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Final

Groundwater Remediation Plan for SWMUs 2B and 2E

Naval Air Station Oceana
Virginia Beach, Virginia

Prepared for

Department of the Navy

Atlantic Division
Naval Facilities Engineering Command

Contract No. N62470-95-D-6007
CTO-0267

June 2004

Prepared by

CH2MHILL

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Virginia Beach, Virginia

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Department of the Navy
Atlantic Division
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Norfolk, Virginia

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Contract Task Order 0267

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Acronyms and Abbreviations

1,1-DCE	1,1-dichloroethene
1,2-DCE	1,2-dichloroethene (*cis* and *trans* isomers)
ARARs	Applicable or relevant and appropriate requirements
bgs	Below ground surface
CMS	Corrective Measures Study
CVOCs	Chlorinated volatile organic compounds
DL	Analytical method detection limits
DO	Dissolved oxygen
DPT	Direct-push technology
ERA	Ecological Risk Assessment
Fe	Iron; Fe(II) and Fe(III) refer to the divalent (ferrous) and trivalent (ferric) forms, respectively
FS	Feasibility Study
HHRA	Human Health Risk Assessment
HRC	Hydrogen Release Compound™
IAS	Initial Assessment Study
IRA	Interim remedial action
MCLs	Maximum contaminant levels
Mn	Manganese; Mn(II) and Mn(IV) refer to the divalent (manganous) and tetravalent (manganic) forms, respectively
NAPL	Non-aqueous phase liquid
NAS	Naval Air Station
NO_2-N	Nitrite-nitrogen
NO_3-N	Nitrate-nitrogen
ORP	Oxidation-reduction potential
ORC	Oxygen Release Compound™
PRG	Preliminary remediation goal
RAO	Remedial Action Objective
RD	Reductive dechlorination
RFI	RCRA Facility Investigation
SOPs	Standard operating procedures
SVOCs	Semi-volatile organic compounds
SWMU	Solid waste management unit
TCE	Trichloroethene
USEPA	United States Environmental Protection Agency
VC	Vinyl chloride (chloroethene)
VOCs	Volatile organic compounds, includes CVOCs and non-chlorinated volatile organics

SECTION 1

Introduction

This Work Plan presents the groundwater remediation to be implemented at Solid Waste Management Units (SWMUs) 2B (the Line Shack 130-134 Disposal Area) and 2E (the Line Shack 109 Disposal Area) at Naval Air Station (NAS) Oceana in Virginia Beach, Virginia. Groundwater remediation will be performed through enhanced, in-situ bioremediation of chlorinated volatile organic compounds (CVOCs) by indigenous microorganisms. The remedial design will consist of injecting reagents in two areas at SWMU 2B (around OW2B-MW01 and OW2B-MW14) and one area at SWMU 2E (around OW2E-MW09). The areas targeted for remediation were identified based on CVOC concentrations measured in recent groundwater monitoring events that exceeded drinking water maximum contaminant levels (MCLs). The CVOCs with detected concentrations greater than their respective MCLs are trichloroethene (TCE) at OW2B-MW01 and vinyl chloride (VC) at OW2B-MW14 and OW2E-MW09. Cis-1,2-dichloroethene (cis-1,2-DCE) and VC concentrations were slightly greater than MCLs at OW2B-MW01 in previous monitoring rounds but were less than MCLs in the most recent event.

The groundwater remediation approach presented in this work plan is consistent with sampling conducted at SWMU 2B as part of the *Final Work Plan for Background Investigation and Hot Spot Groundwater Remediation Pilot Testing SWMUs 1, 2B, and 24* (CH2M HILL, February 2003). This Work Plan included a "baseline" sample event to determine baseline contaminant concentrations at SWMU 2B as input to determining localized groundwater treatment. Following the initial "baseline" sampling event, it was observed that several of the monitoring well locations proposed for localized remediation were indicating CVOC concentrations below their respective MCLs, which would have been the clean up goals if localized remediation were implemented. As a result, it was determined at the June 2003 Tier I NAS Oceana partnering meeting to implement a quarterly monitoring program to evaluate contaminant concentrations prior to performing localized remediation. The groundwater remediation recommendations presented in this work plan for SMWU 2B are based upon the results of the quarterly groundwater sampling conducted following the partnering team agreement.

The quarterly groundwater sampling conducted at SWMUs 1 and 24 as part of the *Final Work Plan for Background Investigation and Hot Spot Groundwater Remediation Pilot Testing SWMUs 1, 2B, and 24* have indicated that no groundwater treatment is necessary.

SWMU 2E has historically shown vinyl chloride (VC) in one monitoring well (OW2E-MW09) at a concentration (8 ug/L) above it's MCL of 2 ug/L. This concentration of VC presented a risk to human health slightly above the acceptable risk of 1x10E-04. Since the VC detection at SWMU 2E was from a groundwater sample event conducted in 2000, OW2E-MW09 was sampled again in February 2004 to evaluate the VC concentration to determine if localized groundwater treatment was necessary. This work plan presents the recommendations for groundwater treatment at SMWU 2E based upon the results of this sampling event (VC was detected at 5.9 ug/L).

Chemical-specific applicable or relevant and appropriate regulations (ARARs) for CVOCs in groundwater at SWMUs 2B and 2E include drinking water MCLs established by the United States Environmental Protection Agency (USEPA). Consequently, the MCLs can be considered to be the ultimate remediation goals for the groundwater at these sites.

The overall goal of this groundwater remediation project is to remediate the localized areas of contamination at SWMUs 2B and 2E identified above. The specific objectives of the remedial design at SWMUs 2B and 2E are to:

1. Conduct an initial round of groundwater monitoring prior to injecting reagents to establish baseline groundwater quality characteristics;
2. Develop injection plans and inject selected reagents into the subsurface of the areas identified for treatment to enhance bioremediation;
3. Conduct groundwater monitoring at selected intervals to track changes in CVOC concentrations and other parameters over time, and;
4. Analyze and interpret monitoring data to evaluate the effectiveness and progress of bioremediation, and report the results.

This Work Plan is divided into five sections. The remainder of Section 1 describes the site location and history, site geology and hydrogeology, and the nature and extent of contamination around the Line Shack 130-134 and 109 areas. Section 2 presents an evaluation of enhanced bioremediation alternatives and the rationale for the selected processes. Section 3 presents the approaches for groundwater remediation. Sections 4 lists references used to prepare this document.

1.1 Location and History of Sites

1.1.1 SWMU 2B

SWMU 2B is located southeast of the main MATWING hangar 122 (Figure 1-1), and encompasses Line Shacks 130 through 135 and the five aircraft cleaning stations northeast of Line Shack 130 (Figure 1-2). The locations of existing monitoring wells at SWMU 2B are also shown on Figure 1-2.

This general area has been used for aircraft maintenance and cleaning. Historically, Naval personnel disposed of various maintenance and cleaning chemicals that potentially included waste oil, hydraulic fluid, PD-680, paint stripper, thinner, Turco, naphtha, benzene, toluene, and derivatives. These chemicals contained various volatile organic compounds (VOCs), including TCE, and semi-volatile organic compounds (SVOCs). TCE is thought to be the primary CVOC parent compound released to the environment.

According to the Initial Assessment Study (IAS) (RGH, 1984), disposal of the chemicals near the Line Shack 400 occurred from 1963 until a hazardous waste recovery program was initiated in the early 1980s. In the 1980s, an oil water separator system was installed in the aircraft cleaning area northeast of Line Shack 130 to separate oil from wash water flowing from the aircraft cleaning area (RGH, 1984).

Construction, including building of a new corrosion control hangar and extension of the flight-line was recently completed at SWMU 2B. Much of the ground surface in the vicinity of the Line Shacks is covered with concrete or asphalt. The limited exposed ground surface between the buildings, parking areas, and tarmac is grassy and is maintained as mowed lawn.

1.1.2 SWMU 2E

SWMU 2E is located in the central area of NAS Oceana (Figure 1-1) and includes Line Shack 109, Building 110, and the surrounding storage yard (Figure 1-3). Line Shack 109 and the adjacent areas have been used for cleaning and maintaining aircraft, and storing equipment and materials since 1963. According to the IAS (RGH, 1984), waste chemicals used for aircraft cleaning and maintenance were discarded on the ground at SWMU 2E. During the Interim RCRA Facility Investigation (RFI), low concentrations of VOCs were detected in groundwater at SWMU 2E, but when floating free-phase hydrocarbons were discovered in 2E-MW1 in January 1993, interim remedial measures were initiated.

The Public Works Department at NAS Oceana implemented interim remedial measures by initiating a monthly program of removing free-phase hydrocarbons from selected monitoring wells. The program in currently ongoing, but does not address CERCLA related contaminants at the site.

The SWMU includes a parking lot west and south of Line Shack 109 and an area of lawn between First Street and the line shacks. About half of the SWMU is in the flight line. The developed areas are either covered with asphalt or have been planted with turf grasses and maintained as lawn.

1.2 Geology and Hydrogeology

Regional geology for NAS Oceana is summarized in Section 1.3.3 of the *Final Feasibility Study for SWMUs 2B, 2C, and 2E, NAS Oceana, Virginia Beach, Virginia* (CH2M HILL, March 2002). Site specific geology and hydrogeology are detailed below.

The subsurface at SWMUs 2B and 2E consists of three stratigraphic units. The uppermost unit is a 4 to 8-foot thick unit of fine sediments, mainly silty clays and silty sands. This is underlain by a 15- to 20-foot layer of poorly graded fine to medium sand with some silty lenses. These two units correspond to the Columbia Group sediments. The Columbia Group is underlain by the Yorktown Formation, which is silty sand interlayered with zones of cleaner sand. Shells and shell hash indicative of the top of the Yorktown Formation were typically encountered at approximately 25 feet below ground surface (bgs).

Based on survey and water level data, the groundwater flow in the vicinity of SWMUs 2B and 2E is generally south to southwest with localized groundwater flow toward nearby stormwater drainage channels. Figure 1-4 depicts SWMU 2B water table elevation contours for data collected in December 2000. Figure 1-5 depicts SWMU 2E water table elevation contours for data collected in December 2000. Historical water level data are tabulated in Tables 1-1 and 1-2. The estimated average hydraulic gradient across SWMU 2B is between 0.0017 ft/ft and 0.0056 ft/ft. The average hydraulic gradient across SWMU 2E is approximately 0.00083 ft/ft. The average velocities of horizontal groundwater flow in the surficial aquifer at SWMUs 2B and 2E are approximately 75 and 40 feet per year, respectively.

1.3 Nature and Extent of Contamination

1.3.1 Previous Investigations at SWMU 2B

Previous investigations at SWMU 2B include the Round 1 Verification Study, Line Shack Site Inspection, Interim RFI, Phase I RFI, Corrective Measures Study (CMS), Phase III RFI, Human Health Risk Assessment (HHRA) and Ecological Risk Assessment (ERA). Table 1-3 presents the previous investigations performed at SWMU 2B, the group performing the work, when the work took place, and the relevant findings/results.

Based upon the results of the HHRA, localized remediation was recommended for monitoring wells OW2B-MW01, OW2B-MW02, OW2B-MW03, OW2B-MW04, OW2B-MW05, OW2B-MW13, OW2B-MW14, OW2B-MW17, and OW2B-MW18. The *Final Work Plan for Background Investigation and Hot Spot Groundwater Remediation Pilot Testing SWMUs 1, 2B, and 24 (CH2M HILL, February 2003)* proposed initial testing of SWMU 2B groundwater, evaluation of analytical results, selection and implementation of an appropriate remediation alternative, and four rounds of follow up groundwater sampling to determine the effectiveness of the treatment. However, based on the concentrations of contaminants observed in the first round of sampling at SWMU 2B (and SWMUs 1 and 24) combined with historical data indicating that natural attenuation was likely occurring, it was determined that four rounds of sampling would be completed prior to performing localized remediation to evaluate if it would be necessary, and if yes, the extent of the effort needed. This determination was discussed at the June 2003 Tier I NAS Oceana partnering meeting after the Work Plan had been finalized. The results of these four rounds of sampling are summarized in Section 1.3.3.

1.3.2 Previous Investigations at SWMU 2E

Previous investigations conducted at SWMU 2E include the Interim RFI, Phase I and Phase II RFI, CMS, HHRA, and ERA. Table 1-4 presents these investigations, along with who performed the work, when the work was conducted, and the relevant findings/results.

Based upon the results of the HHRA and the February 2000 sampling event, OW2E-MW09 was identified as the only site well with VOC (VC) contamination at a concentration slightly exceeding its corresponding MCL of 2 ug/L. Analytical results for several other wells: OW2E-MW01, OW2E-MW04, OW2E-MW08, and OW2E-MW16 indicated MCL exceedances for SVOCs that were related to former fuel handling operations at SMWU 2E. These contaminants are not being evaluated or recommended for action in this work plan since they are non-CERCLA related compounds. The non-CERCLA compounds were identified as posing the greatest risk to human health. The VC concentration (8 ug/L) in OW2E-MW09 presented a human health risk slightly above the acceptable risk of 1x10E-04 in the HHRA (CH2M HILL, January 2002).

Based on the results of a product thickness survey conducted as part of the CMS, there are no free-phase hydrocarbons in OW2E-MW09. The low concentrations of contaminants at the SWMU in historical groundwater data indicating that natural attenuation is occurring. One additional round of sampling was completed in February 2004 to evaluate if the VC in OW2E-MW09 had naturally attenuated to below the MCL or if groundwater treatment were necessary. The results of this round of sampling and the February 2000 sampling are summarized in Section 1.3.4.

1.3.3 Summary of SWMU 2B Contamination

Analytical data for SWMU 2B wells collected after 1999 are presented in Table 1-5. Additional analytical data collected prior to 2000 can be found in the RFI and CMS reports. The results of the last four rounds of sampling at SWMU 2B are shown on Figure 1-6. These sample rounds were conducted in place of the four post-remediation sample rounds proposed in the *Final Work Plan for Background Investigation and Hot Spot Groundwater Remediation Pilot Testing – SWMUs 1,2B, and 24* (CH2M HILL, February 2003). The samples were collected to assess the extent to which natural attenuation was taking place prior to selecting a remediation approach. Contaminants found in the groundwater during the last four rounds of sampling at SWMU 2B at concentrations exceeding MCLs are TCE, cis-1,2-DCE, and VC (CH2M HILL, 2003). Concentrations of CVOCs exceeded MCLs in only two of the SWMU 2B wells, OW2B-MW01 and OW2B-MW14.

Figure 1-6 summarizes the results of the groundwater sampling conducted at SMWU 2B in 2003 and 2004. With the exception of OW2B-MW01 and OW2B-MW14, none of the monitoring wells indicated MCL exceedances in any of the sample events. OW2B-MW04 had a historic groundwater exceedance of an SVOC, bis(2-ethylhexyl)phthalate, which was evaluated in the groundwater monitoring events. This compound was not detected in the last two sample rounds and no groundwater remediation is proposed. Based upon the detections of TCE, cis-1,2-DCE, and VC in OW2B-MW01 in the last four rounds of monitoring, groundwater remediation is proposed in the vicinity of this monitoring well. In addition, VC has been detected above its MCL in OW2B-MW14 in each of the monitoring events and groundwater remediation is recommended in this vicinity as well.

1.3.4 Summary of SWMU 2E Contamination

Analytical data collected at SWMU 2E in 2000 and 2004 are presented in Table 1-6. OW2E-MW09 was the only well sampled during these events because it was the only well with historic organic MCL exceedances of VOCs. Analytical results for sampling efforts prior to 2000 can be found in the RFI and CMS reports. The results of the two most recent rounds of sampling are shown on Figure 1-7. One CVOC, VC, was detected in groundwater from OW2E-MW09 at concentrations slightly greater than the MCL during the 2000 and 2004 sampling events.

1.3.5 Focus of the Work Plan

This work plan has been developed to evaluate localized groundwater remediation in the vicinity of monitoring wells at SWMUs 2B and 2E based upon the results of recent groundwater monitoring events. Two monitoring wells at SWMU 2B (OW-2BMW01and OW2B-MW14) and one monitoring well at SWMU 2E (OW2E-MW09) require localized groundwater remdiation to reduce CVOC contaminants in groundwater. The following sections include a brief technology evaluation and describe the recommended groundwater treatment in these target areas.

TABLE 1-1
Historical Water-Table Data for SWMU 2B
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Well	Date Installed	Measuring Point Elevation (ft above MSL)	Ground Surface Elevation (ft above MSL)	Total Depth (ft)	Screened Interval (ft BGS)	Water-Table Elevation (ft)									
						Sep-88	Nov-90	Feb-93	Mar-94	May-94	Dec-00	Jan-03	Jul-03	Nov-03	Jan-04
2B-MW1	4/3/86	21.59[a]	21.8	19	9-19	13.87	12.37	14.76	15.4	14.45	13.78	14.6	15.32	14.58	14.89
2B-MW1D	12/8/92	21.73	21.7	46	36-46	-	-	14.61	15.5	-	12.38	-	-	-	-
2B-MW2	4/1/86	20.34	18.9	25	15-25	13.17	12.25	14.5	15.39	13.74	-	-	-	-	-
2B-MW3	4/2/86	19.23	18	20	10-20	13.23	12.04	14.58	-	-	-	-	-	-	-
2B-MW4	9/2/88	20.93	20.9	19	9-19	13.75	11.75	14.42	15.46	-	13.63	-	-	12.71	13.67
2B-MW5	9/1/88	21.78	21.8	18	8-18	13.64	12.52	14.36	-	-	12.47	13.54	14.84	13.46	13.58
2B-MW5D	12/10/92	21.76[b]	21.8	47	37-47	-	-	14.42	15.34	13.48	13.06	-	-	-	-
2B-MW6	9/6/88	21.01	21	15	5-15	13.62	12.61	14.56	15.76	13.67	-	-	-	-	-
2B-MW7	6/27/90	20.95	18.7	14	9-14	-	12.01	13.87	14.43	13.29	12.97	-	-	-	-
2B-MW8	6/29/90	20.02	18	20	10-20	-	11.76	14.47	15.34	13.62		-	-	-	-
2B-MW9	6/29/90	22.27	20.5	20	10-20	-	12.61	14.62	15.43	14.01	12.59	-	-	-	-
2B-MW10	7/11/90	22.07	22.1	18	8-18	-	-	14.42	14.98	14.25	13.71	-	-	-	-
2B-MW11	7/10/90	22.07	22.1	18	8-18	-	-	14.79	-	14.45	13.6	-	-	-	-
2B-MW12	12/4/92	21.29	18.4	22.5	12.5-22.5	-	-	14.39	15.39	13.43	12.25	-	-	-	-
2B-MW13	12/4/92	20.4	17.9	20	10-20	-	-	14.44	15.45	13.54		13.15	14.41	13.27	13.6
2B-MW14	12/4/92	20.41	17.4	20	10-20	-	-	14.13	14.92	13.4	12.66	14.4	15.7	14.64	14.81
2B-MW15	12/4/92	21.97	19	22.5	12-22	-	-	14.39	15.35	13.78	13.22	-	-	-	-
2B-MW16	1/12/93	21.16	21.2	20	10-20	-	-	14.66	15.71	14.13		-	-	-	-
2B-MW17	2/28/94	21.66	21.7	24	10-20	-	-	-	15.56	14.39	13.39	14.91	16.31	15.21	15.84
2B-MW18	2/24/94	22.75	21	24	10-20	-	-	-	15.46	14.06	13.45	14.57	16.11	14.86	14.96
2B-MW19	2/21/94	18.22	18.2	20	10-20	-	-	-	15.11	11.38	12.82	-	-	-	-
2B-MW20	5/9/94	19.08	19.1	20	9.5-19.5	-	-	-	-	13.72	12.65	-	-	-	-

Notes:
(-) Not measured

TABLE 1-2
Historical Water-Table Data for SWMU 2E
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Well	Date Installed	Measuring Point Elevation (ft above MSL)	Ground Surface Elevation (ft above MSL)	Total Depth (ft)	Screened Interval (ft BGS)	Water-Table Elevation (ft)							
						Aug-90	Jan-93	Mar-94	May-94	Oct-94	Mar-95	Dec-00	Mar-04
2E-MW1	6/28/90	22.52	20.3	19	9-19	14.6	10.1	15.7	12.86	-	-	13.19	-
2E-MW2	7/6/90	19.43	19.4	18.5	8-18	14.66	16.66	16.19	14.23	12.71	15.33	-	-
2E-MW3	7/2/90	20.83	18.9	18	8-18	14.7	16.74	16.2	14.25	12.77	15.35	13.07	-
2E-MW4	2/22/94	20.69	20.7	22	4.5-19.5	-	-	14.7	8.59	8.69-10.69[1]	12.02	12.85	-
2E-MW5	2/23/94	20.37	20.4	23	4-19	-	-	15.82	13.94	12.45	15	12.9	-
2E-MW6	2/24/94	20.51	20.5	23	4-19	-	-	16.15	14.06	12.75	15.31	-	-
2E-MW7	3/12/94	20.94	20.9	18	3-18	-	-	16.14	14.19	12.69	15.26	12.93	-
2E-MW8	3/7/94	20.43	20.4	20	3-18	-	-	15.8	11.26	9.07	12.98	12.78	-
2E-MW9	9/21/94	20.74	20.7	18.5	3.5-18.5	-	-	-	-	12.41	14.86	12.63	15.44
2E-MW10	9/22/94	21.64	21.4	20	5-20	-	-	-	-	12.9	15.41	13.08	-
2E-MW11	9/26/94	20.32	20.3	20	5-20	-	-	-	-	12.85	15.42	12.98	-
2E-MW12	9/23/94	20.6	20.6	20	5-20	-	-	-	-	12.54	15.98	12.71	-
2E-MW13	9/26/94	20.35	20.3	20	5-20	-	-	-	-	12.47	15.06	12.71	-
2E-MW14D	3/3/95	20.47	20.5	51	41-51	-	-	-	-	-	14.8	-	-
2E-MW15	3/2/95	18.98	19	20	10-20	-	-	-	-	-	14.6	12.7	-
2E-MW16	3/7/95	17.31	17.3	20	10-20	-	-	-	-	-	14.13	12.25	-

Notes:
(-) Not measured
[1] - Unable to obtain exact measurements so a range was provided

TABLE 1-3
Previous Investigations at SWMU 2B
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Investigation	Completed By	Year	Summary of Findings
Round 1 Verification Study	CH2M HILL	1986	Groundwater is contaminated with chlorinated organic compounds from 2 or more sources.
Line Shack Site Inspection	CH2M HILL	1988	Groundwater is contaminated with chlorinated organic compounds from 2 or more sources.
Interim RCRA Facility Investigation	CH2M HILL	1990	Groundwater is contaminated with chlorinated organic compounds from 2 or more sources.
Phase I RCRA Facility Investigation	CH2M HILL	1993	Defined sources of groundwater contamination and sources areas through sampling, and defined the effects of groundwater discharge to surface water and sediment quality.
Corrective Measures Study	CH2M HILL	1995	Further delineated extent of groundwater, soil, and surface water/sediment contamination and determined need for remedial activities.
Phase III RCRA Facility Investigation	CH2M HILL	1997	Performed follow-up sediment sampling to further characterize sediment contamination at
Human Health Risk Assessment	CH2M HILL	2000	Only potential scenario resulting in hazards and risks is future residential use of the shallow aquifer groundwater, which is highly unlikely.
Ecological Risk Assessment	CH2M HILL	2001	Some small areas that have exceedances of screening criteria, but these areas are isolated and not migrating to other areas. No further action recommended on the basis of ecological

TABLE 1-4
Previous Investigations at SWMU 2E
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Investigation	Completed By	Year	Summary of Findings
Interim RCRA Facility Investigation	CH2M HILL	1990	Groundwater sampling results indicated that parameters analyzed either were detected at low levels or were not detected.
Phase I RCRA Facility Investigation	CH2M HILL	1993	Diesel discovered in one of the wells. Delineated source area and extent of subsurface free-phase diesel fuel. Determined nature and extent of dissolved-phase groundwater contaminant plume.
Phase II RCRA Facility Investigation	CH2M HILL	1995	Characterized extent of free-phase hydrocarbon contamination and continued to characterize dissolved-phase groundwater contamination.
Corrective Measures Study	CH2M HILL	1995	Further delineated aerial and vertical extent of dissolved-phase groundwater contaminant plume.
Groundwater Sampling	CH2M HILL	2000	Assessed site-wide groundwater quality and supported the preparation of the HHRA.
Human Health Risk Assessment	CH2M HILL	2000	Only potential scenarios resulting in hazards and risks are under the future residential use of groundwater at the site, which is highly unlikely.
Ecological Risk Assessment	CH2M HILL	2001	Complete exposure pathways do not likely exist, therefore ecological risk is unlikely. No further action recommended based on ecological considerations.

Table 1-5
SWMU 2B Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2B-MW01						OW2B-MW01D		OW2B-MW02			OW2B-MW03	OW2B-MW04				
Sample ID	OW2B-MW01-R01	OW2B-MW01-03A	OW2B-MW01P-03A	OW2B-MW01-03C	OW2B-MW01-03D	OW2B-MW01-04A	OW2B-MW01D-R01-P	OW2B-MW01D-R01	OW2B-MW02-R01	OW2B-MW02-R01-P	OW2B-MW02D-R01-P	OW2B-MW03-R01	OW2B-MW04-R01	OW2B-MW04-R01-DUP	OW2B-MW04-03D	OW2B-MW04-04A	OW2B-MW05-R01
Sample Date	02/25/00	01/22/03	01/22/03	07/25/03	11/07/03	01/27/04	02/25/00	02/26/00	02/25/00	02/25/00	02/25/00	02/25/00	02/29/00	02/29/00	11/06/03	01/27/04	02/23/00
Chemical Name																	
Volatile Organic Compounds (UG/L)																	
1,1,1-Trichloroethane	5 U	2.1	2	1 U	1 U	1 U	1 U	NA	1 U	NA	1 U	4 U	1 U	NA	NA	NA	1 U
1,1-Dichloroethane	11	1.7 J	1.7 J	1.3	3.6	1 U	1 U	NA	0.4 J	NA	0.3 J	3 J	0.2 J	NA	NA	NA	16
1,1-Dichloroethene	3 J	2 U	2 U	1.1	2 B	1 U	1 U	NA	0.1 J	NA	0.1 J	0.8 J	1 U	NA	NA	NA	0.3 J
1,3-Dichlorobenzene	5 U	NA	NA	NA	NA	NA	1 U	NA	1 U	NA	1 U	4 U	1 U	NA	NA	NA	0.1 J
Acetone	25 R	10 U	10 U	5 U	5 U	7.6	5 R	NA	5 R	NA	5 R	21 R	7 L	NA	NA	NA	5 R
Benzene	5 U	2 U	2 U	1 U	1 U	1 U	1 U	NA	1 U	NA	1 U	4 U	1 U	NA	NA	NA	2
Chloroethane	5 U	2 U	2 U	1 U	1 U	1 U	1 U	NA	1 U	NA	1 U	4 U	1 U	NA	NA	NA	3
Naphthalene	NA	2 U	2 U	0.24 J	1 U	1 U	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	5 U	57	56	36	230	18	1 U	NA	1 U	NA	1 U	4 U	1 U	NA	NA	NA	1 U
Toluene	5 U	2 U	2 U	1 U	1 U	1 U	0.1 J	NA	0.1 J	NA	0.1 J	4 U	0.6 J	NA	NA	NA	0.2 J
Trichloroethene	56 B	160	150	170	270	21	0.2 J	NA	14	NA	13	28 B	1 U	NA	NA	NA	2
Vinyl chloride	13	3.9	4.2	7.8	13	0.69 J	1 U	NA	0.6 J	NA	0.5 J	2 J	1 U	NA	NA	NA	6
cis-1,2-Dichloroethene	120	69	66	130	200	20	0.3 J	NA	12	NA	12	60	0.5 J	NA	NA	NA	3
trans-1,2-Dichloroethene	11	11	10	14	24	1.4	1 U	NA	0.2 J	NA	0.2 J	3 J	1 U	NA	NA	NA	1 U
Semi-volatile Organic Compounds (UG/L)																	
Acenaphthylene	1 UL	NA	NA	NA	NA	NA	1 UL	NA	1 U	NA	1 U	1 U	1 U	NA	10 U	10 U	1.6 J
Fluorene	1 UL	NA	NA	NA	NA	NA	0.024 L	NA	1 U	NA	1 U	1 U	1 U	NA	10 U	10 U	0.12 J
Naphthalene	2 UL	NA	NA	NA	NA	NA	2 UL	NA	2 U	NA	2 U	2 U	2 U	NA	10 U	10 U	0.52 J
Phenanthrene	1 UL	NA	NA	NA	NA	NA	0.045 L	NA	1 U	NA	1 U	1 U	1 U	NA	10 U	10 U	0.045 J
Pyrene	0.1 UJ	NA	NA	NA	NA	NA	0.18 J	NA	0.1 UJ	NA	0.1 UJ	0.1 UJ	0.1 U	NA	10 U	10 U	0.1 UJ
bis(2-Ethylhexyl)phthalate	10 U	NA	NA	NA	NA	NA	1 J	NA	1 J	NA	2 J	10 U	30	NA	10 U	10 U	10 U
Pesticide/Polychlorinated Biphenyls (UG/L)																	
Heptachlor epoxide	0.05 U	NA	NA	NA	NA	NA	0.05 U	NA	0.05 U	NA	0.05 U	0.05 U	0.05 U	NA	NA	NA	0.05 U
beta-BHC	0.05 U	NA	NA	NA	NA	NA	0.05 U	NA	0.05 U	NA	0.05 U	0.05 U	0.05 U	NA	NA	NA	0.028 J
Total Metals (UG/L)																	
Arsenic	2.5 U	NA	NA	NA	NA	NA	2.5 U	NA	2.5 U	NA	2.5 U	2.5 U	11 B	NA	NA	NA	19.7
Barium	19.2 J	NA	NA	NA	NA	NA	26.3 J	NA	8.4 J	NA	5.8 J	29.2 J	56.5 J	NA	NA	NA	96.3 J
Cadmium	0.7 U	NA	NA	NA	NA	NA	0.7 U	NA	0.7 U	NA	0.7 U	0.7 U	0.7 U	NA	NA	NA	0.7 U
Calcium	10,300	NA	NA	NA	NA	NA	36,000	NA	56,400	NA	57,300	68,300	17,700	NA	NA	NA	30,100
Iron	4,450	NA	NA	NA	NA	NA	646	NA	1,140	NA	1,100	4,850	31,700	NA	NA	NA	30,000
Magnesium	15,100	NA	NA	NA	NA	NA	2,780 J	NA	6,830	NA	6,910	9,540	19,600	NA	NA	NA	14,400
Manganese	160	NA	NA	NA	NA	NA	86.9	500 U	410	500 U	417	419	250	500 U	NA	NA	890
Potassium	665 J	NA	NA	NA	NA	NA	8,540	NA	1,170 J	NA	1,170 J	3,080 J	1,160 J	NA	NA	NA	3,190 J
Sodium	32,900	NA	NA	NA	NA	NA	17,000	NA	25,100	NA	25,400	26,900	30,000	NA	NA	NA	11,600
Zinc	3.7 B	NA	NA	NA	NA	NA	11.6 B	NA	1.8 B	NA	6.8 B	16.1 B	16.5 B	NA	NA	NA	2.5 B
Dissolved Metals (UG/L)																	
Aluminum	19 B	NA	NA	NA	NA	NA	20.9 B	NA	31.9 B	NA	20.8 B	15.5 U	29.2 B	NA	NA	NA	20.1 B
Arsenic	2.5 U	NA	NA	NA	NA	NA	2.5 U	NA	2.5 U	NA	2.5 U	2.5 U	4.3 B	NA	NA	NA	19.2
Barium	22 J	NA	NA	NA	NA	NA	25.1 J	NA	5.6 J	NA	5.3 J	31.2 J	56.8 J	NA	NA	NA	86 J
Calcium	11,400	NA	NA	NA	NA	NA	36,400	NA	59,300	NA	61,100	76,700	19,000	NA	NA	NA	26,700
Iron	4,430	NA	NA	NA	NA	NA	266	NA	871	NA	911	5,360	28,900	NA	NA	NA	26,400
Magnesium	16,900	NA	NA	NA	NA	NA	2,830 J	NA	7,180	NA	7,390	10,700	20,600	NA	NA	NA	12,800
Manganese	172	NA	NA	NA	NA	NA	81.6	NA	394	NA	408	467	269	NA	NA	NA	789
Nickel	2.9 J	NA	NA	NA	NA	NA	3.2 J	NA	1.7 U	NA	1.7 U	3.3 J	1.7 U	NA	NA	NA	1.7 U
Potassium	758 J	NA	NA	NA	NA	NA	8,420	NA	1,250 J	NA	1,270 J	3,320 J	1,230 J	NA	NA	NA	2,840 J
Sodium	36,400	NA	NA	NA	NA	NA	18,400	NA	26,600	NA	27,700	30,200	31,600	NA	NA	NA	8,780
Zinc	5 J	NA	NA	NA	NA	NA	3 J	NA	9.6 J	NA	6.4 J	12 J	11.6 B	NA	NA	NA	3.4 J
Wet Chemistry (MG/L)																	
Alkalinity	100	NA	NA	NA	NA	NA	NA	85	135	130	NA	190	155	210	NA	NA	60
Chloride	18	NA	NA	NA	NA	NA	NA	9.9	23	22	NA	15	25	25	NA	NA	8.9
Dissolved oxygen	0.06	NA	NA	NA	NA	NA	NA	0.12	0.05	NA	NA	0.77	0.35	NA	NA	NA	0.2
Ethane	1.95E-04	NA	NA	NA	NA	NA	NA	5.00E-06 U	2.50E-05	5.00E-06 U	NA	5.40E-05	4.78E-04	NA	NA	NA	2.73E-04
Ethene	8.21E-04	NA	NA	NA	NA	NA	NA	4.40E-05	2.50E-05	5.00E-06 U	NA	1.63E-04	5.00E-06 U	NA	NA	NA	8.69E-04
Ferric iron	0.5 U	NA	NA	NA	NA	NA	NA	0.5 U	0.5 U	0.5 U	NA	0.5 U	0.9	0.8	NA	NA	1.5
Ferrous iron	2.7	NA	NA	NA	NA	NA	NA	0.5 U	0.5 U	0.5 U	NA	2.1	24 E	24 E	NA	NA	16
Methane	0.59	NA	NA	NA	NA	NA	NA	0.24	0.00116	3.63E-04	NA	0.0798	22.7	NA	NA	NA	5.07
Nitrate	0.5 U	NA	NA	NA	NA	NA	NA	1.6	0.5 U	0.5 U	NA	0.5 U	0.5 U	0.5 U	NA	NA	0.5 U
Redox (MV)	77.2	NA	NA	NA	NA	NA	NA	-1.01E+02	-6.40E+01	NA	NA	-2.95E+01	-3.40E+01	NA	NA	NA	-1.75E+02
Specific conductance (MS/CM)	199	NA	NA	NA	NA	NA	NA	215	430	NA	NA	665	329	NA	NA	NA	281

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Table 1-5
SWMU 2B Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2B-MW05						
Sample ID	OW2B-MW05-03A	OW2B-MW05P-03A	OW2B-MW05-03C	OW2B-MW05-03D	OW2B-MW05P-03D	OW2B-MW05-04A	OW2B-MW05P-04A
Sample Date	01/22/03	01/22/03	07/25/03	11/07/03	11/07/03	01/26/04	01/26/04
Chemical Name							
Volatile Organic Compounds (UG/L)							
1,1,1-Trichloroethane	1 U	1 U	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethane	1 U	1 U	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethene	1 U	1 U	1 U	1 U	1 U	1 U	1 U
1,3-Dichlorobenzene	NA	NA	NA	NA	NA	NA	NA
Acetone	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Chloroethane	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Naphthalene	1.1	0.69 J	0.44 J	1.1	1	1.4	1.2
Tetrachloroethene	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Toluene	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Trichloroethene	1.4	1.3	0.88 J	0.95 J	0.94 J	0.99 J	0.88 J
Vinyl chloride	0.58 J	1 U	1 U	1 U	1 U	1 U	1 U
cis-1,2-Dichloroethene	1.5	1.5	1.1	0.99 J	1.1	1.2	1.1
trans-1,2-Dichloroethene	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Semi-volatile Organic Compounds (UG/L)							
Acenaphthylene	NA	NA	NA	NA	NA	NA	NA
Fluorene	NA	NA	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	NA	NA	NA	NA
Pesticide/Polychlorinated Biphenyls (UG/L)							
Heptachlor epoxide	NA	NA	NA	NA	NA	NA	NA
beta-BHC	NA	NA	NA	NA	NA	NA	NA
Total Metals (UG/L)							
Arsenic	NA	NA	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	NA	NA
Calcium	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA
Magnesium	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	NA
Potassium	NA	NA	NA	NA	NA	NA	NA
Sodium	NA	NA	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA	NA	NA
Dissolved Metals (UG/L)							
Aluminum	NA	NA	NA	NA	NA	NA	NA
Arsenic	NA	NA	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	NA	NA	NA
Calcium	NA	NA	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	NA	NA
Magnesium	NA	NA	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	NA	NA
Nickel	NA	NA	NA	NA	NA	NA	NA
Potassium	NA	NA	NA	NA	NA	NA	NA
Sodium	NA	NA	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA	NA	NA
Wet Chemistry (MG/L)							
Alkalinity	NA	NA	NA	NA	NA	NA	NA
Chloride	NA	NA	NA	NA	NA	NA	NA
Dissolved oxygen	NA	NA	NA	NA	NA	NA	NA
Ethane	NA	NA	NA	NA	NA	NA	NA
Ethene	NA	NA	NA	NA	NA	NA	NA
Ferric iron	NA	NA	NA	NA	NA	NA	NA
Ferrous iron	NA	NA	NA	NA	NA	NA	NA
Methane	NA	NA	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	NA	NA
Redox (MV)	NA	NA	NA	NA	NA	NA	NA
Specific conductance (MS/CM)	NA	NA	NA	NA	NA	NA	NA

Station ID	OW2B-MW05D	OW2B-MW07		OW2B-MW08	OW2B-MW09	OW2B-MW10	OW2B-MW11	OW2B-MW12		
Sample ID	OW2B-MW05D-R01	OW2B-MW7	OW2B-MW07-R01	OW2B-MW08-R01	OW2B-MW09-R01	OW2B-MW10-R01	OW2B-MW11-R01	OW2B-MW12-R01	OW2B-MW13-R01	OW2B-MW13-03A
Sample Date	02/21/00	03/15/94	02/21/00	02/25/00	02/25/00	02/29/00	02/23/00	02/21/00	02/21/00	01/22/03
Chemical Name										
Volatile Organic Compounds (UG/L)										
1,1,1-Trichloroethane	1 U	NA	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethane	1 U	NA	2	1 U	1 U	2	6	1 U	8	34
1,1-Dichloroethene	1 U	NA	0.3 J	1 U	1 U	0.1 J	4	1 U	1	6.5
1,3-Dichlorobenzene	0.1 J	10 U	1 U	1 U	1 U	1 U	1 U	0.1 J	1 U	NA
Acetone	5 R	NA	5 R	5 R	5 R	3 L	5 R	5 R	3 L	5 U
Benzene	1 U	NA	0.2 J	1 U	1 U	1 U	0.4 J	1 U	0.5 J	1 U
Chloroethane	1 U	NA	0.3 J	1 U	1 U	1 U	1 U	1 U	1	1 U
Naphthalene	NA	NA	NA	NA	NA	NA	NA	NA	NA	1 U
Tetrachloroethene	1 U	NA	1 U	1 U	1 U	1 U	1 U	1 U	1 U	1 U
Toluene	0.2 J	NA	0.2 J	0.2 J	0.1 J	0.3 J	0.1 J	0.2 J	0.2 J	1 U
Trichloroethene	1 U	NA	2	0.7 J	0.1 J	1 U	1 U	1 U	0.4 J	1 U
Vinyl chloride	1 U	NA	2	1 U	1 U	0.3 J	1	1 U	9	2
cis-1,2-Dichloroethene	1 U	NA	3	0.8 J	1 U	4	0.4 J	1 U	4	3.6
trans-1,2-Dichloroethene	1 U	NA	0.1 J	1 U	1 U	0.1 J	1 U	1 U	0.1 J	1 U
Semi-volatile Organic Compounds (UG/L)										
Acenaphthylene	1 UL	2 U	1 U	1 UL	1 U	1 U	1 U	1 U	1 U	NA
Fluorene	0.026 L	1 U	0.059 J	1 UL	1 U	1 U	1 U	1 U	0.028 J	NA
Naphthalene	2 UL	2 U	2 U	2 UL	2 U	2 U	2 U	2 U	2 U	NA
Phenanthrene	0.033 L	1 U	1 U	1 UL	1 U	1 U	1 U	0.034 J	1 U	NA
Pyrene	0.1 UJ	0.5 U	0.1 UJ	0.1 UJ	0.1 UJ	0.1 U	0.1 UJ	0.1 UJ	0.1 UJ	NA
bis(2-Ethylhexyl)phthalate	10 U	10 U	10 U	1 J	3 J	10 U	1 B	10 U	10 U	NA
Pesticide/Polychlorinated Biphenyls (UG/L)										
Heptachlor epoxide	0.05 U	NA	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.062 J	NA
beta-BHC	0.05 U	NA	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	0.05 U	NA
Total Metals (UG/L)										
Arsenic	2.5 U	NA	2.5 U	2.5 U	2.5 U	8.7 B	15	2.8 J	4.3 J	NA
Barium	17.4 J	NA	64.2 J	4.4 J	7 J	19.1 J	75.2 J	4.3 J	17.4 J	NA
Cadmium	0.7 U	NA	0.7 U	0.7 U	0.7 U	0.77 J	0.7 U	0.7 U	0.7 U	NA
Calcium	42,400	NA	7,730	12,400	43,500	31,600	29,400	43,600	61,700	NA
Iron	735	NA	14,000	1,590	2,570	16,700	33,500	1,390	10,200	NA
Magnesium	4,300 J	NA	12,900	2,710 J	5,920	9,190	38,700	8,150	11,700	NA
Manganese	89.4	NA	327	101	292	490	540	300	677	NA
Potassium	4,610 J	NA	951 J	451 J	1,010 J	1,340 J	1,260 J	982 J	1,460 J	NA
Sodium	19,900	NA	14,100	38,400	20,500	25,800	28,500	36,300	21,200	NA
Zinc	17.1 B	NA	14.5 B	3.7 B	2.9 B	36.4	12.6 B	6.2 B	8.8 B	NA
Dissolved Metals (UG/L)										
Aluminum	20.2 B	NA	28.2 B	457 J	15.5 U	24.8 B	54.8 B	51 B	16.9 B	NA
Arsenic	2.5 U	NA	2.5 U	2.5 U	2.5 U	4 B	10.3	2.5 U	3.5 J	NA
Barium	20.7 J	NA	61.7 J	7.1 J	3.3 J	16.6 J	74 J	4.2 J	17.2 J	NA
Calcium	49,200	NA	7,250	15,200	43,200	33,200	29,200	45,400	58,800	NA
Iron	703	NA	12,200	1,440	2,050	10,100	31,600	1,170	9,720	NA
Magnesium	5,240	NA	12,400	2,760 J	5,840	9,700	38,500	8,390	11,200	NA
Manganese	102	NA	313	105	200	511	539	315	648	NA
Nickel	1.7 U	NA	1.7 U	1.7 U	1.9 J	1.9 B	2.4 J	1.7 U	1.7 U	NA
Potassium	5,390	NA	959 J	478 J	995 J	1,370 J	1,230 J	1,020 J	1,390 J	NA
Sodium	21,200	NA	15,100	39,100	20,400	26,800	28,500	38,100	20,000	NA
Zinc	11.2 J	NA	18.7 J	4.6 J	2.5 J	18.3 J	13.1 J	7.8 J	6.2 J	NA
Wet Chemistry (MG/L)										
Alkalinity	140	NA	55	60	120	400	200	100	120	NA
Chloride	15	NA	19	11	18	24	31	21	15	NA
Dissolved oxygen	2.57	NA	0.18	NA	0.12	0.35	0.05	0.35	0.15	NA
Ethane	5.00E-06 U	NA	4.10E-05	1.30E-05	5.00E-06 U	1.08E-04	3.56E-04	5.00E-06 U	1.12E-04	NA
Ethene	8.80E-05	NA	1.58E-04	2.30E-05	5.00E-06 U	5.00E-06 U	7.80E-05	5.00E-06 U	4.79E-04	NA
Ferric iron	0.5 U	NA	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	NA
Ferrous iron	0.5 U	NA	8.4	0.5 U	0.5 U	7.6	22	0.5 U	5.1	NA
Methane	5.08	NA	0.81	0.0117	3.83E-04	0.25	1.08	0.00221	2.01	NA
Nitrate	0.5	NA	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	NA
Redox (MV)	-9.01E+01	NA	-8.05E+01	-3.60E+01	-1.01E+02	-3.19E+01	-6.60E+01	-1.45E+02	-1.28E+02	NA
Specific conductance (MS/CM)	235	NA	156	191	215	329	458	284	320	NA

Table 1-5
SWMU 2B Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2B-MW05							OW2B-MW05D
Sample ID	OW2B-MW05-03A	OW2B-MW05P-03A	OW2B-MW05-03C	OW2B-MW05-03D	OW2B-MW05P-03D	OW2B-MW05-04A	OW2B-MW05P-04A	OW2B-MW05D-R01
Sample Date	01/22/03	01/22/03	07/25/03	11/07/03	11/07/03	01/26/04	01/26/04	02/21/00
Chemical Name								
Sulfate	NA	NA	NA	NA	NA	NA	NA	2.5
Sulfide	NA	NA	NA	NA	NA	NA	NA	0.11
Temperature	NA	NA	NA	NA	NA	NA	NA	[illegible]
Total organic carbon (TOC)	NA	NA	NA	NA	NA	NA	NA	3.1
Turbidity (NTU)	NA	NA	NA	NA	NA	NA	NA	1.5
pH	NA	NA	NA	NA	NA	NA	NA	7.47
Field Parameters								
Dissolved Oxygen (MG/L)	2.07	NA	1.39	0.57	NA	0.49	NA	NA
Depth to Water (Ft)	8.24	NA	6.94	8.32	NA	8.2	NA	NA
Oxidation Reduction Potential (ORP) (MV)	-121	NA	-103	-122	NA	-122	NA	NA
Flow (GPM)	NA	NA	0.043	0.076	NA	0.079	NA	NA
pH	6.93	NA	6.35	6.88	NA	6.54	NA	NA
Salinity (%)	0	NA	0	0.01	NA	0	NA	NA
Specific Conductance (MS/CM)	0.452	NA	0.38	0.29	NA	0.33	NA	NA
Temperature (C)	14.14	NA	19.6	20.2	NA	15.7	NA	NA
Turbidity (NTU)	0	NA	0	0	NA	23	NA	NA
Volume (GAL)	1.5	NA	2.5	NA	NA	3	NA	NA

Station ID	OW2B-MW07		OW2B-MW08	OW2B-MW09	OW2B-MW10	OW2B-MW11	OW2B-MW12		
Sample ID	OW2B-MW7	OW2B-MW07-R01	OW2B-MW08-R01	OW2B-MW09-R01	OW2B-MW10-R01	OW2B-MW11-R01	OW2B-MW12-R01	OW2B-MW13-R01	OW2B-MW13-03A
Sample Date	03/15/94	02/21/00	02/25/00	02/25/00	02/29/00	02/23/00	02/21/00	02/21/00	01/22/03
Chemical Name									
Sulfate	NA	21	25	6.9	8.8	8.7	9	11	NA
Sulfide	NA	0.12	0.12	0.12	0.11	0.1	0.11	0.11	NA
Temperature	NA	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	NA
Total organic carbon (TOC)	NA	23	3.3	4.8	19	12	2.8	11	NA
Turbidity (NTU)	NA	29.8	2.66	22.9	1,835	48.2	2.2	2.3	NA
pH	NA	5.89	5.94	6.94	6.87	5.42	7	6.24	NA
Field Parameters									
Dissolved Oxygen (MG/L)	NA	NA	NA	NA	NA	NA	NA	NA	1.56
Depth to Water (Ft)	NA	NA	NA	NA	NA	NA	NA	NA	7.25
Oxidation Reduction Potential (ORP) (MV)	NA	NA	NA	NA	NA	NA	NA	NA	-49
Flow (GPM)	NA	NA	NA	NA	NA	NA	NA	NA	NA
pH	NA	NA	NA	NA	NA	NA	NA	NA	6.57
Salinity (%)	NA	NA	NA	NA	NA	NA	NA	NA	0
Specific Conductance (MS/CM)	NA	NA	NA	NA	NA	NA	NA	NA	0.254
Temperature (C)	NA	NA	NA	NA	NA	NA	NA	NA	13.79
Turbidity (NTU)	NA	NA	NA	NA	NA	NA	NA	NA	17
Volume (GAL)	NA	NA	NA	NA	NA	NA	NA	NA	2.5

Notes:
Represents detections
B - possible blank contamination
E - concentration has exceeded the calibration range
L - reported value may be biased low
J - analyte present, reported value is estimated
NA - not analyzed
R - unreliable result
U - not detected

Table 1-5
SWMU 2B Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2B-MW13			OW2B-MW14							
Sample ID	OW2B-MW13-03C	OW2B-MW13-03D	OW2B-MW13-04A	OW2B-MW14	OW2B-MW14P	OW2B-MW14-R01	OW2B-MW14-03A	OW2B-MW14-03C	OW2B-MW14P-03C	OW2B-MW14-03D	OW2B-MW14-04A
Sample Date	07/25/03	11/06/03	01/26/04	03/15/94	03/15/94	02/23/00	01/22/03	07/25/03	07/25/03	11/06/03	01/26/04
Chemical Name											
Sulfate	NA	NA	NA	NA	NA	17	NA	NA	NA	NA	NA
Sulfide	NA	NA	NA	NA	NA	0.12	NA	NA	NA	NA	NA
Temperature	NA	NA	NA	NA	NA	[illegible]	NA	NA	NA	NA	NA
Total organic carbon (TOC)	NA	NA	NA	NA	NA	6.3	NA	NA	NA	NA	NA
Turbidity (NTU)	NA	NA	NA	NA	NA	13.1	NA	NA	NA	NA	NA
pH	NA	NA	NA	NA	NA	5.97	NA	NA	NA	NA	NA
Field Parameters											
Dissolved Oxygen (MG/L)	1.7	0.57	0.74	NA	NA	NA	0	2.09	NA	0.56	0.49
Depth to Water (Ft)	5.99	7.13	6.8	NA	NA	NA	6.01	4.71	NA	5.77	5.6
Oxidation Reduction Potential (ORP) (MV)	12	4	47	NA	NA	NA	-28	-46	NA	-79	-47
Flow (GPM)	0.052	0.087	0.085	NA	NA	NA	NA	0.048	NA	0.076	0.087
pH	5.73	5.57	5.72	NA	NA	NA	6.29	6.11	NA	6.34	6.21
Salinity (%)	0	0.01	0	NA	NA	NA	0	0	NA	0	0
Specific Conductance (MS/CM)	0.34	0.28	0.26	NA	NA	NA	0.338	0.44	NA	0.296	0.36
Temperature (C)	17.32	18.7	13.3	NA	NA	NA	16.56	18.2	NA	19.04	14.2
Turbidity (NTU)	13	133	14	NA	NA	NA	2	4.7	NA	34	10
Volume (GAL)	1.5	4	NA	NA	NA	NA	NA	2.5	NA	3.5	4

Notes:
Represents detections
B - possible blank contamination
E - concentration has exceeded the calibration range
L - reported value may be biased low
J - analyte present, reported value is estimated
NA - not analyzed
R - unreliable result
U - not detected

Table 1-5
SWMU 2B Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2B-MW13			OW2B-MW14							
Sample ID	OW2B-MW13-03C	OW2B-MW13-03D	OW2B-MW13-04A	OW2B-MW14	OW2B-MW14P	OW2B-MW14-R01	OW2B-MW14-03A	OW2B-MW14-03C	OW2B-MW14P-03C	OW2B-MW14-03D	OW2B-MW14-04A
Sample Date	07/25/03	11/06/03	01/26/04	03/15/94	03/15/94	02/23/00	01/22/03	07/25/03	07/25/03	11/06/03	01/26/04
Chemical Name											
Volatile Organic Compounds (UG/L)											
1,1,1-Trichloroethane	1 U	1 U	1 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethane	4.2	2.3	7.1	NA	NA	12	4.5	6.6	6.5	4.3	5.5
1,1-Dichloroethene	0.61 J	1 U	0.8 J	NA	NA	1	1 U	0.5 J	0.51 J	1 U	1 U
1,3-Dichlorobenzene	NA	NA	NA	10 U	NA	1 U	NA	NA	NA	NA	NA
Acetone	5 U	5 U	5 U	NA	NA	5 R	5 U	5 U	5 U	5 U	5 U
Benzene	1 U	1 U	1 U	NA	NA	0.1 J	1 U	1 U	1 U	1 U	1 U
Chloroethane	1 U	1 U	1 U	NA	NA	2	0.55 J	1 U	1 U	1 U	1 U
Naphthalene	1 U	1 U	1 U	NA	NA	NA	1 U	1 U	1 U	1 U	1 U
Tetrachloroethene	1 U	1 U	1 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U
Toluene	1 U	1 U	1 U	NA	NA	0.1 J	1 U	1 U	1 U	1 U	1 U
Trichloroethene	1 U	1 U	1 U	NA	NA	1 U	0.95 J	1 U	1 U	1 U	1 U
Vinyl chloride	1 U	1 U	1 U	NA	NA	9	5.4	5.5	5.4	4.3	5.2
cis-1,2-Dichloroethene	1 U	1 U	0.69 J	NA	NA	1	2.4	1.9	1.9	1.4	1.5
trans-1,2-Dichloroethene	1 U	1 U	1 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U
Semi-volatile Organic Compounds (UG/L)											
Acenaphthylene	NA	NA	NA	2 U	2 U	1 U	NA	NA	NA	NA	NA
Fluorene	NA	NA	NA	1 U	1 U	1 U	NA	NA	NA	NA	NA
Naphthalene	NA	NA	NA	2 U	2 U	2 U	NA	NA	NA	NA	NA
Phenanthrene	NA	NA	NA	1 U	1 U	1 U	NA	NA	NA	NA	NA
Pyrene	NA	NA	NA	0.5 U	0.5 U	0.1 UJ	NA	NA	NA	NA	NA
bis(2-Ethylhexyl)phthalate	NA	NA	NA	10 U	NA	6 B	NA	NA	NA	NA	NA
Pesticide/Polychlorinated Biphenyls (UG/L)											
Heptachlor epoxide	NA	NA	NA	NA	NA	0.05 U	NA	NA	NA	NA	NA
beta-BHC	NA	NA	NA	NA	NA	0.05 U	NA	NA	NA	NA	NA
Total Metals (UG/L)											
Arsenic	NA	NA	NA	NA	NA	2.5 U	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	NA	11.7 J	NA	NA	NA	NA	NA
Cadmium	NA	NA	NA	NA	NA	0.7 U	NA	NA	NA	NA	NA
Calcium	NA	NA	NA	NA	NA	58,800	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	9,280	NA	NA	NA	NA	NA
Magnesium	NA	NA	NA	NA	NA	10,800	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	507	NA	NA	NA	NA	NA
Potassium	NA	NA	NA	NA	NA	1,280 J	NA	NA	NA	NA	NA
Sodium	NA	NA	NA	NA	NA	26,800	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA	2.9 B	NA	NA	NA	NA	NA
Dissolved Metals (UG/L)											
Aluminum	NA	NA	NA	NA	NA	37 B	NA	NA	NA	NA	NA
Arsenic	NA	NA	NA	NA	NA	2.5 U	NA	NA	NA	NA	NA
Barium	NA	NA	NA	NA	NA	11.6 J	NA	NA	NA	NA	NA
Calcium	NA	NA	NA	NA	NA	61,800	NA	NA	NA	NA	NA
Iron	NA	NA	NA	NA	NA	9,560	NA	NA	NA	NA	NA
Magnesium	NA	NA	NA	NA	NA	11,100	NA	NA	NA	NA	NA
Manganese	NA	NA	NA	NA	NA	529	NA	NA	NA	NA	NA
Nickel	NA	NA	NA	NA	NA	1.7 U	NA	NA	NA	NA	NA
Potassium	NA	NA	NA	NA	NA	1,360 J	NA	NA	NA	NA	NA
Sodium	NA	NA	NA	NA	NA	28,000	NA	NA	NA	NA	NA
Zinc	NA	NA	NA	NA	NA	4.3 J	NA	NA	NA	NA	NA
Wet Chemistry (MG/L)											
Alkalinity	NA	NA	NA	NA	NA	195	NA	NA	NA	NA	NA
Chloride	NA	NA	NA	NA	NA	19	NA	NA	NA	NA	NA
Dissolved oxygen	NA	NA	NA	NA	NA	0.01	NA	NA	NA	NA	NA
Ethane	NA	NA	NA	NA	NA	3.63E-04	NA	NA	NA	NA	NA
Ethene	NA	NA	NA	NA	NA	0.00117	NA	NA	NA	NA	NA
Ferric iron	NA	NA	NA	NA	NA	0.8	NA	NA	NA	NA	NA
Ferrous iron	NA	NA	NA	NA	NA	6.5	NA	NA	NA	NA	NA
Methane	NA	NA	NA	NA	NA	1.88	NA	NA	NA	NA	NA
Nitrate	NA	NA	NA	NA	NA	0.5 U	NA	NA	NA	NA	NA
Redox (MV)	NA	NA	NA	NA	NA	-1.19E+02	NA	NA	NA	NA	NA
Specific conductance (MS/CM)	NA	NA	NA	NA	NA	372	NA	NA	NA	NA	NA

Table 1-5
SWMU 2B Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2B-MW01						OW2B-MW01D		OW2B-MW02		
Sample ID	OW2B-MW01-R01	OW2B-MW01-03A	OW2B-MW01P-03A	OW2B-MW01-03C	OW2B-MW01-03D	OW2B-MW01-04A	OW2B-MW01D-R01-P	OW2B-MW01D-R01	OW2B-MW02-R01	OW2B-MW02-R01-P	OW2B-MW02D-R01-P
Sample Date	02/25/00	01/22/03	01/22/03	07/25/03	11/07/03	01/27/04	02/25/00	02/26/00	02/25/00	02/25/00	02/25/00
Chemical Name											
Sulfate	30	NA	NA	NA	NA	NA	NA	3.6	9.95	10	NA
Sulfide	0.13	NA	NA	NA	NA	NA	NA	0.12	0.14	0.14	NA
Temperature	[illegible]	NA	NA	NA	NA	NA	NA	[illegible]	[illegible]	NA	NA
Total organic carbon (TOC)	8.2	NA	NA	NA	NA	NA	NA	4	6	2 U	NA
Turbidity (NTU)	30.6	NA	NA	NA	NA	NA	NA	22.9	9.7	NA	NA
pH	5.46	NA	NA	NA	NA	NA	NA	6.94	7.04	NA	NA
Field Parameters											
Dissolved Oxygen (MG/L)	NA	1.64	NA	5.77	0.74	2.71	NA	NA	NA	NA	NA
Depth to Water (Ft)	NA	6.99	NA	0.27	7.01	6.7	NA	NA	NA	NA	NA
Oxidation Reduction Potential (ORP) (MV)	NA	-12	NA	33	-37	126	NA	NA	NA	NA	NA
Flow (GPM)	NA	NA	NA	0.043	0.083	0.087	NA	NA	NA	NA	NA
pH	NA	6.33	NA	5.49	5.91	6.23	NA	NA	NA	NA	NA
Salinity (%)	NA	0	NA	0	0.01	0	NA	NA	NA	NA	NA
Specific Conductance (MS/CM)	NA	0.278	NA	0.31	0.26	0.12	NA	NA	NA	NA	NA
Temperature (C)	NA	15.55	NA	21.6	21.3	15.7	NA	NA	NA	NA	NA
Turbidity (NTU)	NA	20.1	NA	2	0	24	NA	NA	NA	NA	NA
Volume (GAL)	NA	NA	NA	2	2.5	4	NA	NA	NA	NA	NA

Station ID	OW2B-MW03	OW2B-MW04				
Sample ID	OW2B-MW03-R01	OW2B-MW04-R01	OW2B-MW04-R01-DUP	OW2B-MW04-03D	OW2B-MW04-04A	OW2B-MW05-R01
Sample Date	02/25/00	02/29/00	02/29/00	11/06/03	01/27/04	02/23/00
Chemical Name						
Sulfate	22	17	17	NA	NA	1.5
Sulfide	0.15	0.1	0.12	NA	NA	0.19
Temperature	[illegible]	[illegible]	NA	NA	NA	14.4
Total organic carbon (TOC)	6.6	19	NA	NA	NA	12
Turbidity (NTU)	85.3	1.835	NA	NA	NA	23.4
pH	6.42	6.87	NA	NA	NA	6.36
Field Parameters						
Dissolved Oxygen (MG/L)	NA	NA	NA	0.66	0.25	NA
Depth to Water (Ft)	NA	NA	NA	8.22	7.26	NA
Oxidation Reduction Potential (ORP) (MV)	NA	NA	NA	-53	-107	NA
Flow (GPM)	NA	NA	NA	0.087	0.083	NA
pH	NA	NA	NA	5.94	5.78	NA
Salinity (%)	NA	NA	NA	0.02	0	NA
Specific Conductance (MS/CM)	NA	NA	NA	0.31	0.42	NA
Temperature (C)	NA	NA	NA	22.4	18.2	NA
Turbidity (NTU)	NA	NA	NA	53	15	NA
Volume (GAL)	NA	NA	NA	NA	NA	NA

Notes:
Represents detections
B - possible blank contamination
E - concentration has exceeded the calibration range
L - reported value may be biased low
J - analyte present, reported value is estimated
NA - not analyzed
R - unreliable result
U - not detected

Table 1-6
SWMU 2E Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2E-MW01	OW2E-MW03		OW2E-MW04	OW2E-MW05	OW2E-MW07			OW2E-MW08	OW2E-MW09	
Sample ID	OW2E-MW01-R01	OW2E-MW03-R01	OW2E-MW03-R01-P	OW2E-MW04-R01	OW2E-MW05-R01	OW2E-MW07-R01	OW2E-MW07-R01-P	OW2E-MW07-R01-P	OW2E-MW08-R01	OW2E-MW09-R01	OW2E-MW09-04A
Sample Date	03/06/00	03/08/00	03/16/00	03/06/00	03/06/00	03/08/00	03/08/00	03/08/00	03/06/00	03/06/00	03/18/04
Chemical Name											
Volatile Organic Compounds (UG/L)											NA
1,1-Dichloroethane	2 U	1 U	1 U	5 U	1 U	1 U	NA	1 U	5 U	0.2 J	NA
2-Butanone	12 R	5 R	5 R	25 R	5 R	5 R	NA	5 R	25 R	5 R	NA
4-Methyl-2-pentanone	12 U	5 U	5 U	25 U	5 U	5 U	NA	5 U	25 U	5 U	NA
Acetone	12 R	5 R	5 R	25 R	9 L	4 L	NA	2 L	25 R	5 R	NA
Benzene	0.5 J	1 U	1 U	15	0.5 J	1 U	NA	1 U	2 J	0.8 J	NA
Carbon disulfide	2 U	1 U	1 U	5 U	0.4 J	1 U	NA	1 U	5 U	0.6 J	NA
Chlorobenzene	2 U	1 U	1 U	5 U	1 U	1 U	NA	1 U	0.3 J	1 U	NA
Chloromethane	2 U	1 U	0.2 B	5 U	1 U	1 U	NA	1 U	5 U	1 U	NA
Ethylbenzene	0.3 J	1 U	1 U	1 J	0.4 J	1 U	NA	1 U	11	1 U	NA
Toluene	2 U	0.1 J	0.1 J	5 U	0.3 J	0.1 J	NA	0.1 J	0.3 J	1 U	NA
Trichloroethene	2 U	1 U	1 U	5 U	1 U	1 U	NA	1 U	0.2 J	0.8 J	NA
Vinyl chloride	2 U	1 U	1 U	5 U	1 U	1 U	NA	1 U	5 U	8	5.9
Xylene, total	2 U	1 U	0.2 J	2 J	1	1 U	NA	1 U	24	1 U	NA
cis-1,2-Dichloroethene	2 U	1 U	1 U	5 U	0.3 J	1 U	NA	1 U	5 U	13	NA
trans-1,2-Dichloroethene	2 U	1 U	1 U	5 U	1 U	1 U	NA	1 U	5 U	0.9 J	NA
Semi-volatile Organic Compounds (UG/L)											
2-Methylnaphthalene	120	10 U	10 U	110	10 U	10 U	NA	10 U	56	10 U	NA
Acenaphthylene	20 U	1 U	1 U	5 U	1 U	5 U	NA	1 U	50 U	1.8 J	NA
Benzo(a)anthracene	2 U	0.1 U	0.1 U	0.5 U	0.1 U	0.5 U	NA	0.1 U	4.8 J	0.1 U	NA
Fluorene	8.2 J	1 U	1 U	2.9 J	0.28 J	0.06 B	NA	0.04 B	18 J	1 U	NA
Naphthalene	46	2 U	2 U	130	3.2	10 U	NA	2 U	95 J	2 U	NA
Phenanthrene	13 J	1 U	1 U	6.5 J	0.55 J	5 U	NA	1 U	59 J	0.037 J	NA
Pyrene	54 J	0.1 U	0.1 U	10 J	2.3 J	0.5 U	NA	0.1 U	240 J	0.14 J	NA
bis(2-Ethylhexyl)phthalate	50 U	10 U	10 U	10	10 U	1 B	NA	10 U	40 U	10 U	NA
Pesticide/Polychlorinated Biphenyls (UG/L)											
Dieldrin	0.1 U	0.1 U	0.1 U	0.1 UJ	0.1 U	0.1 U	NA	0.1 U	0.1 U	0.1 UJ	NA
beta-BHC	0.061 J	0.05 U	0.05 U	0.05 UJ	0.05 U	0.05 U	NA	0.05 U	0.05 U	0.05 UJ	NA
Total Metals (UG/L)											
Aluminum	34.9 B	104 B	153 B	58.3 B	44.6 B	33.6 B	NA	95.4 B	43.8 B	258 B	NA
Arsenic	26.1	4.5 B	2.9 B	2.5 U	8.7 B	7.9 B	NA	5.7 B	2.5 U	3.2 B	NA
Barium	14.7 J	11 J	10.3 J	24.8 J	28 J	121 J	NA	122 J	30.3 J	27.5 J	NA
Cadmium	0.7 U	0.7 U	0.7 U	0.7 U	0.7 U	0.7 U	NA	0.7 U	0.7 U	0.7 U	NA
Calcium	14,100	7,090	7,120	27,100	28,700	56,300	NA	56,700	18,400	38,800	NA
Chromium	2.6 U	2.6 U	2.6 U	2.6 U	2.6 U	2.6 U	NA	2.6 U	2.6 U	2.6 U	NA
Copper	2.9 U	2.9 U	2.9 U	2.9 U	2.9 U	2.9 U	NA	2.9 U	2.9 U	8.1 B	NA
Iron	43,900	3,020	2,600	15,100	44,000	57,800	NA	58,100	11,600	56,100	NA
Lead	1.4 U	1.4 U	1.4 U	1.4 U	1.4 U	1.4 U	NA	1.4 U	1.4 U	3.1	NA
Magnesium	23,000	8,400	8,580	51,900	27,800	12,800	NA	12,900	16,400	24,600	NA
Manganese	1,590	308	317	1,680	759	1,100	900	1,110	321	1,920	NA
Nickel	1.7 U	1.7 U	1.7 U	2.2 B	2.6 B	1.7 U	NA	1.7 U	1.7 U	39 J	NA
Potassium	586 J	434 J	415 J	830 J	1,940 J	7,560	NA	7,650	1,410 J	1,520 J	NA
Selenium	3.1 U	3.1 B	3.1 U	3.1 U	3.1 U	3.1 B	NA	3.3 B	3.1 U	3.1 U	NA
Sodium	14,700	11,300	11,900	27,700	22,300	18,500	NA	19,800	35,100	26,900	NA
Vanadium	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	NA	2.1 U	2.1 U	2.1 U	NA

Table 1-6
SWMU 2E Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID		OW2E-MW10			OW2E-MW11	OW2E-MW12	OW2E-MW13	OW2E-MW15	OW2E-MW16	OW2E-MW17		
Sample ID	OW2E-MW09P-04A	OW2E-MW10-R01	OW2E-MW10-R01-P	OW2E-MW10-R01-P	OW2E-MW11-R01	OW2E-MW12-R01	OW2E-MW13-R01	OW2E-MW15-R01	OW2E-MW16-R01	OW2E-MW17	OW2E-MW17P	OW2E-MW17-R2
Sample Date	03/18/04	03/08/00	03/08/00	03/08/00	03/08/00	03/06/00	03/06/00	03/06/00	03/06/00	03/06/00	03/08/00	03/08/00
Chemical Name												
Volatile Organic Compounds (UG/L)	NA											
1,1-Dichloroethane	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA
2-Butanone	NA	25 R	NA	NA	2 L	5 R	5 R	5 R	5 R	5 U	5 U	NA
4-Methyl-2-pentanone	NA	25 U	NA	NA	0.8 J	5 U	5 U	5 U	5 U	5 U	5 U	NA
Acetone	NA	8 L	NA	NA	10 L	5 R	3 L	5 R	7 L	9.8 J	10 U	NA
Benzene	NA	3 J	NA	NA	1 U	0.2 J	1 U	1 U	1 U	1 U	1 U	NA
Carbon disulfide	NA	5 U	NA	NA	0.6 J	1 U	0.2 J	1 U	0.3 J	1 U	1 U	NA
Chlorobenzene	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA
Chloromethane	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	0.1 J	1 U	1 U	NA
Ethylbenzene	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA
Toluene	NA	5 U	NA	NA	0.2 J	1 U	1 U	0.2 J	1 U	1 U	1 U	NA
Trichloroethene	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	1 U	1 U	1 U	NA
Vinyl chloride	5.8	5 U	NA	NA	1 U	1 U	0.3 J	1 U	1 U	1 U	1 U	NA
Xylene, total	NA	5 U	NA	NA	0.3 J	1 U	1 U	1 U	1 U	1 U	1 U	NA
cis-1,2-Dichloroethene	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	1 U	NA	NA	NA
trans-1,2-Dichloroethene	NA	5 U	NA	NA	1 U	1 U	1 U	1 U	1 U	NA	NA	NA
Semi-volatile Organic Compounds (UG/L)												
2-Methylnaphthalene	NA	10 U	NA	NA	10 U	10 U	10 U	10 U	10 U	10 U	10 U	NA
Acenaphthylene	NA	1 U	NA	1 R	5 U	5 U	1 U	1 U	1 U	10 U	10 U	1 U
Benzo(a)anthracene	NA	0.1 U	NA	0.1 R	0.5 U	0.5 U	0.1 U	0.1 U	0.1 U	10 U	10 U	0.05 U
Fluorene	NA	1 U	NA	1 R	5 U	0.15 J	0.029 J	1 U	1 U	10 U	10 U	0.1 U
Naphthalene	NA	2 U	NA	2 R	10 U	10 U	2 U	2 U	2 U	10 U	10 U	0.1 U
Phenanthrene	NA	1 U	NA	1 R	5 U	5 U	0.031 J	1 U	1 U	10 U	10 U	0.05 U
Pyrene	NA	0.1 U	NA	0.1 R	0.5 U	0.5 U	0.1 UJ	0.1 UJ	0.1 UJ	10 U	10 U	0.05 U
bis(2-Ethylhexyl)phthalate	NA	10 U	NA	NA	2 B	10 U	10 U	6 J	10 U	10 U	10 U	NA
Pesticide/Polychlorinated Biphenyls (UG/L)												
Dieldrin	NA	0.1 U	NA	NA	0.1 U	0.1 U	0.1 U	0.1 U	0.052 J	NA	NA	NA
beta-BHC	NA	0.05 U	NA	NA	0.05 U	0.05 U	0.05 U	0.05 U	0.05 UJ	NA	NA	NA
Total Metals (UG/L)												
Aluminum	NA	44.4 B	NA	NA	4,020	224 B	121 B	119 B	1,780	NA	NA	NA
Arsenic	NA	55.3	NA	NA	5.4 B	2.9 B	2.5 U	5.5 B	8.2 B	NA	NA	NA
Barium	NA	70.9 J	NA	NA	46.9 J	69.4 J	24 J	9.8 J	19.4 J	NA	NA	NA
Cadmium	NA	0.7 U	NA	NA	1.1 J	0.7 U	0.7 U	0.7 U	0.7 U	NA	NA	NA
Calcium	NA	11,600	NA	NA	19,200	53,500	24,200	22,300	30,200	NA	NA	NA
Chromium	NA	2.6 U	NA	NA	7 J	2.6 U	2.6 U	2.6 U	5.8 J	NA	NA	NA
Copper	NA	2.9 U	NA	NA	5.4 J	2.9 U	2.9 U	2.9 U	40.4	NA	NA	NA
Iron	NA	67,000	NA	NA	7,160	49,900	16,400	10,300	19,600	NA	NA	NA
Lead	NA	1.4 U	NA	NA	5.4 B	1.4 U	1.4 U	1.4 U	10.4	NA	NA	NA
Magnesium	NA	25,200	NA	NA	13,900	12,600	16,300	7,800	7,030	NA	NA	NA
Manganese	NA	533	500 U	NA	578	797	502	306	327	NA	NA	NA
Nickel	NA	1.7 U	NA	NA	5.8 J	2.5 B	3.1 B	2.2 B	6.6 B	NA	NA	NA
Potassium	NA	1,520 J	NA	NA	4,520 J	4,110 J	1,870 J	1,370 J	1,660 J	NA	NA	NA
Selenium	NA	3.1 U	NA	NA	3.1 U	3.1 U	3.1 U	3.1 U	3.8 J	NA	NA	NA
Sodium	NA	24,600	NA	NA	33,100	30,700	28,400	26,100	19,200	NA	NA	NA
Vanadium	NA	2.1 U	NA	NA	10 J	2.1 U	2.1 U	2.1 U	7.4 B	NA	NA	NA

Table 1-6
SWMU 2E Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID	OW2E-MW01	OW2E-MW03		OW2E-MW04	OW2E-MW05	OW2E-MW07			OW2E-MW08	OW2E-MW09	
Sample ID	OW2E-MW01-R01	OW2E-MW03-R01	OW2E-MW03-R01-P	OW2E-MW04-R01	OW2E-MW05-R01	OW2E-MW07-R01	OW2E-MW07-R01-P	OW2E-MW07-R01-P	OW2E-MW08-R01	OW2E-MW09-R01	OW2E-MW09-04A
Sample Date	03/06/00	03/08/00	03/16/00	03/06/00	03/06/00	03/08/00	03/08/00	03/08/00	03/06/00	03/06/00	03/18/04
Chemical Name											
Zinc	11.7 B	6.3 B	9.3 B	9.1 B	13.4 B	8.1 B	NA	10.3 B	12.2 B	62.4	NA
Dissolved Metals (UG/L)											
Aluminum	78.5 B	135 B	89.2 B	47.5 B	44.4 B	NA	NA	NA	38.4 B	30.6 B	NA
Arsenic	24.3	2.5 U	2.7 B	2.5 U	10.4 B	NA	NA	NA	2.5 U	2.8 B	NA
Barium	14.7 J	10.6 J	9.9 J	23.5 J	28.6 J	NA	NA	NA	30.6 J	25.8 J	NA
Cadmium	0.7 U	0.7 U	0.7 U	0.7 U	0.7 U	NA	NA	NA	0.7 U	0.7 U	NA
Calcium	13,900	7,070	6,960	25,400	29,300	NA	NA	NA	19,000	39,300	NA
Chromium	2.6 U	2.6 U	2.6 U	2.6 U	2.6 U	NA	NA	NA	2.6 U	2.6 U	NA
Copper	2.9 U	2.9 U	2.9 U	4.1 B	5.4 B	NA	NA	NA	2.9 U	2.9 U	NA
Iron	42,900	2,240	1,420	14,100	44,700	NA	NA	NA	12,000	44,800	NA
Magnesium	22,600	8,350	8,400	48,500	28,200	NA	NA	NA	16,900	24,400	NA
Manganese	1,560	305	311	1,580	769	NA	NA	NA	331	1,820	NA
Nickel	2 B	12.1 J	1.7 U	2.2 B	3.1 B	NA	NA	NA	5.4 B	3.4 B	NA
Potassium	564 J	432 J	406 J	805 J	2,050 J	NA	NA	NA	1,450 J	1,570 J	NA
Selenium	3.1 U	3.1 U	3.1 U	3.1 U	5.3 K	NA	NA	NA	3.1 U	3.1 U	NA
Sodium	14,700	11,400	11,300	26,500	23,300	NA	NA	NA	35,800	28,600	NA
Vanadium	2.1 U	2.1 U	2.1 U	2.1 U	2.1 U	NA	NA	NA	2.1 U	2.1 U	NA
Zinc	11 B	20.7 B	6.3 B	7 B	14 B	NA	NA	NA	23.1	14.2 B	NA
Wet Chemistry (MG/L)											
Alkalinity	145	75	NA	245	190	250	250	NA	125	NA	NA
Chloride	11	7.9	NA	20	15	22	25	NA	19	NA	NA
Dissolved oxygen	0.5	0.03	NA	0.31	0.19	0.26	NA	NA	0.25	NA	NA
Ethane	5.00E-06	3.20E-05	NA	5.00E-06	5.00E-05	5.00E-06	5.00E-06	NA	5.00E-06	NA	NA
Ethene	5.00E-06	3.20E-05	NA	5.00E-06	1.26E-04	2.60E-05	6.90E-05	NA	5.00E-06	NA	NA
Ferric iron	1.3	0.5 U	NA	0.7	2.1	2.3	2.3	NA	0.5 U	NA	NA
Ferrous iron	37 E	0.8	NA	12 E	36 E	30 E	34 E	NA	8.9	NA	NA
Methane	3.23	0.0117	NA	8.78	4.12	4.62	4.87	NA	7.10	NA	NA
Redox (MV)	-3.54E+01	-1.18E+02	NA	-2.69E+01	-4.99E+01	-5.08E+01	NA	NA	20.5	NA	NA
Specific conductance (MS/CM)	202	117	NA	280	276	531	NA	NA	200	NA	NA
Sulfate	9.5	13	NA	0.5 U	13	0.5 U	0.5 U	NA	1.5	NA	NA
Sulfide	0.1	0.08	NA	0.1	0.1	0.9	0.9	NA	0.13	NA	NA
Temperature	[illegible]	[illegible]	NA	[illegible]	[illegible]	[illegible]	NA	NA	[illegible]	NA	NA
Total organic carbon (TOC)	14	3.1	NA	24	21	12	11	NA	13	NA	NA
Turbidity (NTU)	2,016	23.4	NA	780	2,029	12.7	NA	NA	2,039	NA	NA
pH	6.17	5.52	NA	6.16	6.13	6.13	NA	NA	5.93	NA	NA

Table 1-6
SWMU 2E Monitoring Well Data
SWMU 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Station ID		OW2E-MW10			OW2E-MW11	OW2E-MW12	OW2E-MW13	OW2E-MW15	OW2E-MW16	OW2E-MW17		
Sample ID	OW2E-MW09P-04A	OW2E-MW10-R01	OW2E-MW10-R01-P	OW2E-MW10-R01-P	OW2E-MW11-R01	OW2E-MW12-R01	OW2E-MW13-R01	OW2E-MW15-R01	OW2E-MW16-R01	OW2E-MW17	OW2E-MW17P	OW2E-MW17-R2
Sample Date	03/18/04	03/08/00	03/08/00	03/08/00	03/08/00	03/06/00	03/06/00	03/06/00	03/06/00	03/06/00	03/08/00	03/08/00
Chemical Name												
Zinc	NA	12 B	NA	NA	68.2	8 B	19.7 B	8.1 B	154	NA	NA	NA
Dissolved Metals (UG/L)												
Aluminum	NA	112 B	NA	NA	5,540	55.6 B	53.7 B	30.3 B	28.5 B	NA	NA	NA
Arsenic	NA	40.1	NA	NA	6.6 B	3.9 B	2.5 U	2.5 U	2.5 U	NA	NA	NA
Barium	NA	58.7 J	NA	NA	54.3 J	71.1 J	24.2 J	9.3 B	6.1 B	NA	NA	NA
Cadmium	NA	0.7 U	NA	NA	0.92 J	0.7 U	0.7 U	0.7 U	0.7 U	NA	NA	NA
Calcium	NA	10,900	NA	NA	18,900	55,900	24,900	22,200	24,700	NA	NA	NA
Chromium	NA	2.6 U	NA	NA	9.6 J	2.6 U	2.6 U	2.6 U	2.6 U	NA	NA	NA
Copper	NA	2.9 U	NA	NA	7.1 J	2.9 U	2.9 U	2.9 U	2.9 U	NA	NA	NA
Iron	NA	55,800	NA	NA	7,640	51,600	16,100	7,600	4,570	NA	NA	NA
Magnesium	NA	24,000	NA	NA	13,500	13,200	16,500	7,550	6,330	NA	NA	NA
Manganese	NA	505	NA	NA	550	832	509	303	299	NA	NA	NA
Nickel	NA	1.7 U	NA	NA	7.1 J	1.7 U	1.7 U	1.9 B	1.7 U	NA	NA	NA
Potassium	NA	1,460 J	NA	NA	4,870 J	4,410 J	1,940 J	1,410 J	1,510 J	NA	NA	NA
Selenium	NA	3.1 U	NA	NA	3.1 U	3.1 U	3.1 U	3.1 U	3.1 U	NA	NA	NA
Sodium	NA	24,400	NA	NA	32,500	32,600	28,900	26,400	19,900	NA	NA	NA
Vanadium	NA	2.1 U	NA	NA	14.4 J	2.1 U	2.1 U	2.1 U	2.1 U	NA	NA	NA
Zinc	NA	8.9 B	NA	NA	68.3	10.7 B	13.5 B	11 B	18.1 J	NA	NA	NA
Wet Chemistry (MG/L)												
Alkalinity	NA	170	170	NA	210	275	160	75	65	NA	NA	NA
Chloride	NA	16	16	NA	12	17	13	20	16	NA	NA	NA
Dissolved oxygen	NA	0.03	NA	NA	0.1	0.22	0.18	0.17	0.24	NA	NA	NA
Ethane	NA	5.00E-06	5.00E-06	NA	5.00E-06	5.00E-06	2.50E-05	5.00E-06	5.00E-06	NA	NA	NA
Ethene	NA	2.10E-05	4.90E-05	NA	5.00E-06	5.00E-06	3.30E-05	5.00E-06	5.00E-06	NA	NA	NA
Ferric iron	NA	2.3	1.8	NA	1.6	2.3	0.5	0.5 U	0.5 U	NA	NA	NA
Ferrous iron	NA	40 E	43 E	NA	14 E	39 E	13 E	6.2	3	NA	NA	NA
Methane	NA	3.40	36.0	NA	3.32	10.4	0.993	0.00633	0.01000	NA	NA	NA
Redox (MV)	NA	-1.31E+02	NA	NA	-7.14E+01	-2.89E+01	-3.40E+00	-1.83E+01	7.6	NA	NA	NA
Specific conductance (MS/CM)	NA	416	NA	NA	311	305	170	257	231	NA	NA	NA
Sulfate	NA	4.1	2.96	NA	5.3	0.5 U	8.7	35	23	NA	NA	NA
Sulfide	NA	1.3	0.13	NA	1	0.12	0.13	0.11	0.12	NA	NA	NA
Temperature	NA	-1	NA	NA	-1	-1	-1	-1	-1	NA	NA	NA
Total organic carbon (TOC)	NA	23	44	NA	10	33	10	4.5	5.7	NA	NA	NA
Turbidity (NTU)	NA	21.8	NA	NA	11.7	59.8	65	299	65	NA	NA	NA
pH	NA	6.32	NA	NA	6.05	6	5.91	5.61	5.77	NA	NA	NA

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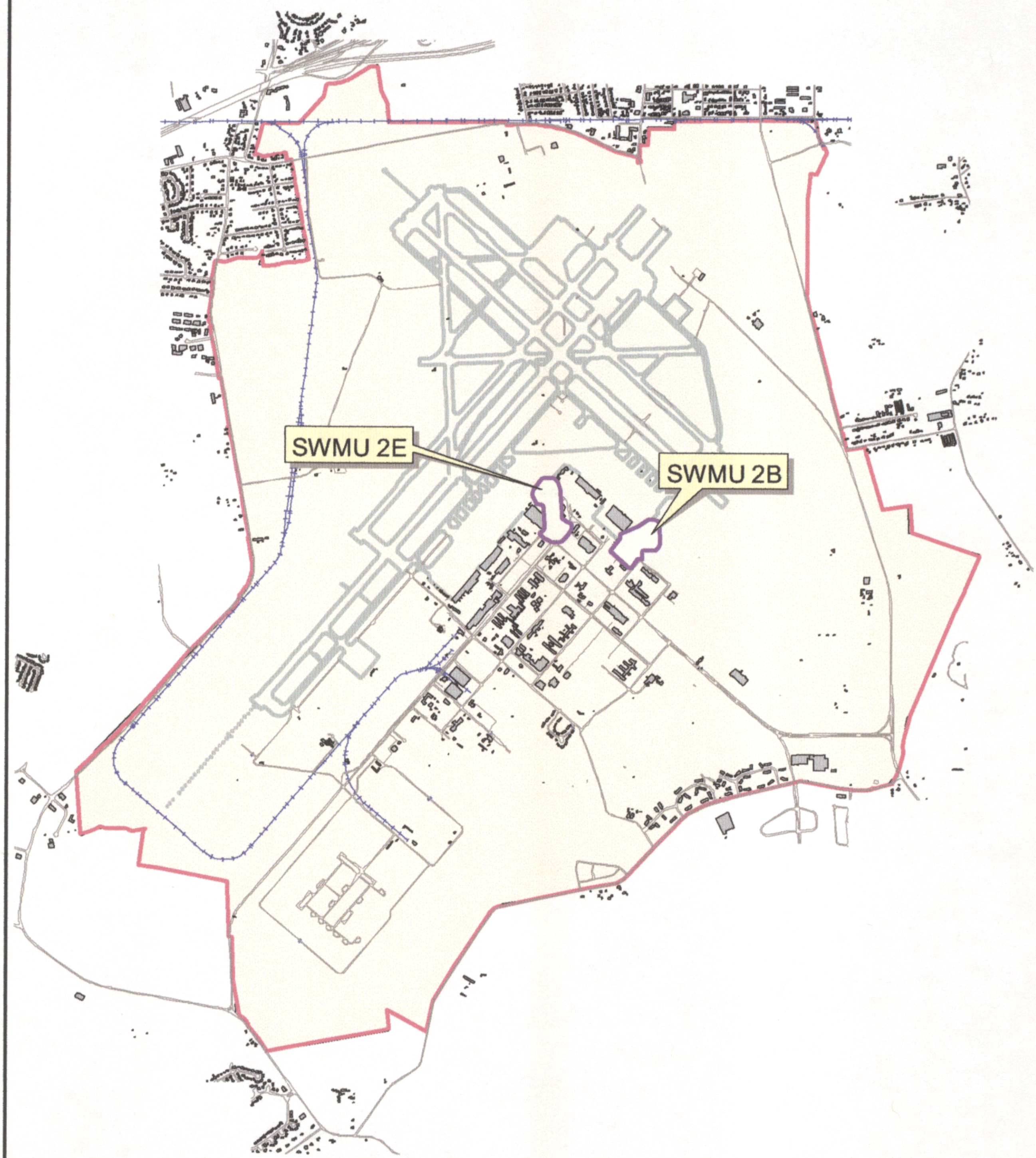

Figure 1-1
SWMU Location Map
NAS Oceana, Virginia Beach, Virginia

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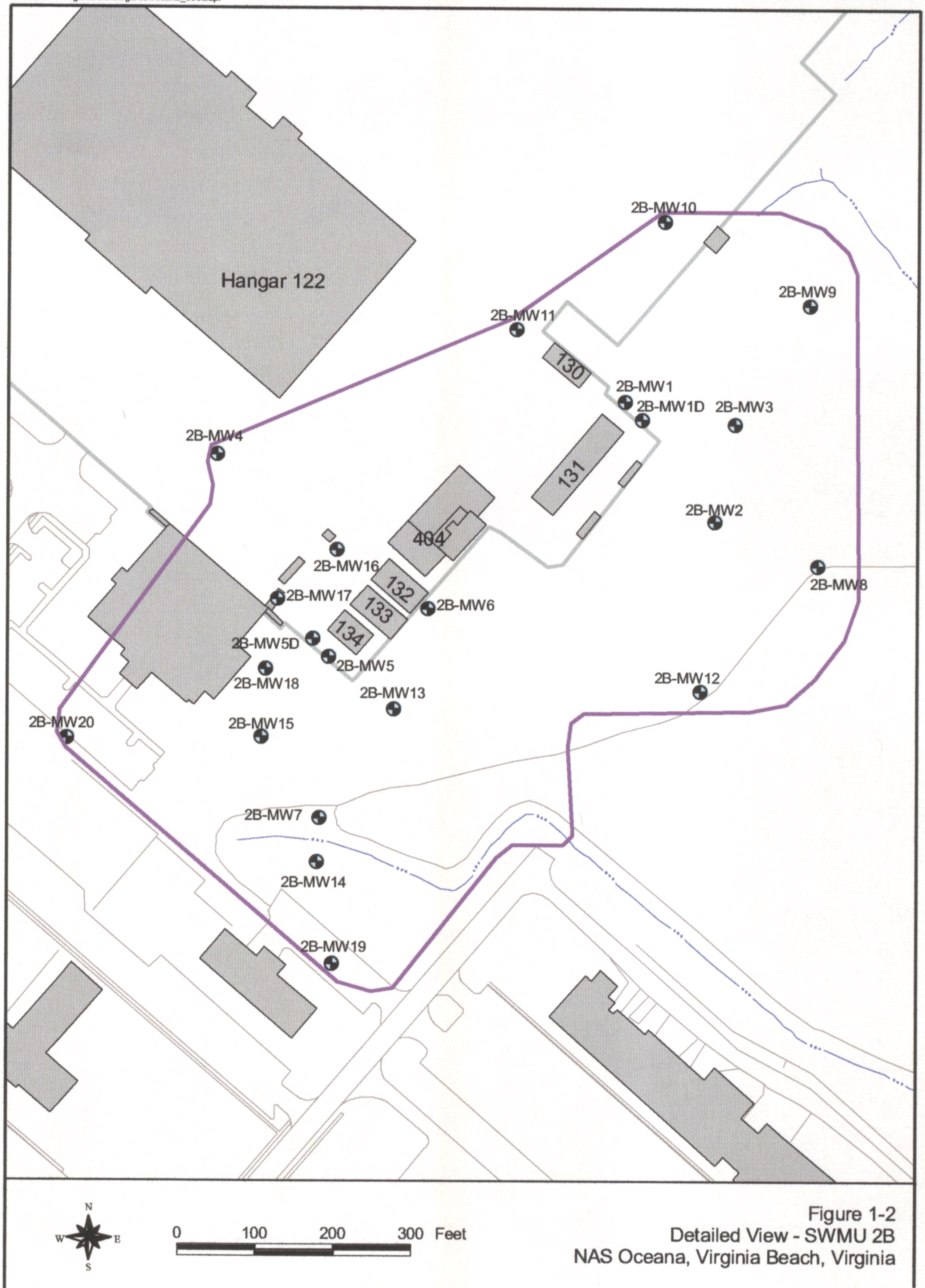

Figure 1-2
Detailed View - SWMU 2B
NAS Oceana, Virginia Beach, Virginia

CH2MHILL

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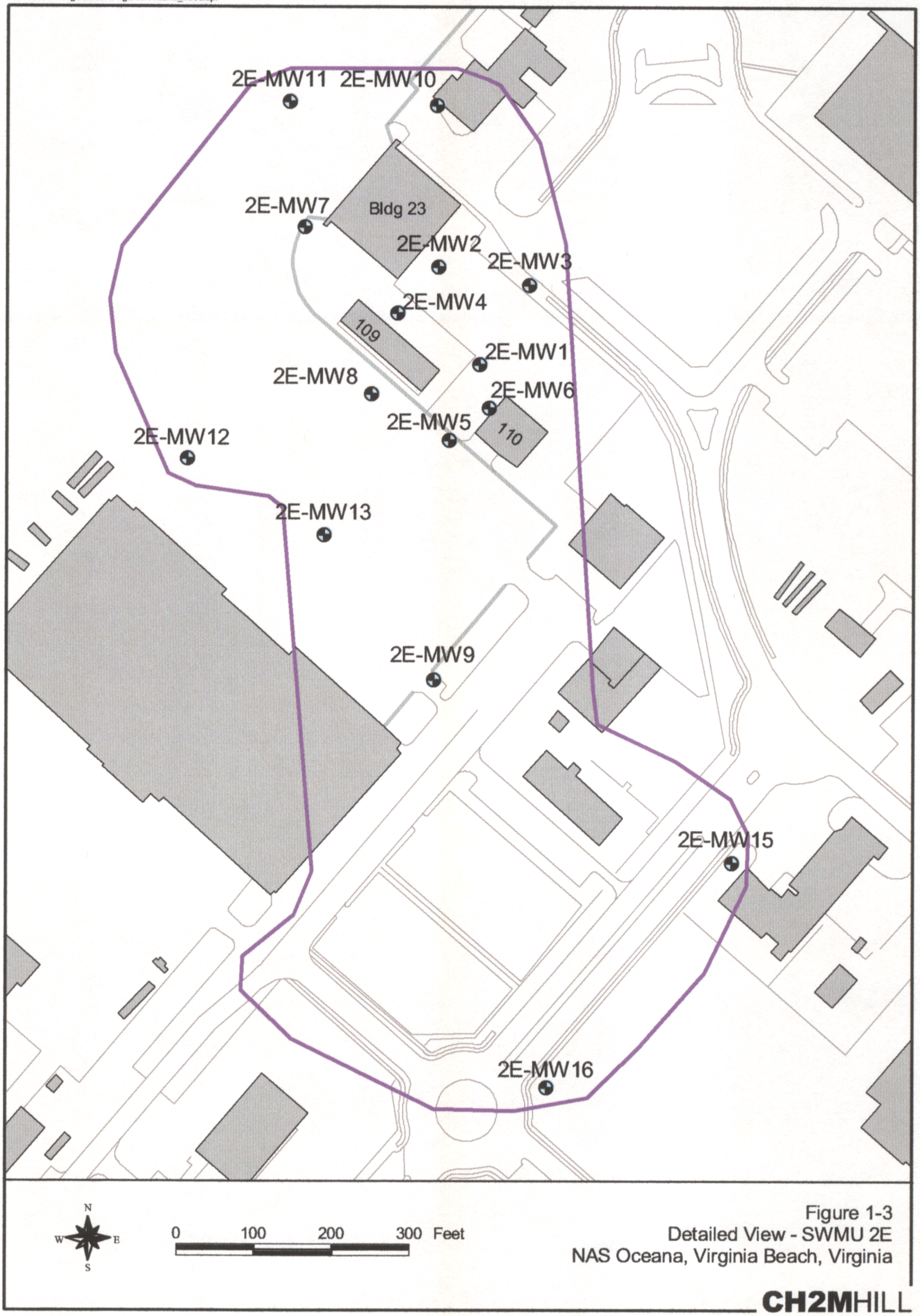

Figure 1-3
Detailed View - SWMU 2E
NAS Oceana, Virginia Beach, Virginia

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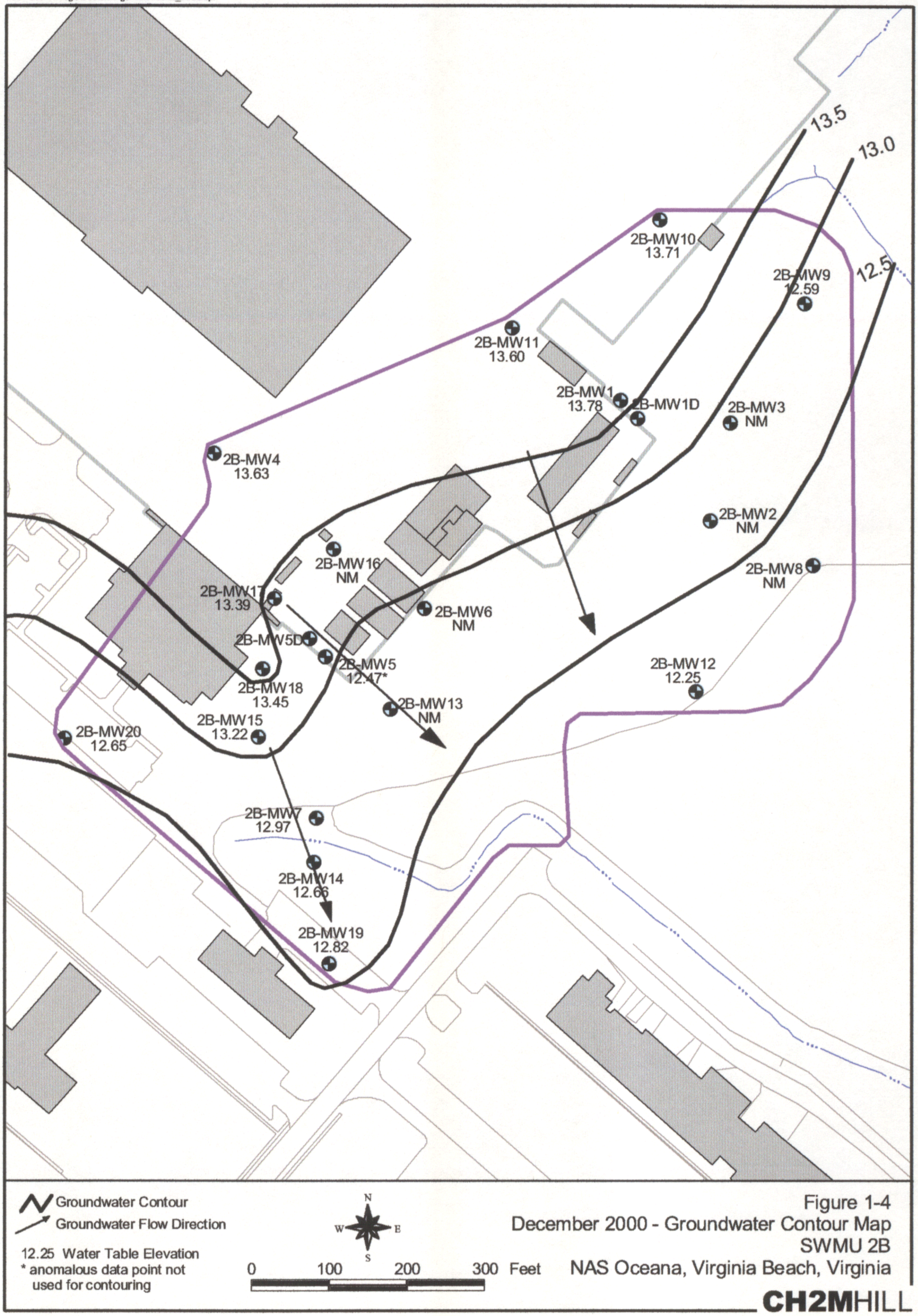

Figure 1-4
December 2000 - Groundwater Contour Map
SWMU 2B
NAS Oceana, Virginia Beach, Virginia

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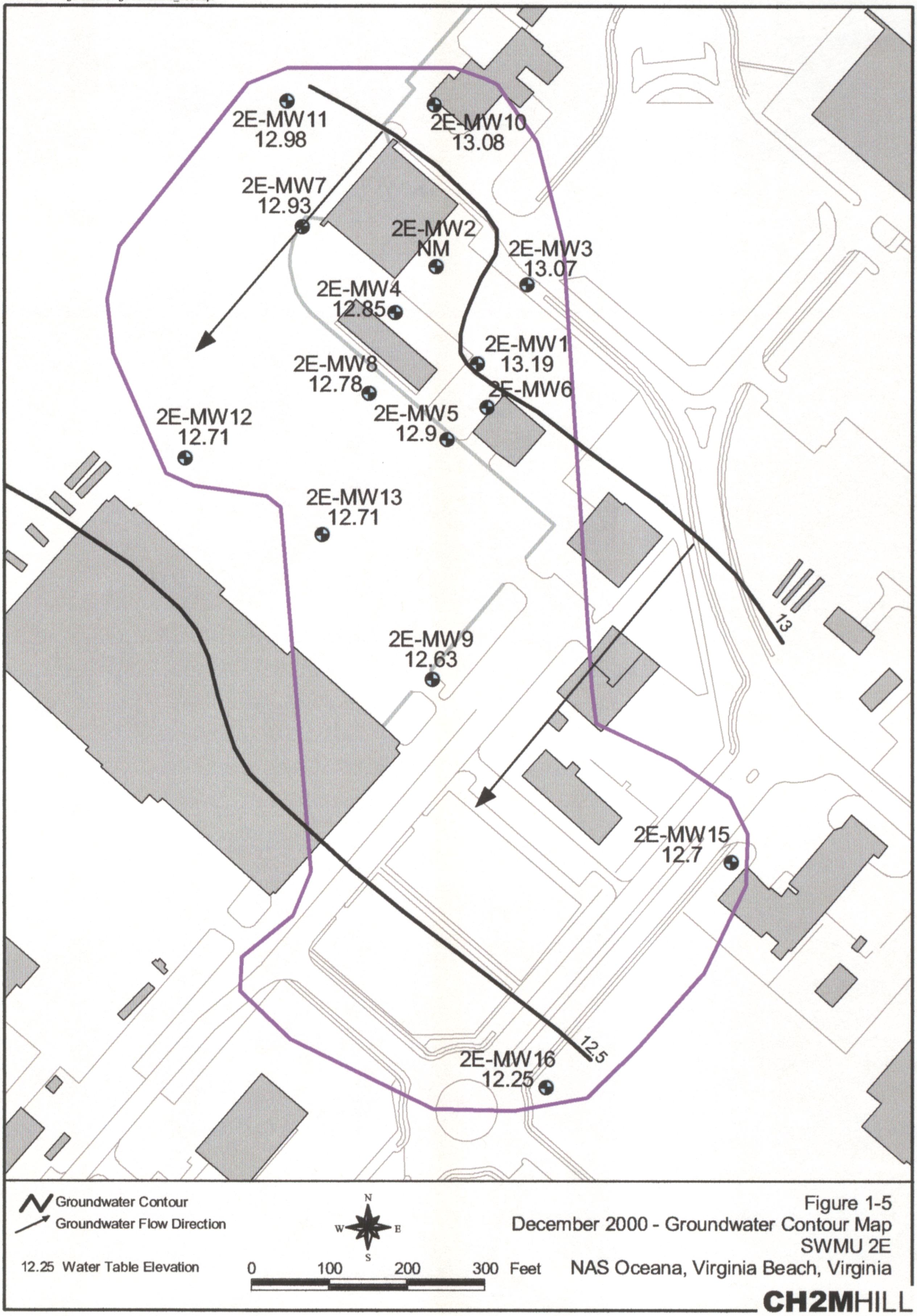

Figure 1-5
December 2000 - Groundwater Contour Map
SWMU 2E
NAS Oceana, Virginia Beach, Virginia

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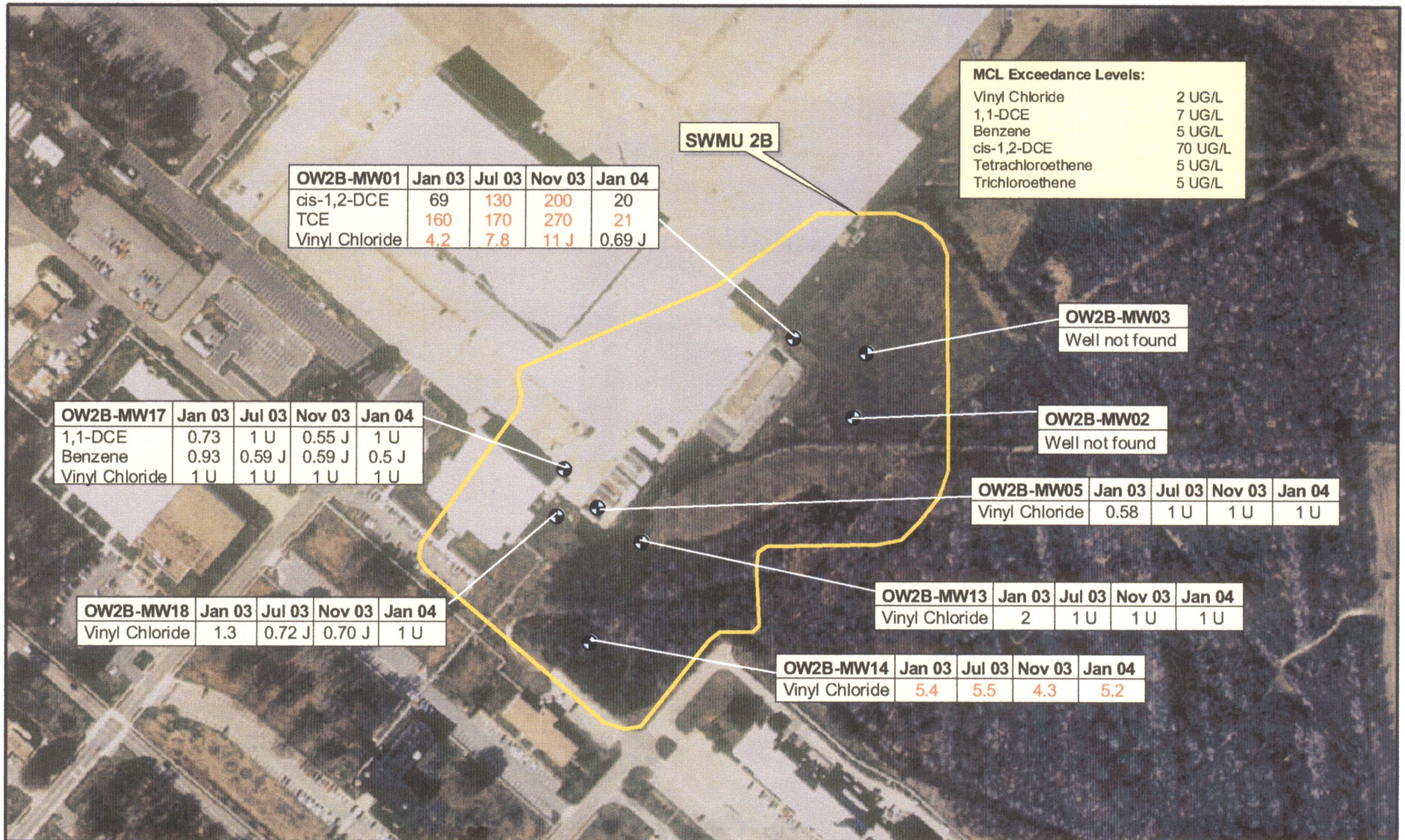

LEGEND

- Monitoring Well
- Site Boundary

Red Text = MCL Exceedance

N

0 100 200 300 Feet

Figure 1-6
Quarterly Analytical Results for Monitoring Wells with Historic MCL Exceedances of CVOCs at SWMU 2B
NAS Oceana
Virginia Beach, Virginia

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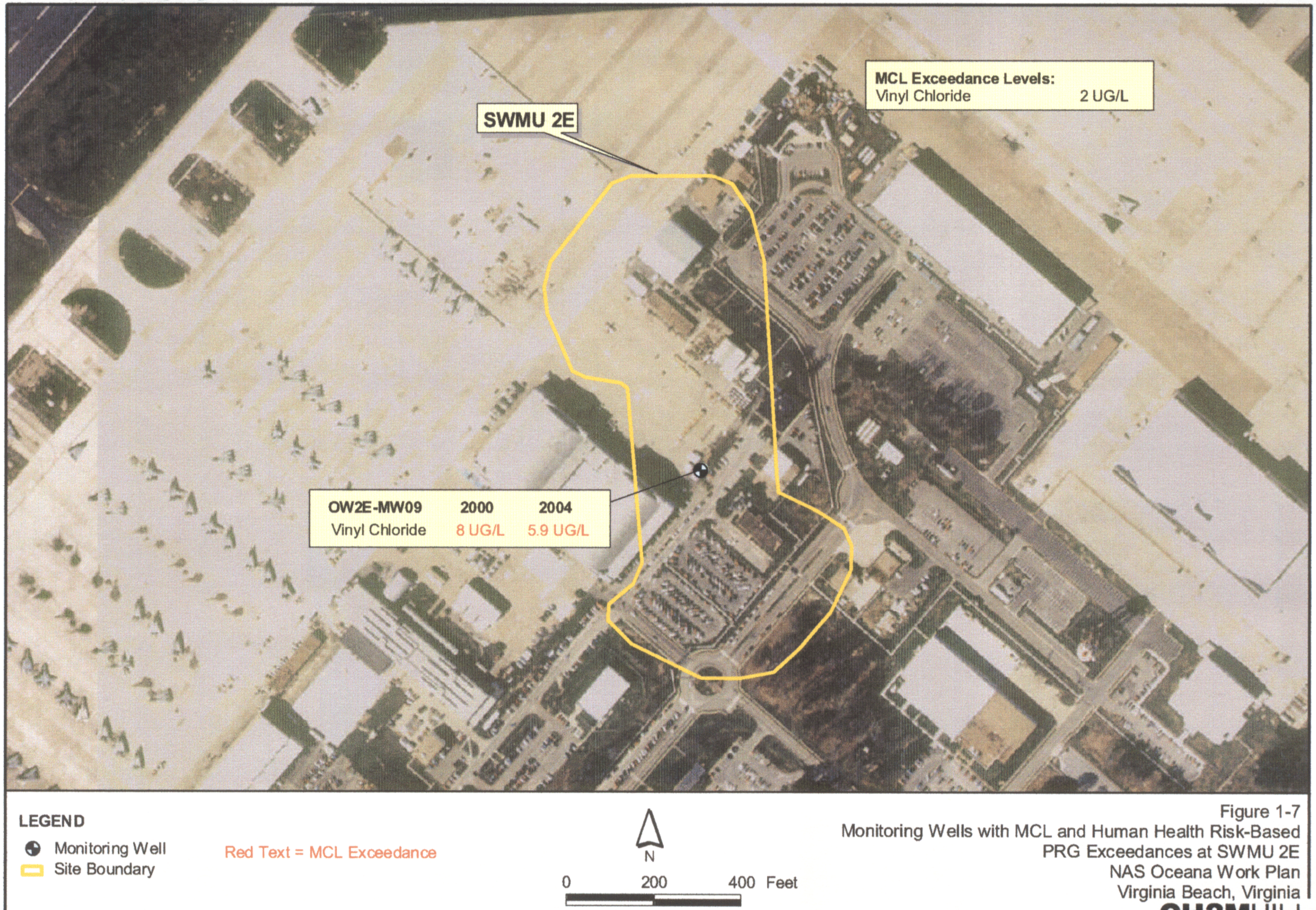

Figure 1-7
Monitoring Wells with MCL and Human Health Risk-Based PRG Exceedances at SWMU 2E
NAS Oceana Work Plan
Virginia Beach, Virginia

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SECTION 2

Remediation Processes and Selection

CVOC concentrations in the areas identified as "hot spots" at SWMUs 2B and 2E, while elevated compared to regulatory required cleanup goals (such as MCLs), are not particularly high compared to levels found at many other CVOC contaminated sites in the U.S. Levels of contamination influence the appropriateness and selection of remediation alternatives. Emerging remediation technologies such as in situ chemical oxidation and in situ chemical reduction have been shown to be potentially effective for CVOC remediation, and may eventually prove to provide viable alternatives for remediating sites where bioremediation approaches may not be feasible because contaminant levels are excessive. In situ chemical oxidation and chemical reduction are defined in Table 2-1, along with in situ bioremediation. These chemical technologies were briefly considered here, but they tend to be relatively expensive compared to bioremediation, have associated implementation issues, and generally were not considered to be warranted for the moderate contaminant concentrations present. Consequently, remediation process screening focused primarily on biological methods.

CVOCs such as TCE, 1,2-DCE, and VC are known to degrade via aerobic (under certain conditions) and anaerobic biological processes. These processes are discussed below, followed by a summary of the selection rationale.

2.1 Aerobic Biodegradation of CVOCs

Two aerobic biodegradation processes are aerobic respiration and cometabolism. Aerobic respiration involves direct oxidation of organic compounds by microorganisms as the primary substrate used for energy and cell growth. During cometabolism, a nonspecific enzyme is produced to metabolize a primary substrate, which fortuitously initiates transformation of another compound. Tetrachloroethene (PCE) and TCE are not amenable to degradation by aerobic respiration. VC is readily biodegraded by aerobic respiration. 1,2-DCE is also reported to be amenable to aerobic respiration, but may not be as susceptible as VC. TCE, 1,2-DCE, and VC are amenable to aerobic cometabolism, although PCE is not.

Enhanced aerobic bioremediation by direct oxidation is implemented by adding oxygen to the subsurface to create aerobic conditions. Oxygen can be added to groundwater by air sparging, injecting oxygenated water (aerated with air or supersaturated with pure oxygen), or by adding a chemical, such as hydrogen peroxide (H_2O_2), which breaks down to release oxygen. While these methods require continuous or intermittent injection to maintain aerobic conditions, "time-release" oxygen source products have been developed and are marketed for the purpose of enhancing aerobic biodegradation. These include Oxygen Release Product (ORC®), a magnesium peroxide (MgO_2) product sold by Regenesis, and PermeOx® Plus, a calcium peroxide product sold by FMC. When injected into the subsurface, these products release oxygen to groundwater over time (typically around 6 months), and, therefore, do not require continuous or frequent operation of fixed injection equipment, which can create high O&M costs and interfere with site activities.

Enhanced aerobic bioremediation by cometabolism typically involves addition of both oxygen and a primary substrate to the subsurface. Primary substrates shown to enhance biotransformation of aliphatic CVOCs include methane, phenol, toluene, propane, butane, and others. The oxygen source and primary substrate chemical are normally injected on a continuous or pulsed basis. Because of the need for routine operation of injection equipment, higher oxygen requirements (due to the primary substrate), the potential for regulatory issues associated with some primary substrates, and the greater complexity of the cometabolic process (relative to direct oxidation), aerobic cometabolism was not considered further in this screening process.

2.2 Anaerobic Biodegradation of CVOCs

Biological reductive dechlorination (RD) is a naturally-occurring, microbially-mediated, anaerobic process in which chlorine atoms on a parent CVOC molecule are sequentially replaced with hydrogen. In the RD process, electrons are transferred from an electron donor source to the CVOC compound, which functions as the electron acceptor. Therefore, an external electron donor source is required for the reaction to occur. Potential electron donor sources include biodegradable organic co-contaminants, native organic matter, or substrates intentionally added to the subsurface. Deeply anaerobic (reducing) conditions are required for RD of many CVOCs, and competing electron acceptors such as dissolved oxygen, nitrate, nitrite, Mn(IV), Fe(III), and sulfate must be depleted.

The principal anaerobic biodegradation pathway for RD of chlorinated ethenes is:

PCE → TCE → *cis*-1,2-DCE → VC → ethene

The transformation rates for each step vary but tend to become slower with progress along the breakdown sequence, often resulting in accumulation of 1,2-DCE and VC. Further breakdown from 1,2-DCE and VC to ethene varies and is based on site specific conditions. In some cases where RD "stalls" at *cis*-1,2-DCE, bioaugmentation (inoculation with a culture of dechlorinating microorganisms) may facilitate complete dechlorination of CVOCs to innocuous end products). Complete dechlorination has been occurring (see Sections 2.3, 2.4, and 2.5) and is expected to continue at SWMUs 2B and 2E.

Enhanced anaerobic bioremediation of CVOCs is implemented by adding a suitable substrate to the subsurface. The introduced substrate serves two purposes: (a) depleting competing electron acceptors and creating strongly reducing conditions, and (b) providing an electron donor source for RD. Enhanced anaerobic bioremediation of CVOCs has been demonstrated in laboratory studies and/or field applications using a wide variety of substrates. Substrate types can be categorized as soluble or insoluble.

Soluble substrates include benzoate, lactate, acetate, propionate, butyrate, methanol, ethanol, sucrose, molasses, and hydrogen (H_2). These substrates are water-soluble, degrade rapidly, and are transported with groundwater flow. Continuous or frequent injections are necessary to maintain the substrate levels in the target zone.

The most commonly used insoluble substrates are Hydrogen Release Compound (HRC®) and vegetable oil. HRC is a patented "time-release" substrate sold by Regenesis (San Clemente, CA) for the purpose of enhancing RD. After injection into an aquifer, HRC hydrolyzes into lactate over time, which is further transformed into lower molecular weight organic acids and H_2. HRC can be applied as a viscous liquid using direct-push technologies, and may serve as an electron donor source for 6 months to 1 year. Vegetable oil is injected as an emulsified liquid, which dissolves over time into the groundwater, providing a source of dissolved organic carbon and hydrogen for RD. Vendors estimate that vegetable oil may serve as an electron donor for at least 1 year to as much as 3 years depending on site specific conditions. There are at least two suppliers of emulsified vegetable oil products for this type of application, and they can be applied via DPT points.

It is also possible to prepare a vegetable oil emulsion in combination with a water soluble substrate, such as lactate. In concept, injecting a combination of soluble and insoluble substrates could provide the desirable features of both types. The soluble substrate should provide rapid initial depletion of competing electron acceptors as well as elevated electron donor availability to stimulate RD, whereas the insoluble substrate should provide a continuous, long-term source of electron donors to sustain RD over time without frequent injection. The soluble/insoluble substrate combination can be applied by formulating the oil emulsion with lactate and/or by injecting a aqueous solution of lactate after the oil emulsion as a "chase" to promote more extensive distribution of the vegetable oil.

2.3 SWMU 2B Alternative Selection

The localized areas of contamination at SWMU 2B are located around monitoring wells OW2B-MW01 and OW2B-MW14. Remediation alternative selection for both locations is summarized in the following sections.

2.3.1 Target Area OW2B-MW01

CVOC contamination at OW2B-MW01 primarily consists TCE, cis-1,2-DCE, and VC (Figure 1-6). Since CVOC-based cleaning compounds such as TCE have been used in this area, it is likely that TCE was released to the subsurface, and anaerobically degraded to cis-1,2-DCE and VC.

Since TCE is not biodegradable under aerobic conditions without co-metabolism, and groundwater studies indicate that a limited amount of RD is occurring, in-situ enhanced anaerobic bioremediation has been selected for groundwater remediation at the OW2B-MW01 target area.

HRC has been selected as an time-release soluble substrate mixture to enhance RD because of its long-term, slow-release characteristics, and may require less remediation time compared to other time release electron donor options (such as emulsified oil). Enhanced anaerobic bioremediation using HRC has been successfully implemented at a wide variety of sites.

2.3.2 Target Area OW2B-MW14

VC is the principal CVOC detected at monitoring well OW2B-MW14. Although VC is a RD daughter product of PCE, TCE, and DCE, the concentrations of these CVOCs are below MCLs. Groundwater CVOC data suggest that RD has occurred, but that intrinsic (naturally-occurring) bio-reduction of VC to ethene is not occurring quickly enough to prevent and accumulation of VC.

In situ enhanced aerobic bioremediation offers the potential for accelerating biodegradation of VC, with the side benefit of reducing concentration of dissolved iron and manganese. Therefore, in-situ enhanced aerobic bioremediation has been selected for the groundwater remediation at the OW2B-MW14 target area. Use of a time-release oxygen product has been selected to preclude continuous/frequent injection and the need for fixed injection facilities, which would interfere with site activities. This plan assumes that ORC will be used as the time-release oxygen source, but PermeOx Plus could be substituted.

2.4 SWMU 2E Alternative Selection

VC is the principal CVOC detected at monitoring well OW2E-MW09. Although VC is a RD daughter product of PCE, TCE, and DCE, the concentrations of these CVOCs are below MCLs. For reasons similar to those discussed for the OW2B-MW14 target area, in situ enhanced aerobic bioremediation using a time-release oxygen product (ORC assumed) has been selected for groundwater remediation at the SWMU 2E target area.

A baseline groundwater sampling event will be conducted prior to the injection of ORC to confirm current geochemistry and VC concentrations, and quantify additional parameters including total petroleum hydrocarbons. TPH represents an electron donor source that will exert an oxygen demand, which is a consideration in the ORC quantity calculations. The oxygen demand created by site hydrocarbon contamination may interfere with remediation of CVOCs. Consequently, site hydrocarbon contamination has been addressed as part of the reagent calculation for SWMU 2E.

TABLE 2-1
In-Situ Remediation Technology Overview
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Remediation Technology	Description
Chemical Oxidation	An oxidizing agent such as hydrogen peroxide, potassium permanganate, or Fenton's reagent is injected into the subsurface to chemically oxidize CVOCs to H_2O, CO_2, and Cl^-.
Chemical Reduction	A reducing agent such as zero valent iron or a reduced sulfur compound is injected into the subsurface to chemically reduce CVOCs to less chlorinated or completely dechlorinated products.
Enhanced Bioremediation	**Anaerobic** - A substrate such as HRC, lactate, vegetable oil, etc. is injected into the subsurface to promote biological reductive dechlorination of CVOCs.
	Aerobic (direct oxidation) - An oxygen source such as O2, H2O2, or ORC is injected into the subsurface to promote aerobic biodegradation of CVOCs.
	Aerobic (cometabolic) - An oxygen source and a suitable primary substrate such as methane, phenol, toluene, etc. are injected into the subsurface to promote aerobic cometabolism of CVOCs.

SECTION 3

Groundwater Remediation Approach

3.1 Introduction

This groundwater remedial design includes remedial action at SWMUs 2B and 2E. In the target area around monitoring well OW2B-MW01 (SWMU 2B), enhanced anaerobic biodegradation using HRC will be implemented. The reagent will be injected to serve as an electron donor in order to accelerate biological reductive dehalogenation of TCE, 1,2-DCE, and VC. In the target areas around monitoring wells OW2B-MW14 (SWMU 2B) and OW2E-MW09 (SWMU 2E) , enhanced aerobic biodegradation using ORC will be implemented. ORC will be injected to increase dissolved oxygen, and accelerate aerobic biological oxidation of VC.

Remedial action activities include:

1. establishing a groundwater monitoring network comprised of both existing and new monitoring wells;
2. performing an initial round of groundwater monitoring prior to reagent injection to establish baseline groundwater characteristics (CVOC and geochemical conditions) and confirm treatment reagent quantity calculations;
3. injecting ORC or HRC into the subsurface to enhance biodegradation of CVOCs;
4. conducting groundwater monitoring over the well network at selected intervals to track remediation progress, and;
5. analyzing the data to evaluate the effectiveness and progress of bioremediation, and reporting results.

3.2 SWMU 2B Remediation

3.2.1 OW2B-MW01 Target Area

The following subsections present the reagent specifications, injection grid design, injection amounts, and injection methodologies for HRC application in the OW2B-MW01 target area.

3.2.1.1 Design Grid and Rationale

HRC will be injected directly into the aquifer matrix in a grid pattern encompassing an area intended to cover the horizontal extent and vertical depth of the contamination. The exact extent of contamination surrounding OW2B-MW01 is unknown since the well is not located in close proximity to other existing monitoring wells and depth specific sampling has not been conducted. However, historic CVOC concentrations are relatively low and do not exceed MCLs in OW2B-MW01D. Thus, the treatment grid is designed to encompass the area surrounding the target well only. Emulsion will be injected into the aquifer from 7 to 20 feet bgs to encompass the expected vertical extent of contamination. The target treatment area is approximately 45-feet wide be 45 feet long (Figure 3-1).

The target area treatment grid (Figure 3-2) will consist of 14 injection points (3 or 4 points per row with 4 rows). Injection point spacing is approximately 15 feet within cross-gradient rows and 15 feet between rows (with-gradient) . The estimated radius of influence for each injection is approximately 7 to 10-feet. The HRC Grid Design worksheet developed by Regenesis was used as guidance in selecting the injection point spacing and HRC injection rates. The completed worksheet, including the aquifer characteristics and design concentrations modeled, is presented in Appendix A.

3.2.1.2 HRC Application Rate

The recommended HRC injection quantity is approximately 4 pounds per foot of injection (lb/ft). Given the injection point spacing, the injection rate (lb/ft), and the depth of injection, the estimated total initial application amount of HRC required in the target area is:

> OW2B-MW01 Target Area - (14 injection points) x (4 lbs HRC/injection) x (13 ft) = 728 lbs of HRC.

3.2.1.3 HRC Application Method

Prior to injection HRC will be heated to a recommended minimum temperature of 105 °F to reduce its viscosity, which will facilitate dispersion in the subsurface. A direct push hydraulic rig will be used to inject HRC into the subsurface. Drive rods will be pushed to the target depth of approximately 20-feet bgs and the HRC injected as the rods are withdrawn. The estimated radius of injection is 7 to 10 feet. At each location, HRC will be injected beginning at 20 feet bgs to 7 feet bgs or to the top of the water table.

3.2.2 OW2B-MW14 Target Area

The following subsections present the injection grid design, application rates, and injection methods for ORC application around the OW2B-MW14 target area. ORC is supplied by Regenesis Bioremediation Products.

3.2.2.1 ORC Design Grid and Rationale

An ORC/water slurry mixture will be injected directly into the aquifer matrix in a grid pattern over an area intended to cover the aerial extent and the vertical depth of the contamination. The exact extent of contamination surrounding OW2B-MW14 is unknown since the well is not located in close proximity to other existing monitoring wells and depth specific sampling has not been conducted. However, CVOC concentrations are relatively low compared to MCLs. Thus, the treatment grid is designed to encompass the area surrounding the target well only. ORC will be injected into the aquifer from 6 feet bgs or the top of the water table to 20 feet bgs, to encompass the expected vertical extent of contamination. The target treatment area is approximately 45 feet wide by 45 feet long (Figure 3-1).

CVOC and geochemical data from monitoring well OW2B-MW14 were used to represent conditions in the surrounding area. The ORC Grid Design worksheet developed by Regenesis was used as guidance in selecting the injection point spacing and ORC injection rates. The completed worksheet, including the aquifer characteristics and design concentrations modeled, is presented in Appendix A. As shown in Figure 3-3, 13 injection points will be used to cover this area. Injection point spacing is approximately 15 feet within cross-gradient rows and 15 feet between rows (with-gradient).

3.2.2.2 ORC Application Rate

The recommended ORC injection amount in the target area is approximately 3.0 lb/ft of well depth. Regenesis recommends using a minimum of 3.0 lb/ft. Given the injection point spacing and injection rate (lb/ft), the estimated total initial application amount of ORC required for each target area is:

> Target Area - (13 injection points) x (3 lbs ORC/ft of depth) x (14 ft depth/injection point) = 546 lbs of ORC.

3.2.2.3 ORC Application Method

ORC will be applied as a 30 percent ORC/water slurry mixture. A direct push hydraulic rig will be used to inject ORC into the subsurface. Drive rods will be pushed to the target depth of 20-feet bgs and the ORC slurry injected as the rods are withdrawn. The estimated radius of injection is 7 to 10 feet. At each location, ORC will be injected beginning at 20 feet bgs and injecting upward to 6 feet bgs or to the top of the water table.

3.3 Remediation at SWMU 2E

The following subsections present the injection grid design, application rates, and injection methods for ORC application in the SWMU 2E CVOC remediation target area.

3.3.1 ORC Design Grid and Rationale

An ORC/water slurry mixture will be injected directly into the aquifer matrix in a grid pattern over an area intended to cover the aerial extent and the vertical depth of the contamination. The exact extent of contamination surrounding OW2B-MW14 is unknown since the well is not located in close proximity to other existing monitoring wells and depth specific sampling has not been conducted. However, CVOC concentrations are relatively low compared to MCLs. Thus, the treatment grid is designed to encompass the area surrounding the target well only. ORC will be injected into the aquifer from 5 feet bgs (or the top of the water table) to 20 feet bgs, to encompass the expected vertical extent of contamination. The target area is approximately 45 feet wide by 45 feet long (Figure 3-4).

CVOC and geochemical data from monitoring well OW2E-MW09 were used to represent conditions in the surrounding area. The ORC Grid Design worksheet developed by Regenesis was used as guidance in selecting the injection point spacing and ORC injection rates. The completed worksheet, including the aquifer characteristics and design concentrations modeled, is presented in Appendix A. As shown in Figure 3-5, 13 injection points will be used to cover this area. Injection point spacing is approximately 15 feet within cross-gradient rows and 15 feet between rows (with-gradient).

3.3.2 ORC Application Rate

The recommended ORC injection amount in the target areas is approximately 3.0 lb/ft of well depth. This quantity was calculated based on CVOC concentrations and a conservative estimate of TPH contamination at OW2E-MW09. Regenesis recommends using a minimum of 3.0 lb/ft.

Given the injection point spacing and injection rate (lb/ft), the estimated total initial application amount of ORC required for each target area is:

> Target Area - (13 injection points) x (3 lbs ORC/ft of depth) x (14.75 ft depth/injection point) = 576 lbs of ORC.

3.3.3 ORC Application Method

ORC will be applied as a 30 percent ORC/water slurry mixture. A direct push hydraulic rig will be used to inject ORC into the subsurface. Drive rods will be pushed to the target depth of 20-feet bgs and the ORC slurry injected as the rods are withdrawn. The estimated radius of injection is 7 to 10 feet. At each location, ORC will be injected beginning at 20 feet bgs and moving upward to 5 feet bgs or to the top of the water table.

3.4 Groundwater Monitoring, Sampling, and Analysis

Bioremediation effectiveness will be monitored by collecting and analyzing groundwater samples from an established monitoring well network prior to, and throughout the duration of, the treatability study. Table 3-1 summarizes the wells that comprise the groundwater monitoring network for SWMUs 2B and 2E. Because of the low CVOC levels in the target areas, groundwater performance monitoring will be conducted at the single existing well in each area. The depths and screen specifications for each of the monitoring wells are presented in Table 3-1. The following subsections describe monitoring well installation, groundwater monitoring frequency, and groundwater sampling and analysis.

3.4.1 Groundwater Monitoring Frequency

Five rounds of groundwater sampling are planned to monitor remediation performance. Sampling will be conducted prior to injection (baseline), and then at 2, 4, 8, and 12 months after injection of the reagents. Baseline sampling will establish current geochemistry and contaminant concentrations. At SWMU 2E, additional parameters will be measured during baseline sampling including total petroleum hydrocarbons (TPH).

The monitoring times were selected to assess short term and long term effects of substrate injection on geochemistry and CVOC concentrations. However, the monitoring schedule may be modified, if appropriate, based on the interim results.

3.4.2 Groundwater Sampling and Analysis

Groundwater samples will be analyzed using a combination of offsite analytical laboratory analyses, field test kits and field instruments. Table 3-2 summarizes the analyses that will be conducted on groundwater samples. Method reporting limits (MRL) will be equal to or less than those for the January 2004 groundwater sampling event. Laboratory detection limits shall be low enough to detect low level VOC concentrations and determine if the CVOCs are below MCLs.

Quality Assurance and Quality Control (QA/QC) samples will be collected at the frequency outlined in Table 3-3. QC samples include field duplicates, matrix spike, matrix spike duplicates, field blanks, trip, blanks, and equipment blanks.

3.5 Data Analysis, Interpretation, and Reporting

Technical memoranda will be prepared and submitted to the Navy following each post-injection monitoring event. The interim memoranda following the first three events will briefly document field activities and monitoring data for the most recent interval and provide a brief discussion of treatability study progress to date. The final technical memorandum will include a comprehensive discussion of the data and treatment effectiveness at the site, including whether RAOs were achieved, and provide recommendations regarding a recommendation for site closeout under CERCLA, or additional monitoring and/or remedial activities, as appropriate.

TABLE 3-1
Monitoring Well Network
SWMU 2B Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Sampling Point	Relative Location	Total Depth (ft bgs)	Depth of Screened Interval (ft bgs)
OW2B-MW01			
OW2B-MW01	Treatment Area	19	9-19
OW2B-MW14			
OW2B-MW14	Treatment Area	20	10-20
OW2E-MW09			
OW2E-MW09	Treatment Area	18.5	3.5-18.5

TABLE 3-2
Monitoring Parameters
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

Parameter	Method	OW2B-MW01 (anaerobic)	OW2B-MW14 (aerobic)	OW2E-MW09 (aerobic)
VOCs	EPA 8260B	X	X	X
Methane, Ethane, Ethene	EAP RS Kerr Lab SOP-147	X		
Temperature	Field test	X	X	X
Dissolved oxygen	Field test	X	X	X
pH	Field test	X	X	X
ORP	Field test	X	X	X
Turbidity	EPA 180.1	X	X	X
Conductivity	Field test	X	X	X
Alkalinity	EPA 310.1	X	X	X
Nitrate	EPA 300.0	X	X	X
Ferrous Iron (or dissolved iron)	Field test (or EPA 200.7*)	X	X	X
Sulfate	EPA 300.0	X	X	X
Sulfide	Field test	X		
Chloride	EPA 300.0	X	X	X
Total organic carbon	EPA 9060	X	X	X
VFAs	HPLC method	X		

* Field -filtered samples

TABLE 3-3
Quality Control Sampling Frequency
SWMUs 2B and 2E Groundwater Remediation Plan
NAS Oceana, Virginia Beach, Virginia

QC Samples	Collection Frequency
Field Duplicates	10% of total samples collected or one duplicate per day per sampling event, which every is more frequent
Field Blanks	One per sampling event
Matrix Spikes	5% of total samples collected
Matrix Spike Duplicates	5% of total samples collected
Equipment Blanks	One per day per sampling event
Trip Blanks	One set per cooler containing samples collected for VOC analysis

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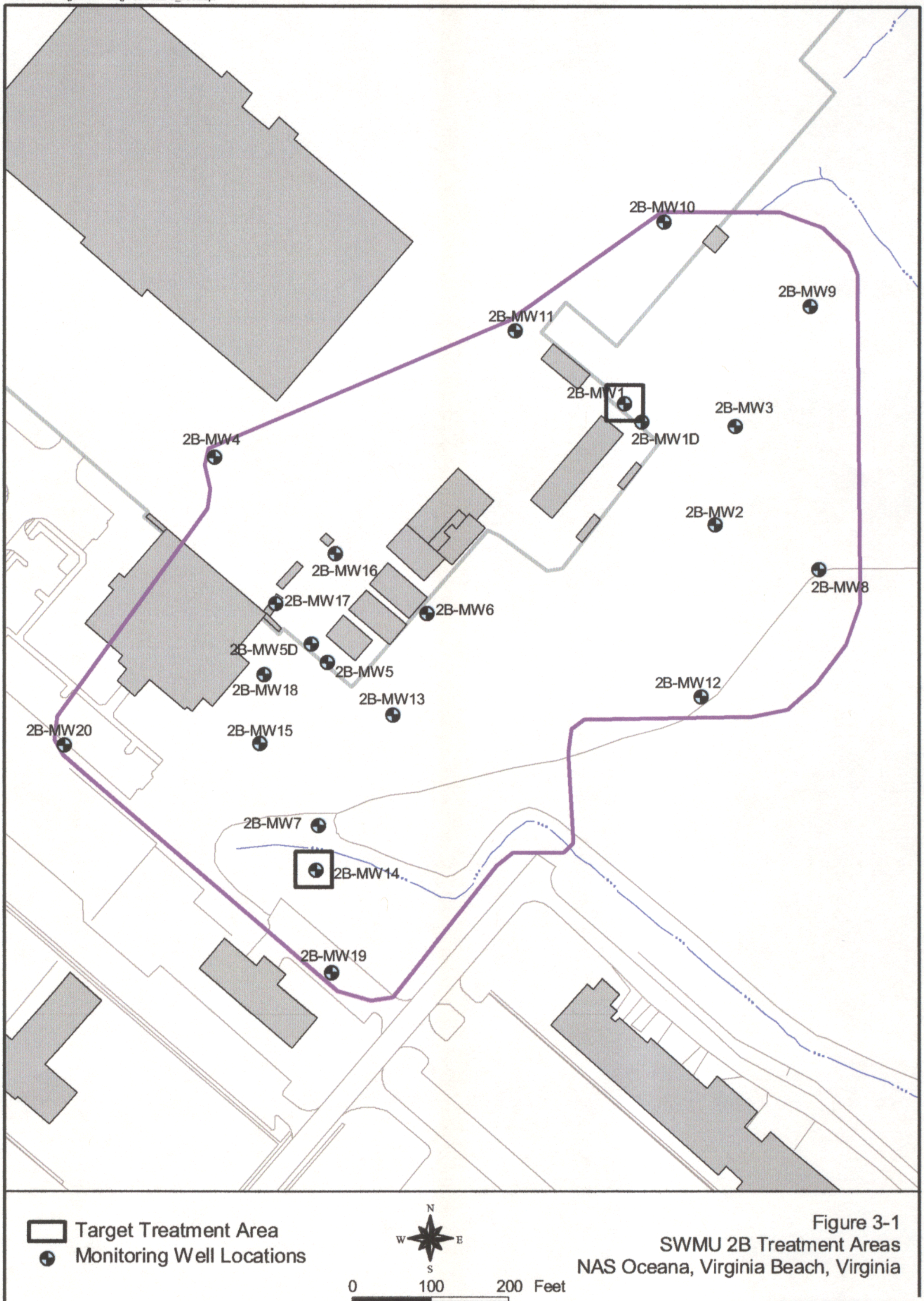
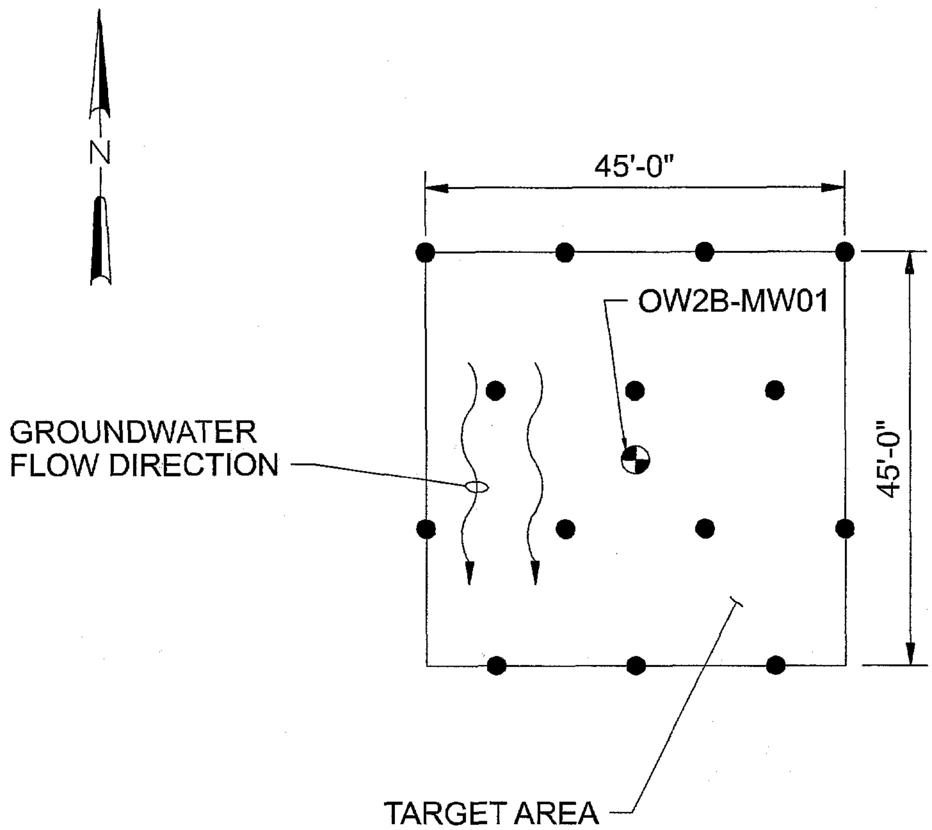


Figure 3-1
SWMU 2B Treatment Areas
NAS Oceana, Virginia Beach, Virginia

CH2MHILL

00648 D 034



LEGEND

- ● HRC INJECTION POINT
- —— TARGET AREA BORDER

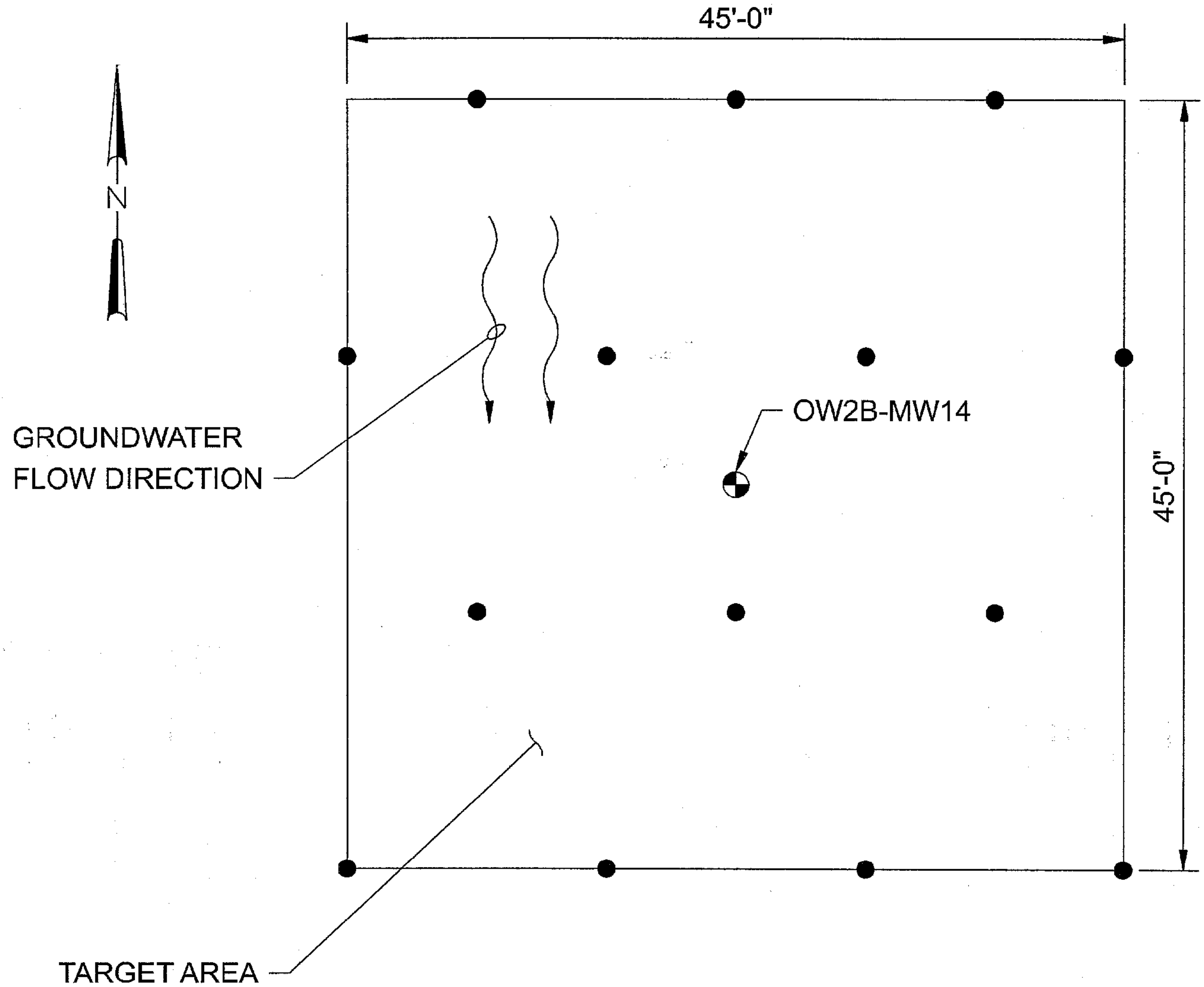
NOTES

1. INJECTION POINT SPACING IN THE TARGET AREA IS 15 FEET WITHIN ROWS WITH ROWS 15 FEET APART.

FIGURE 3-2
PROPOSED INJECTION LOCATIONS
FOR OW2B-MW01
SWMU 2B, NAS OCEANA, VIRGINIA BEACH
VIRGINIA

NOT TO SCALE

CH2MHILL



LEGEND

● ORC INJECTION POINT

—— TARGET AREA BORDER

NOTES

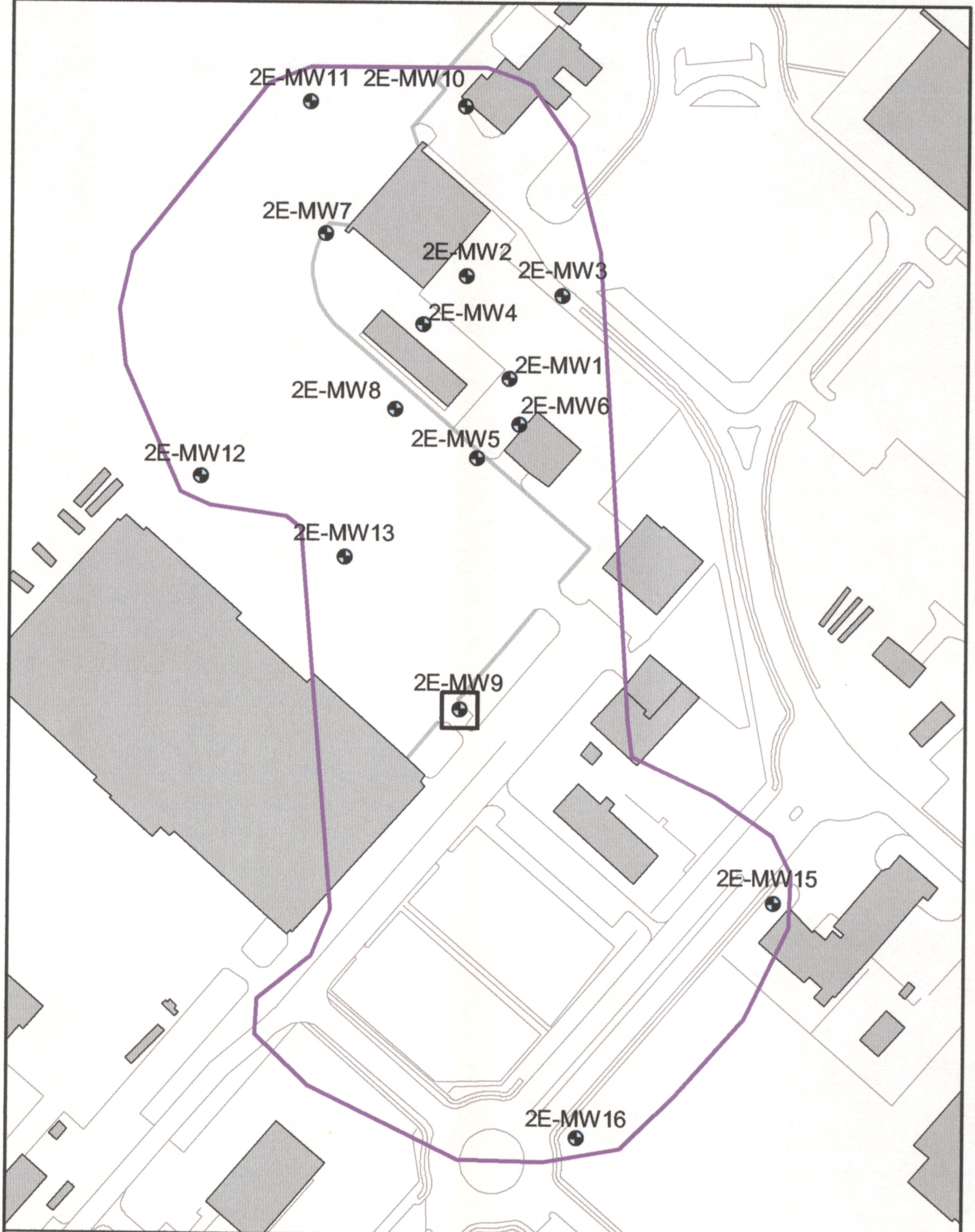
1. INJECTION POINT SPACING IN THE TARGET AREA IS 15 FEET WITHIN ROWS WITH ROWS 15 FEET APART.

FIGURE 3-3
PROPOSED INJECTION LOCATIONS
FOR OW2B-MW14
SWMU 2B, NAS OCEANA, VIRGINIA BEACH
VIRGINIA

NOT TO SCALE

CH2MHILL

File Path: v:\18gis\oceana\figures\oceana_0500.apr



Target Treatment Area
Monitoring Well Locations

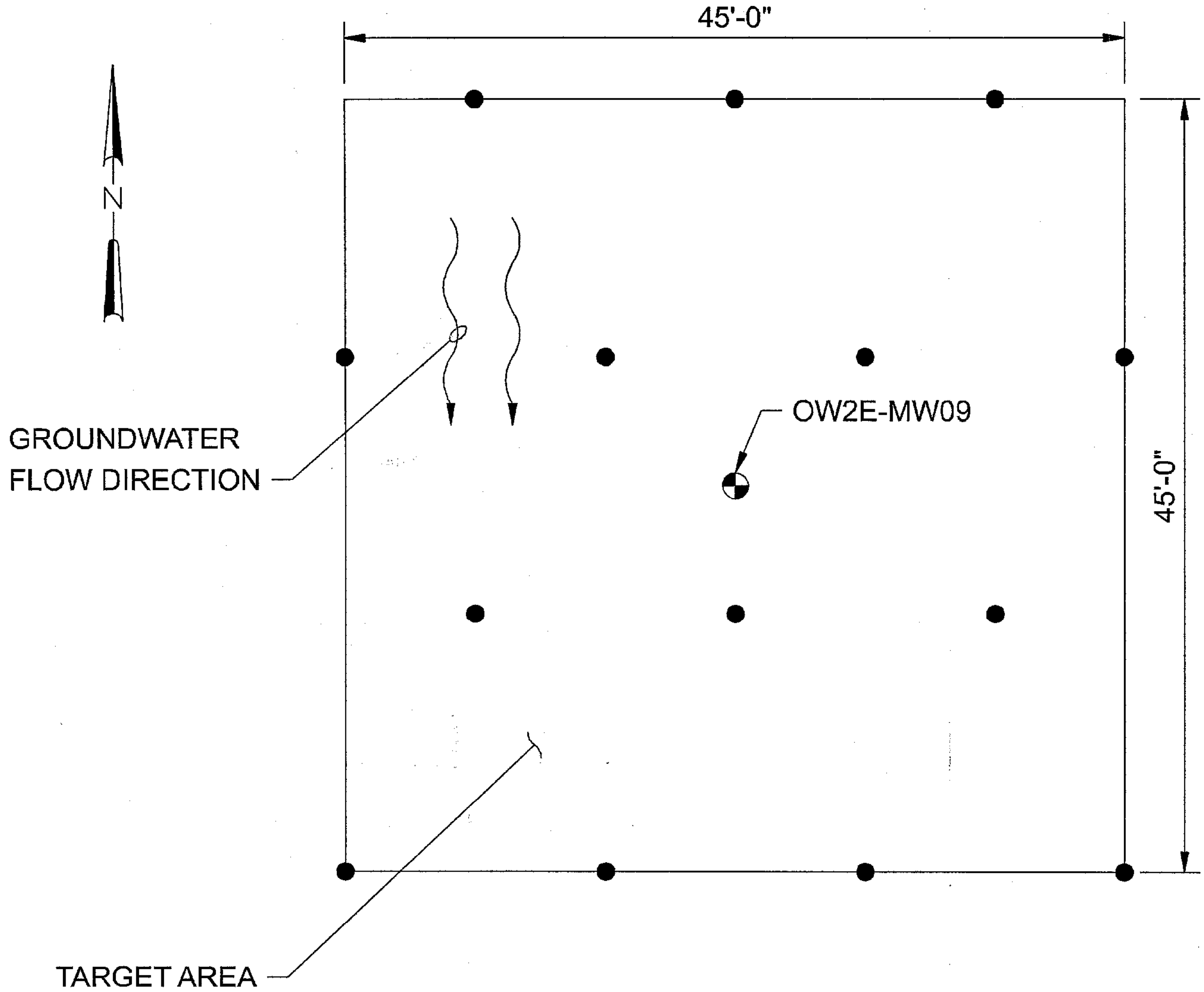
N W E S

0 100 200 Feet

Figure 3-4
SWMU 2E Treatment Area
NAS Oceana, Virginia Beach, Virginia

CH2MHILL

00648 D 044



LEGEND

● ORC INJECTION POINT

—— TARGET AREA BORDER

NOTES

1. INJECTION POINT SPACING IN THE TARGET AREA IS 15 FEET WITHIN ROWS WITH ROWS 15 FEET APART.

FIGURE 3-5
PROPOSED INJECTION LOCATIONS
FOR OW2E-MW09
SWMU 2E, NAS OCEANA, VIRGINIA BEACH
VIRGINIA

NOT TO SCALE

CH2MHILL

SECTION 4

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ORC Design Software for Grid Applications Using Slurry Injection

US Version 3.1

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: SWMU 2B
Location: MW-14
Consultant: CH2M HILL

Site Conceptual Model/Extent of Plume Requiring Remediation

Width of plume (intersecting gw flow direction)	45	ft		
Length of plume (parallel to gw flow direction)	45	ft =	2,025	sq. ft.
Depth to contaminated zone	6	ft		
Thickness of contaminated saturated zone	14	ft		
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	silty sand			
Total porosity	0.3	Eff. porosity	0.25	
Hydraulic conductivity	2	ft/day =	7.1E-04	cm/sec
Hydraulic gradient	0.0017	ft/ft		
Seepage velocity	5.0	ft/yr =	0.014	ft/day
Treatment Zone Pore Volume	8,505	ft^3 =	63,626	gallons

Dissolved Phase Oxygen Demand:

Individual species that represent oxygen demand:	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoich. (wt/wt) O_2/contam.	ORC (lb) (10% O_2)
benzene	0.00	0.0	3.1	0
toluene	0.00	0.0	3.1	0
ethylbenzene	0.00	0.0	3.2	0
xylenes	0.00	0.0	3.2	0
MTBE	0.00	0.0	2.7	0
dichloroethene	0.01	0.0	0.7	0
vinyl chloride	0.01	0.0	1.3	0
User added, also add stoichiometric demand	0.00	0.0	0.0	0
User added, also add stoichiometric demand	0.00	0.0	0.0	0
reduced metals: Fe (+2) and Mn(+2)	20.00	10.6	0.10	11
Measures of total oxygen demand				
Total Petroleum Hydrocarbons	0.00	0.0	3.1	0
Biological Oxygen Demand (BOD)	0.00	0.0	1	0
Chemical Oxygen Demand (COD)	0.00	0.0	1	0

Estimates for Sorbed Phase Oxygen Demand:

Soil bulk density	1.76	g/cm^3 =	110	lb/cf
Fraction of organic carbon: foc	0.005	range: 0 to 0.01		

(Estimated using Soil Conc=foc*Koc*Cgw)
(Adjust Koc as nec. to provide realistic est.)

Individual species that represent oxygen demand:	Koc (L/kg)	Contaminant Conc (mg/kg)	Contaminant Mass (lb)	Stoich. O_2/contam.	ORC (lb) (10% O_2)
benzene	83	0.00	0.0	3.1	0
toluene	135	0.00	0.0	3.1	0
ethylbenzene	95	0.00	0.0	3.2	0
xylenes	240	0.00	0.0	3.2	0
MTBE	12	0.00	0.0	2.7	0
dichloroethene	80	0.00	0.0	0.7	0
vinyl chloride	2.5	0.00	0.0	1.3	0
User added, also add stoichiometric demand	0.0	0.00	0.0	0.0	0
User added, also add stoichiometric demand	0.0	0.00	0.0	0.0	0
Measures of total oxygen demand					
Total Petroleum Hydrocarbons	178	0.00	0.0	3.1	0
Biological Oxygen Demand (BOD): Use a multiple of dissolved phase ->	1.00		0.0	1	0
Chemical Oxygen Demand (COD): Use a multiple of dissolved phase ->	1.00		0.0	1	0

Summary of Estimated ORC Requirements	ORC for Dissolved Phase (lbs)	ORC for Sorbed Phase (lbs)	Add Dem Factor (1 to 10x)	ORC Total w/ Add Dem Factor	ORC Cost at $ 10.00
Individual Species: Total BTEX, MTBE (selected)	11	0	5	54	$ 536 <-
Total Petroleum Hydrocarbons	-	-	2	-	$ -
Biological Oxygen Demand (BOD)	-	-	2	-	$ -
Chemical Oxygen Demand (COD)	-	-	1	-	$ -

Select above measure (button) to specify required ORC quantity (in 30 lb increments) ------> 60 **pounds ORC**

Delivery Design for ORC Slurry

Spacing within rows (ft)	15.0	feet
# points per row	3	points/row
Spacing between rows (ft)	15.0	ft
# of rows	3	rows
Advective travel time bet. rows (days)	1103	days
Number of points in grid	9	points
Required ORC per foot (Minimum Dose Override->)	3.0	lbs/foot
Total ORC (Minimum Dose Override->)	378	lbs of ORC

Slurry Mixing Volume for Injections

Pounds per location	42
Buckets per location	1.4
Design solids content (20-40% by wt. for injections)	30%
Volume of water required per hole (gal)	12
Total water for mixing all holes (gal)	106
Simple ORC Backfilling: min hole dia. for 67% slurry	2.9
Feasibility for slurry injection in sand: ok up to 15 lb/ft	(ok)
Feasibility for slurry injection in silt: ok up to 10 lb/ft	(ok)
Feasibility for slurry injection in clay: ok up to 5 lb/ft	(ok)

Project Summary		
ORC bulk material for slurry injection (lbs)		378
Number of 30 lb ORC buckets		12.6
ORC bulk material cost	$	11.00
Cost for bulk ORC material	$	4,158
Shipping and Tax Estimates in US Dollars		
Sales Tax (rate: 0%)	$	-
Total Matl. Cost	$	4,158
Shipping (call for amount)	$	-
Total Regenesis Material Cost	**$**	**4,158**

ORC Slurry Injection Cost Est. (responsibility of customer to contract work)		
Footage for each inj. point = uncontaminated + HRC inj. interval (ft)		20
Total length for direct push for project (ft)		180
Estimated daily installation rate (ft per day: 400 for push, 150 for drilling)		400
Estimated points per day (15 to 30 is possible for direct push)		20.0
Required number of days		1
Mob/demob cost for injection subcontractor	$	1,000
Daily rate for inj. Sub. ($1-2K for push $3-4K for drill rig)	$	1,500
Total injection subcontrator cost for application	$	2,500
Total Install Cost (not including consultant, lab, etc.)	**$**	**6,658**

Other Project Cost Estimates		
Design	$	-
Permitting and reporting	$	-
Construction management	$	-
Groundwater monitoring and rpts	$	-
Other	$	-
Other	$	-
Other	$	-
Other	$	-
Total Project Cost	**$**	**6,658**

HRC Design Software for Plume Area/Grid Treatment

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: SWMU 2B
Location: MW-01
Consultant: CH2M HILL

Site Conceptual Model/Extent of Plume Requiring Remediation

Width of plume (intersecting gw flow direction)	45	ft		
Length of plume (parallel to gw flow direction)	45	ft	=	2,025
Depth to contaminated zone	7	ft		
Thickness of contaminated saturated zone	13	ft		
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	silty sand			
Total porosity	0.3		Eff. porosity:	0.25
Hydraulic conductivity	2	ft/day	=	7.1E-04
Hydraulic gradient	0.0017	ft/ft		
Seepage velocity	5.0	ft/yr	=	0.014
Treatment Zone Pore Volume	7,898	ft^3	=	59,081

Dissolved Phase Electron Donor Demand	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoich. (wt/wt) contam/H_2
Tetrachloroethene (PCE)	0.02	0.0	20.7
Trichloroethene (TCE)	0.02	0.0	21.9
cis-1,2-dichloroethene (DCE)	0.02	0.0	24.2
Vinyl Chloride (VC)	0.02	0.0	31.2
Carbon tetrachloride	0.00	0.0	19.2
Chloroform	0.00	0.0	19.9
1,1,1-Trichloroethane (TCA)	0.00	0.0	22.2
1,1-Dichlorochloroethane (DCA)	0.00	0.0	24.7
Hexavalent Chromium	0.00	0.0	17.3
User added, also add stoichiometric demand	0.00	0.0	0.0
Jser added, also add stoichiometric demand	0.00	0.0	0.0

Sorbed Phase Electron Donor Demand

Soil bulk density	1.76	g/cm^3	=	110
Fraction of organic carbon: foc	0.005	range: 0.0001 to 0.01		

(Values are estimated using Soil Conc=foc*Koc*Cgw) (Adjust Koc as nec. to provide realistic estimates)	Koc (L/kg)	Contaminant Conc (mg/kg)	Contaminant Mass (lb)	Stoich. (wt/wt) contam/H_2
Tetrachloroethene (PCE)	263	0.03	0.1	20.7
Trichloroethene (TCE)	107	0.01	0.0	21.9
cis-1,2-dichloroethene (DCE)	80	0.01	0.0	24.2
Vinyl Chloride (VC)	2.5	0.00	0.0	31.2
Carbon tetrachloride	110	0.00	0.0	19.2
Chloroform	34	0.00	0.0	19.9
1,1,1-Trichloroethane (TCA)	183	0.00	0.0	22.2
1,1-Dichlorochloroethane (DCA)	183	0.00	0.0	24.7
User added, also add stoichiometric demand	0	0.00	0.0	0.0
User added, also add stoichiometric demand	0	0.00	0.0	0.0

Competing Electron Acceptors	Electron Acceptor Conc (mg/L)	Electron Acceptor Mass (lb)	Stoich. (wt/wt) elec acceptor/H_2
Oxygen	0.06	0	8.0
Nitrate	0.50	0	12.4
Est. Mn reduction demand (potential amt of Mn2+ formed)	0.17	0	27.5
Est. Fe reduction demand (potential amt of Fe2+ formed)	4.43	2	55.9
Estimated sulfate reduction demand	30.00	15	12.0

Microbial Demand Factor	3	Recommend 1-4x
Safety Factor	2	Recommend 1-4x

Injection Point Spacing and Dose:

Injection spacing within rows (ft) 15.0 # points per row: 3

Injection spacing between rows (ft)	15.0	# of rows:	3
Advective travel time bet. rows (days)	1103	Total # of points:	9
		Minimum req. HRC dose per foot (lb/ft)	4.0

Project Summary				
Number of HRC delivery points (adjust as nec. for site)			9	
HRC Dose in lb/foot (adjust as nec. for site)			4.0	<-Minumum Dose Override
Corresponding amount of HRC per point (lb)			52	
Number of 30 lb HRC Buckets per injection point			1.7	
Total Number of 30 lb Buckets			16	
Total Amt of HRC (lb)			480	
HRC Cost		$	8.00	
Total Material Cost		**$**	**3,840**	
Shipping and Tax Estimates in US Dollars				
Sales Tax	rate: 0%	$	-	
Total Matl. Cost		$	3,840	
Shipping of HRC (call for amount)		$	-	
Total Regenesis Material Cost		**$**	**3,840**	

ORC Design Software for Grid Applications Using Slurry Injection

US Version 3.1

Regenesis Technical Support: USA (949) 366-8000, www.regenesis.com

Site Name: SWMU 2E
Location: NAS Oceana
Consultant: CH2M HILL

Site Conceptual Model/Extent of Plume Requiring Remediation

Width of plume (intersecting gw flow direction)	45	ft			
Length of plume (parallel to gw flow direction)	45	ft	=	2,025	sq. ft.
Depth to contaminated zone	5.25	ft			
Thickness of contaminated saturated zone	15	ft			
Nominal aquifer soil (gravel, sand, silty sand, silt, clay)	silty sand				
Total porosity	0.3		Eff. porosity	0.25	
Hydraulic conductivity	2	ft/day	=	7.1E-04	cm/sec
Hydraulic gradient	0.00083	ft/ft			
Seepage velocity	2.4	ft/yr	=	0.007	ft/day
Treatment Zone Pore Volume	9,113	ft^3	=	68,171	gallons

Dissolved Phase Oxygen Demand:

Individual species that represent oxygen demand:	Contaminant Conc (mg/L)	Contaminant Mass (lb)	Stoich. (wt/wt) O_2/contam.	ORC (lb) (10% O_2)
benzene	0.00	0.0	3.1	0
toluene	0.00	0.0	3.1	0
ethylbenzene	0.00	0.0	3.2	0
xylenes	0.00	0.0	3.2	0
MTBE	0.00	0.0	2.7	0
dichloroethene	0.01	0.0	0.7	0
vinyl chloride	0.01	0.0	1.3	0
User added, also add stoichiometric demand	0.00	0.0	0.0	0
User added, also add stoichiometric demand	0.00	0.0	0.0	0
reduced metals: Fe (+2) and Mn(+2)	10.00	5.7	0.10	6
Measures of total oxygen demand				
Total Petroleum Hydrocarbons	10.00	5.7	3.1	176
Biological Oxygen Demand (BOD)	30.00	17.1	1	171
Chemical Oxygen Demand (COD)	60.00	34.1	1	341

Estimates for Sorbed Phase Oxygen Demand:

Soil bulk density	1.76	g/cm^3	=	110 lb/cf
Fraction of organic carbon: foc	0.005	range: 0 to 0.01		

(Estimated using Soil Conc=foc*Koc*Cgw)
(Adjust Koc as nec. to provide realistic est.)

Individual species that represent oxygen demand:	Koc (L/kg)	Contaminant Conc (mg/kg)	Contaminant Mass (lb)	Stoich. O_2/contam.	ORC (lb) (10% O_2)
benzene	83	0.00	0.0	3.1	0
toluene	135	0.00	0.0	3.1	0
ethylbenzene	95	0.00	0.0	3.2	0
xylenes	240	0.00	0.0	3.2	0
MTBE	12	0.00	0.0	2.7	0
dichloroethene	80	0.01	0.0	0.7	0
vinyl chloride	2.5	0.00	0.0	1.3	0
User added, also add stoichiometric demand	0.0	0.00	0.0	0.0	0
User added, also add stoichiometric demand	0.0	0.00	0.0	0.0	0
Measures of total oxygen demand					
Total Petroleum Hydrocarbons	178	8.90	29.7	3.1	921
Biological Oxygen Demand (BOD): Use a multiple of dissolved phase ->		1.00	17.1	1	171
Chemical Oxygen Demand (COD): Use a multiple of dissolved phase ->		1.00	34.1	1	341

Summary of Estimated ORC Requirements	ORC for Dissolved Phase (lbs)	ORC for Sorbed Phase (lbs)	Add Dem Factor (1 to 10x)	ORC Total w/ Add Dem Factor	ORC Cost at $ 10.00
Individual Species: Total BTEX, MTBE (selected)	6	0	5	30	$ 295 <-
Total Petroleum Hydrocarbons	176	921	2	2,194	$ 21,940
Biological Oxygen Demand (BOD)	171	171	2	682	$ 6,821
Chemical Oxygen Demand (COD)	341	341	1	682	$ 6,821

Select above measure (button) to specify required ORC quantity (in 30 lb increments) ------> 30 **pounds ORC**

Delivery Design for ORC Slurry

Spacing within rows (ft)	15.0	feet
# points per row	3	points/row
Spacing between rows (ft)	15.0	ft
# of rows	3	rows
Advective travel time bet. rows (days)	2259	days
Number of points in grid	9	points
Required ORC per foot (Minimum Dose Override->)	3.0	lbs/foot
Total ORC (Minimum Dose Override->)	405	lbs of ORC

Slurry Mixing Volume for Injections

Pounds per location	45
Buckets per location	1.5
Design solids content (20-40% by wt. for injections)	30%
Volume of water required per hole (gal)	13
Total water for mixing all holes (gal)	113
Simple ORC Backfilling: min hole dia. for 67% slurry	2.9
Feasibility for slurry injection in sand: ok up to 15 lb/ft	(ok)
Feasibility for slurry injection in silt: ok up to 10 lb/ft	(ok)
Feasibility for slurry injection in clay: ok up to 5 lb/ft	(ok)

Project Summary		
ORC bulk material for slurry injection (lbs)		405
Number of 30 lb ORC buckets		13.5
ORC bulk material cost	$	11.00
Cost for bulk ORC material	$	4,455
Shipping and Tax Estimates in US Dollars		
Sales Tax (rate: 0%)	$	-
Total Matl. Cost	$	4,455
Shipping (call for amount)	$	-
Total Regenesis Material Cost	$	4,455

ORC Slurry Injection Cost Est. (responsibility of customer to contract work)		
Footage for each inj. point = uncontaminated + HRC inj. interval (ft)		20
Total length for direct push for project (ft)		182
Estimated daily installation rate (ft per day: 400 for push, 150 for drilling)		400
Estimated points per day (15 to 30 is possible for direct push)		19.8
Required number of days		1
Mob/demob cost for injection subcontractor	$	1,000
Daily rate for inj. Sub. ($1-2K for push $3-4K for drill rig)	$	1,500
Total injection subcontrator cost for application	$	2,500
Total Install Cost (not including consultant, lab, etc.)	$	6,955

Other Project Cost Estimates		
Design	$	-
Permitting and reporting	$	-
Construction management	$	-
Groundwater monitoring and rpts	$	-
Other	$	-
Other	$	-
Other	$	-
Other	$	-
Total Project Cost	$	6,955

STANDARD OPERATING PROCEDURE

Low-Flow Groundwater Sampling from Monitoring Wells

I. Purpose and Scope

This procedure presents general guidelines for the collection of groundwater samples from monitoring wells. Low-flow purging and sampling procedures are specifically addressed. Operations manuals should be consulted for specific calibration and operating procedures.

II. Equipment and Materials

- Flow-through cell with inlet/outlet ports for purged groundwater and watertight ports for each probe
- Meters to monitor pH, specific conductance, turbidity, dissolved oxygen, Eh, and temperature measurements (e.g., Horiba® U-22 or similar)
- Water-level indicator
- In-line disposable 0.45μ filters (QED® FF8100 or equivalent)
- Adjustable-rate, positive-displacement pump or peristaltic pump
- Generator
- Disposable polyethylene tubing
- Plastic sheeting
- Well-construction information
- Calibrated bucket or other container and watch with second indicator to determine flow rate
- Sample containers
- Shipping supplies (labels, coolers, and ice)
- Field book

III. Procedures and Guidelines

A. Setup and Purging

1. For the well to be sampled, information is obtained on well location, diameter(s), depth, and screened interval(s), and the method for disposal of purged water.
2. Instruments are calibrated according to manufacturer's instructions.
3. The well number, site, date, and condition are recorded in the field logbook.

4. Plastic sheeting is placed on the ground, and the well is unlocked and opened. All decontaminated equipment to be used in sampling will be placed only on the plastic sheeting until after the sampling has been completed.

5. Water level measurements are collected in accordance with SOP *Water Level Measurements*. **Do not measure the depth to the bottom of the well at this time**; this reduces the possibility that any accumulated sediment in the well will be disturbed. Obtain depth to bottom information from well installation log.

6. Sampling equipment is cleaned and decontaminated before sampling in accordance with SOP *Decontamination of Personnel and Equipment*.

7. Lay out polyethylene sheeting and place all equipment on the sheeting. To avoid cross-contamination, do not let any downhole equipment touch the ground surface.

8. Attach and secure the polyethylene tubing to the low-flow pump. Lower the pump slowly into the well and set it at approximately the middle of the screen. Place the pump intake at least 2 feet above the bottom of the well to avoid mobilization of any sediment present in the bottom. Preferably, the pump should be in the middle of the screen. Start purging the well at 0.2 to 0.5 liters per minute. Avoid surging. Purging rates for more transmissive formations could be started at 0.5 to 1 liter per minute.

9. The measurement probes are inserted into the flow-through cell. The purged groundwater is directed through the cell, allowing measurements to be collected before the water contacts the atmosphere. The initial field parameters of pH, specific conductance, dissolved oxygen, Eh, turbidity, and temperature of water are measured and recorded in the field logbook.

10. The water level should be monitored during purging, and, ideally, the purge rate should equal the well recharge rate so that there is little or no drawdown in the well (i.e., less than 0.5 feet). The water level should stabilize for the specific purge rate. There should be at least 1 foot of water over the pump intake so there is no risk of the pump suction being broken, or entrainment of air in the sample. Record adjustments in the purge rate and changes in depth to water in the logbook. Purge rates should, if needed, be decreased to the minimum capabilities of the pump (0.1 to 0.2 liters per minute) to avoid affecting well drawdown.

11. During purging, the field parameters are measured frequently (every 3 to 5 minutes) until the parameters have stabilized. Field parameters are considered stabilized when measurements meet the following criteria:

    - pH: within 0.1 pH units
    - Specific conductance: within 3 percent

- Dissolved oxygen: within 10 percent
- Turbidity: within 10 percent or as low as practicable given sampling conditions
- Eh: within 10 mV

B. Sample Collection

Once purging has been completed, the well is ready to be sampled. The elapsed time between completion of purging and collection of the groundwater sample from the well should be minimized. Typically, the sample is collected immediately after the well has been purged, but this is also dependent on well recovery.

Samples will be placed in bottles that are appropriate to the respective analysis and that have been cleaned to laboratory standards. Each bottle typically will have been previously prepared with the appropriate preservative, if any.

The following information, at a minimum, will be recorded in the logbook:

1. Sample identification (site name, location, and project number; sample name/number and location; sample type and matrix; whether the sample is filtered or not; time and date; sampler's identity)
2. Sample source and source description
3. Field observations and measurements (appearance, volatile screening, field chemistry, sampling method), volume of water purged prior to sampling, number of well volumes purged, and field parameter measurements
4. Sample disposition (preservatives added; laboratory sent to, date and time sent; laboratory sample number, chain-of-custody number, sample bottle lot number)

The steps to be followed for sample collection are as follows:

1. The cap is removed from the sample bottle, and the bottle is tilted slightly.
2. The sample is slowly discharged from the pump so that it runs down the inside of the sample bottle with a minimum of splashing. The pumping rate should be reduced to approximately 100 ml per minute when sampling VOCs.
3. Samples may be field filtered before transfer to the sample bottle. Filtration must occur in the field immediately upon collection. Inorganics, including metals, are to be collected and preserved in the filtered form as well as the unfiltered form. The recommended method is through the use of a disposable in-line filtration module (0.45-micron filter) using the pressure provided by the pumping device for its operation.

4. Samples for analysis for volatile organic compounds should be collected first, if such samples are required.

5. Adequate space is left in the bottle to allow for expansion, except for VOC vials, which are filled to overflowing and capped.

6. The bottle is capped, then labeled clearly and carefully following the procedures in SOP *Packaging and Shipping Procedures*.

7. Samples are placed in appropriate containers and, if necessary, packed with ice in coolers as soon as practical.

C. Additional remarks

1. If the well goes dry during purging, wait until it recovers sufficiently to remove the required volumes to sample all parameters. It may be necessary to return periodically to the well but a particular sample (e.g., large amber bottles for semivolatile analysis) should be filled at one time rather than over the course of two or more visits to the well.

2. It may not be possible to prevent drawdown in the well if the water-bearing unit has sufficiently low permeability. If the water level was in the screen to start with, do not worry about it because there is no stagnant water in the riser above the screen to begin with.

   If the water level in the well is in the riser above the screen at the beginning of purging, then be sure you pump out sufficient volume from the well to remove the volume of water in the riser above the screen. For a 2-inch diameter well, each foot of riser contains 0.163 gallons; for a 4-inch riser, each foot of riser contains 0.653 gallons; for a 6-inch riser, each foot of riser contains 1.47 gallons.

   Alternatively, the water in the riser above the screen can be removed by lowering the pump into the well until the pump intake is just below the water level, starting the pump, running it at a low rate, and slowly lowering the pump as the water level in the riser declines. This approach can be terminated when the water level reaches the top of the screen, at which time the stagnant water in the riser has been removed. This may not be a practical approach for dedicated sampling equipment. As with typical low-flow sampling, the flow rate should be kept as low as practicable.

3. Nondedicated sampling equipment is removed from the well, cleaned, and decontaminated in accordance with SOP *Decontamination of Personnel and Equipment*. Disposable polyethylene tubing is disposed of with PPE and other site trash.

IV. Attachments

None.

V. Key Checks and Preventative Maintenance

Maintain field equipment in accordance with the manufacturer's recommendations. This will include, but is not limited to:

- Inspect sampling pump regularly and replace as warranted
- Inspect quick-connects regularly and replace as warranted
- Verify battery charge, calibration, and proper working order of field measurement equipment prior to initial mobilization and daily during field efforts

Other key issues:

- Avoid stirring up sediment from the bottom of the well
- Maintain flow rate as low as practicable
- Impose as little drawdown as possible

STANDARD OPERATING PROCEDURE

Groundwater Sampling from Monitoring Wells

I. Purpose and Scope

This procedure presents general guidelines for the collection of groundwater samples from monitoring wells. The procedure does not address purging and sampling using "low-flow" techniques (see SOP *Low-Flow Groundwater Sampling from Monitoring Wells*). Operations manuals should be consulted for specific calibration and operating procedures.

II. Equipment and Materials

- Probe box with inlet/outlet ports for purged groundwater and watertight ports for each probe
- pH meter: Orion® Model SA250 or equivalent
- Temperature/conductivity meter: YSI® Model 33 or equivalent
- Dissolved oxygen meter: YSI® Model 57 or equivalent
- In-line disposable 0.45µ filters: QED® FF8100 or equivalent
- Bailer, teflon or stainless steel
- Peristaltic pump, bladder pump, or submersible sampling pump with tubing, support cables, and power supply (may not be required if well yield is low)

III. Procedures and Guidelines

A. Setup and Purging

1. For the well to be sampled, information is obtained on well location, diameter(s), depth, and screened interval(s), and the method for disposal of purged water.
2. A pump will be used for well purging if the well yield is adequate; otherwise, a bailer may be used.
3. Instruments are calibrated according to manufacturer's instructions.
4. The well number, site, date, and condition are recorded in the field logbook.
5. Plastic sheeting is placed on the ground, and the well is unlocked and opened. All decontaminated equipment to be used in sampling will be

placed only on the plastic sheeting until after the sampling has been completed.

6. Water level measurements are collected in accordance with SOP *Water Level Measurements*, and the total depth of the well is measured.

7. The volume in gallons of water in the well casing or sections of telescoping well casing is calculated as follows:

$0.052 (\pi r^2h) = 0.163 (r^2h) = \text{gallons}$

where: $\pi = 3.14$

r = Radius of the well pipe in inches
h = height of water in well in feet

The volume of water in typical well casings may be calculated as follows:

2-inch diameter well:
0.163 gal/ft x ___ (linear feet of water) = gallons

4-inch diameter well:
0.653 gal/ft x ___ (linear feet of water) = gallons

6-inch diameter well:
1.469 gal/ft x ___ (linear feet of water) = gallons

The initial field parameters of pH, specific conductance, and temperature of water are measured and recorded in the field logbook. The measurement probes are inserted into the probe box. The purged groundwater is directed through the box, allowing measurements to be collected before the water contacts the atmosphere.

8. Sampling equipment is cleaned and decontaminated prior to sampling in accordance with SOP *Decontamination of Personnel and Equipment*.

9. If a bailer is being used, it is removed from either its protective covering or the well casing and attached to a cord compatible with constituents and long enough to reach the bottom of the well. If a sampling pump is being used, the airline, discharge line, and support cable or rope is attached to the pump. The support line should bear the weight of the pump. If the well is purged using dedicated tubing, it is lowered into the well to the top of the screened zone.

10. The sampling device is lowered to the well interval from which the sample is to be collected. The pump intake will be placed above the top of the screen, where possible. If a bailer is being used, it is allowed to fill with a minimum of surface disturbance to prevent sample water aeration. When the bailer is raised, the bailer cord must not touch the ground.

During purging, the field parameters are measured at least once for each well volume. In productive wells, the well purging end point is determined using the field measurements. In nonproductive wells, the well is repeatedly bailed dry to obtain a minimum of three well volumes, then allowed to recover before sampling.

12. Three to five well volumes are purged (more may be purged if parameters do not stabilize). Purging is stopped when field parameters have stabilized over three consecutive well volumes. Field parameters are considered stabilized when pH measurements agree within 0.5 units, temperature measurements agree within 1°C, and specific conductance and dissolved oxygen measurements agree within 10 percent.

B. Sample Collection

Once purging has been completed, the well is ready to be sampled. The elapsed time between completion of purging and collection of the ground-water sample from the well should be minimized. Typically, the sample is collected immediately after the well has been purged, but this is also dependent on well recovery.

Samples will be placed in bottles that are appropriate to the respective analysis and that have been cleaned to laboratory standards. Each bottle typically will have been previously prepared with the appropriate preservative, if any.

The following information, at a minimum, will be recorded in the log book:

1. Sample identification (site name, location, and project number; sample name/number and location; sample type and matrix; time and date; sampler's identity)

2. Sample source and source description

3. Field observations and measurements (appearance, volatile screening, field chemistry, sampling method), volume of water purged prior to sampling, number of well volumes purged, and field parameter measurements

4. Sample disposition (preservatives added; laboratory sent to, date and time sent; laboratory sample number, chain-of-custody number, sample bottle lot number)

5. Additional remarks

The steps to be followed for sample collection are as follows:

1. All VOC samples will be collected first.

2. The cap is removed from the sample bottle, and the bottle is tilted slightly.

3. The sample is slowly poured from the bailer or discharged from the pump so that it runs down the inside of the sample bottle with a minimum of splashing. The pumping rate should be reduced to approximately 100 ml per minute when sampling VOCs. Samples may

be field filtered before transfer to the sample bottle. Filtration must occur in the field immediately upon collection. Inorganics, including metals, are to be collected and preserved in the filtered form as well as the unfiltered form. The recommended method is through the use of a disposable in-line filtration module (0.45 micron filter) using the pressure provided by the pumping device for its operation. When a bailer is used, filtration may be driven by a peristaltic pump.

4. VOC samples from wells purged using dedicated tubing and a sampling pump will be collected using a bailer

5. Adequate space is left in the bottle to allow for expansion, except for VOC vials, which are filled to overflowing and capped.

6. The bottle is capped, then labeled clearly and carefully.

7. Samples are placed in appropriate containers and, if necessary, packed with ice in coolers as soon as practical.

8. If the sampler is dedicated, it is returned to the well and the well is capped and locked. Nondedicated samplers are cleaned and decontaminated in accordance with SOP *Decontamination of Personnel and Equipment.*

IV. Attachments

None.

V. Key Checks and Preventative Maintenance

Maintain field equipment in accordance with the manufacturer's recommendations. This will include, but is not limited to:

- Inspect sampling pump regularly and replace as warranted
- Bring supplies for replacing the bladder if using a positive-displacement bladder pump
- Inspect tubing regularly and replace as warranted
- Inspect air/sample line quick-connects regularly and replace as warranted
- Verify battery charge, calibration, and proper working order of field measurement equipment prior to initial mobilization and daily during field efforts