CORRECTIVE MEASURES STUDY WORK PLAN PHASE 1 GROUNDWATER DELINEATION SOLID WASTE MANAGEMENT UNIT 70 (SWMU70) ZONE E WITH TRANSMITTAL CNC CHARLESTON SC

12/21/2000

CH2M HILL

CORRECTIVE MEASURES STUDY WORK PLAN

Phase 1 - Groundwater Delineation

Solid Waste Management Unit 70, Zone E

Charleston Naval Complex
North Charleston, South Carolina

SUBMITTED TO
U.S. Navy Southern Division
Naval Facilities Engineering Command

PREPARED BY
CH2M-Jones

December 2000

Revision 1
Contract N62467-99-C-0960

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December 21, 2000

John Litton, P.E.
Director
Division of Hazardous and Infectious Wastes
South Carolina Department of health and
Environmental Control
Bureau of Land and Waste Management
2600 Bull Street
Columbia, SC, 29201

Dear Mr. Litton:

Enclosed, please find four copies of Revision 1 of the *Corrective Measures Study Work Plan, Phase 1 – Groundwater Delineation, Solid Waste Management Unit 70, Zone E, Charleston Naval Complex*. This submittal has been prepared pursuant to agreements by the CNC BRAC Cleanup Team for completing the RCRA Corrective Action process.

Please contact me at 352-335-5877, ext. 396, if you have any questions or comments.

Sincerely,

Paul J. Favara, P.E.
Project Engineer

XC: [redacted]Navy
Mihir Mehta/SCDHEC
Dann Spariosu/USEPA
Gary Foster/CH2M HILL

Certification Page for Corrective Measures Study Work Plan for SWMU 70, Zone E

Phase I Groundwater Delineation

I, Dean Williamson, certify that this report has been prepared under my direct supervision. The data and information are, to the best of my knowledge, accurate and correct, and the report has been prepared in accordance with current standards of practice for engineering.

South Carolina

Temporary Permit No. T2000342

Dean Williamson, P.E.

12/19/2000

Date

SOUTH CAROLINA
CH2M HILL, INC.
No. C00201
CERTIFICATE OF AUTHORIZATION

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
1,2-DCE	1,2-dichloroethene
bls	below land surface
BRAC	Base Realignment and Closure Act
CA	Corrective Action
CB	chlorobenzene
CMS	Corrective Measures Study
CMS WP	Corrective Measures Study Work Plan
CNC	Charleston Naval Complex
COPC	Constituent of Potential Concern
CSAP	Comprehensive Sampling and Analysis Plan
DMP	Data Management Plan
DO	Dissolved oxygen
DPT	Direct Push Technology
DQO	Data Quality Objectives
EPA	U.S. Environmental Protection Agency
ESDSOPQAM	Environmental Services Division Standard Operating Procedures and Quality Assurance Manual
ft bls	feet below land surface
GIS	geographical information system
HHR	human health risk
HI	Hazard Index
IDW	investigative-derived waste
MCL	maximum contaminant limit
µg/L	micrograms per liter
mg/L	milligrams per liter
MNA	monitored natural attenuation
MW	monitoring well
NAVBASE	Naval Base
ORP	Oxidation Reduction Potential
PCE	tetrachloroethene

Acronyms and Abbreviations

QAP	Quality Assurance Plan
RCRA	Resource Conservation and Recovery Act
RFI	RCRA Facility Investigation
SCDHEC	South Carolina Department of Health and Environmental Control
SOP	standard operating procedure
SWMU	Solid Waste Management Unit
TBD	to be determined
TCE	trichloroethene
VOC	volatile organic compound

SECTION 1.0

Introduction

1.0 Introduction

In 1993, Naval Base (NAVBASE) Charleston was added to the list of bases scheduled for closure as part of the Defense Base Realignment and Closure Act (BRAC), which regulates closure and transition of property to the community. The Charleston Naval Complex (CNC) was formed as a result of the dis-establishment of the Charleston Naval Shipyard and NAVBASE on April 1, 1996.

CNC Corrective Action (CA) activities are being conducted under the Resource Conservation and Recovery Act (RCRA) with the South Carolina Department of Health and Environmental Control (SCDHEC) as the lead agency for CA activities at the site. All RCRA CA activities are performed in accordance with the Final Permit (Permit No. SC0 170 022 560).

In April 2000, CH2M-Jones was awarded a contract to provide environmental investigation and remediation services at CNC. This submittal has been prepared by CH2M-Jones to document the basis for a Corrective Measures Study (CMS) at Solid Waste Management Unit (SWMU) 70 in Zone E of the CNC.

This submittal is a revision to the November 2000 (Revision 0) submittal, which has been updated to incorporate responses to SCDHEC comments. Appendix D contains responses to SCDHEC comments.

1.1 Background for Phase I Corrective Measures Study Work Plan

Previous soil and groundwater investigations at SWMU 70 at the CNC have revealed the presence of significant concentrations of chromium in groundwater. Concentrations in one monitoring well (MW) were reported as high as 52,500 micrograms per liter (µg/L) (E070FW001D). Five other MWs showed consistent maximum contaminant limit (MCL) exceedances of chromium (100 µg/L).

Prior to completing a CMS for SWMU 70, the distribution of chromium in groundwater must be more clearly defined. This Phase I CMS Work Plan (CMS WP) presents a plan for conducting additional site characterization work to better delineate the extent of chromium in groundwater at SWMU 70. Once additional characterization data have been collected and evaluated, CH2M-Jones will prepare a Phase II CMS WP that presents the plan for implementation of a field-scale treatability study. However, if the site characterization data indicate that a pilot study is not warranted, CH2M-Jones will prepare a Phase II CMS WP that addresses the remedial alternatives to be considered in the CMS for SWMU 70.

1.1.1 Phase I CMS WP Purpose and Objectives

The primary objective of the Phase I CMS for SWMU 70 is to determine more precisely the extent and spatial distribution of the high-concentration source areas of chromium in the shallow and deep groundwater at SWMU 70 as quickly as possible. Additionally, as the concentration of cadmium was reported to exceed MCLs at E025GW003, it will also be assessed. Table 1-1 lists the historical chromium and cadmium groundwater results reported at MWs in SWMU 70. Only limited data for hexavalent chromium were available from the subject area, as presented in Table 1-1. Figure 1-1 shows the location of the MWs referenced in Table 1-1.

1.1.2 Data Collection Approach

The primary data collection approach for the Phase I CMS involves the collection and analysis of shallow and deep groundwater samples. A groundwater profiling device, such as the Waterloo™ profiler or Geoprobe's Groundwater Profiler, will be the primary sampling device for collecting groundwater samples at vertically discrete intervals from borings installed in the suspected source area. No more than three discrete groundwater samples will be collected from each boring. The technical approach for this task is described in detail in Section 2.0.

In addition to the collection of discrete groundwater interval samples, samples from selected existing MWs will be analyzed for monitored natural attenuation (MNA) parameters. As the final remedy for SWMU 70 may incorporate chemical or biotic reduction processes, MNA parameter data will help evaluate the feasibility of such a remedy. Finally, as MWs will be sampled and purged to collect MNA parameter data, fractions for analysis of volatile organic compound (VOC) will also be collected from several MWs to evaluate the change in concentrations that has occurred since the last data collection in February 1997. Appendix A contains results of historical trichloroethene (TCE), tetrachloroethene (PCE), chloroform, and total 1,2-dichloroethene (1,2-DCE) drawn from MWs in the SWMU 70 area.

1.2 Site Background and RFI Summary

Located at the northwest corner of Building 5, the Building 5 Dip Tank, referred to as SWMU 70, is a former dip tank that was used to treat wood with a fire retardant chemical.

No information is available to ascertain when operations started; however, it is known that the tank was removed in 1981, when the shop began receiving pre-treated lumber. Figure 1-2 presents an aerial view of the SWMU 70 area.

Soil and groundwater were investigated as part of the RCRA Facility Investigation (RFI) activities conducted in SWMU 70. Findings from the investigation are reported in the Draft (Revision 0) RFI. (Note: The Draft RFI has not yet been approved by SCDEHC or the U.S. Environmental Protection Agency [EPA].)

As reported in the Revision 0 RFI, antimony, chromium, thallium, chloroform, 1,2-DCE (total), PCE, and TCE were identified in deep groundwater at concentrations that equal a risk above 1×10^{-6} and/or a Hazard Index (HI) above 1 (2.1×10^{-5} and 698, respectively). Chromium was reported as the source of the HI. Aluminum, antimony, cadmium, chromium, benzene, chlorobenzene (CB), 1,2-DCE (total), and TCE were identified in the shallow groundwater as Constituents of Potential Concern (COPCs). Chromium was reported to be the most significant component of the HI at MWs E07GW001, E07GW002, and E549GW003. The RFI also reported that human health risk (HHR) under current land use conditions is not a significant factor, since the groundwater is not used as a potable water source (EnSafe Inc., 2000).

1.3 Organization of Phase I CMS Work Plan

This CMS WP consists of the following four sections, including this introductory section:

1.0 Introduction — Presents the purpose of the CMS WP and background information relating to the proposed investigation.

2.0 Technical Approach — Provides a description of the technical approach for completing the characterization of the extent of chromium in groundwater at the site.

3.0 Investigative-Derived Waste — Describes the procedures to be implemented for management of investigative-derived waste (IDW).

4.0 References — Lists the references used in this document.

TABLE 1-1
Cadmium and Chromium Results from Groundwater Samples Collected in SWMU 70 and Vicinity
CMS Work Plan, SWMU 70, Zone E

			Chromium			Cadmium			
SiteID	StationID	SampleID	AnaValue	Units	ProjQual	AnaValue	Units	ProjQual	DateCollected
025	E025GW001	025GW00101	12.6	μg/L	=	1	μg/L	U	4/25/96
025	E025GW001	025GW00102	15.8	μg/L	=	0.5	μg/L	U	7/25/96
025	E025GW001	025GW00103	11.5	μg/L	=	0.5	μg/L	U	12/2/96
025	E025GW001	025GW00104	9.1	μg/L	J	0.5	μg/L	U	2/14/97
025	E025GW002	025GW00201	177	μg/L	=	6.3	μg/L	=	4/25/96
025	E025GW002	025GW00202	192	μg/L	=	6.4	μg/L	=	7/26/96
025	E025GW002	025GW00203	159	μg/L	=	6	μg/L	=	12/2/96
025	E025GW002	025GW00204	119	μg/L	=	4.5	μg/L	J	2/14/97
025	E025GW003	025GW00301	843	μg/L	=	84	μg/L	=	4/26/96
025	E025GW003	025GW00302	1200	μg/L	=	85.3	μg/L	=	7/26/96
025	E025GW003	025GW00303	3260	μg/L	=	88.1	μg/L	=	12/2/96
025	E025GW003	025GW00304	1550	μg/L	=	85.8	μg/L	=	2/13/97
025	E025GW004	025GW00401	127	μg/L	=	1.2	μg/L	J	4/26/96
025	E025GW004	025GW00402	72.5	μg/L	=	0.77	μg/L	J	7/26/96
025	E025GW004	025GW00403	54.5	μg/L	=	0.73	μg/L	J	12/2/96
025	E025GW004	025GW00404	42.8	μg/L	=	1	μg/L	J	2/13/97
067	E067GW001	067GW00103	4.8	μg/L	U	0.5	μg/L	U	12/4/96
067	E067GW001	067GW00104	1.9	μg/L	U	0.3	μg/L	U	2/19/97
070	E070GW001	070GW00101	7350	μg/L	=	3.5	μg/L	J	4/25/96
070	E070GW001	070GW00102	6800	μg/L	=	4	μg/L	J	7/29/96
070	E070GW001	070GW00103	6330	μg/L	=	2.8	μg/L	J	12/3/96
070	E070GW001	070GW00104	5790	μg/L	=	5.6	μg/L	=	2/18/97
070	E070GW002	070GW00201	440	μg/L	=	1.7	μg/L	J	4/26/96
070	E070GW002	070GW00202	261	μg/L	=	0.76	μg/L	J	7/29/96
070	E070GW002	070GW00203	302	μg/L	=	0.63	μg/L	J	12/3/96
070	E070GW002	070GW00204	395	μg/L	=	0.43	μg/L	J	2/18/97
070	E070GW01D	070GW01D01	52500	μg/L	=	1	μg/L	U	4/26/96
070	E070GW01D	070GW01D02	47700	μg/L	=	1.1	μg/L	J	7/29/96
070	E070GW01D	070GW01D03	42200	μg/L	=	0.73	μg/L	J	12/3/96
070	E070GW01D	070GW01D04	40700	μg/L	=	1	μg/L	J	2/18/97
070	E070GW01D	070GW01DF5	2200	μg/L	=				
070	E070GW01D	070GW01DU5	2190	μg/L	=				
539	E539GW001	539GW00101	1	μg/L	U	1	μg/L	U	4/29/96
539	E539GW001	539GW00102	5	μg/L	U	0.5	μg/L	U	7/29/96
539	E539GW001	539GW00103	2.8	μg/L	U	0.5	μg/L	U	12/13/96

TABLE 1-1
Cadmium and Chromium Results from Groundwater Samples Collected in SWMU 70 and Vicinity
CMS Work Plan, SWMU 70, Zone E

			Chromium			Cadmium			
SiteID	**StationID**	**SampleID**	**AnaValue**	**Units**	**ProjQual**	**AnaValue**	**Units**	**ProjQual**	**DateCollected**
539	E539GW001	539GW00104	1.5	µg/L	J	0.3	µg/L	U	2/27/97
539	E539GW01D	539GW01D01	1	µg/L	U	1	µg/L	U	4/29/96
539	E539GW01D	539GW01D02	2.2	µg/L	U	0.5	µg/L	U	7/29/96
539	E539GW01D	539GW01D03	1.3	µg/L	U	0.5	µg/L	U	12/13/96
539	E539GW01D	539GW01D04	1	µg/L	U	0.3	µg/L	U	2/27/97
549	E549GW001	549GW00101	5	µg/L	U	1	µg/L	U	4/24/96
549	E549GW001	549GW00102	0.8	µg/L	U	0.5	µg/L	U	8/1/96
549	E549GW001	549GW00103	0.8	µg/L	U	0.5	µg/L	U	11/25/96
549	E549GW001	549GW00104	0.8	µg/L	U	0.5	µg/L	U	2/13/97
549	E549GW002	549GW00201	5	µg/L	U	1	µg/L	U	4/25/96
549	E549GW002	549GW00202	0.8	µg/L	U	0.5	µg/L	U	8/1/96
549	E549GW002	549GW00203	0.8	µg/L	U	0.5	µg/L	U	11/25/96
549	E549GW002	549GW00204	1.6	µg/L	J	0.5	µg/L	U	2/13/97
549	E549GW003	549GW00301	1850	µg/L	=	1	µg/L	U	4/24/96
549	E549GW003	549GW00302	1540	µg/L	=	0.5	µg/L	U	7/29/96
549	E549GW003	549GW00303	1430	µg/L	=	0.5	µg/L	U	11/25/96
549	E549GW003	549GW00304	1620	µg/L	=	0.5	µg/L	U	2/14/97
549	E549GW003	549GW003F5	426	µg/L	=				
549	E549GW003	549GW003U5	686	µg/L	=				
559	E559GW001	559GW00101	5	µg/L	U	1	µg/L	U	5/3/96
559	E559GW001	559GW00102	1.7	µg/L	U	0.5	µg/L	U	7/26/96
559	E559GW001	559GW00103	0.8	µg/L	U	0.5	µg/L	U	11/22/96
559	E559GW001	559GW00104	0.8	µg/L	U	0.5	µg/L	U	2/6/97
GDE	EGDEGW028	GDEGW02801	31.4	µg/L	=	0.5	µg/L	U	10/30/96
GDE	EGDEGW028	GDEGW02804	1	µg/L	U	0.3	µg/L	U	10/7/97
GDE	EGDEGW028	GDEGW028A2	7.5	µg/L	J	0.3	µg/L	U	3/5/97
GDE	EGDEGW028	GDEGW028A3	1.1	µg/L	J	0.3	µg/L	UJ	6/24/97
GDE	EGDEGW28D	GDEGW28D01	1.7	µg/L	J	0.5	µg/L	U	10/30/96
GDE	EGDEGW28D	GDEGW28D04	1.4	µg/L	J	0.3	µg/L	U	10/7/97
GDE	EGDEGW28D	GDEGW28DA2	5	µg/L	U	0.3	µg/L	U	3/5/97
GDE	EGDEGW28D	GDEGW28DA3	2.4	µg/L	J	0.3	µg/L	UJ	6/25/97

= Result is equal to reported value.
J Result is estimated and below quantitation limit.
U Result is not detected below reported level.
UJ Result is not detected below estimated reported value.

Figure 1-1
Highlighted Wells in SWMU 25/70 Vicinity
Charleston Naval Complex

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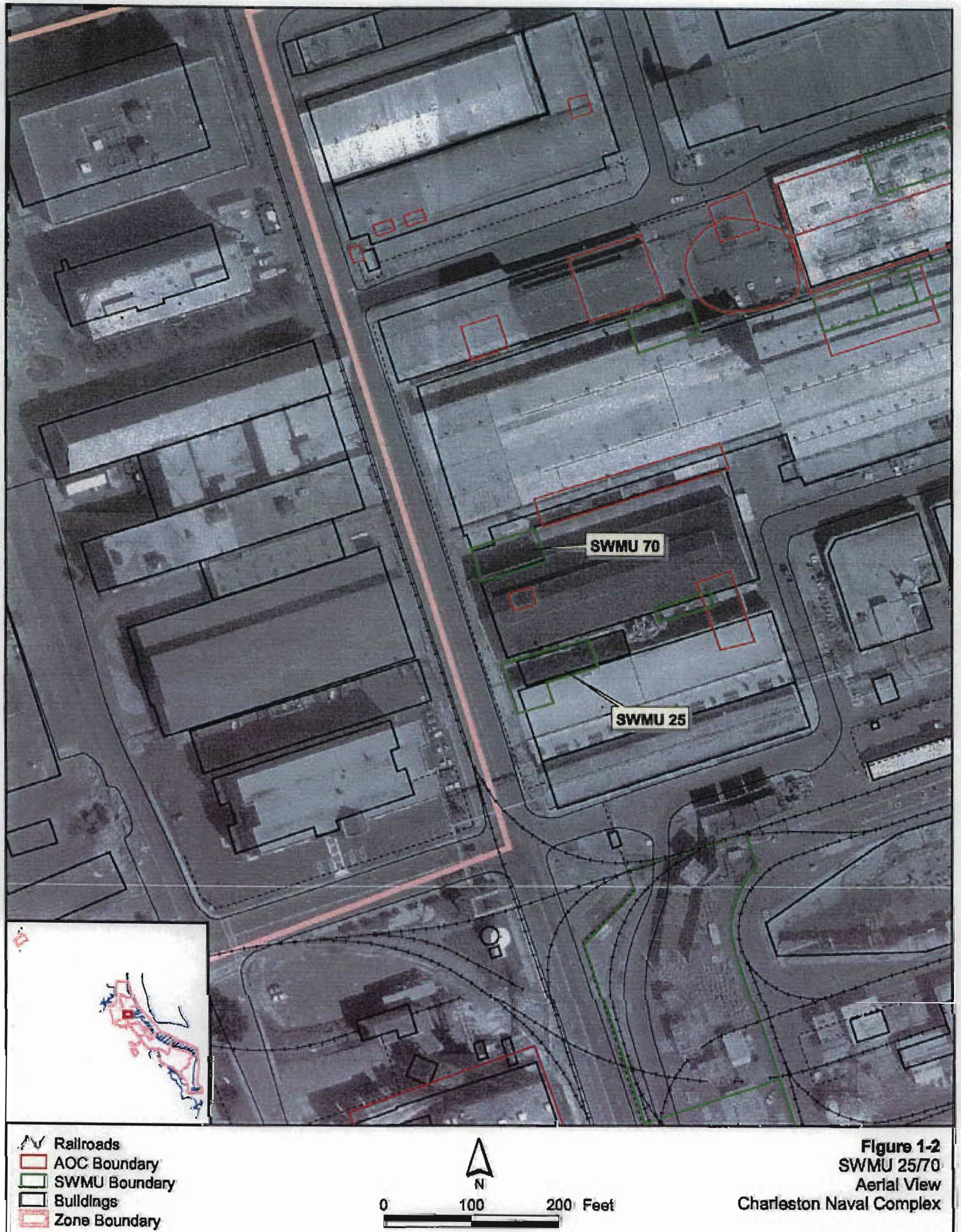

Figure 1-2
SWMU 25/70
Aerial View
Charleston Naval Complex

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SECTION 2.0

Technical Approach

2.0 Technical Approach

This section outlines the technical approach for the chromium source area delineation of SWMU 70. In this approach, the underground utilities in the area surrounding the proposed vertical profiler borings will first be identified, and the boring locations will be properly cleared prior to initiation of the boring. Discrete groundwater samples will be collected at various depths in each location, as described in the following sections. Collected samples will be shipped overnight to a certified laboratory for analysis.

2.1 Groundwater Profiling

Groundwater profiling involves a direct-push technology (DPT) sampling instrument designed to collect depth-discrete groundwater samples in a single hole with one probe entry. Using this method, the site investigation will quickly delineate vertical profiles of contaminants that are dissolved in the groundwater.

However, this investigation may involve two different groundwater sampling methods. One method uses the Waterloo™ profiler, or similar, instrument for sample collection. The second method uses DPT to collect groundwater samples at discrete intervals. To determine the appropriate profiling technology, both methods will be evaluated in the field at two sampling locations.

Using the data from the two sampling locations, a CH2M-Jones representative will determine the appropriate location-specific sampling methods. For example, if it is determined that a significant level of detail is needed at a specific location, the Waterloo™ profiler or similar type of instrument may be used. If an area is determined to be either uncontaminated or have low levels of contamination, the DPT method may be used.

2.1.1 Waterloo™ Profiler (or similar instrument) Sampling Method

The Waterloo™-type profiler collects discrete groundwater samples from various depths during a single push (see Appendix B for Waterloo™ product literature). Typically, a profiler consists of screened ports located behind the tip of the tool. The tip is attached to 3-foot lengths of heavy-duty threaded steel pipe that extend to the ground surface. The profiler is advanced by pushing, pounding, or vibrating the steel pipe into the ground. Three-foot lengths of pipe are continually added as the tool is advanced deeper into the ground to the first sampling depth. Groundwater samples are conveyed to the surface via small-diameter tubing that is attached to a fitting inside of the profiler tip and passes up through the inside of the threaded steel pipes. The internal tube is made of either stainless steel or Teflon® to minimize sorption of organic compounds.

At sites at which groundwater is shallow (i.e., less than 25 feet below land surface [ft bls]), samples are collected with a peristaltic suction-lift pump. Samples are collected and preserved in containers that are appropriate for the specific analytical method to be performed.

Groundwater samples will be collected at up to three discrete depth intervals for each sample location represented in Figure 2-1. To assist in determining the depth interval that samples will be collected, a total of four soil conductivity logs, using a continuous read-out soil conductivity probe, will be developed to the top of the Ashley formation. The location of the log locations are presented in Figure 2-1. Also, two soil cores will be collected (depicted in Figure 2-1) to correlate soil conductivity data with visual observations. Data from these two subsurface geotechnical investigations will be evaluated to determine the most appropriate depth from which groundwater samples will be collected. Appendix C presents a boring log for a deep well installed at SWMU 70.

To prevent the ports from clogging as the tool is pushed through the soil, de-ionized water is slowly pumped through the inner tube and out of the sampling ports as the tool is being advanced. Because the tubing is purged between samples, several depth-discrete groundwater samples are collected in one push, without having to remove, clean, and re-insert the tool. In addition, because the tool can be pushed through clay and silt beds without plugging, the profiler is effective for sampling multiple water-bearing zones at sites with stratified geology.

2.1.2 Direct Push Technology

The DPT sampling tool consists of a stainless steel screen with a tip attached to a heavy-duty threaded steel pipe that extends to the ground's surface. The sampling tool is advanced by pushing, pounding, or vibrating the steel pipe into the ground. Pipe lengths are continually added as the tool is advanced deeper into the ground to the first sampling depth. Groundwater samples are conveyed to the surface via small-diameter tubing that is attached to a fitting inside of the sampling tip and passes upward through the inside of the threaded steel pipes. The internal tube is made of either stainless steel or Teflon® to minimize sorption of organic compounds.

At sites at which groundwater is shallow (i.e., less than 25 ft bls), samples are collected with a peristaltic suction-lift pump. A centrifugal pump is used for sample collection at deeper depths. However, unlike the Waterloo™ profiling type device, after the sample is collected, the sampling tool must be brought back to the surface and decontaminated prior to being driven deeper. Samples are collected and preserved in containers that are appropriate for the specific analytical method to be performed.

Groundwater samples will be collected at up to three discrete depth intervals for each sample location represented in Figure 2-1. To assist in determining the depth interval that samples will be collected, a total of four soil conductivity logs, using a continuous read-out soil conductivity probe, will be developed to the top of the Ashley formation. The location of the log locations is presented in Figure 2-1. Also, two soil cores will be collected (depicted in Figure 2-1) to correlate soil conductivity data with visual observations. Data from these two subsurface geotechnical investigations will be evaluated to determine the most appropriate depth from which groundwater samples will be collected. Appendix C presents a boring log for a deep well installed at SWMU 70.

2.2 Boring Installation and Locations

The profiler will be advanced at 13 predetermined grid locations, which are presented in Figure 2-1. The grid was developed to encompass the area at which chromium (Figure 2-2) and cadmium (Figure 2-3) in excess of MCLs have been reported. Dissolved sample fractions will be collected (i.e., the sample will be collected and filtered prior to preservation and analysis) and analyzed for total chromium, hexavalent chromium, and cadmium (as presented in Table 2-1). Only dissolved fractions will be analyzed since push point samples typically have solids entrained with the samples, resulting in a significant positive bias and concentrations reported. Cadmium will also be targeted for analysis since it was reported to consistently exceed its MCL of 10 μg/L at E025GW003, and is a co-analyte in the laboratory method for chromium.

The vertical profiler locations will be identified as E070GP001, E070GP002, in sequence through E070GP013. The depth will be added to the location identification following a hyphen. For example, a sample collected at a total depth of 11 feet will be reported as E070GP001-11.

2.3 Groundwater Monitor Well Sampling

Groundwater samples will also be collected from several individual groundwater MWs. Data from the MWs will be compared to historical data results as well as the discrete groundwater samples collected in the area. Table 2-1 presents the MWs to be sampled as well as the associated target parameters. VOC parameters were added as target analytes to several selected wells to evaluate potential changes in concentrations since the last sampling event in February 1997. Both total and dissolved metal fractions will be collected from monitoring wells.

2.4 Field Operations

CH2M-Jones will subcontract with a vendor to advance the vertical profiler points in the proposed locations and collect groundwater samples. The vendor will be a State of South Carolina-certified driller. CH2M-Jones will provide a field hydrogeologist or engineer who will be responsible for all field operations.

Samples will be delivered to the laboratory to be analyzed according to the methods specified in Table 2-2. Additionally, some MNA parameters will be analyzed in the field. EPA methods and/or standard operating procedures (SOPs) for screening methods will be followed to meet Data Quality Objectives (DQOs) Level II Criteria. The subcontracted laboratory will meet EPA DQO Level II Criteria, as specified in the Comprehensive Sampling and Analysis Plan (CSAP) (EnSafe Inc., 1996).

2.5 Groundwater Sampling and Testing

Field procedures and groundwater analyses will follow the SOPs in the approved CSAP portion of the RFI Work Plan (Ensafe Inc., 1994). The CSAP outlines all monitoring procedures to be performed during the investigation to characterize the environmental setting, source, and releases of hazardous constituents. The CSAP also includes the Quality Assurance Plan (QAP) and Data Management Plan (DMP) to verify that all information and data are valid and properly documented. Unless otherwise noted, the sampling strategy and procedures will be performed in accordance with the EPA Environmental Services Division *Standard Operating Procedures and Quality Assurance Manual* (ESDSOPQAM, 1996).

The completed vertical profiler holes will be filled to the ground surface with a bentonite grout, in accordance with Rule 61-71.10.B of the South Carolina Well Standards and Regulations. The bentonite grout will be placed into the borehole after removal of the profiling device. The hole will be grouted with a tremmie pipe from bottom to top. The soil brought to the surface will be managed as IDW. Locations will be marked with wooden stakes, flags, or paint (indoors only) for the survey team to establish location coordinates and elevation of ground surface.

The results of the groundwater characterization investigation will be summarized in a Phase II CMS WP, which will be submitted to the Navy and SCDHEC approximately 6 weeks after completion of the field operations. The Phase II CMS WP will document the field activities completed during the study, summarize groundwater results, and provide a proposed approach to abate the source areas. CH2M-Jones will incorporate the data into a geographic information systems (GIS) database.

2.6 DHEC Well Installation Request

In accordance with R.61-79.265 Subpart F of the South Carolina Hazardous Waste Management Regulations and R.61-71 of the South Carolina Well Standards and Regulations, a request for the advancement of the vertical profiler locations will be submitted to SCDHEC 2 weeks prior to the scheduled activity. The written request will provide the purpose of the vertical profiler activity and will consist of well construction details, if required, as well as a map depicting the proposed vertical profiler locations. Because the vertical profiler locations are considered temporary, the request will also provide the method used for abandonment.

TABLE 2-1
Analysis of Collected Groundwater Samples
CMS Work Plan, SWMU 70, Zone E

Samples	Analysis
E070VP001-E070VP013	Dissolved Chromium, Hexavalent Chromium, Cadmium
E025GW001, E025GW002, E025GW002;E070GW002, E549GW004, E549GW001	Total and Dissolved Chromium, Hexavalent Chromium, Cadmium
E025GW003, E070GW01D, E070GW001, E549GW003	Total and Dissolved Chromium, Hexavalent Chromium, Cadmium;
	MNA Parameters (Refer to Table 2-2)
E070GW001, E07GW01D, E549GW003, E549GW001	Total and Dissolved Chromium, Hexavalent Chromium, Cadmium
	MNA Parameters (Refer to Table 2-2)
	VOCs

TABLE 2-2
Analytical Methods and Data Use
CMS Work Plan, SWMU 70, Zone E

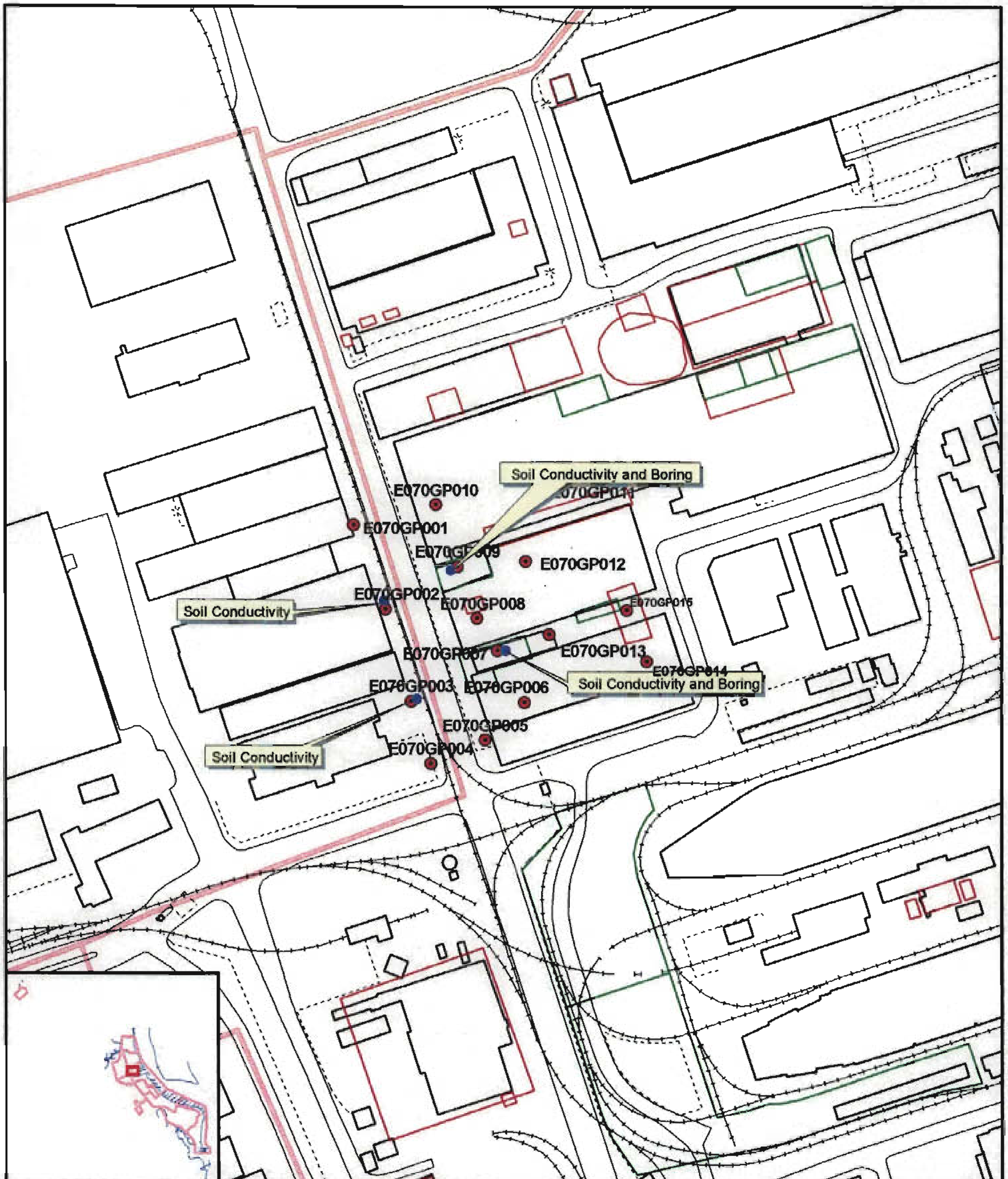
Analysis	Method	Comments	Data Use	Field or Fixed-Base Laboratory
Total and Dissolved Chromium, Hexavalent Chromium, and Cadmium	TBD	Determine extent of chromium and hexavalent chromium contamination. Cadmium exceeded MCLs at 025GW003; limited cadmium data will be collected around this area.	Data will be used to evaluate potential remedial approach(es) to be field-tested as part of pilot study.	Fixed-base
Oxygen[a]	**DO meter calibrated in the field according to the supplier's specifications.**		**Concentrations < 0.5 mg/L generally indicate an anoxic pathway.**	**Field**
Nitrate	**Ion Chromatography Method E300**		**Substrate for microbial respiration if oxygen is depleted.**	**Fixed-Base**
Soluble Manganese [MN (II)]	**Colorimetric Hach Company Method 8149**	**Filter if turbidity interferes with analysis.**	**May indicate an anoxic degradation process due to depletion of oxygen, nitrate, and manganese.**	**Field**
Ferrous Iron [FE(II)]	**Colorimetric Hack Company Method 8146**	**Filter if turbidity interferes with analysis.**	**May indicate an iron-reducing environment.**	**Field**
Sulfate	**IC Method E300**		**Substrate for anoxic microbial respiration.**	**Fixed-Base**
Hydrogen Sulfide	**Color Disk Methylene Blue Method**	**Hack Catalog Number 2238-01**	**The presence of H_2S suggests a sulfate-reducing environment.**	**Field**
Methane	**SW-846 method 3810 Modified**		**The presence of CH_4 suggests biodegradation via methanogenesis.**	**Fixed-Base**

TABLE 2-2
Analytical Methods and Data Use
CMS Work Plan, SWMU 70, Zone E

Analysis	Method	Comments	Data Use	Field or Fixed-Base Laboratory
Oxidation Reduction Potential (ORP)	**ASTM Method A2580B**	**Measurements made with electrodes and meter; protect sample from oxygen. Report results against the hydrogen electrode (Eh) by adding a correction factor specific to the electrode used.**	**The ORP of groundwater reflects the relative oxidizing or reducing nature of the groundwater system. ORP is influenced by the nature of the biologically mediated degradation of contaminants, and may range from 800 mV (oxygenated) to less than -400 (strongly reducing).**	**Field**
pH	Field probe with direct-reading meter calibrated in the field according to the supplier's specifications		Aerobic and anoxic processes are pH-sensitive; abiotic reduction of chromium is pH sensitive.	Field
Temperature	Field probe with direct-reading mater			Field
Conductivity	E120.1/SW-846 Method 9050, direct meter reading		General water quality parameters are used as markers to verify that site samples are obtained from the groundwater system.	Field
Hydrogen	**Equilibration with gas; determined with reduction gas detector (Microseeps)**		**Determine terminal electron accepting process. Under biotic conditions, hydrogen may act as an electron donor.**	Fixed-Base

[a]Items highlighted in bold represent MNA parameters.

ASTM American Society for Testing and Materials
DO Dissolved oxygen
TBD To be determined
mg/L Milligrams per liter



Soil Boring/Conductivity Location
Groundwater Profile Location
Railroads
Shoreline
AOC Boundary
SWMU Boundary
Buildings
Zone Boundary

N

0 200 400 Feet

Figure 2-1
Proposed Groundwater Probe Locations
SWMU 70 Vicinity
Charleston Naval Complex

CH2MHILL

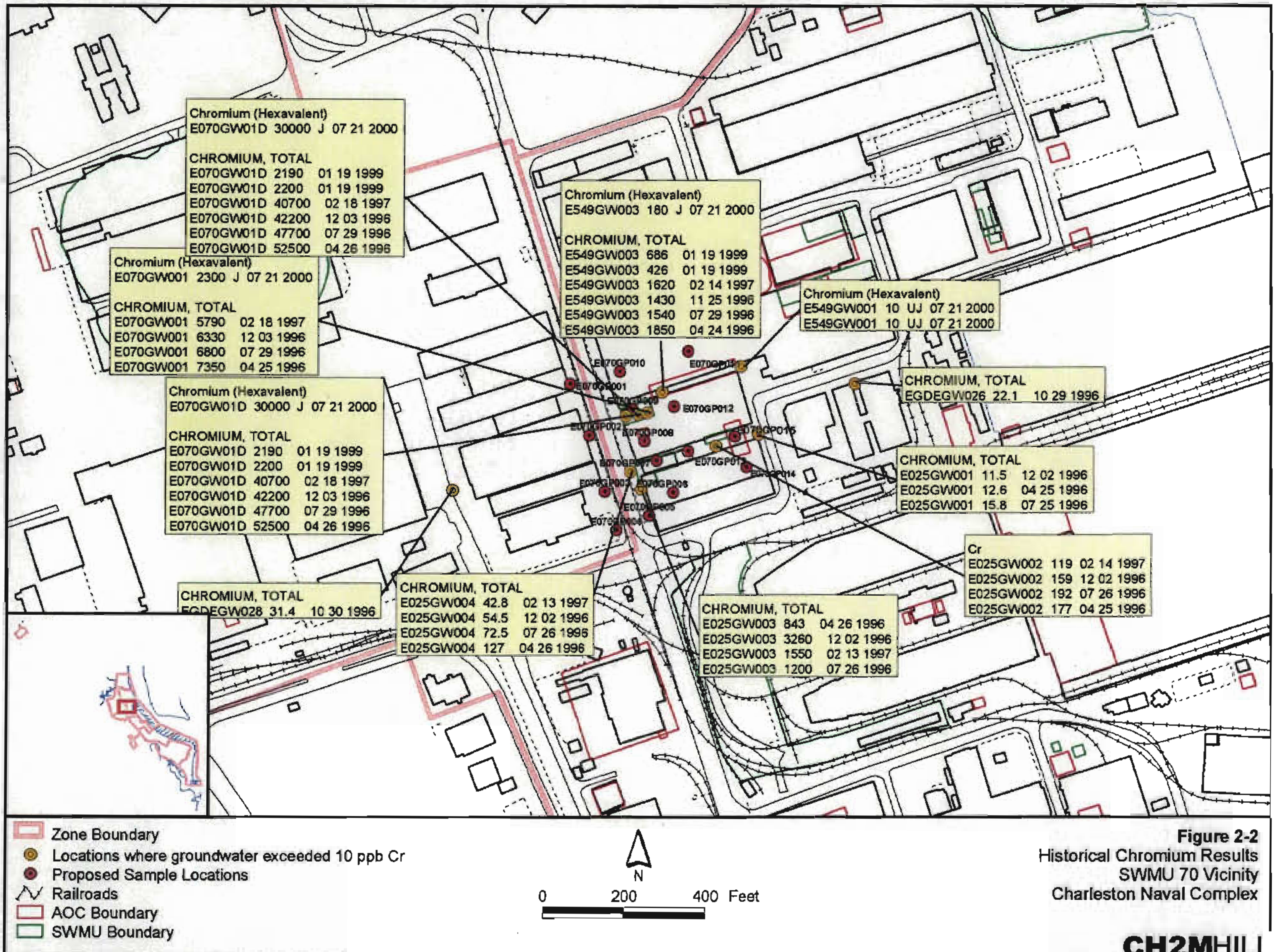


Figure 2-2
Historical Chromium Results
SWMU 70 Vicinity
Charleston Naval Complex

File Path: c:\paulsarcview\aprs\swmu70up.apr, Date: 19 Dec 2000 15:33, User: PFAVARA

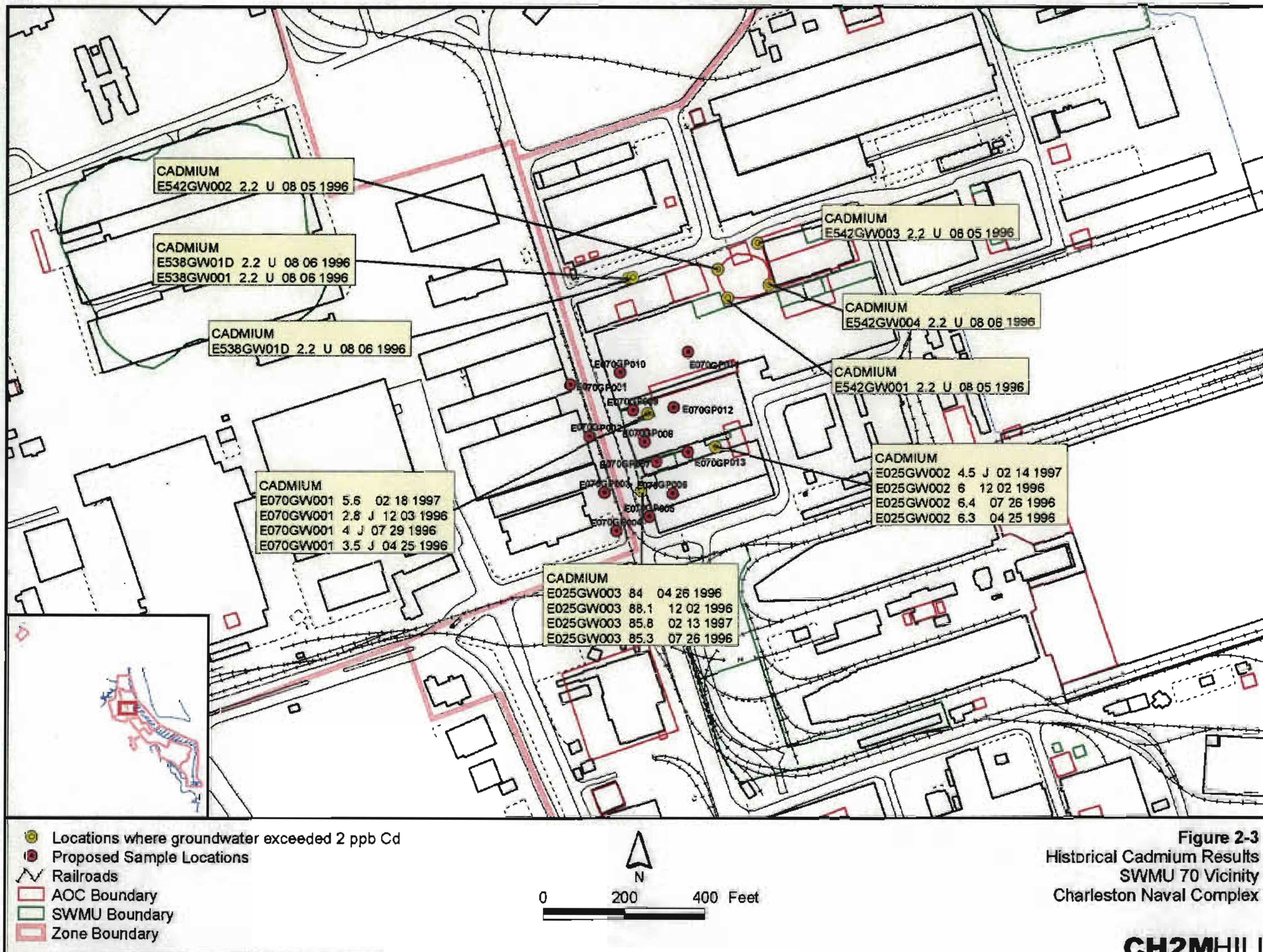


Figure 2-3
Historical Cadmium Results
SWMU 70 Vicinity
Charleston Naval Complex

CH2MHILL

File Path: c:\psu\ssrcview\aprs\swmu70up.apr, Date: 19 Dec 2000 15:39, User: PFAVARA

SECTION 3.0

Investigative-Derived Waste

3.0 Investigative-Derived Waste

IDW that is generated during this effort will include purge water from the groundwater sampling activities and possibly soil cuttings. IDW will be collected in labeled 55-gallon drums or a portable tank for proper handling. Contained IDW will remain onsite temporarily until transported to the fewer-than-90-days storage facility located at Building 1824. Once the analytical results have been reviewed, the 55-gallon drums or the portable tank containing the groundwater contents will be transported, as required, to a permitted and licensed facility for treatment or disposal.

SECTION 4.0

References

4.0 References

EnSafe Inc. *Draft Zone E RCRA Facility Investigation Report*. May 5, 2000.

EnSafe Inc./Allen & Hoshall. *Final Comprehensive Corrective Action Management Plan.* August 30, 1994.

EnSafe Inc./Allen & Hoshall. *Final Comprehensive Sampling and Analysis Plan*. RCRA Facility Investigation. July 30, 1996.

U.S. Environmental Protection Agency (EPA). *Environmental Services Division Standard Operating Procedures and Quality Assurance Manual*. Region IV, Environmental Services Division. 1996.

Appendix A

TCE

10/26/2000

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
025	E025GW001	025GW00102	TCE	5	UG/L	U	07/25/1996
025	E025GW001	025GW00103	TCE	2	UG/L	J	12/02/1996
025	E025GW001	025GW00104	TCE	5	UG/L	UJ	02/14/1997
025	E025GW001	025GW00101	TCE	5	UG/L	U	04/25/1996
025	E025GW002	025GW00201	TCE	5	UG/L	U	04/25/1996
025	E025GW002	025GW00202	TCE	5	UG/L	U	07/26/1996
025	E025GW002	025GW00203	TCE	5	UG/L	U	12/02/1996
025	E025GW002	025GW00204	TCE	5	UG/L	UJ	02/14/1997
025	E025GW003	025GW00303	TCE	18	UG/L	=	12/02/1996
025	E025GW003	025GW00304	TCE	11	UG/L	U	02/13/1997
025	E025GW003	025GW00302	TCE	5	UG/L	=	07/26/1996
025	E025GW003	025GW00301	TCE	4	UG/L	J	04/26/1996
025	E025GW004	025GW00402	TCE	2	UG/L	J	07/26/1996
025	E025GW004	025GW00403	TCE	1	UG/L	J	12/02/1996
025	E025GW004	025GW00404	TCE	5	UG/L	U	02/13/1997
025	E025GW004	025GW00401	TCE	2	UG/L	J	04/26/1996
070	E070GW001	070GW00104	TCE	12	UG/L	=	02/18/1997
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070	E070GW002	070GW00201	TCE	6	UG/L	=	04/26/1996
070	E070GW002	070GW00202	TCE	6	UG/L	=	07/29/1996
070	E070GW01D	070GW01D01	TCE	22	UG/L	=	04/26/1996
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549	E549GW001	549GW00104	TCE	5	UG/L	U	02/13/1997
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549	E549GW002	549GW00203	TCE	5	UG/L	U	11/25/1996
549	E549GW002	549GW00204	TCE	5	UG/L	U	02/13/1997
549	E549GW002	549GW00201	TCE	5	UG/L	U	04/25/1996
549	E549GW003	549GW00303	TCE	54	UG/L	=	11/25/1996
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559	E559GW001	559GW00103	TCE	5	UG/L	U	11/22/1996
559	E559GW001	559GW00104	TCE	5	UG/L	U	02/06/1997
559	E559GW001	559GW00101	TCE	5	UG/L	U	05/03/1996
559	E559GW002	559GW00201	TCE	5	UG/L	U	05/02/1996
559	E559GW002	559GW00202	TCE	5	UG/L	U	07/26/1996
559	E559GW002	559GW00203	TCE	5	UG/L	U	11/21/1996

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
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559	E559GW003	559GW00303	TCE	5	UG/L	U	11/25/1996
559	E559GW003	559GW00304	TCE	5	UG/L	U	02/07/1997
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559	E559GW004	559GW00402	TCE	5	UG/L	U	07/31/1996
559	E559GW004	559GW00403	TCE	5	UG/L	U	11/25/1996
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070	E070GW001	070GW00101	PCE	5	UG/L	U	04/25/1996
070	E070GW001	070GW00102	PCE	5	UG/L	U	07/29/1996
070	E070GW001	070GW00103	PCE	5	UG/L	U	12/03/1996
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070	E070GW002	070GW00201	PCE	5	UG/L	U	04/26/1996
070	E070GW002	070GW00202	PCE	5	UG/L	U	07/29/1996
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070	E070GW01D	070GW01D02	PCE	8	UG/L	=	07/29/1996
070	E070GW01D	070GW01D03	PCE	12	UG/L	=	12/03/1996
070	E070GW01D	070GW01D04	PCE	15	UG/L	=	02/18/1997
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549	E549GW001	549GW00104	PCE	5	UG/L	U	02/13/1997
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559	E559GW002	559GW00203	PCE	5	UG/L	U	11/21/1996

PCE

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
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559	E559GW003	559GW00301	PCE	5	UG/L	U	05/03/1996
559	E559GW004	559GW00402	PCE	5	UG/L	U	07/31/1996
559	E559GW004	559GW00403	PCE	5	UG/L	U	11/25/1996
559	E559GW004	559GW00404	PCE	5	UG/L	U	02/11/1997
559	E559GW004	559GW00401	PCE	5	UG/L	U	05/06/1996
559	E559GW005	559GW00504	PCE	5	UG/L	U	02/11/1997
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559	E559GW03D	559GW03D02	PCE	5	UG/L	U	07/29/1996
559	E559GW03D	559GW03D03	PCE	5	UG/L	U	11/25/1996
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559	E559GW04D	559GW04D04	PCE	5	UG/L	U	02/11/1997
559	E559GW04D	559GW04D02	PCE	5	UG/L	U	07/31/1996
559	E559GW04D	559GW04D01	PCE	5	UG/L	U	05/08/1996
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GDE	EGDEGW028	GDEGW028A2	PCE	5	UG/L	U	03/05/1997
GDE	EGDEGW028	GDEGW028A3	PCE	5	UG/L	U	06/24/1997
GDE	EGDEGW028	GDEGW02801	PCE	5	UG/L	U	10/30/1996
GDE	EGDEGW28D	GDEGW28DA3	PCE	5	UG/L	U	06/25/1997
GDE	EGDEGW28D	GDEGW28D01	PCE	5	UG/L	U	10/30/1996
GDE	EGDEGW28D	GDEGW28D04	PCE	5	UG/L	UJ	10/07/1997
GDE	EGDEGW28D	GDEGW28DA2	PCE	5	UG/L	U	03/05/1997

Chloroform

10/26/2000

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
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025	E025GW001	025GW00104	TCLME	15	UG/L	U	02/14/1997
025	E025GW001	025GW00101	TCLME	5	UG/L	U	04/25/1996
025	E025GW002	025GW00201	TCLME	5	UG/L	U	04/25/1996
025	E025GW002	025GW00202	TCLME	5	UG/L	U	07/26/1996
025	E025GW002	025GW00203	TCLME	5	UG/L	U	12/02/1996
025	E025GW002	025GW00204	TCLME	5	UG/L	U	02/14/1997
025	E025GW003	025GW00303	TCLME	5	UG/L	U	12/02/1996
025	E025GW003	025GW00304	TCLME	5	UG/L	U	02/13/1997
025	E025GW003	025GW00302	TCLME	5	UG/L	U	07/26/1996
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025	E025GW004	025GW00402	TCLME	5	UG/L	U	07/26/1996
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025	E025GW004	025GW00404	TCLME	5	UG/L	U	02/13/1997
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070	E070GW001	070GW00104	TCLME	5	UG/L	U	02/18/1997
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070	E070GW001	070GW00102	TCLME	5	UG/L	U	07/29/1996
070	E070GW001	070GW00103	TCLME	5	UG/L	U	12/03/1996
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070	E070GW002	070GW00201	TCLME	5	UG/L	U	04/26/1996
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070	E070GW01D	070GW01D02	TCLME	6	UG/L	=	07/29/1996
070	E070GW01D	070GW01D03	TCLME	5	UG/L	U	12/03/1996
070	E070GW01D	070GW01D04	TCLME	5	UG/L	U	02/18/1997
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549	E549GW003	549GW00302	TCLME	5	UG/L	U	07/29/1996
549	E549GW003	549GW00304	TCLME	5	UG/L	U	02/14/1997
559	E559GW001	559GW00102	TCLME	2	UG/L	J	07/26/1996
559	E559GW001	559GW00103	TCLME	5	UG/L	U	11/22/1996
559	E559GW001	559GW00104	TCLME	5	UG/L	U	02/06/1997
559	E559GW001	559GW00101	TCLME	5	UG/L	U	05/03/1996
559	E559GW002	559GW00201	TCLME	5	UG/L	U	05/02/1996
559	E559GW002	559GW00202	TCLME	5	UG/L	U	07/26/1996
559	E559GW002	559GW00203	TCLME	5	UG/L	U	11/21/1996

chloroform

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
559	E559GW002	559GW00204	TCLME	5	UG/L	U	02/06/1997
559	E559GW003	559GW00303	TCLME	5	UG/L	U	11/25/1996
559	E559GW003	559GW00304	TCLME	5	UG/L	U	02/07/1997
559	E559GW003	559GW00302	TCLME	5	UG/L	U	07/29/1996
559	E559GW003	559GW00301	TCLME	5	UG/L	U	05/03/1996
559	E559GW004	559GW00402	TCLME	5	UG/L	U	07/31/1996
559	E559GW004	559GW00403	TCLME	5	UG/L	U	11/25/1996
559	E559GW004	559GW00404	TCLME	5	UG/L	U	02/11/1997
559	E559GW004	559GW00401	TCLME	5	UG/L	U	05/06/1996
559	E559GW005	559GW00504	TCLME	5	UG/L	U	02/11/1997
559	E559GW005	559GW00501	TCLME	5	UG/L	U	05/07/1996
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559	E559GW005	559GW00503	TCLME	25	UG/L	U	11/22/1996
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559	E559GW03D	559GW03D01	TCLME	5	UG/L	U	05/09/1996
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559	E559GW04D	559GW04D04	TCLME	5	UG/L	U	02/11/1997
559	E559GW04D	559GW04D02	TCLME	5	UG/L	U	07/31/1996
559	E559GW04D	559GW04D01	TCLME	1	UG/L	J	05/08/1996
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GDE	EGDEGW028	GDEGW028A2	TCLME	5	UG/L	U	03/05/1997
GDE	EGDEGW028	GDEGW028A3	TCLME	5	UG/L	U	06/24/1997
GDE	EGDEGW028	GDEGW02801	TCLME	1	UG/L	J	10/30/1996
GDE	EGDEGW28D	GDEGW28DA3	TCLME	5	UG/L	U	06/25/1997
GDE	EGDEGW28D	GDEGW28D01	TCLME	5	UG/L	U	10/30/1996
GDE	EGDEGW28D	GDEGW28D04	TCLME	5	UG/L	U	10/07/1997
GDE	EGDEGW28D	GDEGW28DA2	TCLME	5	UG/L	U	03/05/1997

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
025	E025GW001	025GW00102	DCE12TO	5	UG/L	U	07/25/1996
025	E025GW001	025GW00103	DCE12TO	5	UG/L	U	12/02/1996
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025	E025GW001	025GW00101	DCE12TO	5	UG/L	U	04/25/1996
025	E025GW002	025GW00201	DCE12TO	5	UG/L	U	04/25/1996
025	E025GW002	025GW00202	DCE12TO	5	UG/L	U	07/26/1996
025	E025GW002	025GW00203	DCE12TO	5	UG/L	U	12/02/1996
025	E025GW002	025GW00204	DCE12TO	5	UG/L	U	02/14/1997
025	E025GW003	025GW00303	DCE12TO	5	UG/L	J	12/02/1996
025	E025GW003	025GW00304	DCE12TO	4	UG/L	J	02/13/1997
025	E025GW003	025GW00302	DCE12TO	1	UG/L	J	07/26/1996
025	E025GWJ03	025GW00301	DCE12TO	2	UG/L	J	04/26/1996
025	E025GW004	025GW00402	DCE12TO	5	UG/L	U	07/26/1996
025	E025GW004	025GW00403	DCE12TO	5	UG/L	U	12/02/1996
025	E025GW004	025GW00404	DCE12TO	5	UG/L	U	02/13/1997
025	E025GW004	025GW00401	DCE12TO	5	UG/L	U	04/26/1996
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070	E070GW001	070GW00101	DCE12TO	6	UG/L	=	04/25/1996
070	E070GW001	070GW00102	DCE12TO	10	UG/L	=	07/29/1996
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549	E549GW003	549GW00301	DCE12TO	18	UG/L	=	04/24/1996
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559	E559GW001	559GW00102	DCE12TO	5	UG/L	U	07/26/1996
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559	E559GW002	559GW00201	DCE12TO	5	UG/L	U	05/02/1996
559	E559GW002	559GW00202	DCE12TO	5	UG/L	U	07/26/1996
559	E559GW002	559GW00203	DCE12TO	5	UG/L	U	11/21/1996

SiteID	StationID	SampleID	ParamID	AnaV	Units	ProjQu	DateCollected
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559	E559GW003	559GW00302	DCE12TO	5	UG/L	U	07/29/1996
559	E559GW003	559GW00301	DCE12TO	5	UG/L	U	05/03/1996
559	E559GW004	559GW00402	DCE12TO	5	UG/L	U	07/31/1996
559	E559GW004	559GW00403	DCE12TO	5	UG/L	U	11/25/1996
559	E559GW004	559GW00404	DCE12TO	5	UG/L	U	02/11/1997
559	E559GW004	559GW00401	DCE12TO	5	UG/L	U	05/06/1996
559	E559GW005	559GW00504	DCE12TO	2	UG/L	J	02/11/1997
559	E559GW005	559GW00501	DCE12TO	5	UG/L	J	05/07/1996
559	E559GW005	559GW00502	DCE12TO	2	UG/L	J	07/29/1996
559	E559GW005	559GW00503	DCE12TO	25	UG/L	U	11/22/1996
559	E559GW02D	559GW02D04	DCE12TO	5	UG/L	U	02/07/1997
559	E559GW02D	559GW02D03	DCE12TO	5	UG/L	U	12/06/1996
559	E559GW02D	559GW02D02	DCE12TO	5	UG/L	U	07/26/1996
559	E559GW02D	559GW02D01	DCE12TO	5	UG/L	U	05/08/1996
559	E559GW03D	559GW03D01	DCE12TO	5	UG/L	U	05/09/1996
559	E559GW03D	559GW03D02	DCE12TO	5	UG/L	U	07/29/1996
559	E559GW03D	559GW03D03	DCE12TO	5	UG/L	U	11/25/1996
559	E559GW03D	559GW03D04	DCE12TO	5	UG/L	U	02/07/1997
559	E559GW04D	559GW04D03	DCE12TO	3	UG/L	J	11/25/1996
559	E559GW04D	559GW04D04	DCE12TO	4	UG/L	J	02/11/1997
559	E559GW04D	559GW04D02	DCE12TO	2	UG/L	J	07/31/1996
559	E559GW04D	559GW04D01	DCE12TO	1	UG/L	J	05/08/1996
GDE	EGDEGW028	GDEGW02804	DCE12TO	1	UG/L	J	10/07/1997
GDE	EGDEGW028	GDEGW028A2	DCE12TO	5	UG/L	U	03/05/1997
GDE	EGDEGW028	GDEGW028A3	DCE12TO	5	UG/L	U	06/24/1997
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GDE	EGDEGW28D	GDEGW28D01	DCE12TO	54	UG/L	=	10/30/1996
GDE	EGDEGW28D	GDEGW28D04	DCE12TO	41	UG/L	=	10/07/1997
GDE	EGDEGW28D	GDEGW28DA2	DCE12TO	56	UG/L	=	03/05/1997

Appendix B

PRECISION

TECHNICAL NOTE No.3

The Waterloo Profiler for Groundwater Sampling

The Waterloo Profiler is a new direct-push (DP) groundwater sampling tool developed by researchers at the University of Waterloo in Ontario, Canada[1]. The Profiler is the only DP tool designed to collect depth-discrete groundwater samples in a single hole with one probe entry. With the Waterloo Profiler, site investigators can quickly delineate vertical profiles of contaminants dissolved in groundwater.

Why Vertical Profiling is Necessary

Recent long-term natural gradient tracer studies show that in most granular aquifers, very little vertical mixing of contaminants occurs as the groundwater flows along its flow path[2,3,4,5]. Depth-discrete groundwater sampling (referred to as vertical profiling) at these sites shows that the concentration of dissolved organic compounds often varies by several orders of magnitude over vertical distances of one foot or less. This indicates that significant vertical mixing does not occur in most environments; if it did, the contaminants would be more evenly distributed and concentrations would be more uniform.

Groundwater mixing, also referred to as hydrodynamic dispersion, is a function of the groundwater velocity and the dispersivity (α) of the formation. Numerical simulations of data collected during the natural gradient tracer tests show that vertical dispersivity (α_V), which controls vertical mixing, is much lower than was thought in the 1970s and early 1980s[2]. This explains why very little vertical mixing of contaminants occurs in nature, even in relatively homogeneous materials.

If dissolved contamination is highly stratified, can samples collected from conventional monitoring wells provide an accurate representation of the true concentration and distribution of contaminants in groundwater? The answer is no. When a conventional monitoring well is sampled, clean or slightly-contaminated water is drawn into the well, diluting the sample. Therefore, even with screen lengths as short as 5 or 10 feet, monitoring wells yield samples that are composited over the screened interval. Thus, high concentrations of contaminants present in a thin zone – and even non-aqueous phase liquids (NAPLs) – are significantly diluted in the process of sampling conventional monitoring wells. In some cases, the contamination can be diluted below the detection limit of the chemical analytical method.

Moreover, for non-biodegradable contaminants (like most chlorinated solvents and MTBE), if significant mixing with clean water does not occur as groundwater flows in the subsurface, the high solute concentrations in the contaminated zone are maintained. Thus, thin zones with high concentrations of contaminants can flow for great distances without being diluted. A recent investigation at an industrial facility – where detailed vertical monitoring was performed – identified a high-strength core of contamination that extends for over 7 kilometers[6].

Figure 1. Depth-discrete groundwater samples are drawn through screened ports in the tip of the sampling tool. The ports are connected to an internal fitting inside of the tool (shown at left). Tubing attached to the internal fitting and running inside of the steel pipe conveys the water sample to the surface.

Inaccurate delineation of groundwater contamination can have tremendous consequences. Without an accurate understanding of the true magnitude and distribution of contamination, it is not possible to make intelligent corrective action decisions. Underestimating the maximum contaminant concentrations invalidates any risk assessment. Not identifying free product or localized contaminant hot spots may expose nearby receptors to unacceptable risks. And, without knowing the true distribution of subsurface contamination, it is impossible to design effective active or passive remediation systems.

Regulators and site investigators across North America are discovering that collecting multiple, closely-spaced, depth-discrete groundwater samples – i.e., vertical groundwater profiling – is necessary to define the true extent and distribution of dissolved contaminants in the subsurface.

Description and Operation of the Waterloo Profiler

The Waterloo Profiler collects discrete groundwater samples from numerous depths during a single push. Figure 1 shows the tip of the Waterloo Profiler, which has screened ports located at the tip of the tool. The Profiler tip is attached to 3-foot lengths of heavy-duty threaded steel pipe that extend to the ground surface. The Profiler is advanced by pushing, pounding, or vibrating the steel pipe into the ground using one of Precision's custom-made sampling rigs. Three-foot lengths of pipe are continually added as the tool is advanced deeper into the ground to the first sampling depth. Groundwater samples are conveyed to the surface via small-diameter tubing that is attached to a fitting inside of the Profiler tip and passes up through the inside of the threaded steel pipes.

At sites where groundwater is shallow (i.e., less than 25 feet below the ground surface), samples can be collected using a peristaltic suction-lift pump (Figure 2). Samples are collected in 40 ml glass vials placed in the sampling line, upstream from the peristaltic pump. Positioning the glass vials in the sampling line upstream from the peristaltic pump minimizes the loss of volatile organic compounds (VOCs) since the sample is never exposed to the atmosphere. However, at sites where groundwater has high concentrations of dissolved gases such as carbon dioxide or methane, pressure changes during sampling can cause bubbling in the sample line as the dissolved gases come out of solution. In such environments, VOCs in the groundwater can partition into the bubbles, reducing the concentration in the water. A recent study by Baerg et al. indicates that the negative bias in samples collected using a peristaltic pump is on the order of 12% for tetrachloroethene (PCE) and 7% for trichloroethylene (TCE)[7]. While this error is not insignificant, the advantage of being able to delineate the plumes in detail outweighs the sampling bias caused by the sample collection method, especially when the natural variation in the samples is in the order of three to four orders of magnitude. Nevertheless, the investigator is cautioned to be aware that negative biases exist when using peristaltic pumps, and to consider not only the partial pressures of dissolved gases, but also the volatility of the target analyte. Additional discussion of sample bias associated with the Waterloo Profiler is presented by Pitkin, et al.[8].

Once a sample is collected in the 40 ml vials, new glass vials are placed in the sample holder and the Profiler is pushed to the next sampling depth. The next sampling depth can be any distance below the previous depth, but usually ranges between 2 and 5 feet deeper. To prevent the ports from clogging as the tool is pushed through the soil, deionized water is slowly pumped through the inner tube and out of the sampling ports as the tool is being advanced. Note that only a very small amount of water is injected – typically less than 10 milliliters per minute – just enough to keep the ports from becoming plugged. For injection pressures up to approximately 50 pounds per square inch (psi), the water is injected by reversing the flow on the peristaltic pump. In addition to keeping the ports open, injecting DI water while advancing the tool purges the tubing of the water left over from the previous sampling event. This prevents cross contamination of the next groundwater sample.

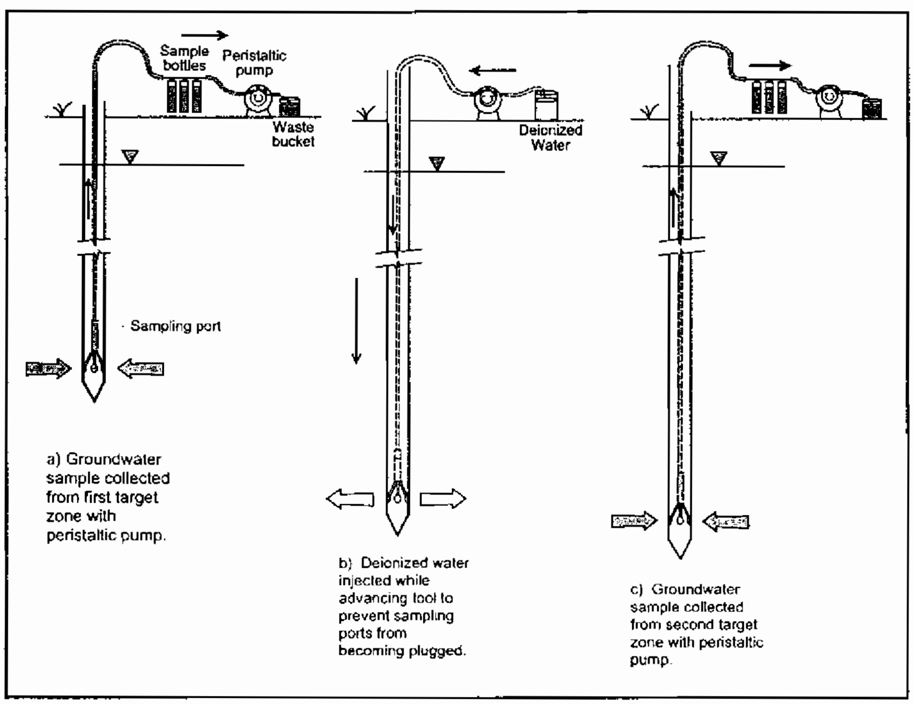

Figure 2. Collecting depth-discrete groundwater samples with the Waterloo Profiler

Note that the pressure/flow relationship of the injection water can be monitored to provide an indication of the hydraulic conductivity of the formation. This way, geologic contacts (i.e., the contact between a sand and an underlying clay confining unit) can be accurately identified as the profiler tool is advanced.

Once the tool has been advanced to the next sampling depth, the flow of the pump is reversed, and groundwater from the aquifer is again extracted. Purging of the system is required, since the tubing and ports now contain DI water that had been pumped down through the system. The electrical conductivity of the extracted groundwater can be monitored during purging. Several other chemical parameters such as salinity, temperature, pH, and dissolved oxygen (DO) can be monitored using in-line sensors mounted in flow-cells in the sampling line. Once the investigator is confident that formation water is being extracted, the 40 ml glass sample vials are removed and capped, ready to be analyzed by the on- or off-site laboratory.

The primary advantage of the Waterloo Profiler is that because the tubing is purged between samples, several depth-discrete ground-water samples can be collected in one push, without having to remove, clean, and re-insert the tool.

Sealing the Hole Created with the Waterloo Profiler

Probe holes should be sealed to prevent the holes from becoming conduits for contaminant migration. This is espe-

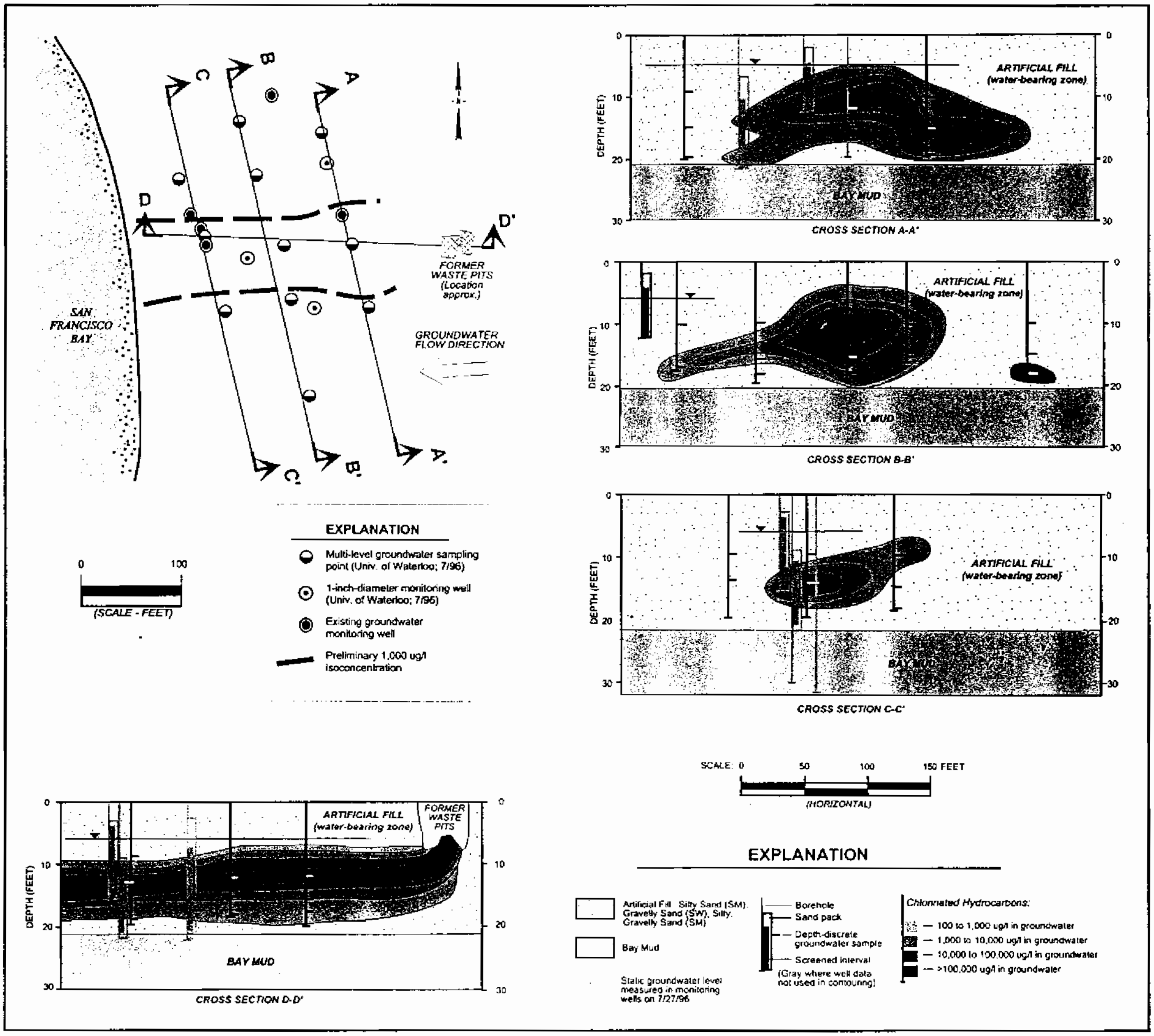

Figure 3. Map and transects from a site characterization at Alameda Naval Air Station in California. Note the great vertical variation in the concentration of dissolved contaminants, even in this homogeneous sand.

cially important at sites where DNAPL is present that could flow down the open probe holes and contaminate deeper aquifers. In most homogeneous sands, the sand will collapse as soon as the Profiler is withdrawn, restoring the original permeability of the formation. However, in other geologic formations, the soil may not collapse, and other methods of sealing the probe hole are necessary. The Waterloo Profiler is equipped with a knock-out disposable tip that facilitates reliable retraction grouting (Figure 1). Once the last groundwater sample has been collected, cement or bentonite grout is pumped down the steel pipe using a high-pressure grout pump. The disposable tip separates from the rest of the tool upon pull back, and grout flows out of the pipe into the probe hole. The grout is continuously pumped, filling the probe hole as the pipe is removed. This ensures that the probe hole is effectively sealed. Retraction grouting using the Waterloo Profiler is much more reliable than re-entry methods used with other sealed-screen groundwater sampling systems[9].

Case Study

The Waterloo Profiler was used to delineate the areal and vertical extent of a plume of chlorinated organics and petroleum hydrocarbons at a portion of Alameda Naval Air Station in California. The investigation was performed to define the optimum location and depth of an innovative in-situ reactive-wall funnel and gate remediation system[10]. Continuous soil cores were first collected with Precision's Enviro-Core system to define the site geology (the Enviro-Core soil coring system is described in Technical Note # 1). Next, depth-discrete groundwater samples were collected with the Waterloo Profiler at 14 locations (Figure 3). The locations were along three transects drawn perpendicular to the presumed plume orientation. Groundwater samples were analyzed on site for chlorinated organic compounds and petroleum hydrocarbons by GC/MS methods.

As shown in Figure 3, Precision's investigation accurately delineated the dissolved plume in three dimensions. The plume does indeed have a very concentrated core, with concentrations of vinyl chloride as high as 130,000 ug/l, that had been missed by the existing conventional monitoring wells. Projection of concentration contours to the ground surface shows that the plume emanates from a former waste disposal pit, and flows to the west where it discharges into San Francisco Bay. Note that groundwater samples collected from the base of the aquifer had much lower concentrations of all compounds than samples collected higher up in the aquifer. This is conclusive evidence that a pool of DNAPL does not occur atop the Bay Mud aquitard in that part of the site.

The site characterization was comprehensive and yielded accurate data that the investigators needed to install the passive remediation system. Yet, the investigation was neither lengthy nor costly. Precision performed the entire investigation in 4 days at a cost slightly under $10,000.

Maximum Depth, Productivity, and Limitations

Like other direct-push groundwater sampling tools, the Waterloo Profiler is intended for use in unconsolidated sand and gravel formations. The maximum sampling depth depends on the site-specific soil conditions. It has been advanced to depths greater than 100 feet near Cape Canaveral, Florida and Cape Cod, Mass.

Sample collection is the most time-consuming part of the operation; advancing the sampling tool usually takes very little time. In coarse-grained sands and gravels, sample collection takes less than 10 minutes per sample. In fine- to medium-grained sand, 20 to 30 minutes is typically required to purge and collect a sample. In sediment finer than a fine-grained sand, collecting groundwater samples with the Waterloo Profiler is time consuming and may not be economically feasible.

References

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Appendix C

EnSafe/Allen & Hoshall

Monitoring Well NBCE07001D

Project: ZONE E – Naval Base Charleston	Coordinates: 2316582.98 E, 376673.33 N
Location: Charleston, SC	Surface Elevation: 9.0 feet msl
Started at 1315 on 1-10-96	TOC Elevation: 8.76 feet msl
Completed at 1445 on 1-10-96	Depth to Groundwater: 6.21 feet TOC Measured: 3/13/96
Drilling Method: Rotasonic (6.5" OD casing, 3.8" ID coring bit)	Groundwater Elevation: 2.55 feet msl
Drilling Company: Alliance Environmental (SC Cert# 889)	Total Well Depth: 33.1 feet bgs
Geologist: T. Kafka	Well Screen: 23.1 to 32.6 feet bgs

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)
25			3	100	0
30					
35			4	100	0
40					

SOIL CLASS (top to bottom): SM/SC, SM, SC/CL, SP/CL, SW/SC, SC/CL, SW, ML/CL

GEOLOGIC DESCRIPTION

interpspersed pods of gray-green clay at 19.3, 20.1, 20.3-20.6 ft.; soft, low to medium plasticity.

Sand: light gray to brown-gray grading to orange and olive-brown at 22', very fine to fine, with orange and brown silty stringers, wet; brown to olive-brown, FeOx-rich clay stringers at 21-21.1' and 21.9- 22.1'.

Clay: red to olive-brown, soft to firm, low/medium plasticity, with brown-tan, FeOx-rich, very fine to fine sand stringers throughout.

Clay: dark gray, silty, medium plastictiy, with fine to medium sand stringers and very fine to medium shell hash.

Interbedded sand and clay: 0.3-0.5' dark gray sand beds, very fine to fine, well-sorted, silty, with trace to some very fine shell hash, wet; 0.4-0.5' dark gray, silty clay beds, with fine laminae of very fine sand and shell hash throughout, wet.

Sand: dark gray, very fine to medium, 25% fine to medium shell hash, 0.2' dark gray clay lenses at 28' and 29.4'.

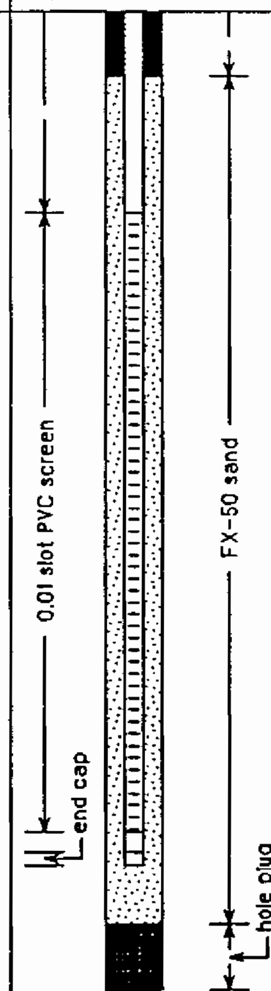
Clay: dark gray, silty, with 10-15% very fine to fine sand and < 5% very fine to fine shell hash.

Sand/Shell Lag deposit: very fine to coarse, poorly sorted sand, 30- 40% fine to coarse shells; sticky, soft, dark gray clay at 31.5-32'; 30-40% PO_4 nodules of 3-8 cm size at 32.2-32.4'.

Silt: olive-brown, clayey, firm, low plasticity, trace very fine to fine sand, moist to wet--Ashley Formation.

ELEV. (ft-msl): -11.8, -13.8, -17.3, -19, -21, -21.5, -23.4, -26

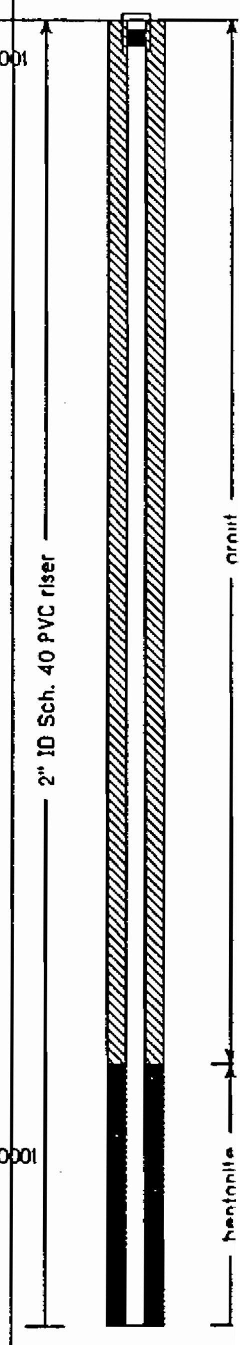
WELL DIAGRAM



EnSafe/Allen & Hoshall	Monitoring Well NBCE07001D
Project: ZONE E – Naval Base Charleston	Coordinates: 2316582.98 E, 376673.33 N
Location: Charleston, SC	Surface Elevation: 9.0 feet msl
Started at 1315 on 1-10-96	TOC Elevation: 8.76 feet msl
Completed at 1445 on 1-10-96	Depth to Groundwater: 6.21 feet TOC Measured: 3/13/96
Drilling Method: Rotasonic (6.5" OD casing, 3.8" ID coring bit)	Groundwater Elevation: 2.55 feet msl
Drilling Company: Alliance Environmental (SC Cert# 889)	Total Well Depth: 33.1 feet bgs
Geologist: T. Kafka	Well Screen: 23.1 to 32.6 feet bgs

DEPTH IN FEET	LITHOLOGIC SAMPLE	ANALYTICAL SAMPLE	SAMPLE NO.	% RECOVERY	PID (ppm)	GRAPHIC LOG	SOIL CLASS	GEOLOGIC DESCRIPTION	ELEV. (ft-msl)
								Surface conditions: concrete	8.400001
							SP	Sand: light-medium brown, very fine to fine, well-sorted, trace to some silt, with concrete fragments in upper 0.5', moist to wet.	7
5			1	40	0				4
							SP	Sand: light gray to green-gray, very fine to fine, well-sorted, trace silt, saturated (flowing).	3.5
							SC	Sand: gray with orange-brown mottling, very fine to fine trace medium , well-sorted, wet; gray, low plasticity clay and FeOx stains throughout.	2.5
							SM	Sand: brown-orange, fine to medium, well-sorted, silty, with red FeOx concretions in upper 0.1', trace to some clay, saturated.	1.8
10							SM/SP	Sand: light tan, very fine to fine, well-sorted, silty, wet, some coarsening in grain size at 8-9' and 11-11.5'. Color change to brown-orange. Color change to medium brown with orange.	-5
15			2	90	0				-6
							SM	Sand: brown-orange to orange with red and brown silty stringers, very fine to fine, well-sorted, no clay, saturated.	-7.2
							SM/SC	Sand: light to brown-gray to orange, very fine to fine, silty, wet; 20% soft, low plasticity clay with trace medium sand from 16.2-16.6'.	-8.400001
							SC/CL	Clay: brown-gray with orange mottling, soft, low plasticity, with 15- 20% very fine to fine sand, well-sorted, wet.	-9.5
20							SM/SC	Sand: light gray to brown with orange mottling, very fine to fine, well-sorted, orange silt;	

WELL DIAGRAM



Appendix D

Appendix D

Response to SCDEHC Comments to Phase 1 – Source Area Delineation

CMS Work Plan
SWMU 70 Zone E

Comments 1-5 from Monsour Malik

1. The title for this CMS-WP is Phase 1- Source Area Delineation. It indicates delineating all the impacted media in SWMU 70. Section 1.1.1 set the primary and the only goal as to determine the extent and spatial distribution of the high concentration source areas of chromium in the shallow and deep groundwater. If the Navy is investigating only this issue, the title for this CMS-WP should then be more specific.

   Response: The document title will be changed to "Corrective Measures Study Work Plan , Phase 1 – Groundwater Delineation, Solid Waste Management Unit 70, Zone E."

2. Section 1.2 Site Background and RFI Summary, Lines 3-6: The text mentioned a NFA was recommended for the soil media for the SWMU 70. The Department has not yet approved the referenced RFI. If this CMS-WP is meant to target source area delineation for the SWMU as a whole, the Department recommends investigating the soil media as well or else deleting all references to other media.

   Response: CH2M-Jones will replace the first paragraph on page 1-3 with the following: "Soil and groundwater were investigated as part of the RFI activities conducted in SWMU 70. Findings from the investigation are reported in the Draft (Rev. 0) RFI (the Draft RFI has not yet been approved by SCDEHC or EPA)."

3. Fig 2-1: Some of the proposed groundwater probe locations 005,006,013,008,012,010,011 lie within the footprints of the surrounding buildings. The Department in viewing non-predictable surface obstructions that might lead to change of proposed locations would like to reiterate that dislocation of more than 10 feet diameter away from the proposed locations would not be permissible without the Department approval prior to field implementation.

   Response: Comment noted. The locations presented in Figure 2-1 have been visited to ensure they are accessible. However, in the event that we need to relocate a sampling location greater than 10-feet from the planned locations, we hope the Department will be able to approve the request in the same business day.

Appendix D

Response to SCDEHC Comments to Phase 1 – Source Area Delineation

CMS Work Plan
SWMU 70 Zone E

4. Section 2.1.1 Waterloo Profiler, Line 8: Choosing sampling depth at regular intervals of 11, 22 and 33 feet will only be beneficial if we are dealing with a uniform homogenous aquifer. Given the facies inhomogenity in this area, vertical profiling will be more of a value if it is selective of each distinctive aquifer layer. Given that geophysical electric conductivity can help in delineating the litholohgical units, please verify if it is possible to apply the profiler in the way described.

   Response: The above comment proposes an excellent recommendation. Lines 8 through 11 on page 2-2 and Lines 1-4 on page 2-3 will be replaced with the following text: "Groundwater samples will be collected at up to three discrete depth intervals for each sample locations represented on Figure 2-1. To assist in determining the depth interval that samples will be collected, a total of four soil conductivity logs, using a continuous read-out soil conductivity probe, will be developed to the top of the Ashley formation. The location of the log locations are presented in Figure 2-1. Also, two soil cores will be collected (depicted in Figure 2-1) to correlate soil conductivity data with visual observations. Data from these two subsurface geotechnical investigations will be evaluated to determine the most appropriate depth from which groundwater samples will be collected."

5. Appendix A: The appendix includes tables that show historical results for VOCs. As it appears that the VOCs are not part of this CMS-WP study, please clarify why this information is presented in this document. The Department recommends in bringing up such data, comments relevant to what the data is brought in for, is required.

   Response: The VOC data was added to the target analyte list because previous verbal comments made by Department personnel requested this type of information be collected in the event the site was subject to a groundwater sampling effort. Also, knowing the VOC concentrations will help engineers and scientists determine if the remediation technology applied to chromium will be effective in reduction of VOCs as well.

Appendix D

Response to SCDEHC Comments to Phase 1 – Source Area Delineation

CMS Work Plan
SWMU 70 Zone E

Comments 6-8 from Susan Peterson

6. VOCs. The Department understands that the Navy plans to analyze monitoring wells for VOCs to evaluate the change in concentrations that has occurred since the last data collection in February 1997. Given that the primary objective of this CMS WP is to more clearly determine the distribution of chromium in groundwater, the Department requests that the Navy limit the CMS content to chromium.

   The VOC concentrations, listed in Appendix A of this document, exceed MCLs. Thus noted, complete source and release characterization of VOCs is required to complete the RFI at this site.

   Response: Please see response to Comment No. 5.

7. Rationale to justify proposed sampling locations needed: During the November 2000 BCT meeting, the Navy discussed a figure (Figure 1) that listed the concentrations of chromium > 10 ppb. The Department requests that the Navy incorporate Figure 1 into this document and transpose the proposed sampling locations (CMS WP Figure 2-1) onto Figure 1. The Department requires a rationale in order to evaluate the proposed sampling locations. The rationale should at a minimum consist of the figure described above, a figure showing existing chromium contamination plume(s), and more descriptive text.

   Response: The requested figure will be included in the Rev. 1 Work Plan. As the text in Sec. 2.2 clearly states the objective of sampling location placement is to encompass the areas in which chromium was reported in concentrations in excess of MCLs, no further descriptive text is necessary. When the report is prepared to present the data, appropriate isocontour lines will be presented to delineate the chromium plume.

8. Note: This document references information from the Zone E RFI report, which the Department has not yet approved. Please note that the approval of this CMS WP does not constitute approval of the Zone E RFI report.

   Response: Comment noted.