INTERIM MEASURES WORK PLAN
AOC A — NORTHSIDE FLUVIAL DEPOSITS GROUNDWATER

NAVAL SUPPORT ACTIVITY MID-SOUTH
MILLINGTON, TENNESSEE

Revision: 0

Comprehensive Long-Term Environmental Action Navy
Contract Number: N62467-89-D-0318
CTO-0094

Prepared for:

Department of the Navy
Southern Division
Naval Facilities Engineering Command
North Charleston, South Carolina

Prepared by:

ENSAFE

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The Contractor, EnSafe Inc., certifies that, to the best of its knowledge and belief, the technical data delivered herewith under Contract No. N62467-89-D-0318 are complete, accurate, and comply with all requirements of the contract.

Date:	November 10, 2003
Signature:	[signature]
Name:	John Stedman, Jr.
Title:	Task Order Manager

ENSAFE

EnSafe Inc. Environmental and Management Consultants

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November 10, 2003

Commander
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Subject: CTO-0094; NSA Mid-South, AOC A, Millington, Tennessee

Document Transmittal – *Interim Measures Work Plan, Naval Support Activity Mid-South, AOC A – Northside Fluvial Deposits Groundwater, Revision 0,* November 10, 2003

Reference: Contract N62467-89-D-0318 (CLEAN II)

Dear Sir:

This letter is provided to document submittal of the *Interim Measures Work Plan, Naval Support Activity Mid-South, AOC A – Northside Fluvial Deposits Groundwater, Revision 0,* November 10, 2003. The document has been distributed as shown on the attached NSA Mid-South RFI Distribution List.

If you have any questions or comments of a technical nature, please contact me at 901/372-7962. Comments or questions of a contractual nature should be directed to Scott Nye at 901/386-9344.

Sincerely,

EnSafe Inc.

By: John Stedman, Jr.
Task Order Manager

Enclosures: As Stated

cc: Contracts File: CTO-0094 (w/out enclosure)
Project File: 0094-34-000 (w/out enclosure)
SOUTHDIV: Mr. Robert Rivers/Code 0233RR (w/out enclosure)
Other: See attached NSA Mid-South Distribution List

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List of Acronyms

1,1-DCA	1,1-dichloroethane
1,1-DCE	1,1-dichloroethylene
1,2-DCA	1,2-dichloroethane
1,2-DCE	1,2-dichloroethylene
A-A	anaerobic-aerobic
AOC	area of concern
BCT	BRAC Cleanup Team
bls	below land surface
BRAC	Base Realignment and Closure
CMS	Corrective Measures Study
CO_2	carbon dioxide
COC	chemical of concern
CSI	confirmatory sampling investigation
DO	dissolved oxygen
DPT	direct-push technology
EISOPQAM	Environmental Investigation Standard Operations Procedures and Quality Assurance Manual
gpm	gallon per minute
H_2	hydrogen
ID	inside diameter
MCL	maximum contaminant level
mg/L	milligrams per liter
MNA	monitored natural attenuation
MSCHD	Memphis and Shelby County Health Department
NA	not applicable
ND	not detected
NPDES	National Pollution Discharge Elimination System
NS	not sampled
NSA	Naval Support Activity
O&M	operation and maintenance
ORP	oxidation-reduction potential
OSWER	Office of Solid Waste and Emergency Response
PCE	tetrachloroethylene

List of Acronyms (continued)

PLFA	phospholipid fatty acid
psi	pounds per square inch
PVC	polyvinyl chloride
QAPP	Quality Assurance Project Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA facility investigation
RGO	remedial goal option
S	Storage Capacity
SOUTHDIV	Southern Division Naval Facilities Engineering Command
SWMU	solid waste management unit
T	Transmissivity
TCA	trichloroethane
TCE	trichloroethylene
TDEC	Tennessee Department of Environment and Conservation
TOC	total organic carbon
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
VC	vinyl chloride
VFA	volatile fatty acids
VOC	volatile organic compound
µg/L	micrograms per liter

1.0 INTRODUCTION

Interim Measures (IM) are a valuable corrective measure option available in the Resource Conservation and Recovery Act (RCRA). The goal of the RCRA corrective action process is to evaluate, design, and implement the most appropriate long-term remedy at the site. While long-term remedies are being designed or evaluated, there is often a need to control or mitigate existing threats to human health and the environment, and prevent or lessen the further spread of contamination. The IM process is the mechanism by which existing contamination or threats are addressed and contained while long-term remedies are being pursued.

The interim measures effort at any one site builds on work that has already been initiated at many other previous corrective action sites. Although they are intended to be implemented more quickly than traditional remedial measures, IMs may be short-term or long-term and are developed to complement the final, comprehensive remedy for the facility.

A Corrective Measures Study (CMS) report recommended that full-scale enhanced bioremediation with monitored natural attenuation (MNA) as the final, long-term remedy be implemented at Area of Concern (AOC A), Northside Fluvial Deposits Groundwater, located on the former Northside of Naval Support Activity (NSA) Mid-South, Millington, Tennessee (EnSafe, 2003). Tennessee Department of Environment and Conservation (TDEC) and United States Environmental Protection Agency (USEPA) concurred with this recommendation in letters dated May 28, 2003 and June 30, 2003, respectively. This IM work plan outlines design, construction, and operation and maintenance (O & M) requirements for the enhanced bioremediation at AOC A. It also provides implementation and submittal schedules. These IMs are designed to mitigate hazards and threats to human health and the environment from groundwater contamination at AOC A in the more contaminated locations, while MNA is being implemented as the long-term remedy.

This IM work plan has been organized according to the Office of Solid Waste and Emergency Response (OSWER) Directive 9902.4, *RCRA Corrective Action Interim Measures Guidance* (Final, June 1998).

- **Section 1, Introduction:** This section presents the purpose of the report.

- **Section 2, Site Description:** This section presents the history and background of AOC A and the results of previous investigations, including the RCRA Facility Investigation (RFI) and supplemental CMS sampling.

- **Section 3, Enhanced In Situ Bioremediation:** This section summarizes the remedial objectives, technology description, design, and results of the pilot study conducted at AOC A.

- **Section 4, System Design:** This section outlines the system/well design of the full-scale enhanced bioremediation system, modeling results, dye tracer study design, and bioaugmentation design.

- **Section 5, Permitting:** The section discusses the appropriate permits that are necessary to implement this remedial technology.

- **Section 6, Effectiveness Monitoring:** This section summarizes the field procedures, laboratory information, scheduling, and reporting.

- **Section 7, Schedule and Reporting:** This section provides a time line of the events that will take place during the IM.

- **Section 8, References:** This section lists applicable references used to prepare the IM work plan.

- **Section 9, Signatory Requirement:** This section provides the applicable signatory requirements for the IM work plan.

2.0 SITE DESCRIPTION AND ENVIRONMENTAL SETTING

2.1 General

As a result of the Base Realignment and Closure Act (BRAC) of 1988[1], a portion of NSA Mid-South has been closed and transferred to the city of Millington. To expedite this transfer, the BRAC Clean-up Team (BCT) decided to designate groundwater in the fluvial deposits aquifer beneath a large part of NSA Mid-South Northside as AOC A. Figure 2-1, a topographic map of the facility and the surrounding area, shows the NSA Mid-South Northside and Southside base boundaries that were in place before property transfer in January 2000.

AOC A Solid Waste Management Units (SWMUs) and Sites

SWMU 1	Fire Department Drill Area
SWMU 3	Building — 121 Plating Shop Dry Well
SWMU 5	Aircraft Fire Fighting Training Facility
SWMU 7	Building — 126 Plating Shop Dry Well
SWMU 8	Cemetery Disposal Area
SWMU 10	Demolition/Construction Debris Landfill
SWMU 15	Building — 94 Underground Tank Farm
SWMU 18	Building — 112 Underground Waste Tank
SWMU 21	Building — 10 Underground Waste Tank
SWMU 27	Northside Sewage Treatment Plant
SWMU 40	Salvage Yard No. 1
SWMU 60	Northside Landfill
SWMU 62	— 21 Arresting Gear
North Fuel Farm	
Background Location 5	

[1]Adopted October 24, 1988 and extensively amended in 1990, 1994 and 1996.

Interim Measures
Work Plan
AOC A - Northside Fluvial
Deposits Groundwater
NSA Mid-South
Millington, TN

Figure 2-1
USGS Topographic Map
Naval Support Activity Mid-South

D:\projects\NsaMidSouth\aoc_a\aoc_a.apr\nsa_midsouth.lyt

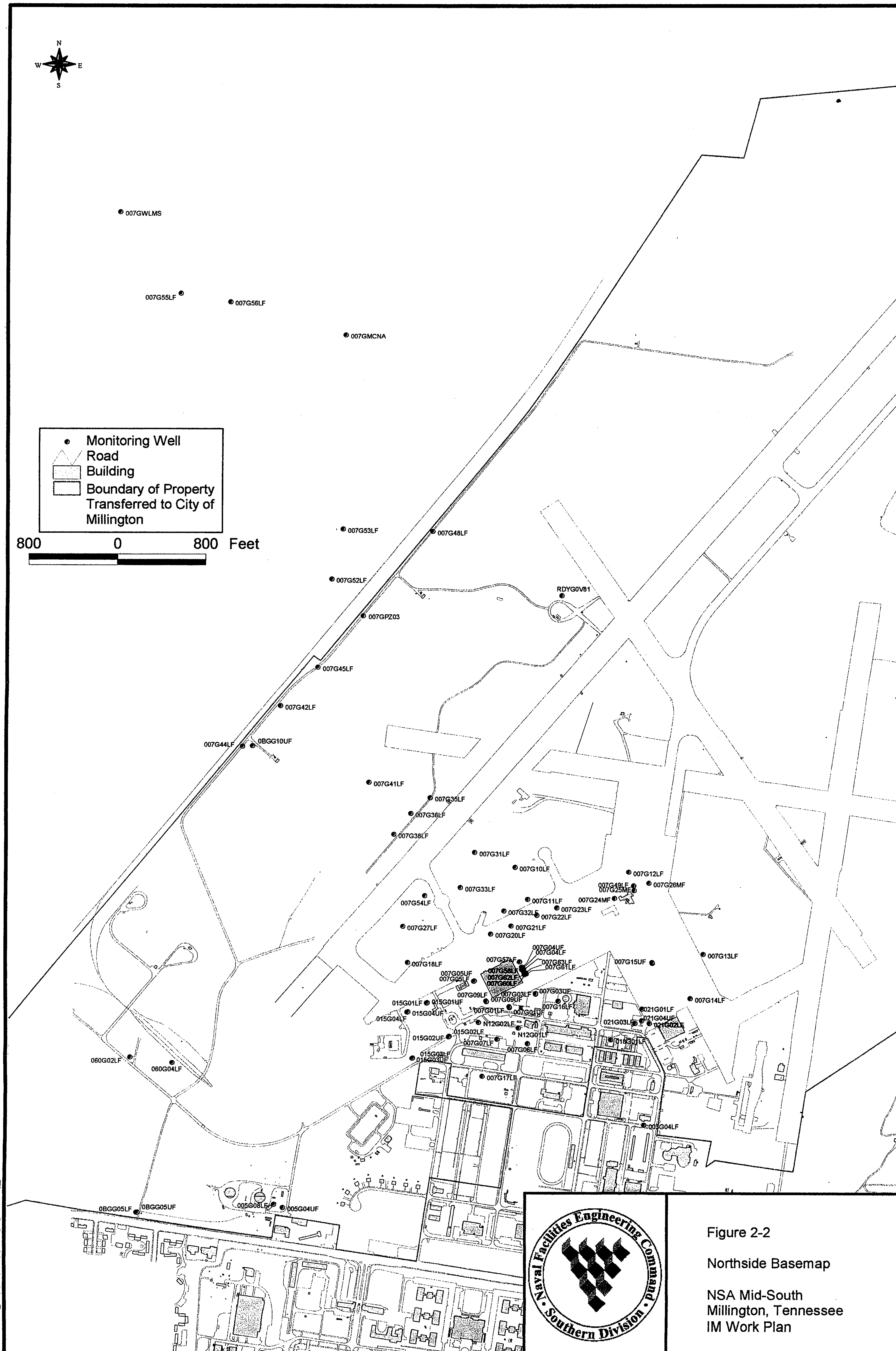
Figure 2-2 is a northside (AOC A) base map showing several features, including property boundary, roads, and buildings. The figure also shows monitoring and other wells where fluvial deposits groundwater data have been collected during RFIs or Confirmatory Sampling Investigations (CSIs) at NSA Mid-South Northside SWMUs and sites within AOC A. The investigations at SWMUs identified for RFI or CSI characterization have been completed, including preparation of RFI reports, addendums, and technical memorandums with investigation results.

2.2 Site Geology and Hydrogeology

The geology of AOC A has been broken into three major lithologic units, which are listed in descending order (youngest to oldest) (Carmichael et al., 1997):

- Pleistocene-age loess
- Pleistocene- to possibly Pliocene-age fluvial deposits
- Eocene-age Cockfield and Cook Mountain Formations (upper units of the Claiborne Group), which overlie the Memphis Sand of Eocene-age and serve as the upper confining unit for the Memphis aquifer

Two principal groundwater units are beneath NSA Mid-South: (1) the alluvial-fluvial deposits aquifer, which is the most prominent surficial aquifer, and (2) the Memphis aquifer, which is the primary drinking-water source for the Memphis area. These aquifers are hydraulically separated by the Cockfield and Cook Mountain Formations.



gissafe:\projects\nsa_mem\groundwater\projects\wellocations.apr\figure 2-2

Figure 2-2 Northside Basemap

The fluvial deposits beneath the former NSA Mid-South airfield apron area and most of the Memphis area consist of poorly sorted sand and gravel, with minor amounts of interstitial clay, and clay lenses generally no more than a few inches thick. Fine to medium sand, which coarsens with depth, is present in the upper sections of the fluvial deposits. Gravel lenses are found in various horizons in the fluvial deposits but are more commonly in the lower part of the unit. The thickness of the fluvial deposits ranges from 26 to 64 feet beneath the airfield area.

The fluvial deposits are overlain and water in the unit from the central part of the former Northside southward is confined or semi-confined by Pleistocene-age loess in the airfield area, a relatively low-permeability unit comprising silt and clayey silt that is 25 to 45 feet thick. A perched groundwater zone is present in the loess unit from about 4 to 8 feet below land surface (bls) beneath most of the airfield area, but is absent beneath much of the apron area because recharge is inhibited by the large concrete pavement area.

The base of the fluvial deposits (approximately 70 to 100 feet bls) is underlain by the Cockfield Formation, which serves as the lower confining unit for the alluvial-fluvial deposits aquifer. The Cockfield Formation consists of interbedded sand, clay, silt, and lignite. Like the fluvial deposits aquifer, the Cockfield Formation is also confined to semi-confined and provides a potentiometric surface similar in shape and altitude to that of the fluvial deposits. The RFI report (EnSafe, 2000a) suggested that the high contrast in grain size and clay content between the Cockfield Formation impedes the downward vertical migration of contaminants.

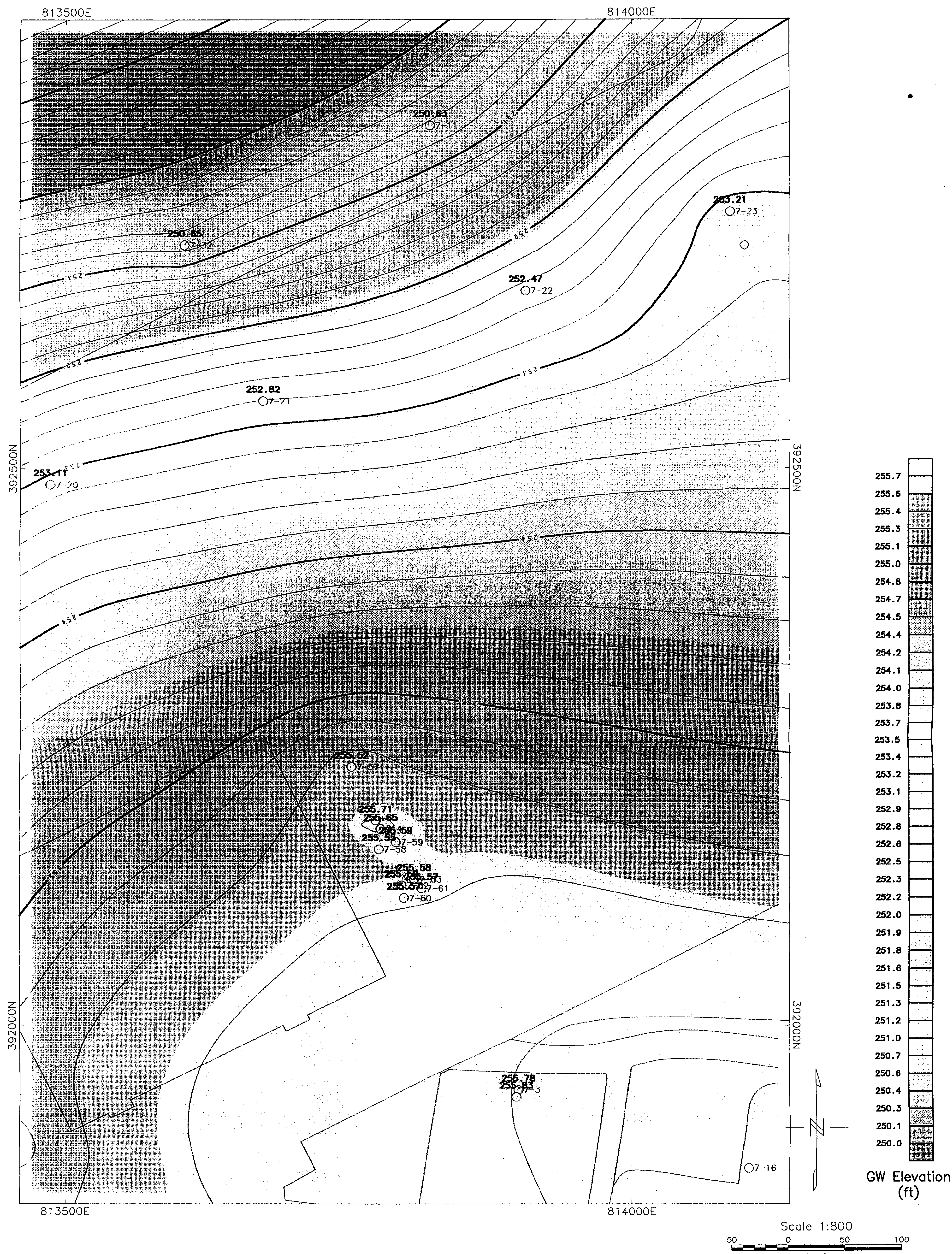
The Cook Mountain Formation underlies the Cockfield Formation and contains the most areally extensive clay in the upper part of the Claiborne Group in Memphis and Shelby County. The Cook Mountain Formation serves as the primary component of the lower confining unit to the fluvial deposits aquifer and the upper confining unit to the Memphis aquifer. The Cook Mountain Formation at NSA Mid-South primarily consists of clay and silt, though minor fine silty sand lenses may also be present locally. Geophysical logs from public-supply wells indicate that the Cook Mountain Formation ranges from 10 to 60 feet thick in the NSA Mid-South area (Carmichael et al., 1997).

Detailed aquifer tests were conducted in August 1999 during the RFI at AOC A to evaluate transmissivity (T), storage capacity (S), and pumping rates for possible containment of groundwater and contaminants in the fluvial deposits and to provide more input data to refine flow modeling conducted as part of the RFI and CMS. Aquifer tests were conducted in three phases over a three-month period. The evaluation included specific capacity, step-draw-down, and constant rate aquifer testing. More details on the aquifer test are provided in the *Aquifer Characterization Test Report Area of Concern A* (EnSafe, 2000c).

T and S were calculated using drawdown and recovery data. T ranged from 1,296 to 4,320 square feet per day (ft^2/d) with a geometric mean of 2,448 ft^2/d. Aquifer properties appear similar across most of the aquifer test area, except east and northwest of the pumping well at the perimeter road where higher T values were calculated based on thickening of the fluvial deposits. Values of S ranged from 0.0015 to 0.000086, with a calculated geometric mean of 0.00018. S values for confined aquifers typically range from 0.001 to 0.00001 (Driscoll, 1986). These values are consistent with the calculated values.

Hydraulic conductivity (K), which ranged from 44.6 to 68.4 feet per day (ft/d) with a geometric mean of 59.1 ft/d, was calculated as the mean T value divided by the aquifer thickness at each monitoring well. Horizontal groundwater velocities for the fluvial deposits aquifer were calculated using Darcy's law. Assuming an effective porosity of 27% (EnSafe, 2000a) and groundwater gradients ranging from 0.0017 to 0.0062, groundwater velocity ranges from 136 feet per year (ft/yr) north of the runway to 494 ft/yr beyond the facility boundary to the northwest.

As shown in Figure 2-3, groundwater elevations in select Northside monitoring wells screened in the fluvial deposits were measured in September 2003 and used to generate computer-contoured potentiometric maps for the Northside. The figures indicate that fluvial deposits groundwater beneath the Northside generally flows north-northwest.



PLOT SUMMARY
- Potentiometric map of fluvial deposits groundwater, September 2003

- Drawing file: NORTH7.DXF
- Plot generated 11-07-03 via Geosoft
- N:\WP51\USERS\LHUGHES\MEMPHIS\GEOCHEM\PLUMES\IM03\WL&INJ\11.P01

Figure 2-3

POTENTIOMETRIC MAP, SEPTEMBER 2003
Fluvial Deposits Groundwater

AOC A - Northside Fluvial Groundwater
Interim Measures Work Plan
NSA Mid-South
Millington, TN

EnSafe Inc.

2.3 Nature and Extent of Contamination

During the November 1994 direct-push technology (DPT) groundwater screening investigation for the SWMU 7 RFI, chlorinated solvents were detected in groundwater in the fluvial deposits aquifer. As the area of investigation expanded while the nature and extent of contamination were being defined, it became apparent that groundwater contamination in the airfield apron area was widespread and that the Building N-126 dry well (SWMU 7) was not the primary source. The focus of the SWMU 7 groundwater investigation then shifted from the dry well to the entire airfield apron area, and ultimately to the entire NSA Mid-South Northside area as scattered pockets of contaminated groundwater in the fluvial deposits were identified.

Locations where contaminants were identified in the fluvial deposits groundwater beneath the NSA Mid-South Northside were grouped together and designated AOC A to expedite the CMS process by collectively evaluating SWMUs and sites investigated as groundwater contamination source areas. Since the AOC A consolidation, five DPT investigations, an initial/confirmatory groundwater sampling event, a second monitoring well installation round, an aquifer test (see Section 2.3), and three comprehensive long-term groundwater sampling events have been conducted at AOC A (July 2000, August 2001, and September 2002).

The BCT decided that a single RFI should be conducted for all SWMUs that impact or are related to NSA Mid-South Northside fluvial deposits groundwater contamination. As such, substantial data were collected and presented in the *AOC A RFI Report* (EnSafe, 2000a) and *AOC A RFI Report Addendum* (EnSafe, 2000b). The RFI report identified nine primary COCs in NSA Mid-South Northside fluvial deposits groundwater: tetrachloroethylene (PCE), trichloroethylene (TCE), 1,2-dichlroethylene (1,2-DCE), 1,2-dichloroethane (1,2-DCA), 1,1-dicholroethylene (1,1-DCE), 1,1-dichloroethane (1,1-DCA), carbon tetrachloride, chloroform, and benzene. Results from the last three sampling events are presented in Appendix A.

The site is characterized by multiple plumes, many of which have spatial dimensions similar to the nominal well spacing. In order to distinguish the plumes and determine if adjacent wells were sampling the same plume, an extensive geochemical analysis was performed. Based upon the data and hydrological information, a relative advective-dispersive ratio was determined for each plume. From these findings, plumes were interpreted in plan view, digitized, and generated as color images by gridding software. Interpolated plume maps for the eight chlorinated solvent COCs detected in NSA Mid-South Northside fluvial deposits groundwater were presented in the RFI Report Addendum (EnSafe, 2000b) and the A-A Sequential Bioremediation Report (EnSafe, 2002). Because TCE is the most prevalent and widely distributed COC, four versions of the plume map for this compound were presented in the CMS Report (EnSafe, 2003). The most recent plume map from September 2002 is presented in Figure 2-4.

Because the distribution of the other chlorinated volatile organic compounds (VOCs) tends to coincide with that of TCE, their plume maps are not included in this report (they are presented in the RFI Report Addendum).

Additional samples were collected for analysis during the anaerobic-aerobic (A-A) sequential treatment system pilot study and the monitored natural attenuation (MNA) evaluation conducted from March to December 2000. Pilot study results are detailed in the *AOC A Anaerobic-Aerobic Sequential Bioremediation Pilot Study Report* (EnSafe, 2002). They are discussed further in Section 3.0 of this report as they apply to remedial technology development; applicable MNA results are also discussed in this section.

o monitoring well
. dpt
red contour is MCL

Scale 1:4000
250 0 250 500 750
(feet)

PLOT SUMMARY
- Contaminant conceptual model based on TCE sampling Sep 2002

- Drawing files: NORTHWAT.DXF, NORTHBLD.DXF
- Plot generated 11-06-03 via Geosoft
- N:\WP51\USERS\LHUGHES\MEMPHIS\GEOCHEM\PLUMES\IM03\FIG2-4\11.P01

Figure 2-4
TCE PLUME MAP, SEPTEMBER 2002
Fluvial Deposits Aquifer

AOC A - Northside Fluvial Groundwater
Interim Measures Work Plan
NSA Mid-South
Millington, TN

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3.0 ENHANCED IN SITU BIOREMEDIATION

Enhanced in situ bioremediation is the engineered manipulation or modification of groundwater geochemical and redox conditions to stimulate the biodegradation of dissolved-phase chlorinated solvents. Redox modification (reduction in most cases) is achieved by the addition of a nutrient (a synthetic or natural carbon compound that can be used as a source of energy) to the groundwater. The carbon is used by native groundwater microorganisms to consume any dissolved oxygen present and ensure an anaerobic environment, which is essential for TCE biodegradation.

The carbon also provides a continual energy source for native microorganisms as they slowly acclimate to reducing conditions and begin using chlorinated solvents as electron acceptors. The process is termed reductive dechlorination, by which the chlorine atoms of PCE and TCE are replaced with hydrogen to transform these compounds into lesser chlorinated daughter products, such as 1,2-DCE and vinyl chloride (VC). If properly engineered, the process could result in partial or complete reduction of TCE to harmless end-products.

3.1 Technology Description

To achieve reducing (anaerobic) conditions, the subsurface is augmented by engineering means to accelerate the biodegradation of organic contamination. To create an anaerobic zone, simple carbohydrates (e.g., fructose or acetate) and micro-nutrients are added to the groundwater. The carbohydrates provide a food source that stimulates microbial activity, manipulates groundwater redox conditions, and creates an anaerobic zone which is necessary for TCE and PCE degradation. TCE intercepted in the anaerobic zone breaks down fairly early to lesser chlorinated compounds such as 1,2-DCE or VC, which are subsequently degraded to innocuous end products either by continued reductive dechlorination, induced aerobic oxidation (described below), or by natural attenuation.

Unlike PCE and TCE, the daughter products 1,2-DCE and VC are more readily degraded in an aerobic environment. If a natural downgradient aerobic zone is not present, it can be created by injecting air into the aquifer using sparging wells connected to an aboveground blower.

The aerobic degradation of DCE and VC forms innocuous end products such as ethane, ethene, carbon dioxide (CO_2), and water.

If desired, an active system could be created. In this case, flow through anaerobic and aerobic zones could be accelerated by installing low-flow extraction wells downgradient of the aerobic zone and reinjecting extracted groundwater upgradient of the anaerobic zone. Carbon and nutrients would then be added to the extracted groundwater before it is reinjected upgradient of the extraction wells. The recirculation process (extraction and reinjection) would continue until an anaerobic zone is gradually created near the reinjection wells.

Other types of enhanced bioremediation systems include vegetable oil injection. This biohancement technology manipulates the oxidation reduction potential (ORP) of groundwater in an aquifer by supplying a slow-release carbon source to the chlorinated VOC contaminated plume. Adding vegetable oil creates a strongly anaerobic environment that results in PCE and TCE reduction. This technology is designed to produce a strong enough anaerobic environment (i.e., methanogenic conditions) such that *cis*-1,2-DCE and VC are also dechlorinated. The vegetable oil injection alternative combines the low-cost benefit of the soluble carbon source alternative with the relative ease of a one-time amendment application. Vegetable oil is an inexpensive, innocuous, food- or feed-grade carbon source not regulated as a contaminant by the USEPA. Again, because vegetable oil is a nonaqueous phase liquid, it is plausible that a single, low-cost injection could provide sufficient carbon to drive reductive dechlorination for many years.

3.2 AOC A Pilot Study

Two enhanced in situ bioremediation approaches have been evaluated at AOC A: A-A Sequential Bioremediation and vegetable oil injection.

3.2.1 A-A Sequential Bioremediation Pilot Study

Also known as "two-zone interception treatment," A-A sequential bioremediation relies on groundwater flow through sequential anaerobic and aerobic zones to treat the chlorinated solvent contamination. An A-A sequential bioremediation pilot study was performed to evaluate the feasibility of using enhanced in situ bioremediation to remediate the AOC A groundwater plume, specifically the area of higher chlorinated solvent contamination in near monitoring well 007G04LF (southeast side of Building N–126). The following briefly describes the A-A pilot study and its findings. The pilot study area is shown in Figure 3-1.

The pilot study was performed in the area around monitoring wells 04LF and 04UF, where the highest TCE concentration of 4,400 micrograms per liter (µg/L) was measured in March 1999. This pilot system consisted of one extraction well (57LF), two injection wells (60LF and 61LF), and four monitoring wells (58LF, 59LF, 62LF, and 63LF). During the pilot study, groundwater was pumped from the extraction well to a 500-gallon holding tank, and then reinjected into the two injecton wells. Prior to reinjection, the pumped water was periodically augmented or dosed with designed quantities of nutrients (a synthetic carbon and nitrogen source). Groundwater wells in the test area were monitored for field geochemical parameters such as pH, dissolved oxygen (DO), ORP, and CO_2 to optimize system operation and assess the response of the treatability study during the evaluation process. Details of this pilot study are presented in the *A-A Sequential Bioremediation Report* (EnSafe, 2002).

A-A Pilot Study Results

The A-A pilot study system operated from March 14, 2000, to December 15, 2000. The results collected during the nine-month treatability study showed that reductive dechlorination of PCE and TCE is feasible via enhanced bioremediation. The most significant observation was the two-order-of-magnitude increase in *cis*-1,2-DCE concentrations in the study area monitoring wells. By March 2001, approximately 50% of the baseline contaminant mass (TCE) had been reduced.

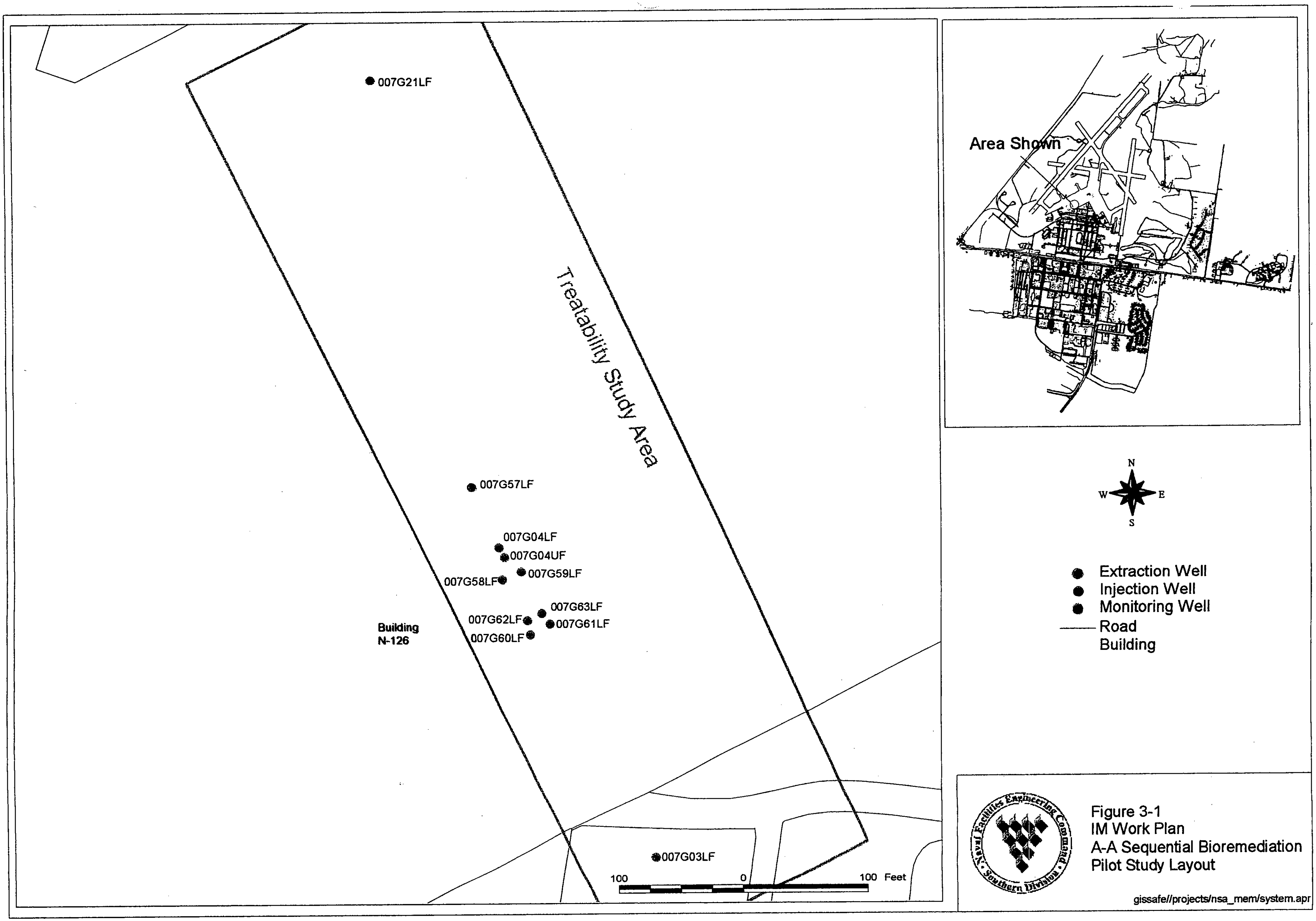

Figure 3-1
IM Work Plan
A-A Sequential Bioremediation
Pilot Study Layout

The attainment of reducing conditions in the fluvial deposits during the study was confirmed by negative ORP measurements, low DO concentrations, and elevated hydrogen concentrations during field geochemical sampling.

Post-Shutdown Results

Following the active study (nine months), the system was monitored under passive conditions to study continued degradation in a sustained anaerobic environment. Field samples were routinely collected from pilot study wells to monitor aquifer geochemistry. Analytical samples were also collected in March and July 2001, as well in February and September 2002, to continue monitoring chlorinated VOC concentrations in the area following system shutdown. Stopping the recirculation system and returning the aquifer to natural hydraulic conditions resulted in a relatively stagnant environment, particularly near the injection wells (7G60LF and 7G61LF) and first row of monitoring wells (7G62LF and 7G63LF). This stagnancy, coupled with ample[2] residual organic carbon in the groundwater, resulted in much stronger anaerobic conditions than expected, resulting in *cis*-1,2-DCE degradation to VC.

Consistent with the analytical results, ORP measurements taken from the injection wells have ranged from -150 to -200 milliVolt since system shutdown, likely low enough for *cis*-1,2-DCE and VC degradation. This phase showed that DCE continued to further degrade to measurable amounts of VC in the aquifer. July 2001 and February 2002 data indicate the VC that was formed is decreasing near the injection wells. Specialized microbial analysis from groundwater samples indicated the presence of bacteria *(dehalococcoides ethenogenes)* that have the ability to fully dechlorinate TCE. In general, the addition of nutrients stimulated the growth of native microorganisms as indicated by biomass counts and comparing populations between upgradient and pilot area monitoring wells.

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[2] Compared with pre-shutdown samples, TOC concentrations in samples from the injection wells and 7G62LF and 7G63LF monitoring wells were one to two orders of magnitude higher after the system was shut down.

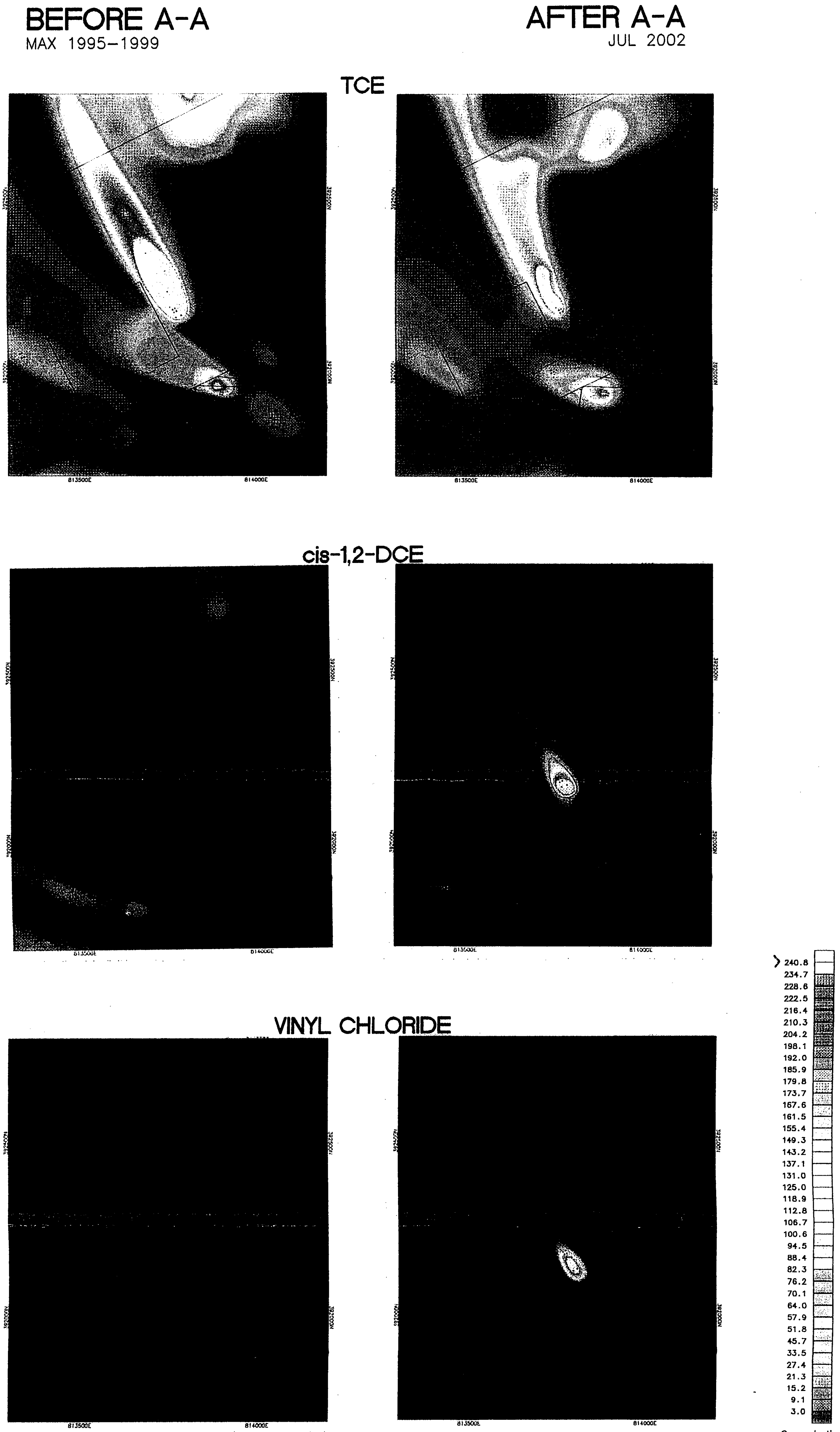
Figure 3-2 illustrates spatial contaminant variations throughout the pilot-study area before and after system implementation.

3.3 Vegetable Oil Pilot Study

Another pilot study was conducted to evaluate the feasibility of using vegetable oil injection to remediate part of the AOC A groundwater plume, specifically the area of higher chlorinated solvent contamination near monitoring wells 007G15UF and 007G15LF at former hangar N–6. Eight vegetable oil injection wells (four pairs each in the upper and lower parts of the fluvial deposits) and 16 monitoring wells (eight pairs) were installed at the northeast end of former hangar N–6 in August 2000. Groundwater wells in the test area were monitored for field geochemical parameters such as pH, DO, ORP, and CO_2 to optimize system operation and assess the response of the treatability study during the evaluation process. The vegetable oil injection study showed that some reductive dechlorination is occurring in the vicinity. Details of this pilot study are presented in the *Field Application to Enhanced In Situ Bioremediation of Chlorinated Solvents via Vegetable Oil Injection at Site N–6, Former Naval Support Activity Mid-South, Millington, Tennessee* (Parsons, 2002).

3.4 Summary

Based on the results of these two pilot studies, it appears that a soluble (rather than an insoluble or slowly soluble) organic substrate would be more effective for enhancing aquifer geochemistry to promote relatively rapid in situ biodegradation at AOC A. In summary, the A-A sequential bioremediation pilot study has shown that passive injection of carbohydrates and micro-nutrients in injection wells can adequately stimulate TCE biodegradation in the aquifer. Post-shutdown results indicate that sufficiently anaerobic conditions can be generated in the lower part of the fluvial deposits aquifer to promote PCE/TCE dechlorination to create both DCE and VC. The A-A system also indicated that VC concentrations are slowly decreasing over time. Finally, microbial analysis indicated that indigenous microbes capable of degrading *cis*-1,2-DCE and VC are present in the aquifer.



PLOT SUMMARY
- Contaminant conceptual model
- Red contours are the MCL boundaries

- Drawing file, base map in color plots: CMSMAP.DXF
- Color plots generated 11-24-03 via Geosoft, inserted to CAD border
- N:\WP51\USERS\LHUGHES\MEMPHIS\GEOCHEM\PLUMES\ISM03\SMALL\16.P01

Naval Facilities Engineering Command · Southern Division ·

INTERIM MEASURES WORK PLAN
AOC A-NORTHSIDE FLUVIAL
DEPOSITS GROUNDWATER
NSA MID-SOUTH
MILLINGTON, TENNESSEE

FIGURE 3-2
TCE, cis-1,2-DCE, AND
VC CONCENTRATIONS IN
A-A PILOT STUDY AREA BEFORE AND
AFTER IMPLEMENTATION

DWG DATE: 11/04/03 | NAME: 0094001B008

Because post-shutdown monitoring was performed essentially under natural hydraulic conditions, the findings indicated that in full-scale, a passive system, whereby the groundwater is augmented to create and sustain a reducing environment, would be a feasible alternative. Because of the inherent aerobic nature of the aquifer and the presence of iron, it is likely that natural attenuation will further degrade any VC that is created and not completely destroyed via the passive system. The AOC A CMS Report (EnSafe, 2003) recommended the implementation of a passive system to remediate the existing AOC A plumes. The following sections describe the design, implementation, and monitoring of a passive enhanced bioremediation system.

4.0 ENHANCED IN SITU BIOREMEDIATION FULL-SCALE DESIGN

The enhanced in-situ bioremediation system will consist of a series of injection wells located in the plumes of concern outlined in Section 3. The most recent plume map shown in Figure 2-4, which is based on groundwater sampling results from the September 2002 event, was used to locate injection wells. In addition, geochemical results and findings of the A-A sequential bioremediation pilot study and groundwater modeling were also used to space the injection wells. The major elements of the initial system design are as follows. Recommendations to enhance the system may be made based on the results of the effectiveness monitoring and proposed dye tracer study described below.

4.1 Selection, Location, and Design of Substrate Injection Wells

The injection wells have been selected based on several criteria. Figure 2-4, the current TCE plume configuration, shows the area (Sub-plume A) surrounding monitoring well MW7-04LF with the highest TCE concentrations. Three additional separate areas are also present: Sub-plume B, which is adjacent to the large plume around monitoring well MW7-22LF; Sub-plume C, which is south of the large plume around MW7-03LF; and Sub-Plume D, which is near former hangar N–6 and location of the vegetable oil pilot study.

4.1.1 Well Transects Design

Because the system is designed as a passive injection system, a total of four transects have been selected perpendicular to the groundwater flow in sub-plumes A and B. Four transects were selected so that groundwater in the entire Sub-plume A and B would be treated passively at the inception of the remedy. As shown in Figure 4-1, Sub-plume A has three transects. Transect I is located approximately 15 feet downgradient of MW7-04LF. Any groundwater flowing from this well and adjacent areas would flow past this transect. Transects II and III in Sub-plume A are located 150 feet and 350 feet from Transect I, respectively, in the direction of groundwater flow as shown in Figure 4-1. The distance between transects was based on groundwater flow in a period of 12 to 18 months, which was based on estimated advective velocities in the area. Also shown in Figure 4-1, Sub-plume B has one transect approximately 15 feet upgradient of MW7-22LF. Any groundwater flowing toward MW7-22LF and adjacent areas would flow past this transect. To address the contamination at Sub-plume C, a single injection well will be located approximately 20 feet upgradient of MW7-03LF, also shown in Figure 4-1.

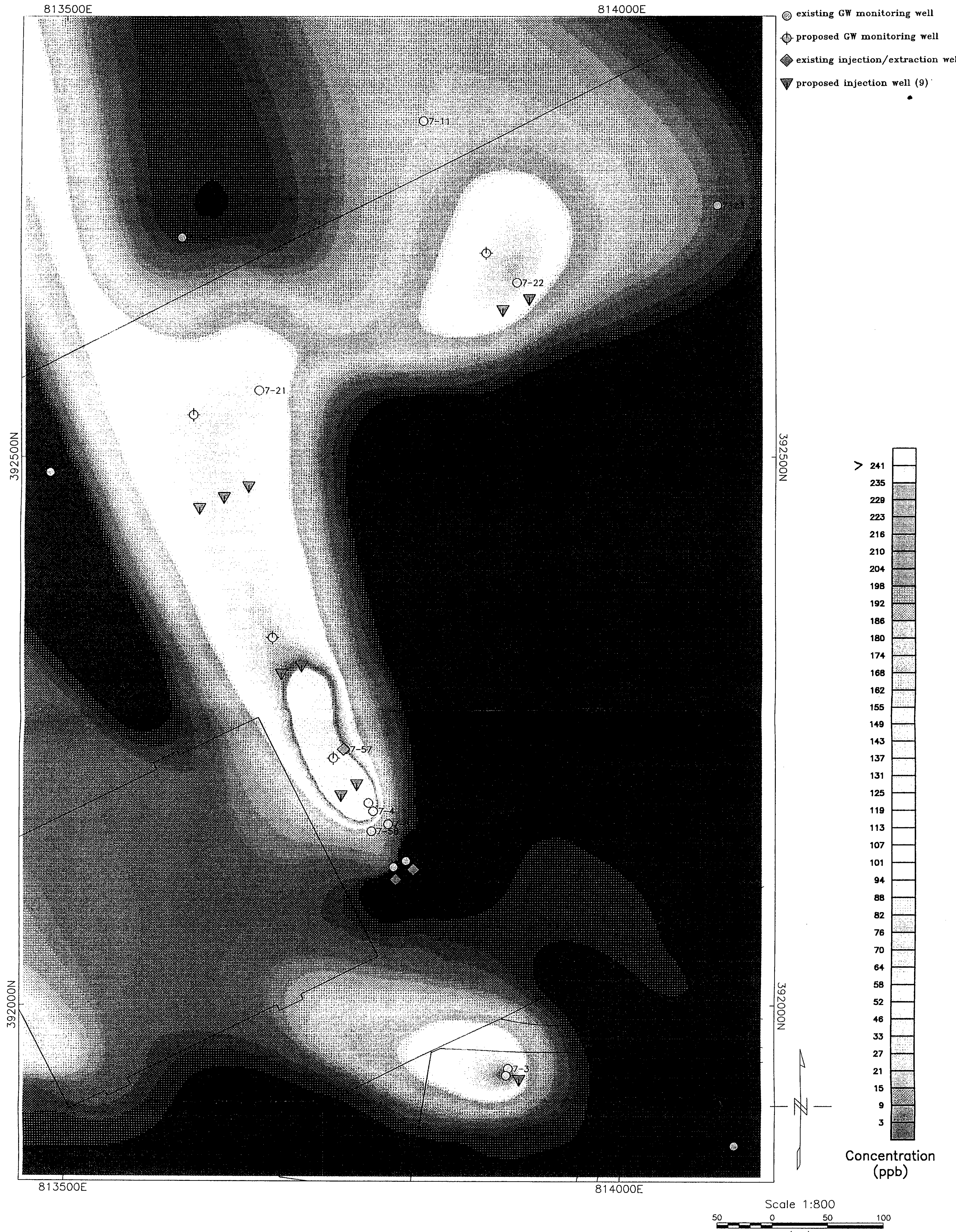
It is expected that the entire plume should be amended with the added carbon substrate within 12 to 18 months. Based on the results of the A-A sequential bioremediation pilot study, reductive dechlorination occurs within 2 to 3 months after substrate injected has been initiated. Therefore, 18 months should be sufficient to reduce the bulk of the chlorinated solvent mass in the aquifer. Quarterly monitoring will be used to decide if more transects are required.

Because of the latest sampling results, monitoring wells in Sub-plume D will continue to be sampled as part of the IM. There is evidence that reductive dechlorination is occurring approximately 30 feet downgradient of the injection wells and organic carbon substrate is moving downgradient despite the very shallow gradient in the area. Though partitioning of the vegetable oil into the groundwater may be slow, there is more that 40,000 pounds of substrate already in the lower fluvial deposits that will likely serve as an electron donor for many years. Therefore, no additional substrate (e.g., acetate) will be injected into this plume unless long-term monitoring results suggest that the plume is migrating and reductive dechlorination has ceased.

4.1.2 Well Spacing

Well spacings within transects are based on the following three criteria:

- Pilot Study Findings
- Analytical Modeling
- Dye Tracer Study (to be performed)



PLOT SUMMARY
- Contaminant conceptual model based on TCE sampling Sep 2002

- Drawing file: NORTH7.DXF
- Plot generated 11-06-03 via Geosoft
- N:\WP51\USERS\LHUGHES\MEMPHIS\GEOCHEM\PLUMES\IM03\WL&INJ\12.P01

Figure 4-1

PROPOSED SUBSTRATE INJECTION WELL LOCATIONS
Lower Fluvial Deposits Groundwater

AOC A - Northside Fluvial Groundwater
Interim Measures Work Plan
NSA Mid-South
Millington, TN

EnSafe Inc.

Pilot Study Findings: The first criteria required an understanding of the chemical and geochemical results of the pilot study, which indicated that the added substrate had a radial influence around the points of injection. Several key geochemical parameters including ORP and DO supported this conclusion. The feasibility of creating a reducing zone in a dispersed fashion around the two injection wells in the pilot study was likely due to the inherent dispersive nature of the aquifer (gravelly nature with sand and silts provide the heterogeneous mix that favors dispersion) and the chemical concentration gradients that are created when a soluble substrate is injected into the aquifer. The pilot study recommended a spacing of 40 feet between wells, resulting in a 20-foot radius of influence.

Analytical Modeling: The second criteria for well spacing used the results of simulated modeling to confirm the injection spacing recommended in the pilot study. The goal of this modeling was to determine a radial distance from each injection well that the injectate could be expected to disperse laterally, based on reasonable estimates of the dependent variables expected to influence it. Based on modeling results, the radial distance from the injection point is approximately 19.5 feet. Doubling this radial dispersion to 39 feet gives the effective injection well spacing to maintain the necessary concentrations as minimum conditions. Complete modeling results are presented in Appendix B.

Based on the pilot study and analytical modeling results, the injection wells along each transect will be spaced approximately 20 feet apart. As shown in Figure 4-1, this spacing would ensure that the injectate would impact the entire plume width transversely along the transects. If more transects are required, they will be designed in similar fashion in a Phase II injection well strategy to be outlined during remediation. In Phase I, ten injection wells will be installed as per the specifications described in Section 4.1.3. The two existing injection wells from the pilot study, i.e., MW-60LF and MW-61LF can also be used for substrate injection in Phase I. In addition to the pilot study and modeling results, the tracer study (described below) and groundwater chemical and biochemical data to be collected during remediation will be used to determine the need for either more wells or transects.

Dye Tracer Study

A tracer study will be performed at the site to confirm groundwater velocity and dispersive characteristics that have been used to locate and space substrate injection wells. Additional wells will be proposed, if needed, based on results of the tracer study. A tracer is a substance in groundwater that carries information about the groundwater system. The tracer study will involve the injection of potable water amended with fluorescent dye into a previously installed injection well (MW7-61LF). After injection, area monitoring wells will be monitored to determine the study progress. Further details of the tracer study is presented in Appendix C.

4.1.3 Well Design

Two types of wells will be installed during remediation as shown in Figure 4-1. The first is a series of substrate injection wells. The second is a set of new remediation effectiveness monitoring wells intended to supplement the existing monitoring well network to provide sufficient data collection points to evaluate remediation effectiveness. As described earlier, the substrate injection wells will be used to periodically inject designed quantities of nutrients (carbon and nitrogen-based compounds) to stimulate reductive dechlorination. The new effectiveness monitoring wells and select existing monitoring wells, including monitoring wells from the vegetable oil pilot study and five perimeter wells as recommended by the USEPA to monitor for any off-site migration, will be sampled periodically for field and laboratory chemical and geochemical analysis. Sampling results from the remediation effectiveness monitoring wells will be used to gauge the effectiveness of the system, recommend and implement changes in the substrate injection strategy as needed, and examine the need for more injection wells.

Figure 4-2 shows the details of the substrate injection well. These wells will be installed to a total depth that corresponds to the base of the lower fluvial deposits and screened across the entire thickness of the unit. The minimum screen length to attain this objective is estimated to be 30 feet. The wells will be constructed of 4-inch-diameter, flush-threaded, Schedule 80 polyvinyl chloride (PVC) riser pipe attached to a 0.02-inch slot size screen constructed of similar material.

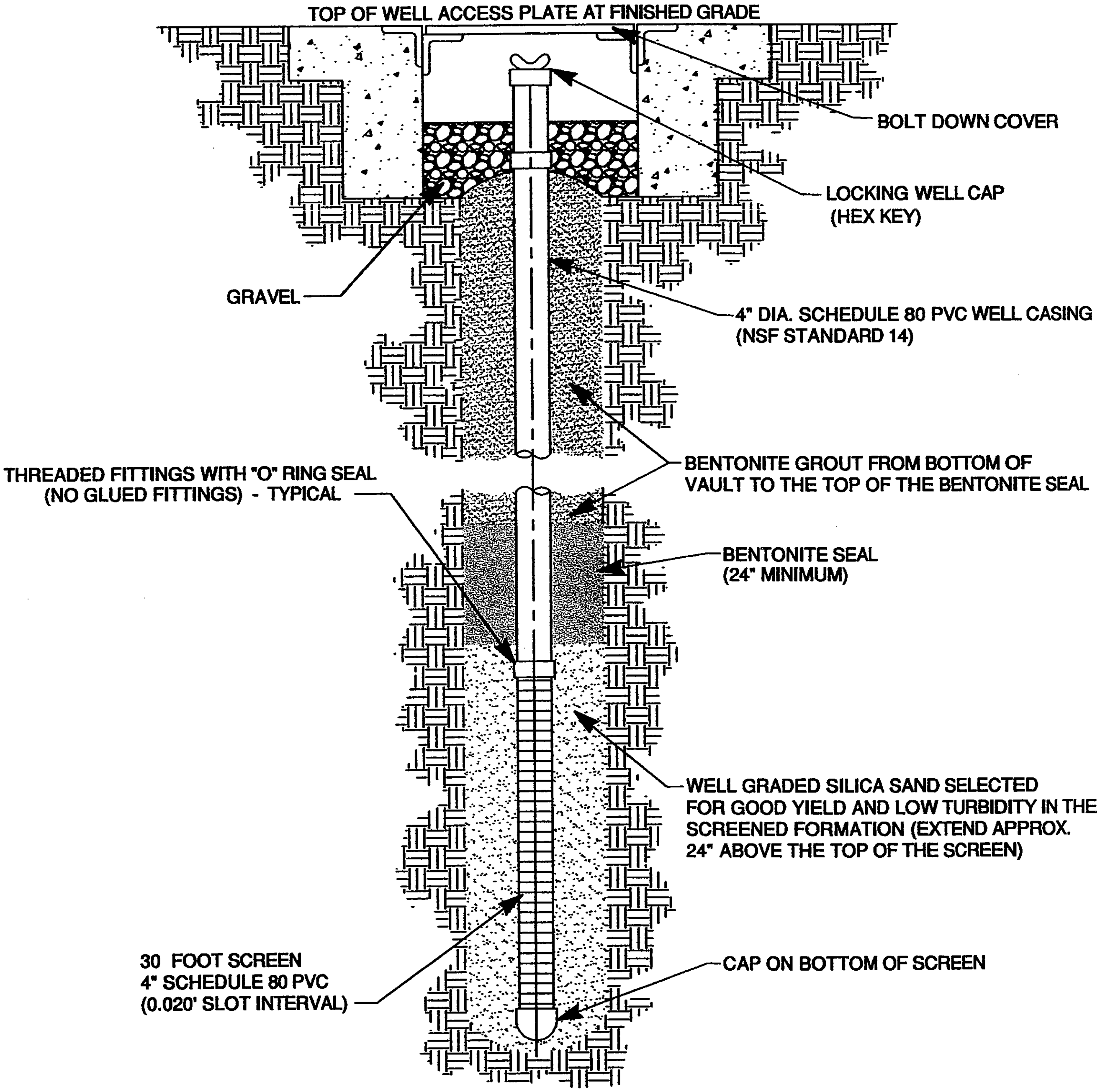
All wells will be completed as flush-mount installations protected by a steel cover as shown in Figure 4-2.

Four new monitoring wells will be installed for sample collection purposes. Each will be installed downgradient of the four transects of injection wells and used to gauge remedial effectiveness. The new monitoring wells have similar specifications as the substrate injection wells, except the well diameter will be 2-inch instead of 4-inch and they will be constructed using Schedule 40 PVC.

All boreholes for the well installations will be drilled using a rotasonic drilling method consistent with the general procedures described in Section 6.3.3 of the EPA Region 4 Environmental Investigations Standard Operating Procedures and Quality Assurance Manual (EISOPQAM). The only soil sampling that will be performed during the well installations will be for lithological characterization and logging. The lithological data will be used to determine well depths and material amounts for the installation. The monitoring wells will be installed in accordance with the well construction procedures outlined in Section 4.5.3 of the *Comprehensive RFI Work Plan* (EnSafe, 1993) prepared for NSA Mid-South and Section 6.4 of the EISOPQAM. All investigation derived waste generated during the installation and subsequent development of the wells will be managed in accordance with Section 4.12 of the *Comprehensive RFI Work Plan.*

4.2 Mechanical Substrate Feed System Design

Substrate injection (injection of the selected soluble carbon compound and nutrients) will be performed using a mechanical feed system. A setup and flow diagram of the mechanical feed system is shown in Figure 4-3. The mechanical mixing and feed system will be mounted on a flat bed trailer that can be attached to a standard 4-wheel truck. A 500-gallon polyethylene tank will be used for mixing. The tank will have connectors to potable water and the chemical feed tank (a 55-gallon sodium acetate tank). An eductor and pump system will be used to vacuum the chemical feed as the tank is being filled with water. The pump will be pneumatically controlled.



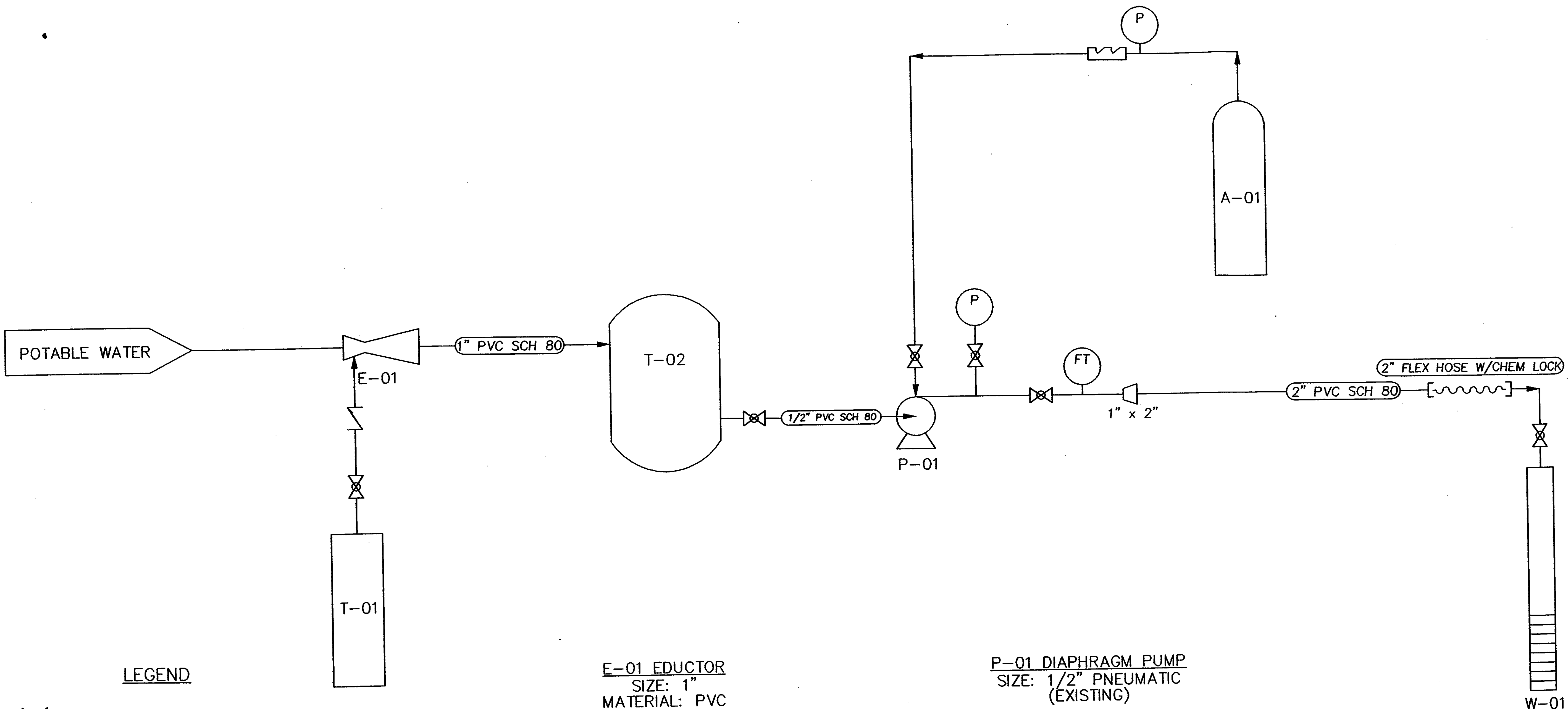
TYPICAL ILLUSTRATION OF

INJECTION WELL CONSTRUCTION

IN CONFINED AQUIFER

NOT TO SCALE

INTERIM MEASURES WORK PLAN AOC A-NORTHSIDE FLUVIAL DEPOSITS GROUNDWATER NSA MID-SOUTH MILLINGTON, TENNESSEE	FIGURE 4-2 TYPICAL INJECTION WELL	
	Date: 11/07/03	DWG Name: 0094001B010



LEGEND

- PVC BALL VALVE
- CHECK VALVE
- REDUCER
- (P) PRESSURE GAUGE
- (FT) FLOW TOTALIZER
- PRESSURE REGULATOR W/OIL LUBE & FILTER
- [ ] CHEM LOCK
- FLEX HOSE

E-01 EDUCTOR
SIZE: 1"
MATERIAL: PVC

T-01 ACETATE TANK
SIZE: 55-GAL.
MATERIAL: POLYETHYLENE

T-02 MIX TANK
SIZE: 500 GAL.
MATERIAL: POLYETHYLENE

P-01 DIAPHRAGM PUMP
SIZE: 1/2" PNEUMATIC
(EXISTING)

A-01 AIR CYLINDER
SIZE: 150 lbs CAPACITY
4 REQUIRED

W-01 INJECTION WELL
SIZE: 4" DIAMETER

NOTE: ACETATE FEED SYSTEM WILL BE MOUNTED ON A FLAT BED TRAILER.

NOT TO SCALE

Naval Facilities Engineering Command · Southern Division ·

INTERIM MEASURES WORK PLAN
AOC A – NORTHSIDE FLUVIAL DEPOSITS GROUNDWATER
NSA MID-SOUTH
MILLINGTON, TENNESSEE

FIGURE 4-3
ACETATE FEED SYSTEM

DWG DATE: 11/06/03 | NAME: 0094001R001

A compressed air tank will be the air source supply as shown in Figure 4-3. The pump also will be used for injecting the chemical-laden water from the tank to the injection wells. The pump has the capacity to inject up to 15 gallons per minute (gpm) at a maximum pressure of 125 pounds per square inch (psi). Flow and pressure regulators are also shown in Figure 4-3 and will be used to control chemical feed into the system.

4.3 Substrate Addition Strategy

The pilot study showed that sodium acetate successfully created the reducing conditions necessary for chlorinated solvent biodegradation. In addition, designed quantities of ammonium phosphate were used as a micronutrient for microorganisms. These biostimulants were mixed in powder form and added to the injection wells in a liquid stream. Full-scale remediation will follow the augmentation/stimulation strategy observed during the pilot study.

One-hundred gallons of dissolved-sodium acetate solution will be added to each injection well monthly. Every one-hundred gallons of solution will contain 50 pounds of dissolved sodium acetate. In addition, one part by weight of ammonium phosphate will be added for every 100 parts by weight of sodium acetate. Both these additives are completely soluble in water at these quantities. It is expected that the quantities added will be sufficient to convert and maintain the plumes in an anaerobic zone and provide the carbon source necessary to reduce chlorinated solvents.

Mixing and injection is expected to be performed in a single day. A written log of mixing and injection will be established. Any changes to the quantities added will be made if needed based on the progress of remediation and groundwater chemical and geochemical data.

5.0 PERMIT REQUIREMENTS

The permits required to perform the interim measures activities are summarized in Table 5-1.

Table 5-1
Treatability Study Permit Summary

Task	Permit Required	Agency/Contact
Monitoring Well Installation	Well construction permits	Memphis and Shelby County Health Department (MSCHD)/Greg Parker
Groundwater Reinjection[1]	Injection well permit/variance	MSCHD/Greg Parker
	Class V Injection Well Authorization	TDEC Division of Water Supply/Bruce Craig
	Dye Trace Registration	TDEC Division of Water Supply/Bruce Craig

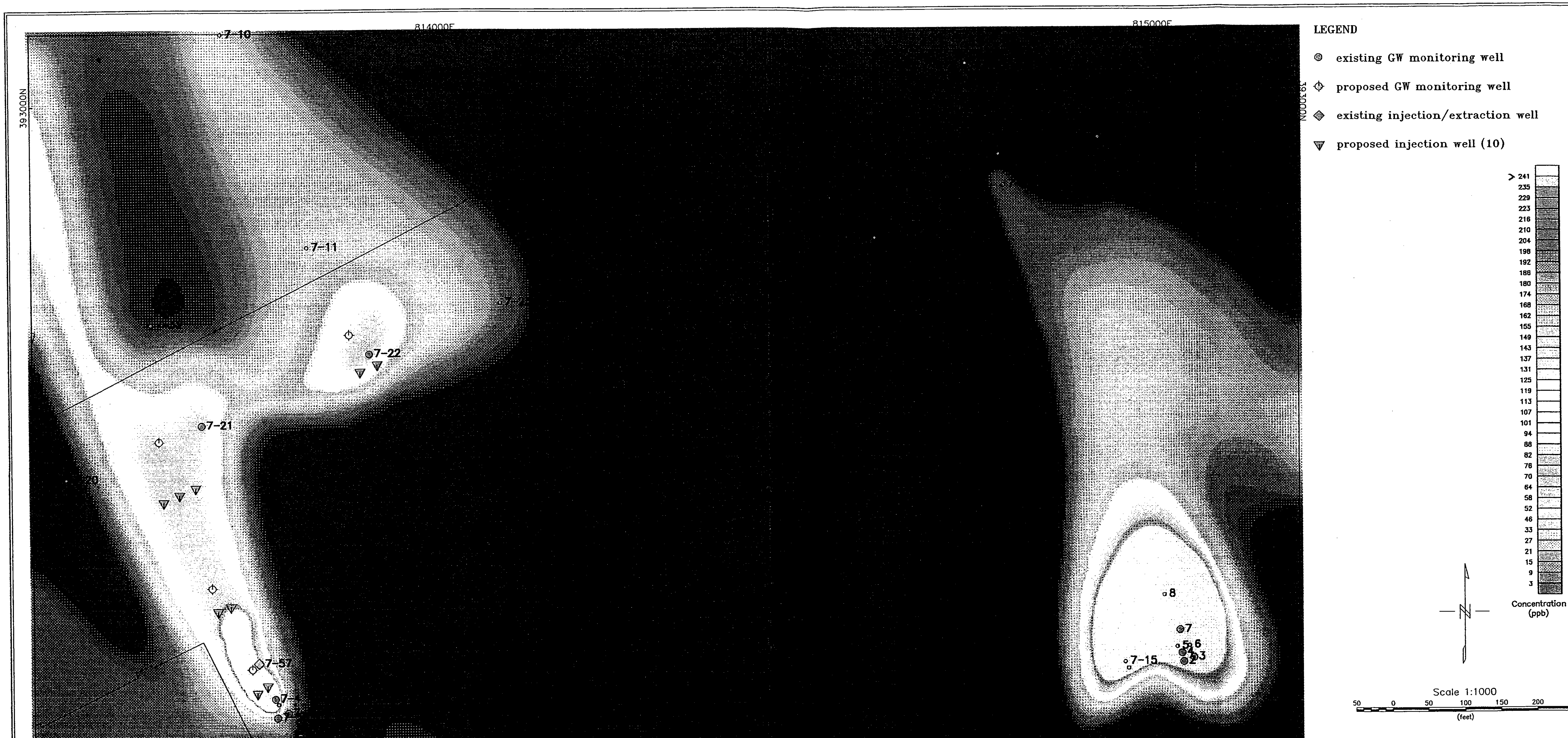
1 Per Section 13 of the Memphis/Shelby County Water Well Regulations, no injection wells of any type shall be allowed in Memphis and Shelby County for the injection of surface or groundwater, or chemically or thermally altered water, or any other fluids into the underground formations. Injection wells for the purpose of improving groundwater quality, however, may be considered under Section 14.02.

6.0 EFFECTIVENESS MONITORING

Groundwater monitoring would be required to assess enhanced in situ reduction. On-site effectiveness monitoring would include routine chemical and geochemical sampling to gauge remediation effectiveness. Ideally, wells would be monitored in the targeted area, upgradient and downgradient of the application; background wells also would be sampled. Because there is substantial evidence that reductive dechlorination is occurring near former hangar N-6 (vegetable oil pilot study area), a select number of wells will continue to be monitored. In addition, five perimeter wells will also be sampled to monitor any off-site migration as recommended by the USEPA. A complete list of monitoring wells are shown below in Table 6-1. Monitoring well locations are shown in Figure 6-1. Perimeter well locations are shown in Figure 2-2.

Table 6-1
Monitoring Wells to be Sampled

Full-Scale Remediation Area near Building N-126	Former Hangar N-6 (vegetable oil pilot study area)	Perimeter Wells
MW03LF	PES-MW2S	MW42LF
MW04LF	PES-MW2D	MW45LF
MW22LF	PES-MW3S	MW48LF
MW57LF	PES-MW3D	MW52LF
MW58LF	PES-MW4S	MWPZ03
MW59LF	PES-MW4D	—
MW60LF	PES-MW7S	—
MW61LF	PES-MW7D	—
MW62LF	—	—
MW63LF	—	—



PLOT SUMMARY
- Proposed monitoring and injection well network
- Contaminant conceptual model based on TCE sampling Sep 2002

- Drawing file: FIG6-1.DXF
- Plot generated 11-07-03 via Geosoft
- N:\WP51\USERS\LHUGHES\MEMPHIS\GEOCHEM\PLUMES\IM03\FIG6-1\11.P01

Figure 6-1

PROPOSED MONITORING WELL NETWORK
Fluvial Deposits Aquifer

AOC A - Northside Fluvial Groundwater
Interim Measures Work Plan
NSA Mid-South
Millington, TN

EnSafe Inc.

In addition to monitoring wells listed in table 6-1, four new monitoring wells would be installed for effectiveness monitoring. The following sections detail the analytical sampling and field monitoring further.

6.1 Groundwater Analytical Sampling

Groundwater samples will be collected before the system is implemented to establish baseline chemical and biochemical data in the study area. Samples will be collected from monitoring wells and analyzed for the parameters listed in Table 6-2. The perimeter wells would be sampled for VOCs only. Samples would be collected quarterly using low-flow groundwater collection techniques. As soon as biodegradation and geochemical trends have been established, the sampling frequency could be reduced to semiannually or annually.

Sampling results would be used to estimate PCE/TCE mass reduction and approximate VOC degradation rates. Reductant redosing rates would depend on the plume management strategy, site-specific biodegredation performance, remedial goal options, and other technical or regulatory considerations.

6.2 Groundwater Field Monitoring

With the exception of the perimeter wells, monitoring wells listed in Table 6-1 will be also be monitored quarterly for geochemical parameters, such as DO and ORP, which will be used in the operation and optimization of the system and to assess the geochemical response of the aquifer. Table 6-2 also lists the parameters to be analyzed for as part of geochemical monitoring.

Water levels will be measured prior to and during bioremediation to assess the hydrogeologic effects of injection into the groundwater. Water levels will be measured in monitoring wells within a 100-foot radius of the system.

Table 6-2
Enhanced In Situ Bioremediation Quarterly Sampling Analytes/Parameters

Analyte	Method
Laboratory	
VOCs	SW8260B
hydrogen	AM20GAX
methane, ethane, and ethene	8015MOD
nitrate	353.3
TOC	SW9060
microbial parameters (DGGE, VFAs, PLFAs, isotopic analysis)	Microbial Institute (Rockford, IN) In-House Methods
major cations	SW6010
Field	
ferrous iron	potable colorimeter
sulfate and sulfide	potable colorimeter
DO	YSI 55 DO meter calibrated prior to use per manufacturer's instructions
ORP	Orion 250A ORP meter or equivalent calibrated prior to use per manufacturer's instructions
pH	pH meter
temperature	temperature probe
alkalinity	potable colorimeter
chlorides	potable colorimeter
phosphorus and ammonia-nitrogen	potable colorimeter

6.3 Groundwater Analytical Sampling QA/QC

Groundwater samples will be collected from area wells and analyzed for chemical and microbial data (Table 6-2). All sampling will be performed in accordance with the Quality Assurance Plan and the Sampling and Analysis Program developed as part of the RFI for this site.

7.0 SCHEDULE AND REPORTING

7.1 Schedule

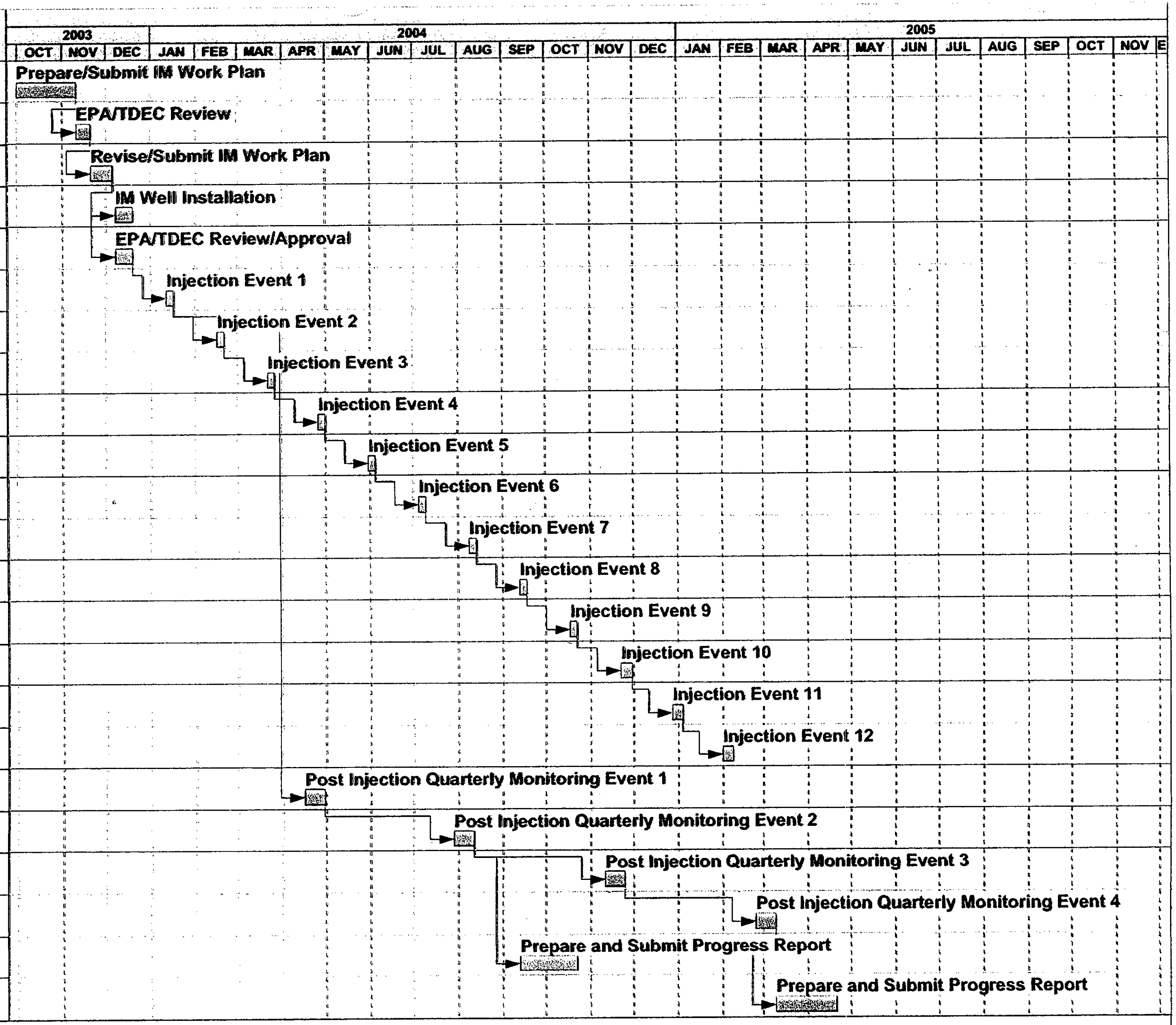
Following submission and approval of the IM work plan, the system will be installed. The IM implementation schedule is shown in Figure 7-1. The schedule is subject to minor variations depending on equipment availability, unexpected weather conditions, unforseen site conditions, and degradation progress during operations.

7.2 Reporting

Post-injection progress reports will be prepared semi-annually. Each report will include:

- Summarization of field activities and field/laboratory data
- Evaluation of the aquifer's geochemical condition
    - DO, ORP, redox zones (redox delineation), etc.
- Evaluation of microbial activity
    - Acclimation of reductive dechlorination
    - Biomass Counts
    - Microbial markers/structure
- Preliminary estimation of degradation rate
- Recommendations for system modifications

TASK	DURATION	PROJECTED START	PROJECTED FINISH
0003	29	10/01/03	11/10/03
0004	8	11/11/03	11/20/03
0005	11	11/21/03	12/05/03
0006	10	12/08/03	12/19/03
0007	10	12/08/03	12/19/03
0008	5	01/12/04	01/16/04
0009	5	02/16/04	02/20/04
0010	5	03/22/04	03/26/04
0011	5	04/26/04	04/30/04
0012	5	05/31/04	06/04/04
0013	5	07/05/04	07/09/04
0014	5	08/09/04	08/13/04
0015	5	09/13/04	09/17/04
0016	5	10/18/04	10/22/04
0017	5	11/22/04	11/29/04
0018	5	12/28/04	01/03/05
0019	5	02/01/05	02/07/05
0020	10	04/16/04	04/29/04
0021	10	07/29/04	08/11/04
0022	10	11/11/04	11/24/04
0023	10	02/24/05	03/09/05
0024	30	09/13/04	10/22/04
0025	30	03/10/05	04/20/05



Start date	10/01/03
Finish date	04/20/05
Project name	EN03
Run date	11/10/03
Page number	1A

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- Progress bar
- Critical bar
- Summary bar
- Progress point
- Critical point
- Summary point
- Start milestone point
- Finish milestone point

NSA MID-SOUTH IM IMPLEMENTATION SCHEDULE

AOC A-NORTHSIDE FLUVIAL GROUNDWATER

Figure 7-1

AOC A IM IMPLEMENTATION
NAVAL SUPPORT ACTIVITY MID-SOUTH
MILLINGTON TN

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9.0 SIGNATORY REQUIREMENTS

State of Tennessee Rule 1200-1-11.07(2)(a)8 states: All reports required by permits and other information requested by the Commissioner shall be signed by a person described in part 7 of this paragraph or by a duly authorized representative of that person. The certification reads as follows:

I certify under penalty of law that this document and all attachments were prepared under my direction or supervision in accordance with a system designed to assure that qualified personnel properly gather and evaluate the information submitted. Based on my inquiry of the person or persons who manage the system, or those persons directly responsible for gathering the information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for knowing violations.

____________________________________ ______________________

Name
NSA Mid-South
Millington, Tennessee

Date

Appendix A
Long-Term Monitoring Sampling Results

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs: 003G04LF	005G04UF	005G08LF	007G01LF	007G01UF	007G03LF	007G03UF	007G04LF	007G04UF	007G05LF
PCE	5*	Jul-00	<5	<5	<5	<5	<5	91	<5	35 J	<3	1 J
		Jul-01	<1	<1	<1	1	1.3	44	2.7	12	<1	2
		Sep-02	<1	<1	<1	<1	5	170 D	0.3 J	24	<1	3 J
TCE	5*	Jul-00	<5	<5	<5	3 J	3 J	14	<5	2,400	15	32
		Jul-01	<1	<1	<1	2.6	2.8	29	12	840 E	2.5	37
		Sep-02	<1	<1	<1	2	3	240 D	<1	960 D	0.5 J	47 DJ
cis-1,2-DCE	70*	Jul-00	<5	<5	<5	<5	4 J	<3	<5	<60	<3	<5
		Jul-01	<1	<1	<1	0.7 J	3.3	<1	<1	570 E	<1	<1
		Sep-02	<1	<1	<1	1	5	8	<1	250 D	<1	<1
1,1-DCE	7*	Jul-00	<5	<5	<5	4 J	2 J	<3	<5	36 J	<3	<5
		Jul-01	<1	<1	<1	2.1	1.6	<1	<1	29	0.96 J	<1
		Sep-02	<1	<1	<1	5	1	<1	<1	23	<1	0.5 J
1,1-DCA	811**	Jul-00	<5	<5	<5	<5	14	<3	<5	<60	<3	<5
		Jul-01	<1	<1	<1	1.7	14	<1	<1	<1	<1	0.39 J
		Sep-02	<1	<1	<1	4	15	<1	<1	0.9 J	<1	<1
1,2-DCA	5*	Jul-00	<5	<5	<5	<5	<5	<3	<5	<60	<3	<5
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<1	1.4
		Sep-02	<1	<1	<1	<1	<1	60 D	<1	<1	<1	0.7 J
Carbon Tetrachloride	5*	Jul-00	<5	10	<5	<5	<5	4	<5	<60	<3	4 J
		Jul-01	<1	9.2	1.5	<1	<1	9.3	<1	3.1	<1	4.9
		Sep-02	<1	7	2	<1	<1	42 D	<1	3	<1	4 J
Chloroform	100*	Jul-00	<5	<5	<5	1 J	<5	4	<5	<60	<3	2 J
		Jul-01	<1	0.96 J	0.45 J	<1	<1	4.7	<1	2.4	<1	2.5
		Sep-02	<1	1	0.5 J	<1	<1	32	<1	2	<1	2 J
Benzene	5*	Jul-00	<5	<5	<5	<5	<5	<3	<5	<60	<3	<5
		Jul-01	<1	<1	0.13 J	0.18 J	0.23 J	<1	<1	0.29 J	<1	<1
		Sep-02	<1	<1	<1	<1	<1	0.2 J	<1	<1	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs: 007G05UF	007G06LF	007G07LF	007G09LF	007G09UF	007G10LF	007G11LF	007G12LF	007G14LF	007G15LF
PCE	5*	Jul-00	<5	7	17	2 J	<5	5 J	36 J	<5	<5	<5
		Jul-01	<1	5.8	14	9.7	<1	11	31	<1	<1	<1
		Sep-02	<1	15	18	19	<1	17	10	<1	<1	<1
TCE	5*	Jul-00	<5	2 J	14	1 J	<5	7	100	<5	<5	11
		Jul-01	<1	1.2	8.9	4.1	<1	21	87	<1	0.28 J	3.2
		Sep-02	<1	2	5	6	<1	31	24	<1	<1	4
cis-1,2-DCE	70*	Jul-00	<5	<5	<5	10	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	0.86 J	6.9	0.66 J	<1	1.1	<1	<1	<1
		Sep-02	<1	<1	0.8 J	18	<1	0.3 J	0.7 J	<1	<1	0.5 J
1,1-DCE	7*	Jul-00	<5	1 J	3 J	1 J	<5	<5	<5	<5	<5	7
		Jul-01	<1	0.44 J	2.5	2.1	<1	<1	<1	<1	<1	3.1
		Sep-02	<1	9	<1	2	<1	<1	<1	<1	<1	3
1,1-DCA	811**	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	1.6	<1	0.5 J	<1	<1	<1	<1	1.2
		Sep-02	<1	<1	0.6 J	1	<1	<1	<1	<1	<1	1
1,2-DCA	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	24 J
		Jul-01	<1	<1	<1	<1	<1	17	6.1	<1	<1	22
		Sep-02	<1	<1	0.3 J	<1	<1	14	11	0.5 J	<1	28
Chloroform	100*	Jul-00	<5	<5	<5	<5	<5	4 J	6	<5	<5	7
		Jul-01	<1	<1	0.88 J	0.42 J	1.8	5.2	5.9	<1	<1	5.1
		Sep-02	<1	<1	0.6 J	<1	3	6	8	0.3 J	<1	7
Benzene	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	0.27 J	0.17 J	<1	0.25 J	<1	<1	0.15 J	<1	0.15 J	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	007G15UF	007G16LF	007G17LF	007G18LF	007G20LF	007G21LF	007G22LF	007G23LF	007G24MF	007G25MF
PCE	5*	Jul-00	<5	<5	<5	<5	<5	7	80 J	2 J	<5	<5
		Jul-01	4	<1	<1	1.8	<1	9.4	44	2	<1	<1
		Sep-02	1	<1	<1	0.4 J	<1	18	75 D	4	<1	0.3 J
TCE	5*	Jul-00	400 D	19	<5	6	<5	25	120	26	<5	27
		Jul-01	580	10	<1	13	<1	43	92	23	<1	25
		Sep-02	630 D	<1	<1	6	<1	180 D	170 D	22	<1	16
cis-1,2-DCE	70*	Jul-00	15	<5	<5	<5	<5	<3	12	<5	<5	<5
		Jul-01	15	<1	<1	0.56 J	<1	0.51 J	2.6	<1	<1	0.65 J
		Sep-02	18	<1	<1	<1	<1	0.6 J	4	0.4 J	<1	0.4 J
1,1-DCE	7*	Jul-00	310 D	<5	<5	<5	<5	<3	<5	<5	<5	<5
		Jul-01	430	<1	<1	0.88 J	<1	<1	<1	<1	<1	3.4
		Sep-02	460 D	<1	<1	<1	<1	0.5 J	<1	<1	<1	6
1,1-DCA	811**	Jul-00	51	<5	<5	<5	<5	<3	<5	<5	<5	<5
		Jul-01	70	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	82 D	<1	<1	<1	<1	0.5 J	<1	<1	<1	0.8 J
1,2-DCA	5*	Jul-00	<5	<5	<5	<5	<5	<3	<5	<5	<5	<5
		Jul-01	<4	<1	<1	1.8	<1	<1	<1	<1	<1	<1
		Sep-02	0.9 J	<1	<1	0.75	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	4 J	16	<5	<5	<5	<3	<5	14	<5	<5
		Jul-01	8.9	17	<1	1.5	<1	0.36 J	13	22	<1	1.5
		Sep-02	10	<1	<1	0.5 J	<1	0.6 J	2	38	<1	2
Chloroform	100*	Jul-00	10	4 J	<5	2 J	<5	<3	2 J	2 J	<5	2 J
		Jul-01	22	3.4	<1	2	<1	0.27 J	6.4	2.5	<1	2.9
		Sep-02	20	<1	<1	1	<1	0.5 J	2	5	<1	2
Benzene	5*	Jul-00	3 J	<5	<5	1 J	<5	<3	<5	<5	<5	<5
		Jul-01	4.4	<1	<1	2	0.2 J	0.28 J	0.14 J	<1	0.12 J	0.14 J
		Sep-02	5	<1	<1	0.2 J	<1	<1	2	<1	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs									
			007G26MF	007G27LF	007G31LF	007G32LF	007G33LF	007G35LF	007G36LF	007G38LF	007G41LF	007G42LF
PCE	5*	Jul-00	<5	8 J	4 J	4 J	<5	<5	5 J	<5	1 J	<5
		Jul-01	<1	<1	5.6	13	<1	0.59 J	4.8	0.58 J	1.2	<1
		Sep-02	<1	0.2 J	8	1	<1	NS	0.5 J	0.7 J	2	<1
TCE	5*	Jul-00		28 J	37	16	<5	10	32	2 J	4 J	<5
		Jul-01	2.8	1.1	68	85	0.84 J	5.5	26	2.8	5	2.1
		Sep-02	<1	2	91 D	7	1	NS	2	6	10	1
cis-1,2-DCE	70*	Jul-00	<5	<5	<5	<5	<5	<5	9	<5	<5	<5
		Jul-01	<1	<1	<1	<1	<1	<1	7.8	0.63 J	<1	<1
		Sep-02	<1	0.7 J	<1	<1	<1	NS	0.8 J	1	3	0.3 J
1,1-DCE	7*	Jul-00	<5	<5	2 J	<5	<5	<5	1 J	<5	<5	<5
		Jul-01	0.73 J	<1	1.9	0.61 J	<1	<1	1.4	<1	<1	<1
		Sep-02	<1	<1	1	<1	<1	NS	<1	<1	0.5 J	<1
1,1-DCA	811**	Jul-00	<5	<5	<5	<5	<5	<5	4 J	<5	<5	<5
		Jul-01	<1	<1	1.4	0.86 J	<1	<1	4.6	<1	<1	<1
		Sep-02	<1	0.2 J	0.8 J	<1	<1	NS	0.2 J	0.6 J	1	0.4 J
1,2-DCA	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	<1	0.5 J	<1	<1	<1	NS	<1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	<5	<5	<5	3 J	<5	<5	6 J	5 J	<5	<5
		Jul-01	<1	<1	0.75 J	3.7	<1	0.43 J	7.7	4.9	2	<1
		Sep-02	<1	<1	0.6 J	<1	<1	NS	0.4 J	5	3	0.2 J
Chloroform	100*	Jul-00	<5	2 J	<5	<5	<5	<5	3 J	2 J	<5	<5
		Jul-01	<1	<1	0.34 J	1.2	<1	0.4 J	3	1.6	<1	0.28 J
		Sep-02	<1	<1	0.5 J	<1	0.2 J	NS	0.2 J	3	2	0.2 J
Benzene	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	0.18 J	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	NS	<1	<1	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs									
			007G44LF	007G45LF	007G48LF	007G49LF	007G52LF	007G53LF	007G54LF	007G56LF	007G57LF	007G58LFA
PCE	5*	Jul-00	<5	1 J	<5	<5	<5	<5	2 J	<5	70 J	
		Jul-01	<1	0.52 J	<1	<1	4.9	<1	2.1	<1	41	5.9 J
		Sep-02	<1	0.4 J	<1	<1	7	0.5 J	3	<1	5.2	0.8 J
TCE	5*	Jul-00	<5	8	<5	<5	<5	<5	8	<5	2,300	2,700
		Jul-01	<1	0.49 J	<1	0.82 J	4.6 J	<1	7.2	<1	1,900E	150
		Sep-02	<1	4	<1	0.8 J	10	0.2 J	9	<1	180 D	30
cis-1,2-DCE	70*	Jul-00	<5	2 J	<5	<5	<5	<5	2 J	<5	<150	<60
		Jul-01	<1	<1	<1	<1	2.1	<1	2.5	<1	86	980
		Sep-02	<1	0.9 J	<1	<1	5	<1	4	<1	6.4	560 D
1,1-DCE	7*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	72 J	56 J
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	48	32
		Sep-02	<1	<1	<1	<1	0.8 J	<1	<1	<1	5	15
1,1-DCA	811**	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<150	<60
		Jul-01	<1	<1	<1	<1	1.4	<1	1.1	<1	<5	<10
		Sep-02	<1	0.4 J	<1	<1	2	<1	0.9 J	<1	<1	0.9 J
1,2-DCA	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<150	<60
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<5	<10
		Sep-02	<1	<1	<1	<1	0.5 J	<1	1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<150	<60
		Jul-01	<1	0.3 J	<1	0.44 J	3	1.7	1.8	<1	<5	<10
		Sep-02	<1	2	<1	0.3 J	2	2	1	<1	<1	<1
Chloroform	100*	Jul-00	<5	<5	<5	<5	<5	<5	2 J	<5	<150	<60
		Jul-01	<1	0.24 J	<1	<1	2.8	0.47 J	1.5	<1	3 J	3.2 J
		Sep-02	<1	1	<1	<1	3	0.8 J	2	<1	<1	0.3 J
Benzene	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<150	<60
		Jul-01	<1	0.22 J	<1	<1	<1	<1	<1	<1	<5	<10
		Sep-02	<1	<1	<1	<1	<1	<1	NS	<1	<1	0.2 J

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs: 007G58LFB	007G59LFA	007G59LFB	007G60LF	007G61LF	007G62LFA	007G62LFB	007G63LFA	007G63LFB	007GMCNA
PCE	5*	Jul-00	63	<60	46 J	66	75	22	28	50	53	<5
		Jul-01	6.3 J	<10	5.7 J	<1	<1	0.72 J	<5	<1	<1	<1
		Sep-02	0.2 J	0.8 J	0.4 J	0.2 J	<1	0.6 J	1	0.2 J	<1	<1
TCE	5*	Jul-00	2,600	2,000	2,400	2,100	2,200	700 D	820 D	1,800D	1,700D	<5
		Jul-01	88	9.4 J	19	0.61 J	<1	<1	<5	<1	<1	<1
		Sep-02	9	23	12	0.3 J	<1	3	18	0.8 J	0.4 J	<1
cis-1,2-DCE	70*	Jul-00	<60	<60	<60	<60	<60	940 D	880 D	22	43	<5
		Jul-01	990	850	1,100	<1	<1	69	480	0.78 J	<1	<1
		Sep-02	320 D	890 D	810 D	19	0.3 J	15	70 D	40 D	14	<1
1,1-DCE	7*	Jul-00	61	33 J	45 J	56 J	62	47	47	39	44	<5
		Jul-01	34	25	35	<1	<1	2.4	12	<1	<1	<1
		Sep-02	10	41 J	34	0.6 J	<1	0.6 J	2	1	<1	<1
1,1-DCA	811**	Jul-00	<60	<60	<60	<60	<60	1 J	<4	1 J	<3	<5
		Jul-01	<10	<10	<10	<1	<1	<1	<5	<1	<1	<1
		Sep-02	1	2	2	1	0.5 J	1	1	2	1	<1
1,2-DCA	5*	Jul-00	<60	<60	<60	<60	<60	<3	<4	<3	<3	<5
		Jul-01	<10	<10	<10	<1	<1	<1	<5	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	<60	<60	<60	<60	<60	<3	<4	<3	<3	<5
		Jul-01	<10	<10	<10	<1	<1	<1	<5	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Chloroform	100*	Jul-00	<60	<60	<60	<60	<60	3	<4	4	<3	<5
		Jul-01	<10	<10	<10	<1	<1	<1	<5	<1	<1	<1
		Sep-02	<1	0.6 J	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	5*	Jul-00	<60	<60	<60	<60	<60	<3	<4	<3	<3	<5
		Jul-01	1.9 J	<10	<10	<1	0.23 J	<1	<5	0.16 J	<1	<1
		Sep-02	<1	0.2 J	0.2 J	<1	0.2 J	<1	0.5 J	0.2 J	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs: 007GPZ03	007GWLMS	015G01LF	015G01UF	015G02LF	015G02UF	015G03LF	015G03UF	015G04LF	015G04UF
PCE	5*	Jul-00	3 J	<5	4 J	<5	<5	<5	<5	<5	<5	<5
		Jul-01	4.2	<1	0.83 J	<25	0.58 J	<1	<1	<1	<1	<1
		Sep-02	4	<1	9 J	<1	<1	<1	<1	<1	<1	<1
TCE	5*	Jul-00	4 J	<5	7	<5	<5	<5	<5	<5	<5	<5
		Jul-01	5.1	<1	1.9	<25	1.6	<1	<1	<1	2	<1
		Sep-02	3	<1	10 J	<1	0.6 J	<1	<1	<1	1	<1
cis-1,2-DCE	70*	Jul-00	2 J	<5	4 J	<5	<5	<5	<5	<5	<5	<5
		Jul-01	1.4	<1	1.4	<25	1.2	<1	<1	<1	0.56 J	<1
		Sep-02	2	<1	1 J	<1	<1	<1	<1	<1	0.5 J	<1
1,1-DCE	7*	Jul-00	<5	<5	<5	<5	8 J	4 J	<5	<5	<5	<5
		Jul-01	<1	<1	3.9	<25	3.7	<1	<1	<1	1.4	<1
		Sep-02	<1	<1	2 J	<1	0.9 J	<1	<1	<1	<1	<1
1,1-DCA	811**	Jul-00	<5	<5	<5	<5	7	4 J	<5	<5	<5	<5
		Jul-01	1.2	<1	4.7	<25	4	0.67 J	<1	<1	<1	<1
		Sep-02	0.7 J	<1	2 J	<1	1	<1	<1	<1	1	<1
1,2-DCA	5*	Jul-00	<5	<5	<5	84	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	<25	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	6 J	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	6.7	<1	<1	<25	<1	<1	<1	<1	<1	<1
		Sep-02	4	<1	2 J	<1	<1	<1	<1	<1	<1	<1
Chloroform	100*	Jul-00	2 J	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	1.3	<1	<1	<25	<1	<1	<1	<1	<1	<1
		Sep-02	1	<1	0.9 J	<1	<1	<1	<1	<1	<1	<1
Benzene	5*	Jul-00	<5	<5	5 J	2,100	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	0.24 J	3,800	<1	4	<1	<1	<1	<1
		Sep-02	<1	<1	<1	2100 D	<1	2	<1	<1	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (µg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs									
			018G01LF	021G01LF	021G02LF	021G03LF	021G04UF	060G02LF	060G04LF	0BGG05LF	0BGG05UF	0BGG10UF
PCE	5*	Jul-00	8	<5	4 J	6 J	<5	<5	<5	36 J	17 J	<5
		Jul-01	74	<1	<1	<1	<1	<1	<1	35	20	<1
		Sep-02	150 D	<1	<1	<1	<1	<1	<1	56 D	38	<1
TCE	5*	Jul-00	27	<5	4 J	4 J	<5	<5	<5	<5	<5	<5
		Jul-01	29	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	4	<1	<1	<1	<1	<1	<1	0.2 J	<1	<1
cis-1,2-DCE	70*	Jul-00	2 J	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	2.9	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	0.9 J	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1-DCE	7*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,1-DCA	811**	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
1,2-DCA	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Carbon Tetrachloride	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	0.72 J	<1	<1	<1	9.9	<1	0.34 J	<1	<1	<1
		Sep-02	0.3 J	<1	<1	<1	22	<1	<1	0.3 J	0.2 J	<1
Chloroform	100*	Jul-00	2 J	<5	<5	2 J	<5	<5	<5	<5	<5	<5
		Jul-01	3.8	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	6	<1	<1	<1	<1	<1	<1	<1	<1	<1
Benzene	5*	Jul-00	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5
		Jul-01	0.16 J	<1	<1	<1	<1	<1	<1	<1	<1	<1
		Sep-02	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1

Table A-1
Long-Term Groundwater Monitoring COC Sampling Results (μg/L)

Compound	MCL/PRG	Sample Date	Monitoring Well IDs N12G01LF	N12G02LF	RDYGOV81	MIN	MAX	E/S
PCE	5*	Jul-00	<5	3 J	4 J	**1 J**	**80 J**	**21/83**
		Jul-01	4.1	2.7	4.3	**0.52**	**74**	**15/83**
		Sep-02	10	6	5	**0.2 J**	**170 D**	**18/82**
TCE	5*	Jul-00	4 J	13	<5	**1 J**	**2,700**	**36/83**
		Jul-01	19	13	0.19 J	**0.19**	**1,900E**	**28/83**
		Sep-02	10	10	0.3 J	**0.2 J**	**960 D**	**28/82**
cis-1,2-DCE	70*	Jul-00	<5	15	<5	**2 J**	**940 D**	**2/83**
		Jul-01	1.5	21	<1	**0.51**	**1,100**	**7/83**
		Sep-02	1	12	<1	**0.3 J**	**890 D**	**6/82**
1,1-DCE	7*	Jul-00	<5	<5	<5	**1 J**	**310 D**	**14/83**
		Jul-01	2.2	<1	<1	**0.44**	**430**	**8/83**
		Sep-02	<1	<1	<1	**0.5 J**	**460 D**	**7/82**
1,1-DCA	811**	Jul-00	<5	<5	<5	**1 J**	**51**	**0/83**
		Jul-01	6.6	1.1	<1	**0.39**	**70**	**0/83**
		Sep-02	2	1	<1	**0.2 J**	**82 D**	**0/82**
1,2-DCA	5*	Jul-00	<5	<5	<5	**84**	**84**	**1/83**
		Jul-01	<1	<1	<1	**1.4**	**1.8**	**0/83**
		Sep-02	<1	<1	0.3 J	**0.3 J**	**60 D**	**1/82**
Carbon Tetrachloride	5*	Jul-00	<5	<5	<5	**3 J**	**24 J**	**6/83**
		Jul-01	5.5	0.96 J	<1	**0.3**	**22**	**13/83**
		Sep-02	2	1	<1	**0.2 J**	**42 D**	**8/82**
Chloroform	100*	Jul-00	<5	<5	<5	**1 J**	**10**	**0/83**
		Jul-01	1.7	0.41 J	<1	**0.24**	**22**	**0/83**
		Sep-02	2	0.5 J	<1	**0.2 J**	**32**	**0/82**
Benzene	5*	Jul-00	<5	<5	<5	**1 J**	**2,100**	**1/83**
		Jul-01	<1	0.16 J	<1	**0.12**	**3,800**	**1/83**
		Sep-02	<1	<1	<1	**0.2 J**	**2,100 D**	**1/81**

Notes

Sample data for wells 007G62LFA and LFB and 007G63LFA and LFB are from August 2000 rather than July 2000.

The highest concentration of the original sample and its duplicate is reported in the table.

μg/L = micrograms per liter

MIN = minimum detection

MAX = maximum detection

E/S = exceedances/total samples

* = maximum contaminant level (MCL)

** = 2000 Region 9 Preliminary remedial goal (PRG) (no MCL available)

NS = not sampled

007G62LFA — A-A pilot study wells

007G15LF — Vegetable oil pilot study wells

13 — MCL or PRG exceedance

Appendix B
Modeling Results

Modeling Results

Fate and transport simulations were run to support the determination of injection well spacing for the remedial design at NSA Mid-South. The preliminary design for the modeling exercise included a line of injection wells that would be located within the plume. As a typical minimum input, a flashinjection of amendment solution would be placed into the aquifer through each well at a rate of 50 gallons every six months (note that actual injection amounts could be higher and more frequent, making this modeling exercise a conservative approach). The injectate would move downgradient away from each injection well and through the plume area by longitudinal dispersion. The injectate would also experience a measure of spreading perpendicular to the dominant flow direction as a result of transverse dispersion. The goal of this modeling was to determine a radial distance (from each injection well) that the injectate could be expected to disperse laterally, based on reasonable estimates of the dependent variables expected to influence it.

The modeling code utilized was one of the PRINCE submodules, a commercially available analytical transport code. Specifically, the submodule uses the Wilson-Miller solution (Wilson and Miller, 1978) for a two-dimensional concentration distribution resulting from mass injected into wells. Because the solution relies on a number of input variables that are difficult to directly quantify, a number of assumptions regarding "reasonableness" for these variables were made. Primarily, these input variables relate directly to the injectate itself and how it interacts with the aquifer media both on a micro and macro-scale. The following table provides the specific values or range of values used for all of the input variables, and the rationale and sources for those values.

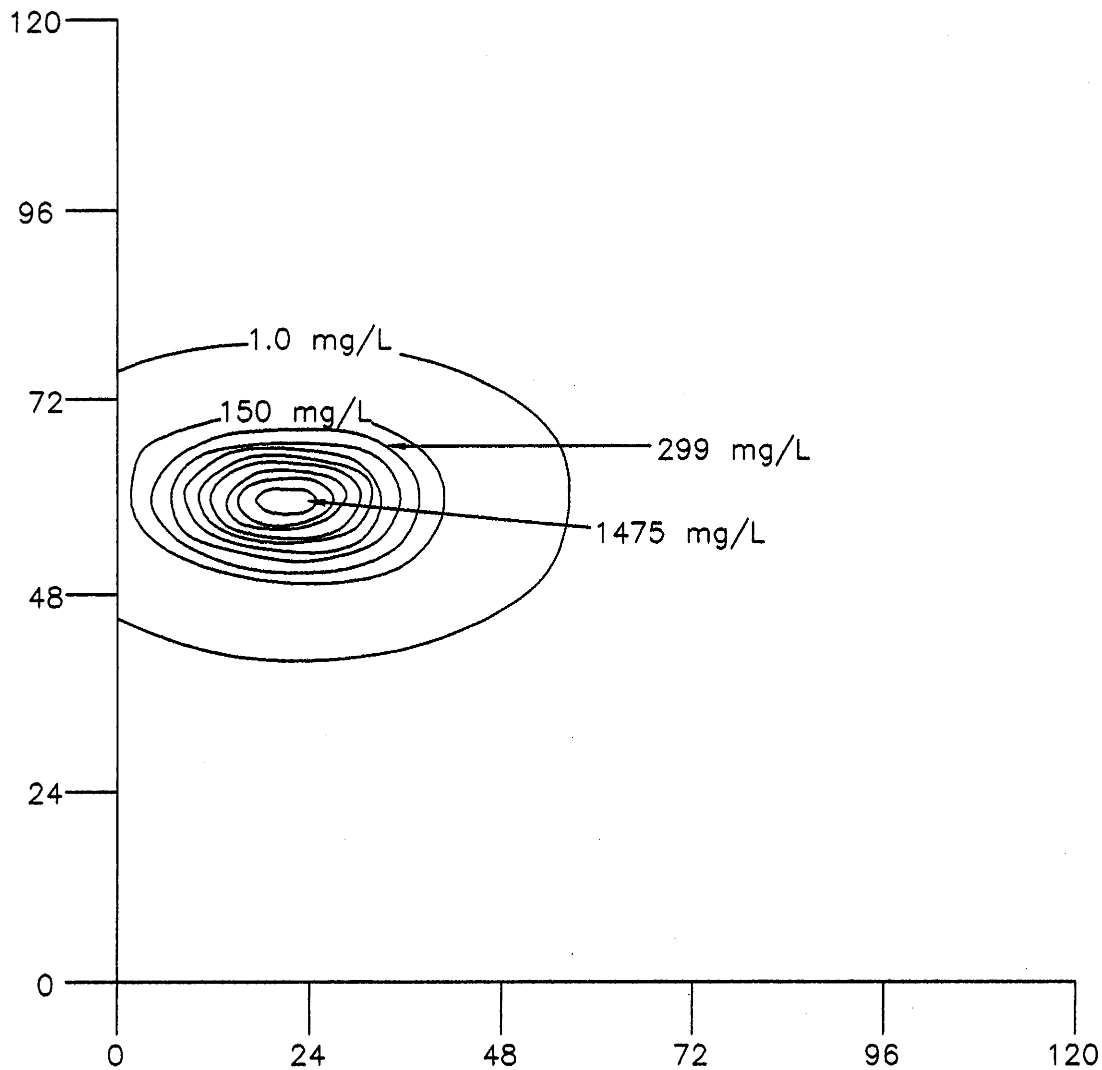
PRINCE Input Variables and their Sources

Input Variable	Value(s) Used	Source
K (first order decay coefficient)	.025	First order mass reduction from biodegradation and chemical breakdown for BTEX reported as high as .025 (Cleary and Ungs, 1994). This value is considered "reasonable" for this modeling to simulate the biological uptake of the sodium acetate.
Dx (longitudinal dispersivity)	.235 sq. meters / day	Site-specific, and scale dependent; calculated assuming a 68 ft plume length for injectate; plume length calculated using advective velocity (.3726 ft/day) x 182.5 days.

PRINCE Input Variables and their Sources		
Input Variable	**Value(s) Used**	**Source**
Dy (transverse dispersivity)	.071 sq. meters / day	Calculated as a ratio of Dy/Dx (0.3); this is considered "reasonable" in the context of the geological facies present.
Theta (angle of flow from x-axis)	0	User preference
®) Retardation Factor	1	Conservatively assumes a velocity equal to that of groundwater; this is considered "reasonable" given that no sorption of sodium acetate is expected.
Q (injection rate)	50 gallons (0.227 cubic meters) per day one day every six months minimum frequency.	Design-specified
Concentration of injectate	460,000 mg/L	Maximum saturation of sodium acetate solution (46% by weight)
Length of injection well screen	10 meters	Design-specified
Time of simulation	182.5 days	Design-specified to determine lateral dispersion over minimum injection intervals.

Utilizing the input variables shown above, the migration of a sodium acetate plume emanating from a single injection well was modeled over a period of 6 months. Figure B-1 provides the simulated plume, with a minimum concentration isopleth of 1.0 milligram per liter (mg/L) mapped (this is the minimum concentration deemed conducive to the designed biological enhancement effects). The highest residual concentration of sodium acetate in the immediate injection well area is 1475 mg/L. The radial distance from the injection point and the 1.0 mg/L isopleth is approximately 19.5 feet.

Doubling this radial dispersion (to 39 feet) gives the effective injection well spacing to maintain these concentrations as minimum conditions.



Naval Facilities Engineering Command • Southern Division •

INTERIM MEASURES WORK PLAN
AOC A –NORTHSIDE FLUVIAL
DEPOSITS GROUNDWATER
NSA MID–SOUTH
MILLINGTON, TENNESSEE

FIGURE B–1
SODIUM ACETATE PLUME

DWG DATE: 11/06/03 | NAME: 0094001B009

Appendix C
Dye Tracer Study

Dye Tracer Study

Objective

A tracer study will be performed at the site to confirm groundwater velocity and dispersive characteristics that have been used to locate and space substrate injection wells. Additional wells will be proposed, if needed, based on results of the tracer study. A tracer is a substance in groundwater that carries information about the groundwater system. The tracer study involves the injection of potable water amended with fluorescent dye into a previously installed injection well. After injection, area monitoring wells will be monitored to determine the study progress. The tracer study area is presented in Figure C-1.

Description of Dye Tracer Study

Dye tracing with a fluorescent dye is proposed for the tracer study. There are several advantages of fluorescent dyes compared to others. One important advantage is that fluorescent dyes are non-toxic and have been approved for tracer studies by the USEPA. Another advantage is that the travel time for the fluorescent dye is similar to that of groundwater. Although there are many tracers available, Rhodamine WT has been chosen for the dye tracer study to be performed at AOC A. It is water soluble, highly detectable, inexpensive, and has a low sorption tendency. Rhodamine WT dye is a commonly used tracer in stream and surface water studies and is considered harmless at low concentrations.

As part of this study, a total of approximately 15 lbs of Rhodamine WT dye will be injected into a single injection well (Well 61LF). This one time injection should result in a dispersed, average concentration of 100 parts per billion (ppb) in about a 40 foot radius within the first six months. The dye should dilute out further within the next six months to less than 1 ppb. Rhodamine WT does not have any toxicity issues at the proposed levels of injection and expected final concentrations.

The dye mixture will comprise approximately 75% dye and 25% water. The tracer injection will occur over one day. Once the solution is properly mixed, the tracer will be injected. Flushing with three borehole volumes of distilled water will be conducted directly after the tracer injection in order to mobilize the released fluorescent dye.

Post-Injection Sampling

Post-injection sampling will be conducted. The monitoring wells will be sampled by using micro-purge/low flow sampling techniques. Samples will be collected from monitoring wells 04LF, 57LF, 58LF, 59LF, and 62LF. Groundwater will be collected and contained in proper glass vials. All samples for the dye tracer study will be sent to Ozark Underground Laboratories or K2 Environmental to be analyzed for fluorescence. Sampling will continue for approximately 3 to 6 months or until sufficient data is gathered. Sampling frequency will be noted as shown in Table C-1.

Table C-1
Sampling Frequency for Dye Tracer Study

Wells to be Sampled	Days Sample Will be Collected after Injection
60LF, 61LF, 62LF	18
60LF, 61LF, 62LF	35
60LF, 61LF, 62LF, 59LF	70
60LF, 61LF, 62LF, 59LF, 58LF	77
60LF, 61LF, 62LF, 59LF, 58LF	89
60LF, 61LF, 62LF, 59LF, 58LF, 04LF	105
60LF, 61LF, 62LF, 59LF, 58LF, 04LF, 57LF	175

Note:
Wells locations where all dye has passed through and is not detected during two consecutive sampling events will be exempted from further sampling.