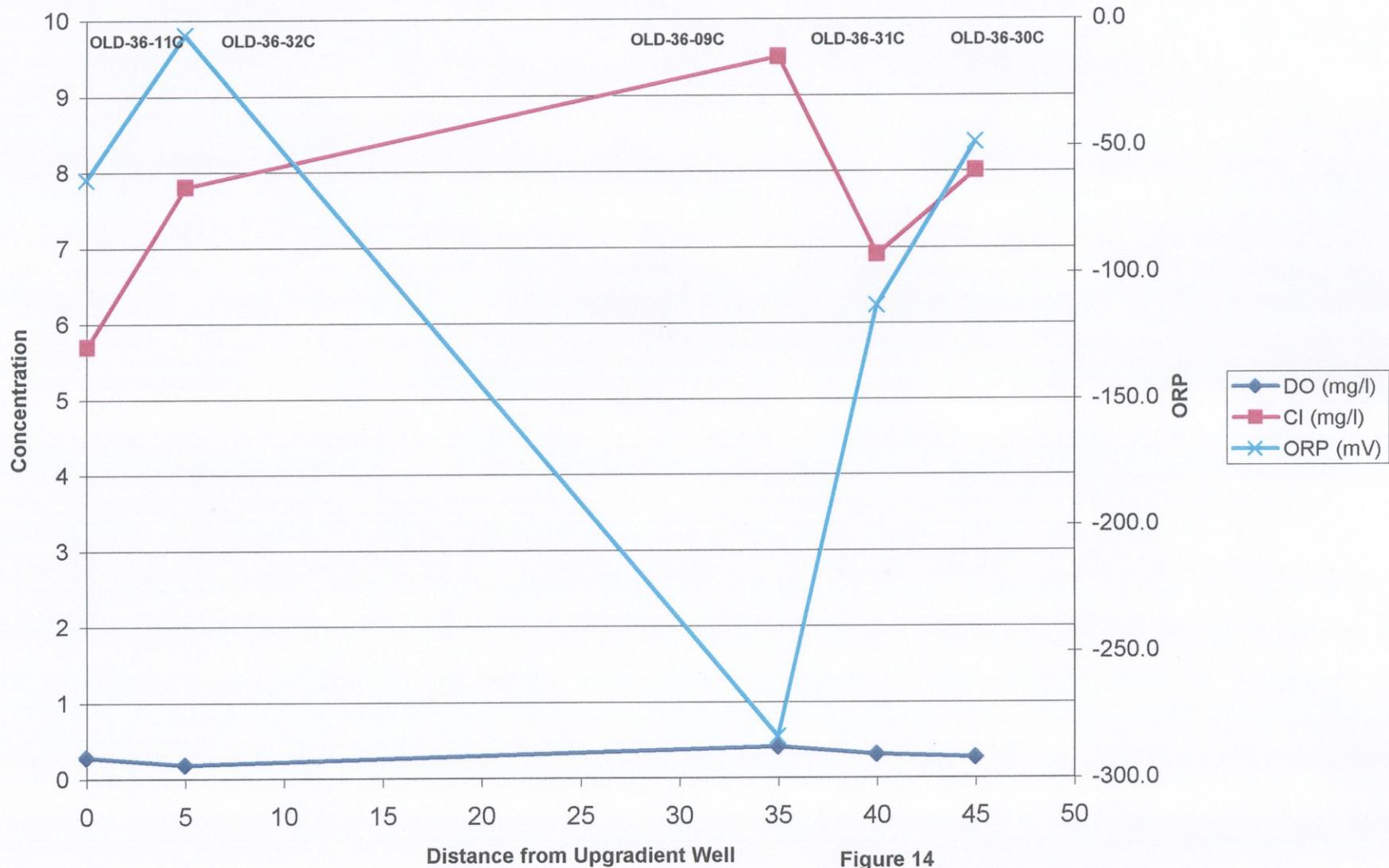


Figure 14
DO, Cl, and ORP Concentrations in Zone C
Study Area 36 Enhanced Bioremediation Study

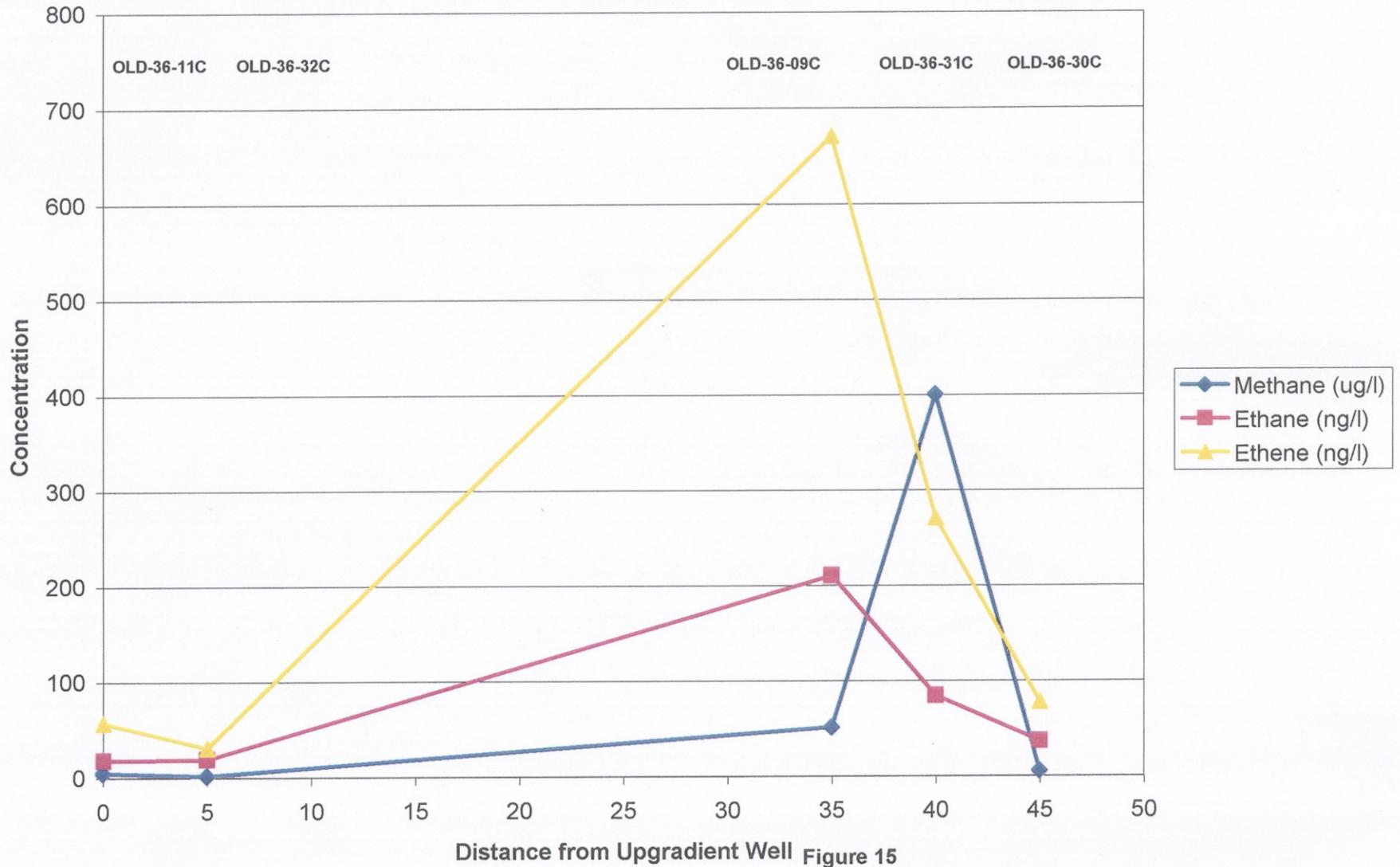


Figure 15
Methane, Ethene, and Ethane Concentrations in Zone C
Study Area 36 Enhanced Bioremediation Study

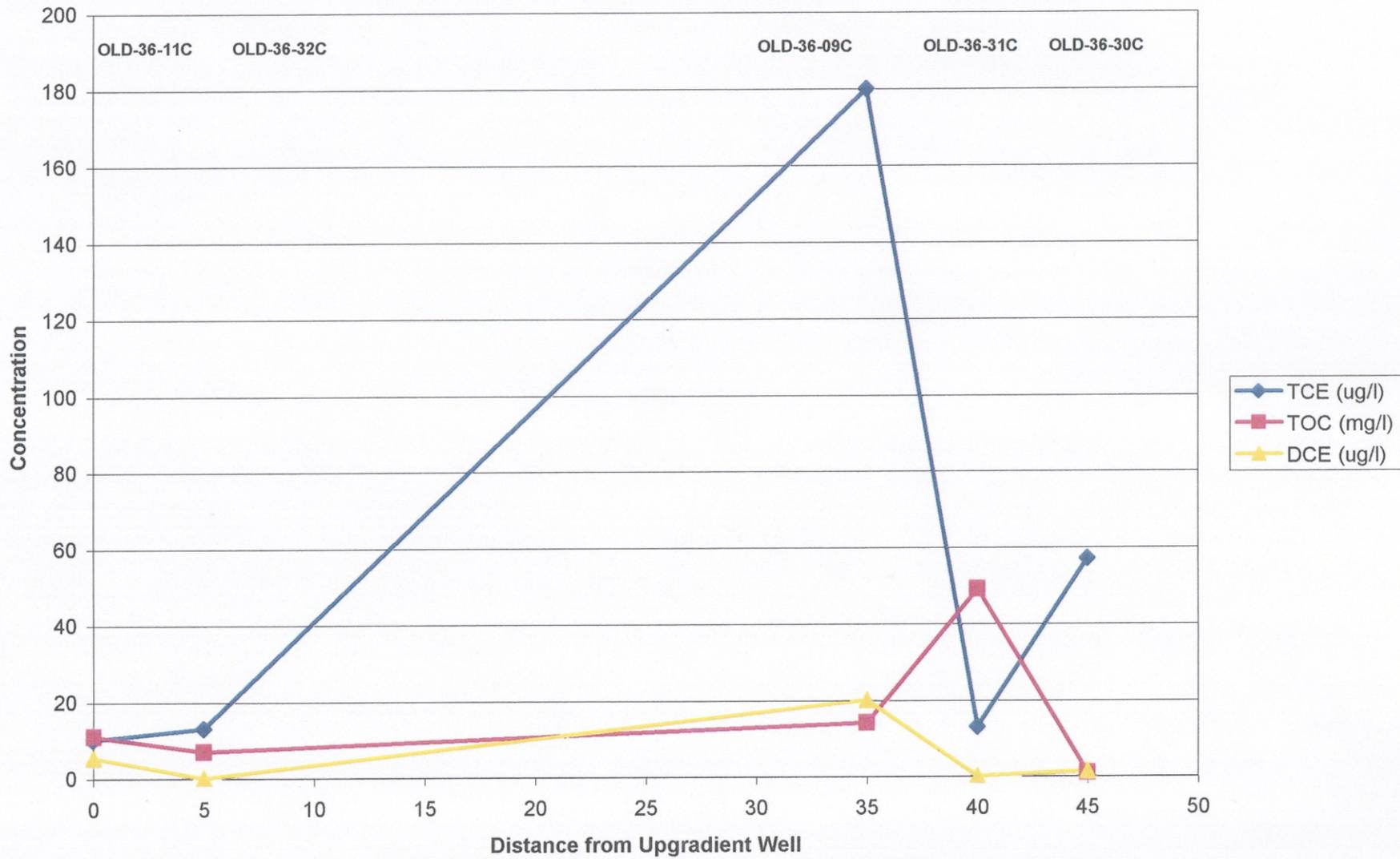


Figure 16
 TCE, TOC, and DCE Concentrations in Zone C
 Study Area 36 Enhanced Bioremediation Study

TABLE 8

Values for Screening the Reductive Dechlorination Process in Groundwater Zone C at SA-36
 Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Reductive Zone Concentration OLD- 36-09C	Description	Points Awarded
Dissolved Oxygen	0.41 mg/L	Indicative of reductive dechlorination	3
Nitrate	Not Detected	Nitrate reducing pathway does not exist	2
Iron II	0.2 mg/L	Indicative of reductive dechlorination, however, concentration above 1 mg/L receives points	0
Sulfate	>200 mg/L	May complete the reductive dechlorination process	0
Sulfide	0.5 mg/L	Indicative of reductive dechlorination, however, concentration above 1 mg/L receives points	0
Methane	0.051 mg/L	Concentration low to be indicative of reductive dechlorination, has increased from not being detected in previous sampling round	0
ORP	-283.7 mV	Reductive pathway likely	2
PH	5<pH<9	Optimal Range for reductive pathway	0
TOC	14 mg/L	Carbon and energy source	0
Temperature	>20 °C	Biological process is accelerated	1
CO ₂	Not Measured	Ultimate oxidative daughter product	0
Alkalinity	21 times background	Indicative of reductive dechlorination	1
Chloride	1.7 times background	Concentration too low to be indicative of reductive dechlorination	0
Dissolved Hydrogen	Not Measured	High concentrations indicative of reductive dechlorination process	0
Volatile fatty acids	Not Detected	Concentration too low to be indicative of reductive dechlorination	0
BTEX	Not Detected	Carbon and energy source	0
PCE	Not Detected		0
TCE	180 µg/L	Material released	0
Cis-1,2-DCE	180 µg/L	Daughter product of TCE	2
Vinyl Chloride	Not Detected		0
Ethene/Ethane	0.000670 / 0.000210 mg/L	Concentration too low to be indicative of reductive dechlorination	0
Total			11

Notes: The total score for the above parameters are interpreted as follows:
 0 to 5 Inadequate evidence for biodegradation of chlorinated organics
 6 to 14 Limited evidence for biodegradation of chlorinated organics
 15 to 20 Adequate evidence for biodegradation of chlorinated organics
 >20 Strong evidence for biodegradation of chlorinated organics

Study Area 36 Conclusions

The groundwater sampling results for SA-36 shows the potential for the enhanced biodegradation to be feasible as a remedial alternative for the TCE due to the following observations:

- Dissolved oxygen concentrations have reduced to below 0.5 mg/L in almost every well at SA-36.
- ORP values have decreased to negative values in almost every well at SA-36, and the ORP is very negative at OLD-36-09C (-283.7 mV).
- The nitrate concentrations are below 1 mg/L in the groundwater zones beneath SA-36; therefore, nitrate reduction should not interfere with the reductive dechlorination process.

It appears that the addition of vegetable oil has created a reducing environment in the groundwater. However, it is apparent that elevated levels of sulfate reported in the baseline sampling round have reduced in almost every well at SA-36. The sulfate reductions are most noticeable in Zones B and C beneath SA-36. The TOC concentrations in most of the wells have either remained the same or reduced since the baseline sampling round and the addition of vegetable oil. Therefore, on the basis of the sulfate and TOC data, it appears that the microorganisms beneath SA-36 have utilized the added TOC (vegetable oil) to reduce the sulfate that is present beneath the site.

Study Area 36 Recommendations

The following recommendations, if implemented, should provide additional data for evaluating the enhanced biodegradation process and enhance the TCE reduction in the groundwater beneath SA-36.

- Groundwater monitoring should continue to be conducted on a quarterly basis.
- The groundwater analysis for methane, ethene, and ethane should be modified by adding carbon dioxide. Alternatively, carbon dioxide can be measured in the field using a HACH test kit.
- The reporting limit for sulfate should be reduced from 50 to 20 mg/L or lower in order to evaluate the potential for reductive dechlorination according to the scoring protocol.
- Dissolved hydrogen concentrations should be obtained using a method developed by Microseeps. The dissolved hydrogen concentrations will allow for the evaluation of the terminal electron accepting process and the proper scoring of the groundwater plume.
- One additional well should be sampled that is screened in Zone A that is located downgradient of OLD-36-27A due to the elevated levels of TCE reported in the well.
- One additional well should be sampled that is screened in Zone B that is located upgradient and/or in an unaffected area of the study area due to the elevated levels of TCE and dissolved gasses (MEE) in OLD-36-08B.
- Another round of vegetable oil injections should be performed at SA-36 due to the demand on the initial injections by the sulfate present in the groundwater. In order for the TCE to be reduced in the groundwater, the sulfate must be reduced first which will require additional TOC. The sulfate will most likely be reduced with an additional round of vegetable oil injections; however, a third round of vegetable oil injections may

be required for the TCE to be reductively dechlorinated due to the second round of vegetable oil injections being consumed by the sulfate reducing microorganisms.

Study Area 39 Groundwater Sampling Results

Groundwater samples were collected from each of the three aquifer zones beneath SA-39. The groundwater samples were collected from the wells in each zone as listed in Table 9 and the analytical results for the baseline and February 2001 samples are listed in Table 10.

TABLE 9
Wells Sampled at Study Area 39
Enhanced Bioremediation Study, Naval Training Center Orlando, Florida

Zone A	Zone B	Zone C
OLD-39-03A	OLD-39-35B	OLD-39-37C
OLD-39-08A	OLD-39-38B	
OLD-39-09A	OLD-39-42B	
OLD-39-47A	OLD-39-43B	
OLD-39-48A	OLD-39-44B	
	OLD-39-45B	
	OLD-39-46B	

Study Area 39 Zone A Groundwater Results

The groundwater data for Zone A at SA-39 shows a change in a few parameters between the baseline and February 2001 results. The significant findings which indicate that natural attenuation may be occurring are as follows:

- The dissolved oxygen in the monitoring wells either remained the same or decreased which is an indication of microbial activity.
- Nitrate concentrations in every well except OLD-39-48A have decreased which is an indication of nitrate reducing conditions.
- The methane, ethane, and ethene concentrations have increased overall in Zone A which indicates that the reductive dechlorination process may be occurring.
- The chloride concentrations have increased in all wells except OLD-39-03A and OLD-39-08A.

The groundwater analytical and field parameters also can be evaluated through the flow path of the plume to evaluate the reductive dechlorination process. For the purposes of this evaluation, well OLD-39-03A was considered the upgradient well location on the basis of the potentiometric map shown in Figure 17. The two wells were considered source wells due to the elevated TCE concentrations OLD-39-47A and OLD-39-48A. The most downgradient well sampled was OLD-39-09A.

TABLE 10
Natural Attenuation Parameters
SA-39, NTC Orlando

Field Test Kit Parameters (mg/L)								Analytical Laboratory Data									
Station ID	Date	Ferrous Iron	Manganese	Hydrogen Sulfide		Dissolved Oxygen	Oxidation Reduction Potential (mV)	Alkalinity (mg/L)	Chloride (mg/L)	Nitrate/Nitrite (mg/L)	TOC (mg/L)	Methane (ug/L)	Ethane (ug/L)	Ethene (ug/L)	Volatile Fatty Acids (mg/L)	PCE (ug/L)	TCE (ug/L)
				Sulfate	Sulfide												
OLD-39-46B	10/04/2000	0.60	0	0.5	60	0.13	92	37	34.5	ND	44.5	9.5	0.045	0.18	ND	1.6 J	ND
OLD-39-46B	02/06/2001	0.65	0	0.3	<50	0.34	72.7	ND	26.5	ND	2.0	2.8	0.023	0.030	ND	15	ND
OLD-39-45B	10/04/2000	0.40	0	0.4	104	0.16	-12	200	32.0	ND	46.4	6.8	0.53	0.34	ND	18	ND
OLD-39-45B	02/06/2001	0.60	0	0.3	<50	0.31	-25.9	68	16.7	ND	6.0	2.6	0.046	0.061	ND	20	0.89 J
OLD-39-38B	10/06/2000	0.80	0	0.6	<50	0.05	26	ND	36.0	ND	3.58	0.68	0.037	0.064	ND	58	ND
OLD-39-38B	02/06/2001	0.75	0	0.4	<50	0.36	60	ND	14.1	ND	ND	4	0.064	0.099	ND	40	0.79 J
OLD-39-42B	10/06/2000	0.35	0.1	0.3	75	0.10	109	78	15.6	ND	23.7	2.0	0.084	0.140	ND	40	1.1 J
OLD-39-42B	02/05/2001	1.00	0	0.8	<50	0.44	-49.20	20	8.4	ND	11.0	38	0.034	0.087	ND	28	0.88 J
OLD-39-44B	10/06/2000	0.40	0	0.6	100	0.15	10	26	21.0	ND	37.8	1.7	0.078	0.120	ND	29	0.79 J
OLD-39-44B	02/06/2001	1.00	0	0.5	<50	0.40	52.1	2.5	8.5	ND	3.0	1.7	0.036	0.096	ND	28	0.73 J
OLD-39-36A	10/06/2000	0.20	0	0.4	>200	0.65	-21	260	18.5	2.24	37.2	22	ND	0.028	ND	0.54 J	ND
OLD-39-43B	10/09/2000	0.30	0.1	0.5	<100	0.10	-180	83	17.2	ND	34.6	1.1	0.036	0.098	ND	25	1.1 J
OLD-39-43B	02/07/2001	0.60	0	0.8	<50	0.42	19.60	8.5	7.0	ND	2.0	21	0.031	0.130	ND	20	0.81 J
OLD-39-35B	10/09/2000	0.70	0	0.25	<50	<0.05	21	ND	11.8	ND	4.41	1.8	ND	0.078	ND	52	1.8 J
OLD-39-35B	02/07/2001	0.50	0	1.5	<50	0.35	20.6	ND	7.9	0.01	ND	69	0.051	0.068	ND	48	1.9 J
OLD-39-37C	10/09/2000	0	0	0.5	<50	0.20	-119	210	5.40	ND	15.5	3.0	0.068	0.510	ND	7.0	0.66 J
OLD-39-37C	02/07/2001	0	0	0.3	40	0.20	-141.3	170	4.90	0.02	12.0	2.8	0.031	0.200	ND	7.2	0.79 J
OLD-39-47A	10/10/2000	0.20	0	0.2	<50	0.70	-136	81	4.60	ND	12.70	0.73	ND	0.029	ND	24	0.76 J
OLD-39-47A	02/07/2001	0	0	0.2	55	0.45	-13.1	29	7.90	ND	12.00	6.8	0.130	0.120	ND	42	1.4 J
OLD-39-48A	10/10/2000	0.10	0	0.1	<50	>1	-81	200	5.80	0.290	7.20	100	ND	0.025	ND	10	ND
OLD-39-48A	02/07/2001	0	0	0	125	1.49	8.5	140	16.10	1.020	8.00	7.9	0.130	0.100	ND	20	0.80 J
OLD-39-08A	10/10/2000	0	0	0.1	150	0.45	-160	74	42.00	7.25	7.69	1.7	ND	0.023	ND	27	ND
OLD-39-08A	02/08/2001	0	0	0	55	0.55	210.5	18	7.90	0.19	9.00	4.2	0.026	0.027	537	30	1.0 J
OLD-39-03A	10/10/2000	0	0	<0.1	<20	>1.0	-59	94	6.30	1.25	5.89	0.26	ND	ND	ND	5.4 J	ND
OLD-39-03A	02/08/2001	0	0	0	<50	>1.0	198.9	67	3.60	1.13	6.00	0.31	ND	ND	50	11	ND
OLD-39-09A	10/10/2000	0	0	<0.1	<50	>1.0	-100	160	2.90	0.360	5.16	0.4	ND	ND	ND	5.5 J	ND
OLD-39-09A	02/08/2001	0	0	0	<50	0.69	191	73	7.30	0.030	12.00	2.3	0.022	0.042	890	19	2.0 J
OLD-39-07B	10/10/2000	0.40	0	0.3	<50	0.1	-2	3.0	3.90	ND	9.92	0.73	ND	0.028	ND	9.6	ND

Reductive dechlorination brings about measurable changes in the chemistry of the groundwater in the affected area. By measuring these changes, one can document and quantitatively evaluate the reductive dechlorination process. Some of the common analytes measured during natural attenuation are discussed below:

Dissolved Oxygen - DO levels should be below 1.0 mg/L for anaerobic degradation

Nitrate - After oxygen is depleted during the degradation process, nitrate may be used as an electron acceptor for anaerobic degradation. Conc's should be low <1.

Ferrous Iron - Also used as an electron acceptor during anaerobic biodegradation. Conc's should be >1 mg/L for reductive pathway.

Sulfate - After oxygen, nitrate, and iron have been depleted, sulfate may be used as the electron acceptor. Sulfate reduction produces sulfide. Conc's should be low (<20)

Sulfide - Concentrations should increase if the sulfate reduction process is occurring. Conc's should be >1 mg/L.

Methane - After oxygen, nitrate, iron and sulfate have been depleted, methanogenesis occurs where carbon dioxide is used as the electron acceptor and methane is produced. The presence of methane in gw is indicative of strongly reducing conditions.

Ethane and Ethene - Are produced during reductive dechlorination. Conc's should increase.

TOC - Total Organic Carbon is used to determine whether anaerobic metabolism of chlorinated solvents is possible in the absence of anthropogenic carbon.

Alkalinity - The total alkalinity of the gw is indicative of a water's capacity to neutralize acid which is generated during aerobic and anaerobic biodegradation. Conc's should increase.

Oxidation Reduction Potential - The redox potential of gw is a measure of electron activity and is an indicator of the relative tendency of a solution to accept or transfer electrons. Redox conc's should be <50 and even better if negative which shows iron, sulfate or methanogenesis reducing conditions.

Chloride - Chloride and conductivity data is used to ensure that water is being collected or measured in the correct hydrogeologic zone.

Volatile Fatty Acids - VFAs are produced as metabolic byproducts during the biodegradation of BTEX compounds. Conc's should be >0.1 mg/L

LEGEND

- EXISTING MONITORING WELL 
- NEW MONITORING WELL 
- DESTROYED MONITORING WELL 
- GROUNDWATER ELEVATION (4-5-01) (FT.)  (101.45)
- GROUNDWATER CONTOUR ELEVATION (FT.)  103.00
- GROUNDWATER FLOW DIRECTION 

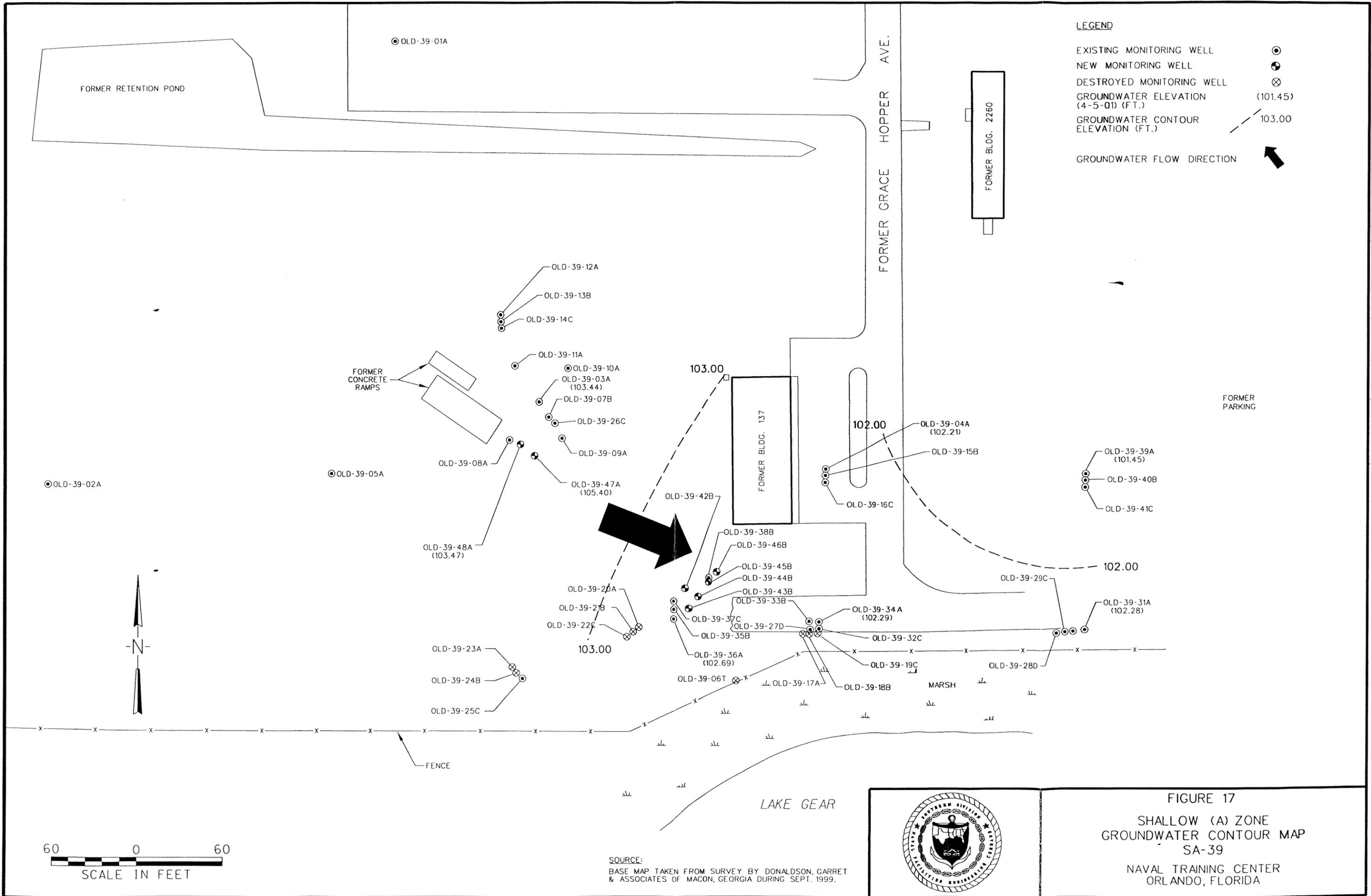


FIGURE 17
 SHALLOW (A) ZONE
 GROUNDWATER CONTOUR MAP
 SA-39
 NAVAL TRAINING CENTER
 ORLANDO, FLORIDA

The DO, ORP, NO₃ and Cl concentrations are plotted along the flow path of the groundwater in Zone A in Figure 18. The plot shows a potential zone of reduction around well OLD-39-47A and OLD-39-48A which is evidenced by a reduction in ORP, NO₃ and DO along with an associated spike in chloride level. In addition, this reductive zone shows an elevation in methane concentration (Figure 19). The PCE and TOC (Figure 20) concentrations vary along the flow path; however, both parameters decrease at OLD-39-48A. There is no TCE, DCE, or vinyl chloride reported in the reductive zone around OLD-39-47A or the remainder of the groundwater plume. On the basis of the groundwater parameters measured for Zone A at SA-39, the associated score for the reductive zone is 10 which is indicative of limited evidence for the reductive dechlorination of chlorinated solvents. The tabulation of this score is shown in Table 11.

Study Area 39 Zone B Groundwater Results

The groundwater data for Zone B at SA-39 shows a change in a few parameters between the baseline and February 2001 results. The intermediate (B zone) groundwater contour map is shown on Figure 21. The significant findings for the indicator parameters for natural attenuation are as follows:

- The dissolved oxygen concentrations increased in all monitoring wells at each site which indicates the microbial activity has reduced, groundwater recharge has increased significantly between sampling events, or the DO meters were not functioning correctly during either the baseline or February 2001 sampling event.
- The ORP in monitoring wells OLD-39-42B and OLD-39-45B decreased which is an indication of microbial activity. However, the ORP did increase in the groundwater at the remaining wells which can be attributed to the increase in DO in the groundwater.
- The ferrous iron concentrations have increased in 5 of the 7 wells and is the same in the remaining two wells which is indicative of iron reducing conditions.
- Sulfate concentrations have reduced in all 7 wells at SA-39 and sulfide concentrations have either increased or remained constant, which is indicative of sulfate reducing conditions.
- The methane, ethane, and ethene concentrations have decreased or remained constant in Zone B which indicates that the reductive dechlorination process may be decreasing or proceeding at a low rate.
- The chloride concentrations have decreased in all wells which indicates that the reductive dechlorination process may be decreasing or proceeding at a low rate.
- The TOC concentrations in each well has decreased which is indicative of microbial activity.

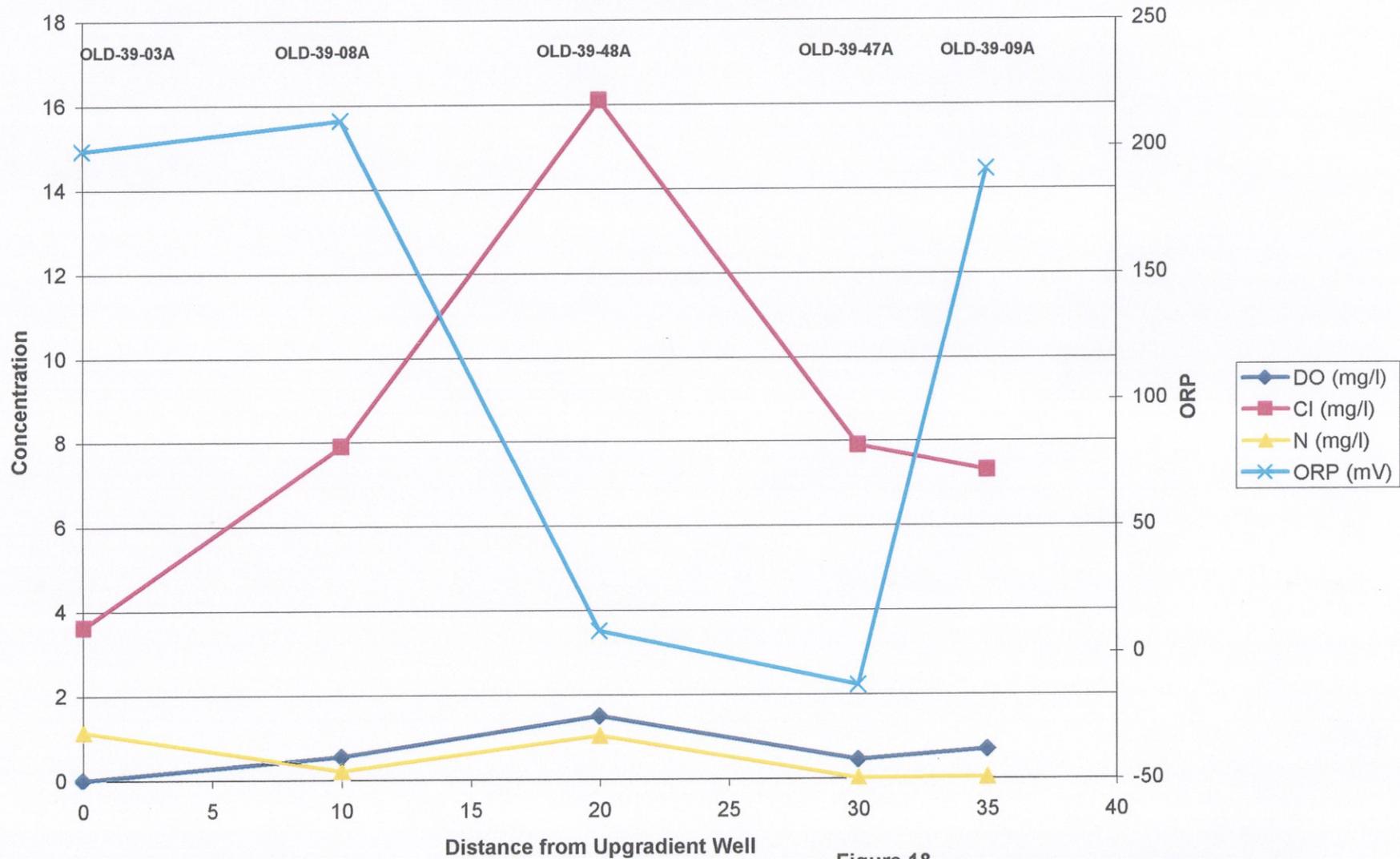


Figure 18
DO, Cl, NO3 and ORP Concentrations in Zone A
Study Area 39 Enhanced Bioremediation Study

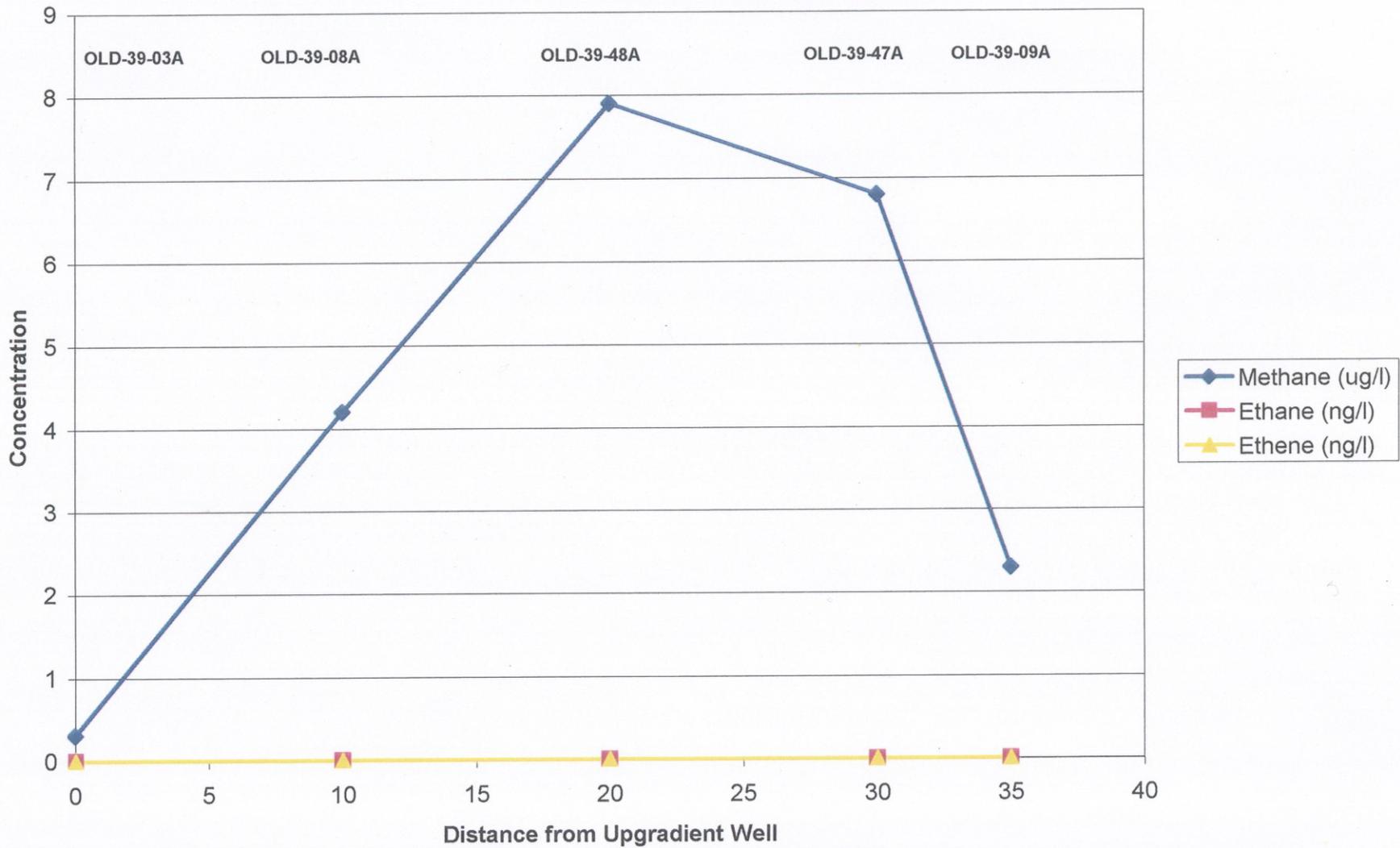


Figure 19
Methane, Ethene, and Ethane Concentrations in Zone A
Study Area 39 Enhanced Bioremediation Study

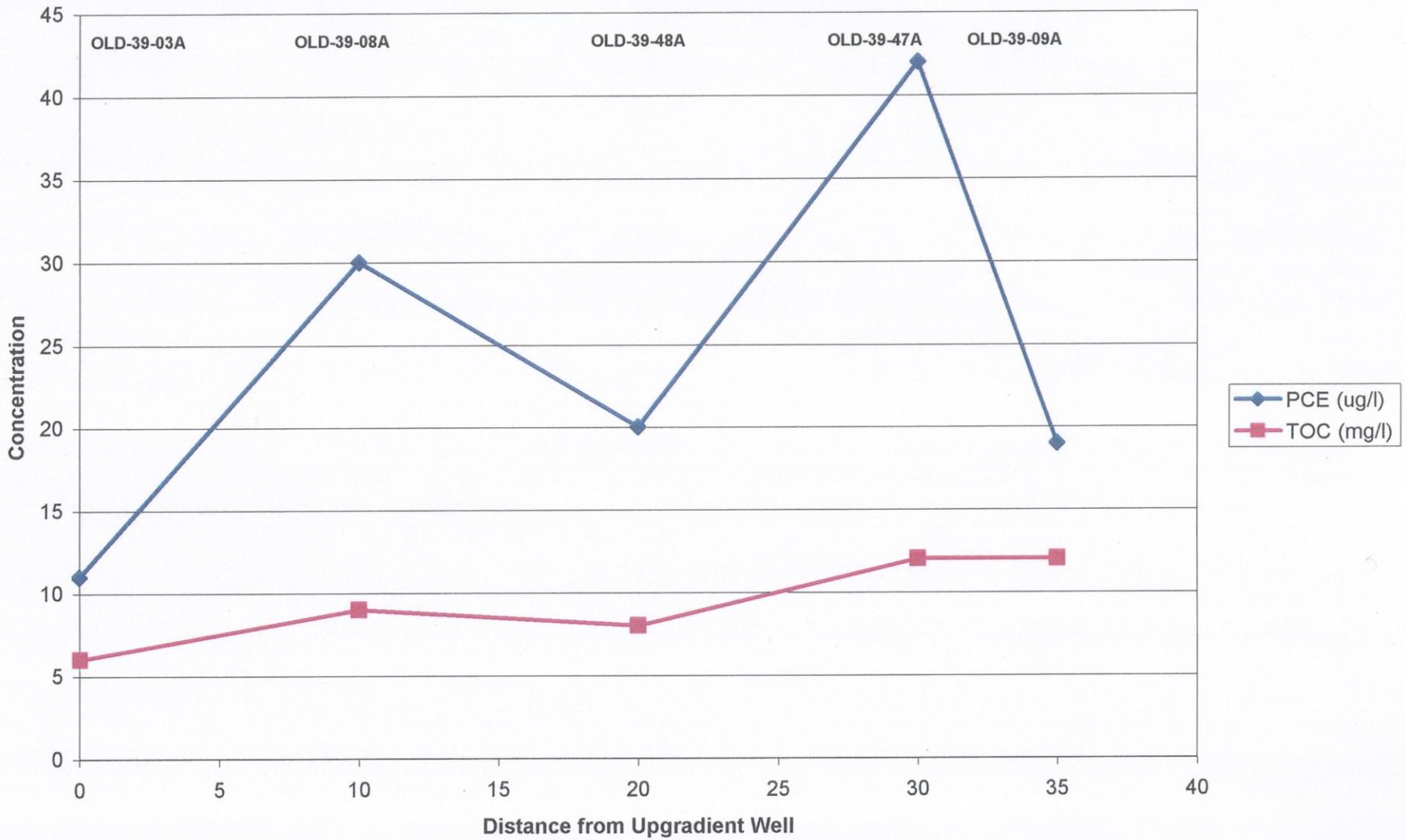
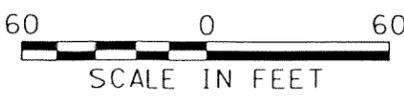
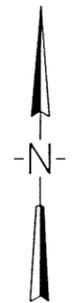
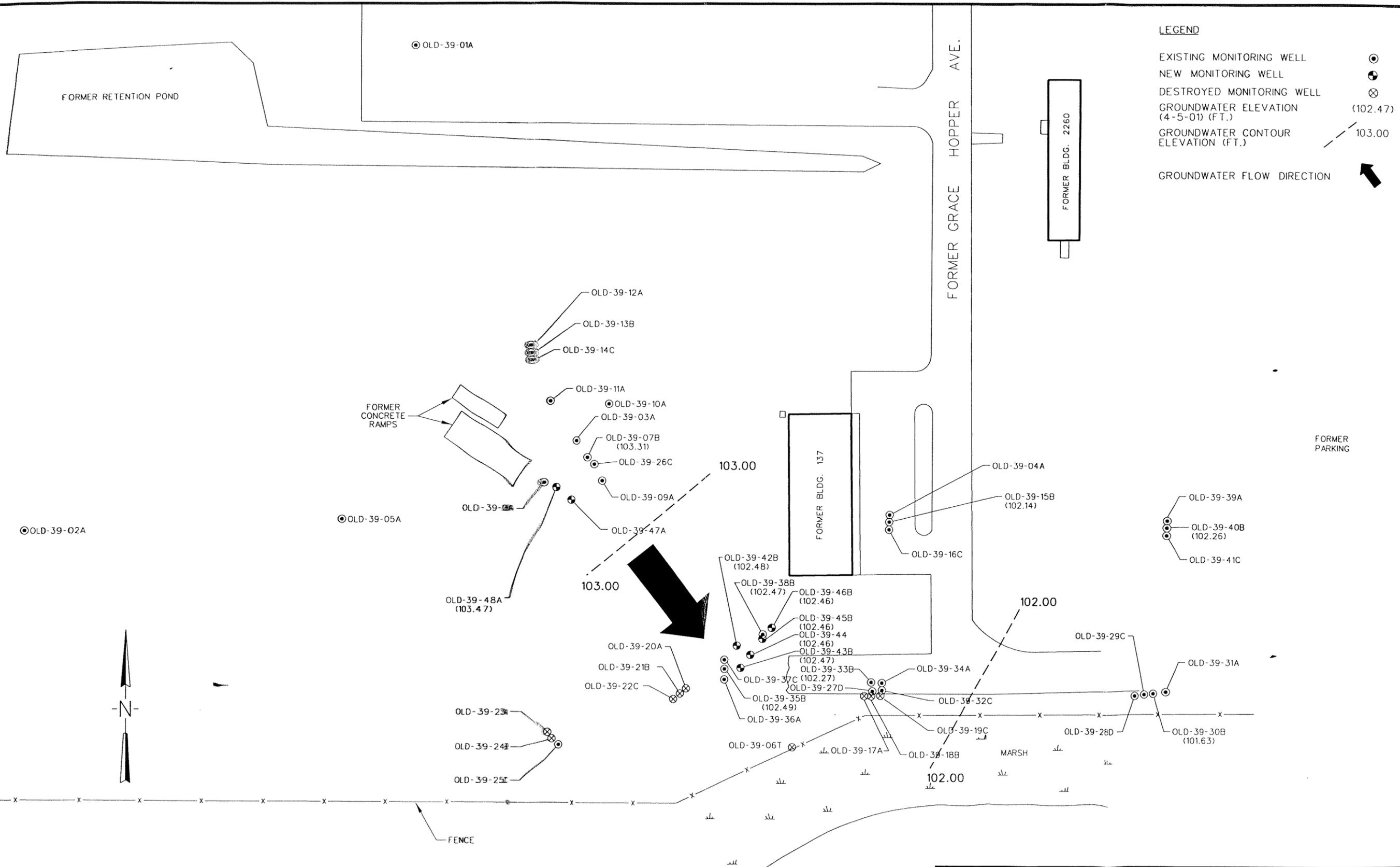


Figure 20
 PCE and TOC Concentrations in Zone A
 Study Area 39 Enhanced Bioremediation Study

LEGEND

- EXISTING MONITORING WELL 
- NEW MONITORING WELL 
- DESTROYED MONITORING WELL 
- GROUNDWATER ELEVATION (4-5-01) (FT.)  (102.47)
- GROUNDWATER CONTOUR ELEVATION (FT.)  103.00
- GROUNDWATER FLOW DIRECTION 



SOURCE:
 BASE MAP TAKEN FROM SURVEY BY DONALDSON, GARRET & ASSOCIATES OF MACON, GEORGIA DURING SEPT. 1999.



FIGURE 21
 INTERMEDIATE (B) ZONE
 GROUNDWATER CONTOUR MAP
 SA-39
 NAVAL TRAINING CENTER
 ORLANDO, FLORIDA

n11x17b.dgn

TABLE 11

Values for Screening the Reductive Dechlorination Process in Groundwater Zone A at SA-39
 Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Reductive Zone Concentration OLD- 39-47A	Description	Points Awarded
Dissolved Oxygen	0.45 mg/L	Indicative of reductive dechlorination	3
Nitrate	Not Detected	Nitrate reducing pathway not present	2
Iron II	Not Detected	Indicative of reductive dechlorination, concentration above 1 mg/L receives points	0
Sulfate	55 mg/L	May complete the reductive dechlorination process	0
Sulfide	0.2 mg/L	Sulfide concentration should be greater than 1 mg/L for reductive dechlorination in the presence of sulfate	0
Methane	0.0068 mg/L	Concentration low to be indicative of reductive dechlorination, has increased from not being detected in previous sampling round	0
ORP	-13.1 mV	Reductive pathway possible	1
PH	5<pH<9	Optimal Range for reductive pathway	0
TOC	12 mg/L	Carbon and energy source	0
Temperature	>20 °C	Biological process is accelerated	1
CO ₂	Not Measured	Ultimate oxidative daughter product	0
Alkalinity	0.43 times background	Low alkalinity	0
Chloride	2.2 times background	Indicative of reductive dechlorination	2
Dissolved Hydrogen	Not Measured	High concentrations indicative of reductive dechlorination process	0
Volatile fatty acids	Not Detected	Concentration too low to be indicative of reductive dechlorination	0
BTEX	Not Detected	Carbon and energy source	0
PCE	42 µg/L	Material Released	0
TCE	1.4 J µg/L	Daughter product of PCE	2
Cis-1,2-DCE	Not Detected		0
Vinyl Chloride	Not Detected		0
Ethene/Ethane	0.000000130 / 0.000000120 mg/L	Concentration too low to be indicative of reductive dechlorination	0
Total			11

Notes: The total score for the above parameters are interpreted as follows:
 0 to 5 Inadequate evidence for biodegradation of chlorinated organics
 6 to 14 Limited evidence for biodegradation of chlorinated organics
 15 to 20 Adequate evidence for biodegradation of chlorinated organics
 >20 Strong evidence for biodegradation of chlorinated organics

On the basis of the groundwater parameters measured for Zone B at SA-39, the associated score for the reductive zone is 11 which is indicative of limited evidence for the reductive dechlorination of chlorinated solvents. The tabulation of this score is shown in Table 12.

TABLE 12

Values for Screening the Reductive Dechlorination Process in Groundwater Zone B at SA-39
Enhanced Bioremediation Study, Naval Training Center, Orlando, Florida

Parameter	Reductive Zone Concentration OLD- 39-35B	Description	Points Awarded
Dissolved Oxygen	0.35 mg/L	Indicative of reductive dechlorination	3
Nitrate	0.01 mg/L	Nitrate reducing pathway not present	2
Iron II	0.50 mg/L	Indicative of reductive dechlorination, concentration above 1 mg/L receives points	0
Sulfate	<50 mg/L	May complete the reductive dechlorination process	0
Sulfide	1.5 mg/L	Sulfide is a byproduct of sulfate reduction	3
Methane	0.069 mg/L	Concentration low to be indicative of reductive dechlorination, has increased from not being detected in previous sampling round	0
ORP	20.6 mV	Reductive pathway possible	1
PH	5<pH<9	Optimal Range for reductive pathway	0
TOC	Not Detected	Carbon and energy source	0
Temperature	>20 °C	Biological process is accelerated	1
CO ₂	Not Measured	Ultimate oxidative daughter product	0
Alkalinity	0.43 times background	Low alkalinity	0
Chloride	0.3 times background	Not indicative of reductive dechlorination	0
Dissolved Hydrogen	Not Measured	High concentrations indicative of reductive dechlorination process	0
Volatile fatty acids	Not Detected	Concentration too low to be indicative of reductive dechlorination	0
BTEX	Not Detected	Carbon and energy source	0
PCE	48 µg/L	Material Released	0
TCE	1.9 J µg/L	Daughter product of PCE	2
Cis-1,2-DCE	Not Detected		0
Vinyl Chloride	Not Detected		0
Ethene/Ethane	0.000000068 / 0.000000051 mg/L	Concentration too low to be indicative of reductive dechlorination	0
Total			12

Notes: The total score for the above parameters are interpreted as follows:
 0 to 5 Inadequate evidence for biodegradation of chlorinated organics
 6 to 14 Limited evidence for biodegradation of chlorinated organics
 15 to 20 Adequate evidence for biodegradation of chlorinated organics
 >20 Strong evidence for biodegradation of chlorinated organics

Study Area 39 Zone C Groundwater Results

One well was sampled that was screened in Zone C which is OLD-39-37C. The results of the groundwater sampling show that no significant changes were present between the baseline and February 2001 samples. The deep (C zone) groundwater contour map is shown on Figure 22. Therefore, the vegetable oil injections in Zones A and B have not affected Zone C within a time period of two months.

Study Area 39 Conclusions

The groundwater sampling results for SA-39 shows the potential for the enhanced biodegradation to be feasible as a remedial alternative for the PCE due to the following observations:

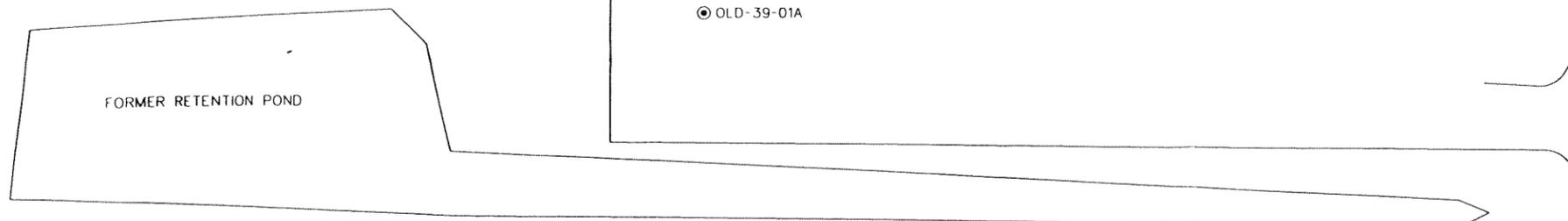
- The sulfate concentrations in the groundwater have reduced due to the vegetable oil injections increasing microbial activity that has produced sulfate reducing conditions. The sulfate reducing conditions are further evidenced by the sulfide concentrations increasing which is a byproduct of sulfate reduction.
- Iron reducing conditions are apparent in the groundwater due to the formation of ferrous iron. It is speculated that the increased microbial activity initiated by the vegetable oil injections has created iron reducing conditions which facilitates Fe III reducing to Fe II.
- The TOC concentrations have reduced significantly in Zone B which is indicative of microbial activity.

However, the chloride levels in Zone B have either stabilized or decreased and the DO levels have increased in the groundwater. In addition, the ORP in the groundwater in Zone B has increased most likely due to the DO increased. These indicator parameters indicate the microbial activity has either decreased or stabilized since the injections.

Although the DO, Cl, and ORP parameters suggest a stabilization in microbial activity in Zone B, it appears that the addition of vegetable oil has created a more reductive environment in the groundwater. The sulfate reduction and sulfide production are most noticeable in Zone B beneath SA-39. In addition, Fe II is being produced in Zone B which is indicative of Fe III being reduced. Finally, the TOC concentrations in most of the wells in Zone B have significantly reduced since the baseline sampling round and the addition of vegetable oil. Therefore, on the basis of the sulfate, sulfide, Fe II, and TOC data, it appears that the microorganisms beneath SA-39 have utilized the added TOC (vegetable oil) to reduce the sulfate and iron that is present beneath the site.

Study Area 39 Recommendations

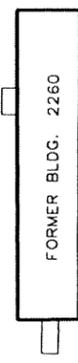
The following recommendations, if implemented, should provide additional data for evaluating the enhanced biodegradation process and enhance the PCE reduction in the groundwater beneath SA-39.



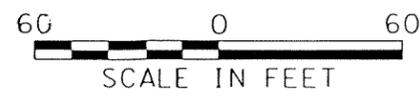
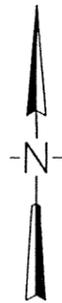
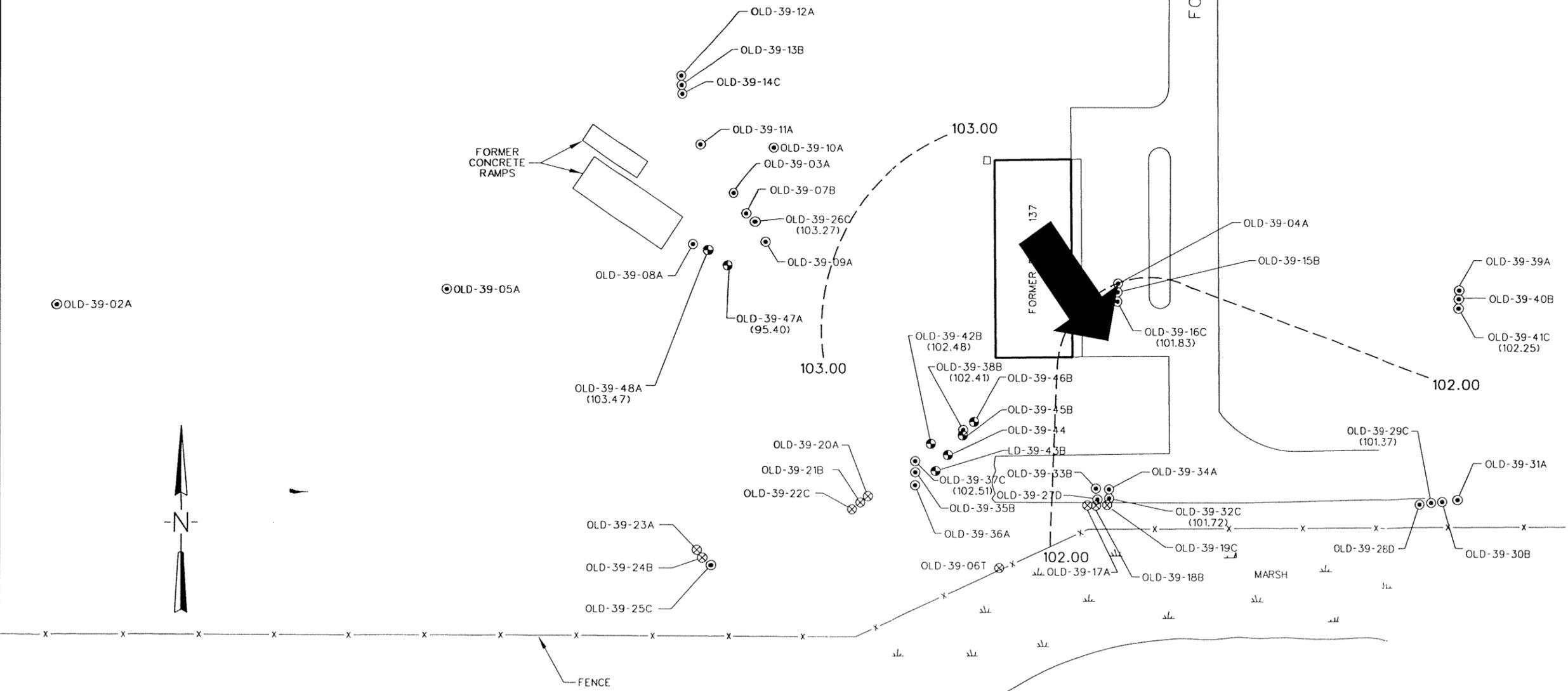
LEGEND

- EXISTING MONITORING WELL
- NEW MONITORING WELL
- DESTROYED MONITORING WELL
- GROUNDWATER ELEVATION (4-5-01) (FT.) 102.25
- GROUNDWATER CONTOUR ELEVATION (FT.) 103.00
- GROUNDWATER FLOW DIRECTION

FORMER GRACE HOPPER AVE.



FORMER PARKING



SOURCE:
BASE MAP TAKEN FROM SURVEY BY DONALDSON, GARRET & ASSOCIATES OF MACON, GEORGIA DURING SEPT. 1999.



FIGURE 22
DEEP (C) ZONE
GROUNDWATER CONTOUR MAP
SA-39
NAVAL TRAINING CENTER
ORLANDO, FLORIDA

- Groundwater monitoring should continue to be conducted on a quarterly basis.
- The groundwater analysis for methane, ethene, and ethane should be modified by adding carbon dioxide. Alternatively, carbon dioxide can be measured in the field using a HACH test kit.
- The reporting limit for sulfate should be reduced from 50 to 20 mg/L or lower in order to evaluate the potential for reductive dechlorination according to the scoring protocol.
- Dissolved hydrogen concentrations should be obtained using a method developed by Microseeps. The dissolved hydrogen concentrations will allow for the evaluation of the terminal electron accepting process and the proper scoring of the groundwater plume.
- The groundwater in Zone B should be analyzed for Fe III. The concentration of Fe III in the groundwater will determine the amount of Fe II that can be formed in the aquifer. The amount of iron reduction that can occur in the groundwater will determine the amount of additional TOC that will be required to reduce the Fe III along with the PCE.
- Two additional wells should be sampled that are screened in Zone B and located upgradient and/or in an unaffected area and downgradient of the study area. The data from the upgradient and downgradient wells will allow for the flow path of the groundwater in Zone B to be evaluated and the groundwater zone can be scored more effectively according to the EPA protocol.
- Another round of vegetable oil injections should be performed at SA-39 due to the demand on the initial injections by the sulfate and iron present in the groundwater. In order for the PCE to be reduced in the groundwater, the sulfate and iron must be reduced first which will require additional TOC. The sulfate and iron will most likely be reduced with an additional round of vegetable oil injections if the Fe III concentrations are not too elevated. However, a third round of vegetable oil injections may be required for the PCE to be reductively dechlorinated due to the second round of vegetable oil injections being consumed by the sulfate and iron reducing microorganisms.