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FINAL FEASIBILITY STUDY REPORT FOR GROUNDWATER AT SITE 22 NWS YORKTOWN VA

09/01/2011

CH2M HILL

Final

Feasibility Study Report for Groundwater at Site 22

Naval Weapons Station Yorktown
Yorktown, Virginia

Naval Facilities Engineering Command
NAVFAC MID-ATLANTIC

Prepared for

Department of the Navy
Naval Facilities Engineering Command
Mid-Atlantic

Contract No.
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Prepared by

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Virginia Beach, Virginia

Executive Summary

This report presents the Feasibility Study (FS) for groundwater at Site 22, Naval Weapons Station (WPNSTA) Yorktown, in Yorktown, Virginia. Based on the results from the Final Remedial Investigation (RI) Report (CH2M HILL, 2009), three site-related constituents of concern (COCs) were identified to be addressed in the FS. The COCs include trichloroethene (TCE), vinyl chloride (VC), and hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX).

Four remedial alternatives are presented as follows.

- Alternative 1 – No Action
- Alternative 2 – Hot Spot Removal of RDX using Enhanced In Situ Bioremediation (EISB) and Associated Performance Monitoring; Monitored Natural Attenuation (MNA) of TCE, VC and RDX, and Land Use Controls (LUCs)
- Alternative 3 – Hot Spot Removal of RDX, TCE and VC using In Situ Chemical Oxidation (ISCO) and Associated Performance Monitoring; MNA of TCE, VC and RDX; and LUCs
- Alternative 4 – Hot Spot Removal of TCE, VC and RDX using EISB and Associated Performance Monitoring; MNA of TCE, RDX and VC; and LUCs

Each of these remedial alternatives was evaluated based on the National Contingency Plan (NCP) criteria. In accordance with this evaluation and the cost of each alternative, Alternative 2 (Hot Spot Removal of RDX using EISB and Associated Performance Monitoring; MNA of TCE, VC and RDX; and LUCs) is the preferred alternative for remediation of the groundwater contamination at Site 22.

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Acronyms and Abbreviations

AFCEE	Air Force Center for Engineering and the Environment
amsl	above mean sea level
ARAR	applicable or relevant and appropriate requirement
bgs	below ground surface
BTAG	Biological Technical Assistance Group
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CHP	catalyzed hydrogen peroxide
CLEAN	Comprehensive Long-term Environmental Action—Navy
CO2	carbon dioxide
COC	constituent of concern
CSM	conceptual site model
CTE	central tendency exposure
DCE	dicholoroethene
DHC	Dehalococcoides
DNAPL	dense non-aqueous phase liquid
DO	dissolved oxygen
DOD	Department of Defense
DON	Department of the Navy
DPT	direct push technology
ECD	electron capture device
EISB	enhanced in situ bioremediation
EO	Executive Order
ER	Environmental Restoration
ERA	Ecological Risk Assessment
ESQD	Explosive Safety Quantity Distance
EVO	emulsified vegetable oil
Fe	iron
FS	Feasibility Study
ft	foot or feet
ft^2	square foot or square feet
ft^3	cubic foot or cubic feet
ft/day	foot or feet per day
GHG	greenhouse gas
GIS	geographic information system
GPS	geographic positioning system

HHRA	human health risk assessment
HI	hazard index
IR	Installation Restoration
ISCO	In Situ Chemical Oxidation
KMnO4	potassium permanganate
LUC	Land Use Control
LUCIP	Land Use Control Implementation Plan
LUC RD	Land Use Control Remedial Design
µg/L	micrograms per liter
mg/L	milligrams per liter
MCL	maximum contaminant level
MIP	membrane interface probe
mL	milliliter
Mn	manganese
MNA	monitored natural attenuation
MnO4	permanganate
mS/cm	milliSiemens per centimeter
mV	millivolts
NAVFAC	Naval Facilities Engineering Command
Navy	United States Navy
NCP	National Contingency Plan
NFA	No Further Action
NOx	nitrogen oxide
NSWC	Naval Surface Warfare Center
O&M	operations and maintenance
OOM	order of magnitude
ORP	oxidation-reduction potential
pH	hydrogen (ion) concentration
PM10	particulate matter less than 10 micrometers in aerodynamic diameter
PRAP	Proposed Remedial Action Plan
PRG	Preliminary Remedial Goal
PVC	polyvinyl chloride
RAGS	Risk Assessment Guidance for Superfund (USEPA)
RAO	Remedial Action Objectives
RBCA	Risk-Based Corrective Action
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
redox	oxidation reduction
RG	Remedial Goal
RGO	Remedial Goal Option
RI	Remedial Investigation
RME	reasonable maximum exposure
ROD	Record of Decision

ROI	radius of influence
RSL	regional screening level
SARA	Superfund Amendments and Reauthorization Act
SER	Sustainable Environmental Remediation
SOx	sulfur oxide
SRT	Sustainable Remediation Tool
SVOC	semivolatile organic compound
TBC	to-be-considered
TCE	trichloroethene
TNT	trinitrotoluene
TOC	total organic carbon
USEPA	United States Environmental Protection Agency
VC	vinyl chloride
VDEQ	Virginia Department of Environmental Quality
VFA	volatile fatty acid
VOC	volatile organic compound
WPNSTA	Naval Weapons Station
yd^3	cubic yard(s)

SECTION 1

Introduction and Background

This report presents the Feasibility Study (FS) for groundwater at Site 22, Naval Weapons Station (WPNSTA) Yorktown, in Yorktown, Virginia. This report was prepared under the United States Navy (Navy), Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic, Comprehensive Long-term Environmental Action—Navy (CLEAN) III, Contract N62470-02-D-3052, Contract Task Order 0220 for submittal to NAVFAC, the United States Environmental Protection Agency (USEPA), and the Virginia Department of Environmental Quality (VDEQ).

The FS was performed in accordance with the process outlined in the Navy's Environmental Restoration (ER) Program, which is consistent with the National Contingency Plan (NCP) and Section 120 of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) as amended by the Superfund Amendments and Reauthorization Act (SARA).

1.1 Objective and Approach

Previous investigations have identified potential human health risks associated with contamination in groundwater at Site 22. The nature and extent of contamination, human health risk assessment (HHRA), and ecological risk assessment (ERA) are documented in the Remedial Investigation (RI) Report for Groundwater at Site 22 (CH2M HILL, 2009). In response to these findings, this FS presents the remedial action objectives (RAOs) developed to protect human health and the environment, identifies applicable or relevant and appropriate requirements (ARARs) and to-be-considered (TBC) criteria, and develops and evaluates remedial alternatives to prevent unacceptable risk from exposure to site-related contaminants at Site 22.

1.2 Report Organization

This report consists of seven sections. Section 1 introduces the FS and summarizes the location and history of WPNSTA Yorktown and Site 22 including a description of the physical setting of the site. Section 2 includes background information, comprising a summary of previous investigations, nature and extent of contamination, fate and transport, and human health and ecological risks; and presents an overall conceptual site model (CSM) for Site 22. The ARARs, RAOs, and Remedial Goals (RGs) intended to adequately protect human health and the environment are discussed in Section 3. Section 4 presents the developed general response actions that address remedial action goals and that identify and screen the technology types and process options. This section includes a preliminary screening of technologies and presents the remedial action alternatives to be considered on the basis of the technologies identified for consideration in the screening step. A detailed evaluation of the remedial alternatives is presented in Section 5. Section 6 presents summaries, conclusions, and a recommended remedial action alternative for Site 22. Section 7 includes references used during preparation of this FS.

1.3 Yorktown Naval Weapons Station Description and History

This section presents a brief summary of the background and physical setting of WPNSTA Yorktown and a description of the general physical setting of the site.

WPNSTA Yorktown is a 10,624-acre installation located on the Virginia Peninsula in York and James City counties and the City of Newport News, Virginia (Figure 1-1). WPNSTA Yorktown is bounded on the northwest by WPNSTA Yorktown Cheatham Annex and the King's Creek Commerce Center; on the northeast by the York River and the Colonial National Historic Parkway; on the southwest by Route 143 and Interstate 64; and on the southeast by Route 238 and the town of Lackey.

Originally named the U.S. Mine Depot, WPNSTA Yorktown was established in 1918 to support the laying of mines in the North Sea during World War I. For 20 years after World War I, the depot continued to receive, reclaim, store, and issue mines, depth charges, and related materials. During World War II, the facility was expanded to include three trinitrotoluene (TNT) loading plants and new torpedo overhaul facilities. A research and development laboratory for experimentation with high explosives was established in 1944. In 1947, a quality evaluation laboratory was developed to monitor special tasks assigned to the facility, which included the design and development of depth charges and advanced underwater weapons. On August 7, 1959, the depot was renamed the U.S. Naval Weapons Station. Today, the primary mission of WPNSTA Yorktown is to provide ordnance, technical support, and related services to sustain the war-fighting capability of the armed forces in support of national military strategy.

1.4 Site 22 Description and History

Site 22, the Burn Pad, consists of a 9-acre area located south of Site 4 (Burning Pad Residue Landfill) and west of Site 21 (Battery and Drum Disposal Area) (Figure 1-2). Site 22 was used for burning waste explosives and spent solvents from loading operations from the early 1940s until 1995. The ash from the burned solvents and explosives was then transported to the landfill at Site 4. A historical photograph is included as Figure 1-3, which shows the numerous burn pads in a circular formation in the central and southern portion of Site 22. In 1996, a biocell was constructed at Site 22 and was used to remediate contaminated soil from other Installation Restoration (IR) sites at WPNSTA Yorktown. Use of the biocell ended in 1999 and it was subsequently removed (Figure 1-2). In addition, Site 22 is located inside an area encumbered by the Explosive Safety Quantity Distance (ESQD) and cannot be developed for real estate purposes.

Site 22 is on a flat, elevated plateau with its ground surface sloping steeply to the east, south, and southwest toward the Eastern Branch of Felgates Creek. An access road runs north-south along the west side of Site 4 and provides vehicle access to Site 22 from the north. Site 22 consists of a grassy field surrounded by woods.

Site 22 is situated along the Eastern Branch of Felgates Creek and its unnamed tributary. Felgates Creek is a tidally influenced tributary to the York River (Figure 1-2). Flow within the Eastern Branch of Felgates Creek reverses because of tidal fluctuation. Groundwater flow from Site 22 is predominantly to the south toward the Eastern Branch of Felgates Creek. A figure showing water table elevations and the approximate groundwater flow

direction is presented as Figure 1-4 and was previously submitted as Figure 6-7 within the Final RI Report for Groundwater at Site 22 (CH2M HILL, 2009). The depth to water at Site 22 is as shallow as 5.5 feet below ground surface (bgs) and is the shallowest on the southern portion of the site. Potentiometric surface measurements used in Figure 1-4 are presented in Table 1-1. Surface water runoff from Site 22 is directed toward the creek and its tributaries.

Based upon the Site 22 hydraulic characteristics of the geologic units, the following hydrogeologic units make up the aquifer system and are further discussed in Section 2.2 of the Final RI Report for Groundwater at Site 22 (CH2M HILL, 2009):

- Columbia aquifer
- Yorktown confining unit
- Yorktown-Eastover aquifer
- Eastover-Calvert confining unit

In the study area where Site 22 is located, unsaturated soils, which are lithologically consistent with the Columbia aquifer or Yorktown confining unit, are typically present at the ground surface. Where groundwater is present in the Columbia aquifer, the saturated thickness is only a few feet (CH2M HILL, 2009). Consequently, the uppermost saturated unit in this area is considered to be the Yorktown-Eastover aquifer, which lies below the 10- to 20-foot (ft) thick Yorktown confining unit. The Yorktown-Eastover aquifer consists of coarse, shelly, gray sands. The Yorktown-Eastover aquifer is approximately 80 ft thick in the vicinity of Site 22 and overlies the approximately 100- to 200-ft thick Eastover-Calvert confining unit. Further details in regard to the hydrogeology of Site 22 are presented in Section 2.2 of the Final RI Report for Groundwater at Site 22 (CH2M HILL, 2009).

TABLE 1-1
Site 22 Potentiometric Surface Measurements
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

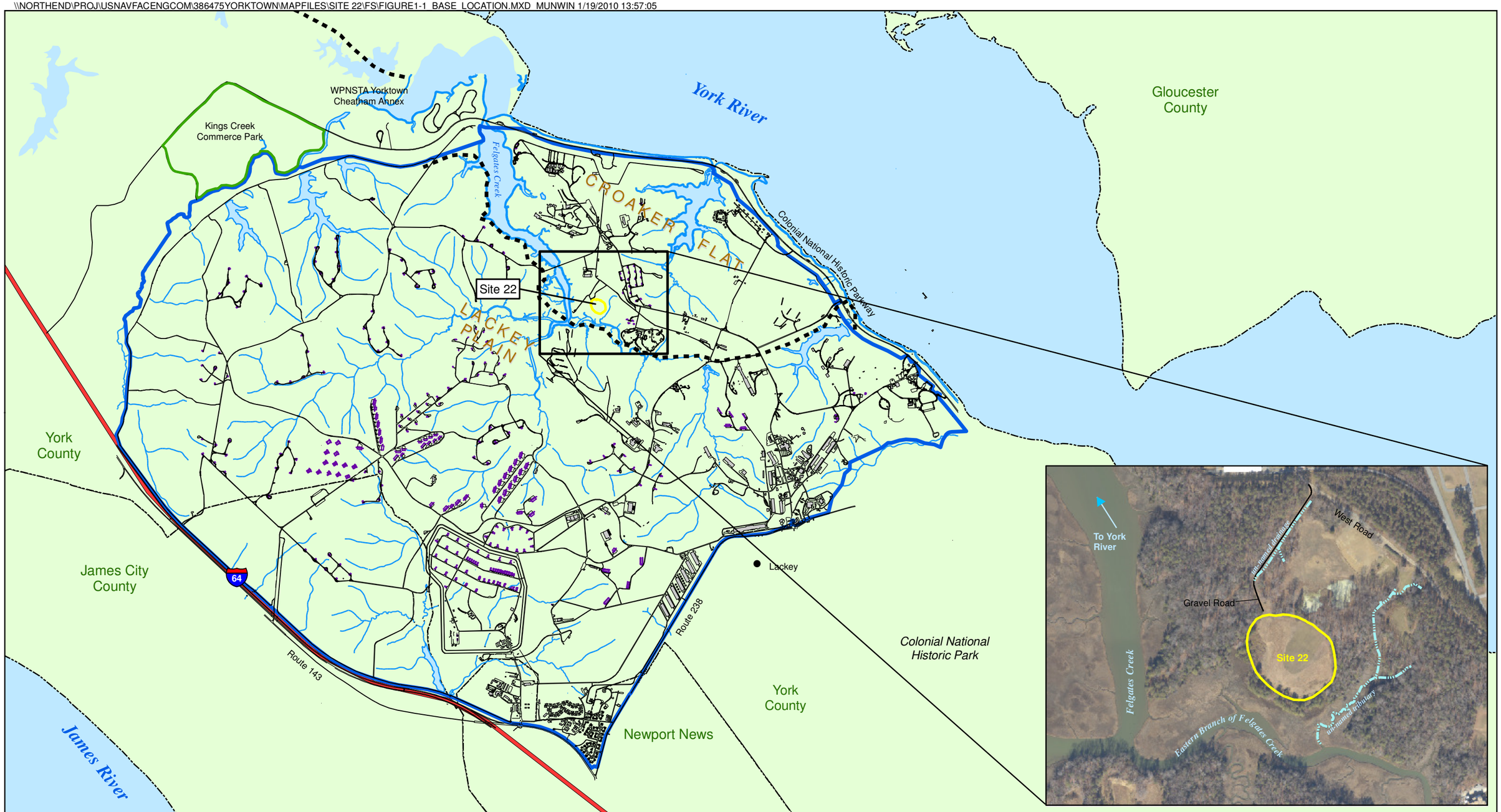
Monitoring Well ID	Date of Survey	Time of Survey	Depth to Bottom (feet)	Depth to Water (feet)	Monitoring Well Elevation (feet amsl)	Water Level Elevation (feet amsl)
YS22-GW01	01/14/08	15:10	25.70	17.95	23.03 [1]	5.08 [1]
YS22-GW01A	01/14/08	15:15	49.80	18.31	23.03 [1]	4.72 [1]
YS22-GW02	01/14/08	14:55	27.68	20.81	29.35 [1]	8.54 [1]
YS22-GW02A	01/14/08	14:50	87.45	23.88	Not Available [2]	Not Available [2]
YS22-GW03	01/14/08	15:30	27.11	19.10	24.91 [1]	5.81 [1]
YS22-GW03A	01/14/08	15:07	85.03	16.52	Not Available [2]	Not Available [2]
YS22-GW04	01/14/08	15:02	26.81	18.23	23.38 [1]	5.15 [1]
YS22-GW04A	01/14/08	15:00	89.50	23.76	Not Available [2]	Not Available [2]
YS22-GW05	01/14/08	15:23	28.18	18.14	23.51 [1]	5.37 [1]
YS22-GW05A	01/14/08	15:25	87.70	20.69	Not Available [2]	Not Available [2]
YS22-GW06	01/14/08	15:04	39.25	23.80	28.98	5.18
YS22-GW07	01/14/08	15:36	44.29	22.52	27.30	4.78
YS22-GW08	01/14/08	15:32	53.80	21.60	26.17	4.57
YS22-GW09	01/14/08	15:22	53.30	15.55	19.27	3.72
YS22-GW10	01/14/08	15:39	53.10	8.02	11.50	3.48
YS22-GW11	01/14/08	15:03	37.30	24.88	32.20	7.32

Notes:

1 - Elevations from shallow monitoring wells installed prior to 2007 were not used to generate contour lines on Figure 1-4 due to aberrant readings or questionable data.

2 - Measuring point elevation not surveyed since deep monitoring wells were installed to confirm MIP results.

\\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE1-1_BASE_LOCATION.MXD MUNWIN 1/19/2010 13:57:05



Legend

- Yorktown Naval Weapons Station Base Boundary
- Study Area*
- Buildings and Structures
- Interstate 64
- Magazines
- Shoreline and Water Bodies
- Camp Peary Scarp
- Kings Creek Commerce Center
- County Lines

*Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.

N

0 3,500 7,000 Feet

Figure 1-1
Base Location Map
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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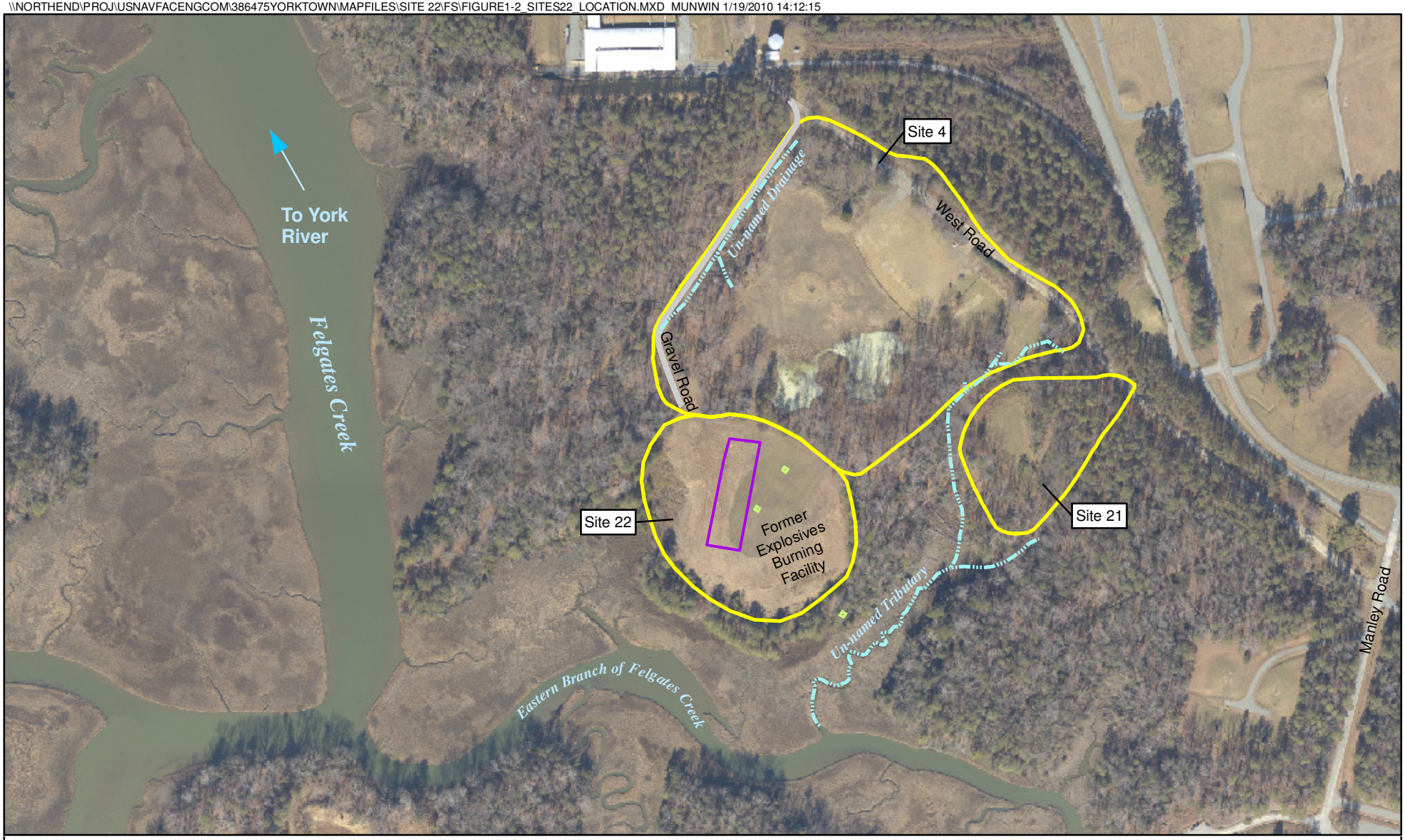
\\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE1-2_SITES22_LOCATION.MXD MUNWIN 1/19/2010 14:12:15



Legend

- Study Areas*
- Drainage
- Gravel Access Road
- Excavation Areas
- Former Biocell Location

*All study area boundaries are solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with a particular site.

N

0 175 350 Feet

Figure 1-2
Site 22 Location Map
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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Figure 1-3
Historical Photograph of Burn Pads at Site 22
Feasibility Study for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

*Source and date of photograph unknown.

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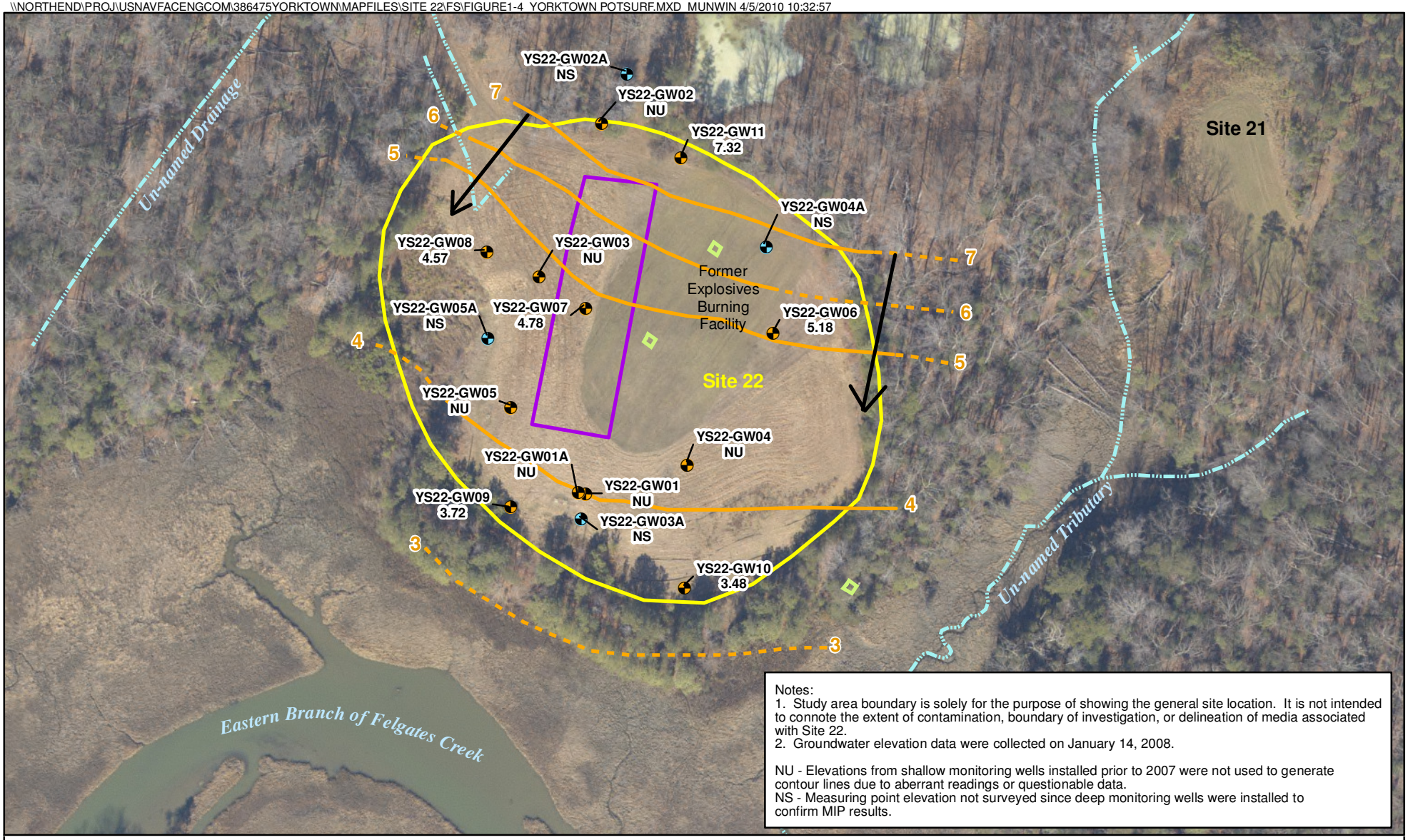
\\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE1-4_YORKTOWN POTSURF.MXD MUNWIN 4/5/2010 10:32:57



Notes:
1. Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
2. Groundwater elevation data were collected on January 14, 2008.

NU - Elevations from shallow monitoring wells installed prior to 2007 were not used to generate contour lines due to aberrant readings or questionable data.
NS - Measuring point elevation not surveyed since deep monitoring wells were installed to confirm MIP results.

Legend

- Study Area
- Excavation Areas
- Former Biocell Location
- Drainage
- Water Table Elevation (ft amsl)
- Shallow Monitoring Well
- Deep Monitoring Well
- Approximate Groundwater Flow Direction

N

0 75 150 Feet

Figure 1-4
Yorktown-Eastover Aquifer Potentiometric Surface Map
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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SECTION 2

Scope and Results of Environmental Investigation

The results of the investigation and risk assessments for these media to be addressed as part of this FS are presented in the Final RI Report (CH2M HILL, 2009) and summarized in the following subsections.

2.1 Previous Investigations

Several previous investigations have been conducted at Site 22, and their findings are included in the following documents:

- *Final Round Two Remedial Investigation Report, Sites 4, 21, and 22, Naval Weapons Station Yorktown* (Baker, 2001a) (including dioxin study)
- *Final Feasibility Study, Sites 4, 21, and 22, Naval Weapons Station Yorktown* (Baker, 2001b).
- *The Final Proposed Remedial Action Plan, Sites 4 and 22, Naval Weapons Station Yorktown* (Baker, 2001c)
- *Final Record of Decision for Site 22, Naval Weapons Station Yorktown, Yorktown, Virginia* (USEPA, 2003)
- *Final Remedial Investigation Report for Groundwater at Sites 4, 21, and 22, Naval Weapons Station Yorktown* (CH2M HILL, 2009)

During the preparation of the Round Two RI Work Plan for Sites 4 and 21, Site 22 was identified by the WPNSTA Yorktown partnering team as a potentially contaminated area (Baker, 2001a). Because of the past burning operations at Site 22 (refer to Section 1.4), the WPNSTA partnering team agreed to include Site 22 in the Round Two RI for Sites 4 and 21, even though it had not been investigated previously.

The results of the Round Two RI indicated the presence of chlorinated volatile organic compounds (VOCs), explosives, and metals in groundwater. Additionally, semivolatile organic compounds (SVOCs) and metals were detected in surface and subsurface soils at concentrations posing unacceptable risk to future human receptors. Ecological risks to terrestrial receptors were identified as related to metals in surface soils. Dioxins concentrations in site media were evaluated during a dioxin study completed in support of the RI, but concentrations were not detected at levels of concern during this study and no additional evaluation for dioxins was determined to be necessary.

Following completion of the Round Two RI, the WPNSTA Yorktown Partnering Team agreed to address groundwater, surface water, and sediment at WPNSTA separately from soil. The team progressed with evaluating remedial alternatives for soil while a remedy evaluation for groundwater was postponed. An FS was conducted for Site 22 in April 2001 to evaluate alternatives for soil at the site. The FS recommended excavation with offsite

disposal as the preferred alternative. The FS did not address groundwater at Site 22, nor surface water or sediment associated with Sites 4, 21, and 22 in the unnamed tributary to Felgates Creek or the Eastern Branch of Felgates Creek. The Proposed Remedial Action Plan (PRAP) was released for public review and comment in 2001. The proposed alternative for Site 22 soil in the PRAP was excavation with offsite disposal (Baker, 2001c).

The excavation and offsite disposal recommended in the FS and PRAP were conducted in fall 2002. Approximately 3,540 cubic yards (yd3) of soil exceeding the remediation goals were removed (Shaw, 2003) in the areas shown on Figure 1-2. Confirmation soil samples were collected from the excavations and were evaluated to have met remediation goals.

Based on the removal actions conducted and the confirmation sampling results, all potential human health and ecological risks in soil at Site 22 were mitigated, and a No Further Action (NFA) Record of Decision (ROD) was signed in September 2003 (USEPA, 2003).

Following completion of the removal action to address contaminated soil, additional investigations of groundwater, surface water, and sediment were initiated. The Final RI Report for these media at Site 22 was prepared and submitted to the WPNSTA Yorktown Partnering Team in November 2009 (CH2M HILL, 2009). The report recommended additional action to address groundwater. A detailed summary of findings from the Final RI Report for Groundwater (CH2M HILL, 2009) at Site 22 is included in Section 2.2 below.

2.2 Summary of Findings to Date

The following discussion provides an overview of the nature and extent, CSM, fate and transport, and risk assessment (human health and ecological) findings made during the Final RI Report for Groundwater (CH2M HILL, 2009) at Site 22.

2.2.1 Nature and Extent of Contamination

Various field activities were conducted in 2007 and 2008 as part of the RI to investigate the nature and extent of groundwater constituents at Site 22 and downgradient in the Eastern Branch of Felgates Creek. Field activities included a membrane interface probe (MIP) investigation and confirmation groundwater sampling. Electron capture device (ECD) response ranges from the MIP investigation are shown on Figure 6-3 in the Final RI Report for Groundwater at Site 22 (CH2M HILL, 2009). Where technically feasible, confirmation samples were collected using direct push technology (DPT) methods. Due to depth limitations of DPT, four deep monitoring wells were installed to collect vertical confirmation samples at the bottom 10 feet of the Yorktown-Eastover aquifer (approximately 85 feet bgs). No constituents of concern (COCs) were identified in any deep monitoring wells. Shallow monitoring well installation with groundwater sampling was also conducted as part of the RI.

Analytical Results

Thirteen VOCs were detected in groundwater within the upper portion of the Yorktown-Eastover aquifer at Site 22 from groundwater monitoring well sampling. Site-related COCs detected in groundwater are shown on Figure 2-1 (refer to Figure 6-8 in the Final RI Report for Groundwater at Site 22 for all VOCs detected). The primary VOCs detected consist of chlorinated VOCs. Trichloroethene (TCE) was detected in samples from 9 of the 12 shallow monitoring wells (maximum concentration of 650 micrograms per liter [µg/L] from YS22-

GW10). TCE concentrations in five monitoring wells exceeded the maximum contaminant level (MCL) (5 µg/L). Vinyl chloride (VC) was detected in samples from 2 of the 12 shallow monitoring wells (maximum concentration of 17 µg/L from YS22-GW10). Both detections of VC exceeded the MCL (2 µg/L). VOC concentrations are below respective 1 percent aqueous solubilities, indicating a dissolved phase plume with no dense non-aqueous phase liquid (DNAPL) present. Consistent with the MIP and DPT data, contaminants appear to be present in highest concentrations in a "corridor" that runs through the middle of the Site from north to south and also appear to extend to the Eastern Branch of Felgates Creek. Site 4 (refer to Figure 1-2) is considered to be the upgradient boundary of VOC contamination in groundwater. VOCs were not detected above applicable MCLs or regional screening levels (RSLs) in Site 4 monitoring wells, which are installed at comparable depths to those at Site 22. Five explosive compounds were detected in groundwater within the upper portion of the Yorktown-Eastover aquifer at Site 22 from groundwater monitoring well sampling. Site-related COCs detected in groundwater are shown on Figure 2-1(refer to Figure 6-8 in the Final RI Report for Groundwater at Site 22 for all explosive compounds detected). Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) was detected in samples from 10 of the 12 shallow monitoring wells (maximum concentration of 150 µg/L from YS22-GW04). All of the detections of RDX exceeded the RSL (0.61 µg/L). Explosives were generally distributed with highest concentrations in the central portion of the site surrounding the Burn Pads shown as Figure 1-3.

Numerous inorganic constituents were detected in groundwater within the upper portion of the Yorktown-Eastover aquifer at Site 22 from groundwater monitoring well sampling. However, concentrations were evaluated not to pose any additional risk except for total arsenic, which was detected at concentrations greater than the MCL. Concentrations of total and dissolved inorganics exceeding screening values are shown on Figure 6-9 in the Final RI Report for Groundwater at Site 22 (CH2M HILL, 2009).

Select geochemical and field parameters are shown on Figure 2-2 indicating that a range of oxidation-reduction (redox) conditions exist at the site, ranging from oxic to reducing. However, reducing conditions appear to be generally predominant throughout the site. Dissolved oxygen (DO) ranged from 0.6 to 2 milligrams per liter (mg/L), oxidation-reduction potential (ORP) varied widely throughout the site from -148 to 356 millivolts (mV), hydrogen (ion) concentration (pH) was slightly acidic with ranges from 4.03 to 6.99, with the lowest pH observed in the southwestern portion of the site, and specific conductivity ranged from 0.196 to 1.04 milliSiemens per centimeter (mS/cm).

2.2.2 Risk Assessment

Human Health Risk Assessment

The HHRA was conducted to evaluate the potential human health risks associated with groundwater at Site 22 (CH2M HILL, 2009). Because no current buildings are present onsite, exposures and risks through the vapor intrusion pathway were not quantified in the risk assessment. However, if a building is constructed at the Site, future evaluation of the vapor intrusion pathway should be performed. The only complete exposure pathway for current receptors is trespasser/visitor through exposure to surface water and sediment, but no risk was identified (CH2M HILL, 2009). No current exposure pathways to groundwater are

present at Site 22 because no groundwater is currently used as a potable or other water source.

TCE, heptachlor epoxide, VC, RDX, and arsenic were identified as human health COCs within the Yorktown-Eastover aquifer at Site 22 under a future exposure scenario. However, the Final RI Report (CH2M HILL, 2009) concluded that no additional action is required for heptachlor epoxide and arsenic. Even though arsenic was considered a human health COC under the reasonable maximum exposure (RME) scenario, concentrations of arsenic did not pose risk under the central tendency exposure (CTE) scenario, and dissolved concentrations did not exceed the MCL. Detections may be a result of geochemical conditions rather than a site-related source. Heptachlor epoxide was detected in a number of samples, but only one sample concentration (YS22-GW03 at 0.21 µg/L) slightly exceeded the MCL (0.2 µg/L). Concentrations of heptachlor epoxide at Site 22 suggest their presence is attributable to routine pesticide treatment activities by the base and not a Comprehensive Environmental Response, Compensation, and Liability Act (CERLCA)-related release.

Ecological Risk Assessment

No COCs were identified for surface water or sediment exposures at Site 22. Similarly, no COCs were identified for food web exposures. Thus, risks to ecological receptors are considered acceptable. NFA was recommended for ecological receptors at Site 22 (CH2M HILL, 2009).

2.2.3 Conceptual Site Model

This section focuses on the CSM (Figure 2-3) and fate and transport mechanisms for contaminants posing risk at Site 22. The CSM presents a conceptual depiction of the contaminant plumes and potential exposure pathways. The geology and hydrogeology are included to present a three-dimensional illustration of Site 22.

Sources of Contamination and Migration

The sources of contamination at Site 22 were releases of chemicals that occurred during waste handling and burning of materials on ground surface. No subsurface burial of materials at Site 22 are known to have occurred. Some of the contaminants that were released to the ground surface leached into the soil as a result of infiltration of surface water, causing downward migration of contamination into subsurface soil and ultimately creating a dissolved phase groundwater plume. Much of the contamination is expected to have remained relatively close to land surface due to adsorption to soil. The most highly contaminated soils at Site 22 have been previously removed. All contaminated soil and waste were excavated and disposed of offsite as part of soil remedies in fall 2002 (refer to Section 2.1). Contaminant concentrations in the groundwater of the Yorktown-Eastover aquifer at Site 22 are likely to decrease in the future because no source is present and there is currently no ongoing release mechanism.

The groundwater seepage velocity at the Site is approximately 0.128 ft/day (CH2M HILL, 2009). However, no contaminants are expected to migrate as rapidly as groundwater because of sorption to soil particles (retardation). Contaminants may also be migrating in groundwater through dispersion, which may slowly increase the size of the contaminant plume in groundwater. Volatilization of some contaminants from the groundwater into the

air is also a possible migration pathway where elevated concentrations of chlorinated solvents are present.

Fate and Transport of Contamination

TCE and VC TCE and its degradation product, VC, are present in Site 22 groundwater. The highest concentrations at the site were detected between 10 and 50 feet bgs along the central portion of the site in sandy soil with a number of silt and clay stringers that may be retarding the mobility of the contaminants. The primary mechanism for reductions in chlorinated VOC concentrations under naturally occurring conditions is degradation. Biodegradation of chlorinated ethenes is a well-understood process whereby these VOCs undergo biodegradation through two primary pathways: use as an electron acceptor by dehalorespiring organisms (reductive dechlorination) or by co-metabolism (a fortuitous destruction of contaminants by organisms intending to metabolize other organic compounds). Biological reductive dechlorination is a microbially mediated process in which chlorinated VOCs serve as the electron acceptor for metabolism, coupled with oxidation of an available electron donor. Reductive dechlorination results in the sequential replacement of a chlorine atom on the chlorinated VOC molecule with hydrogen and can ultimately lead to complete dechlorination to innocuous end-products, such as chloride and ethane. Another process whereby VC undergoes biodegradation is through direct intracellular oxidation by oxygen-dependent microbes, which can use the contaminant as an energy source.

Geochemical and microbial samples were collected from two wells at Site 22 (YS22-GW01 and YS22-GW04) during the RI (CH2M HILL, 2009). Results from these two locations suggest that the site exhibits reducing conditions, which are ideal for degradation of organic contaminants via reductive dechlorination. The reductive dechlorination process is facilitated by a number of species of microbes. However, the Dehalococcoides (DHC) species is the only microbe identified to be capable of degrading chlorinated ethenes completely to ethene. DHC was detected with a concentration of 1.34×10^1 J cells/milliliter (mL) in YS22-GW01. Degradation of chlorinated ethenes is an important mechanism of degradation at Site 22, as evidenced by the presence of TCE daughter products at the Site.

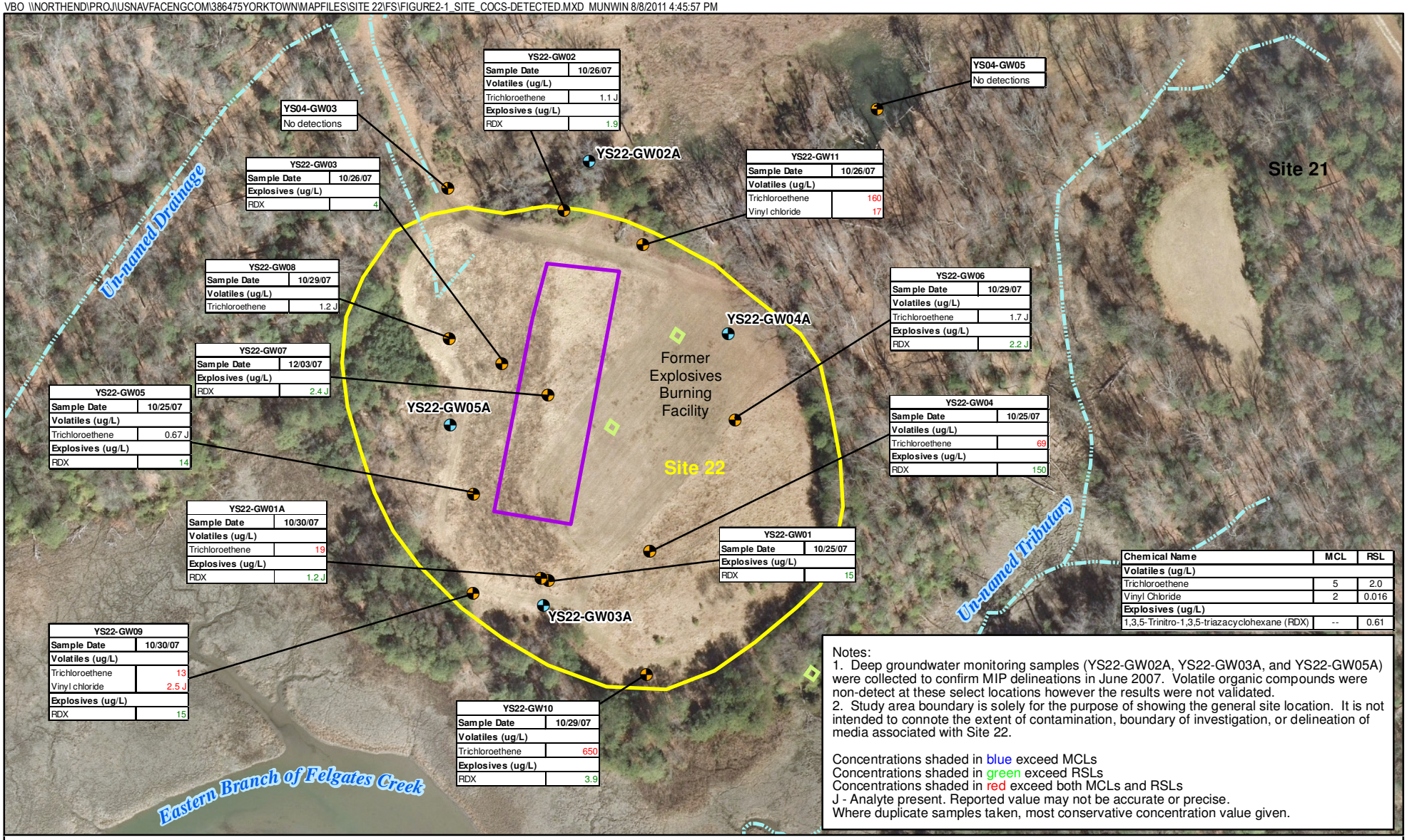
RDX The source of the RDX is most likely scattered minor releases from the burn activities previously conducted at the site. RDX can be biodegraded under most redox conditions and by a variety of microorganisms (Crocker et al., 2006). Three mechanisms for the degradation of RDX have been proposed: two-electron reduction, single-electron reduction/denitration, and direct enzymatic cleavage. The denitration pathway is considered the major pathway for biodegradation in the environment, resulting in the formation of benign products such as nitrite, ammonia, formaldehyde, and formic acid (Annamaria et al., 2010, Crocker et al., 2006). Under ideal (laboratory) conditions, the biodegradation rate for RDX is exponential, and could decay as much as 1 to 5 times in a day (half-lives of 0.2 to 1 day) (Fuller et al., 2010, Kwon and Finneran, 2008, Sherburne et al., 2005). Although there are limited case studies available for biodegradation of RDX in the field, bioremediation of RDX was successfully implemented at Sites 7 and 9 at the Former Naval Surface Warfare Center (NSWC) White Oak, Silver Spring, Maryland (CH2M HILL, 2011;2005) and the Iowa Army Ammunition Plant (Tetra Tech, 2010). Results have shown over 90 percent degradation of initial RDX concentrations ranging between 89 and 4,910 µg/L. RDX is not volatile and not

very mobile, therefore degradation is believed to be the primary attenuation mechanism for this chemical.

2.2.4 Conclusions

In the upper portion of the Yorktown-Eastover aquifer, TCE and VC in groundwater posed risk under future exposure scenarios and exceed MCLs. No MCL exists for RDX, but the concentrations pose risk under future exposure scenarios. COCs were not detected above MCLs or RSLs in the deep portion of the Yorktown-Eastover aquifer. Based on the conclusions of the *Final Remedial Investigation Report for Groundwater at Sites 4, 21 and 22* (CH2M HILL, 2009), additional remedial action is necessary to address TCE, VC, and RDX in the upper portion of the Yorktown-Eastover aquifer only. Remedial alternatives to address these three COCs are addressed in subsequent sections of this report.

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE2-1_SITE_COCS-DETECTED.MXD MUNWIN 8/8/2011 4:45:57 PM



Chemical Name	MCL	RSL
Volatiles (ug/L)		
Trichloroethene	5	2.0
Vinyl Chloride	2	0.016
Explosives (ug/L)		
1,3,5-Trinitro-1,3,5-triazacyclohexane (RDX)	--	0.61

Notes:
1. Deep groundwater monitoring samples (YS22-GW02A, YS22-GW03A, and YS22-GW05A) were collected to confirm MIP delineations in June 2007. Volatile organic compounds were non-detect at these select locations however the results were not validated.
2. Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.

Concentrations shaded in blue exceed MCLs
Concentrations shaded in green exceed RSLs
Concentrations shaded in red exceed both MCLs and RSLs
J - Analyte present. Reported value may not be accurate or precise.
Where duplicate samples taken, most conservative concentration value given.

Legend

- Study Area
- Excavation Areas
- Former Biocell Location
- Drainage
- Shallow Monitoring Well
- Deep Monitoring Well

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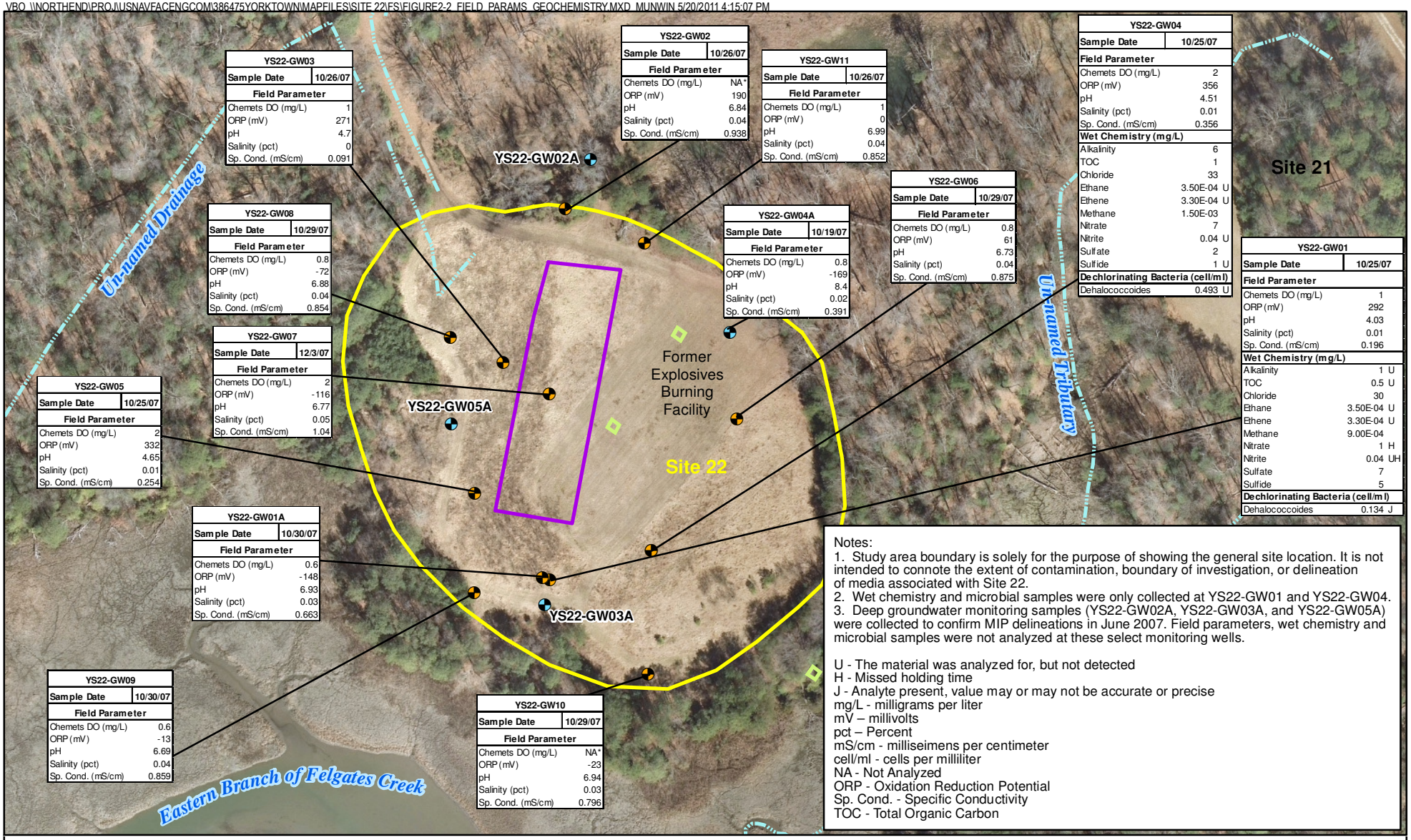
Figure 2-1
Site-Related COCs - Detected in Groundwater
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

CH2MHILL

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE2-2_FIELD_PARAMS_GEOCHEMISTRY.MXD MUNWIN 5/20/2011 4:15:07 PM



Notes:
1. Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
2. Wet chemistry and microbial samples were only collected at YS22-GW01 and YS22-GW04.
3. Deep groundwater monitoring samples (YS22-GW02A, YS22-GW03A, and YS22-GW05A) were collected to confirm MIP delineations in June 2007. Field parameters, wet chemistry and microbial samples were not analyzed at these select monitoring wells.

U - The material was analyzed for, but not detected
H - Missed holding time
J - Analyte present, value may or may not be accurate or precise
mg/L - milligrams per liter
mV – millivolts
pct – Percent
mS/cm - milliseimens per centimeter
cell/ml - cells per milliliter
NA - Not Analyzed
ORP - Oxidation Reduction Potential
Sp. Cond. - Specific Conductivity
TOC - Total Organic Carbon

Legend

- Study Area
- Excavation Areas
- Former Biocell Location
- Drainage
- Shallow Monitoring Well
- Deep Monitoring Well

*Readings were not collected by the field team at these locations due to improper readings from the DO meter.

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Figure 2-2
Field Parameters and Geochemistry Results
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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SECTION 3

Remedial Action Objectives and Applicable or Relevant and Appropriate Requirements

This section discusses the NCP and CERCLA objectives, and identifies the Site 22 RAOs and ARARs for the remedial action alternatives considered in this FS. This chapter presents general and site-specific RAOs and identifies corresponding ARARs for Site 22.

Because the site characterization and remediation process at WPNSTA Yorktown is being conducted in accordance with the guidelines established under CERCLA, the general RAOs are defined by the NCP and CERCLA as amended by SARA. CERCLA defines the statutory requirements for developing remedies. Site-specific RAOs relate to specific contaminated media and the potential exposure routes.

Site-specific RAOs, which require an understanding of the contaminants and the physical properties in their respective media, are based on an evaluation of the risks to public health and to the environment and evaluation of the ARARs.

Section 121(d) of SARA mandates that site remediation under CERCLA must achieve a level or standard of control for hazardous substances that at least attains such levels as specified in ARARs. Only promulgated Federal and State laws and regulations can be considered ARARs.

3.1 National Contingency Plan and Comprehensive Environmental Response, Compensation, and Liability Act Objectives

The NCP requires that the selected remedy meet the following objectives:

- Each remedial action selected shall be protective of human health and the environment [40 Code of Federal Regulations (CFR) 300.430 (f)(ii)(A)].
- Onsite remedial actions that are selected must attain those ARARs identified at the time of the ROD signature [40 CFR 300.430 (f)(ii)(B)].
- Each remedial action selected shall be cost-effective, provided that it first satisfies the threshold criteria set forth in §300.430(f)(1)(ii)(A) and (B). A remedy shall be deemed cost-effective if its costs are proportional to its overall effectiveness.
- Each remedial action shall use permanent solutions and alternative treatment technologies or resource-recovery technologies to the maximum extent practicable [40 CFR 300.430 (f)(ii)(E)].

The statutory scope of CERCLA was amended by SARA to include the following general objectives for remedial action at all CERCLA sites:

- Remedial actions "shall attain a degree of cleanup of hazardous substances, pollutants, and contaminants released into the environment and of control of further releases at a minimum which assures protection of human health and the environment" (Section 121(d)(1)).
- Remedial actions in which treatment that "permanently and significantly reduces the volume, toxicity, or mobility of the hazardous substances, pollutants, and contaminants is a principal element are to be preferred" (Section 121(b)(1)). If the treatment or recovery technologies selected is not a permanent solution, an explanation must be published (Section 121 (b)(1)(G)).
- The least-favored remedial actions are those that include "offsite transport and disposal of hazardous substances or contaminated materials without treatment" where practicable treatment technologies are available (Section 121(b)(1)).
- The selected remedy must comply with or attain the level of any standard, requirement, criteria, or limitation under federal environmental law or any promulgated standard, requirement, criteria, or limitation under a state environmental or facility siting law that is more stringent than any federal standard, requirement, criteria, or limitation (Section 121(d)(2)(A)).

3.2 Remedial Action Objectives

Both the level of contamination and the potential exposure routes are considered when developing medium-specific and site-specific RAOs for protecting public health and the environment.

Additional action is necessary to address site-related COCs of TCE, VC, and RDX within the groundwater at Site 22 (CH2M HILL, 2009). The RAOs for the protection of human health and the environment for groundwater are:

- To reduce contaminant concentrations in groundwater to established RGs for TCE, VC, and RDX.
- To maintain land use controls (LUCs) to prevent human (residential and construction worker) exposure to groundwater until risk-based RGs are met.
- To ensure groundwater concentrations are not increasing to levels that may pose unacceptable risk to ecological receptors in adjacent surface water bodies.
- The ESQD arc does not impact the overall RAOs for the site. The ESQD arc will be in effect as long as ordnance and munitions activities are being conducted at WPNSTA Yorktown. However, the RAO to maintain LUCs is necessary in the event that ordnance activities and development restrictions posed by the ESQD arc are discontinued at the Base.

3.3 Applicable or Relevant and Appropriate Requirements

As required by Section 121 of CERCLA, remedial actions carried out under Section 104 or secured under Section 106 must attain the levels of standards of control for hazardous substances, pollutants, or contaminants specified by the ARARs of federal and state environmental laws and state facility-siting laws, unless waivers are obtained. According to USEPA guidance, remedial actions should also be based on non-promulgated TBC criteria or guidelines if the ARARs do not address a particular situation.

ARARs are identified by USEPA as either being applicable to a situation or relevant and appropriate to it:

- "Applicable" requirements are standards and other environmental protection requirements of federal or state law dealing with a hazardous substance, pollutant, contaminant, action being taken, location, or other circumstance at a CERCLA site.
- "Relevant and appropriate" requirements are standards and environmental protection criteria of federal or state law that, although not "applicable" to a hazardous substance, pollutant, contaminant, action being taken, location, or other circumstance, address problems or situations sufficiently similar to those encountered at the CERCLA site that their use is well suited to the particular site. Once included in a Record of Decision, a requirement that is relevant and appropriate must be met as if it were applicable.

TBC criteria are non-promulgated advisories or guidance issued by federal or state government that are not legally binding, and do not have the status of potential ARARs. TBCs are evaluated along with ARARs and may be implemented by USEPA when ARARs are not fully protective of human health and the environment.

Onsite CERCLA response actions must meet substantive requirements but not administrative requirements. Substantive requirements deal directly with actions or with conditions in the environment. Administrative requirements implement the substantive requirements by prescribing procedures, such as fees, permitting, and inspection, that make substantive requirements effective. This distinction applies to onsite actions only; offsite response actions are subject to all applicable standards and regulations, including administrative requirements such as permits.

Three classifications of requirements are defined by USEPA in the ARAR determination process: chemical-specific, location-specific, and action-specific. These classifications are described below. The remedial action alternatives developed in this FS were analyzed for compliance with the potential federal and state ARARs which are presented in Appendix A.

Chemical-specific ARARs are health or risk management-based numbers or methodologies that result in the establishment of numerical values for a given medium that would meet the NCP "threshold criterion" of overall protection of human health and the environment. These requirements generally set protective cleanup concentrations for the COCs in the designated media or set safe concentrations of discharge for response activity. Federal and Commonwealth of Virginia chemical-specific regulations that have been reviewed are summarized in Appendix A.

Location-specific ARARs restrict response activities and media concentrations based on the characteristics of the surrounding environments. Location-specific ARARs may include restrictions on response actions within wetlands or floodplains, near locations of known endangered species, or on protected waterways. Since wetland areas adjacent to Site 22 will remain undisturbed during the remedial alternatives identified in this FS, ARARs associated with wetland and floodplains do not apply to Site 22. Federal and Commonwealth of Virginia location-specific regulations that have been reviewed are summarized in Appendix A.

Action-specific ARARs are usually technology- or activity-based requirements or limitations on actions taken with respect to hazardous substances. Federal and Commonwealth of Virginia action-specific ARARs that may affect the development and conceptual arrangement of response alternatives are summarized in Appendix A.

3.3.1 Development of Risk-Based Preliminary Remedial Goals

Preliminary Remedial Goals (PRGs) have been developed for site-related COCs (TCE, VC, and RDX) presenting a potential risk to human health under future exposure scenarios.

Human Health Remedial Goals

MCLs were established as the PRGs for TCE and VC in groundwater (5 µg/L and 2 µg/L, respectively). MCLs are considered to be protective and allow for unlimited use and unrestricted exposure. Because no MCL has been established for RDX, a risk-based PRG of 6 µg/L was calculated. The PRG was determined based on Remedial Goal Option (RGO) calculations (USEPA, 1991) which incorporated the ingestion, dermal absorption, and inhalation of volatiles and particulate pathways for future residents and the same exposure assumptions as the HHRA. Details of the calculation methods are presented in Appendix B. Since RDX is carcinogenic, the PRG was selected based on an incremental cancer target risk level of 10-5 and an HI of 1. The RGs for site-related COCs and corresponding groundwater concentrations are presented in Table 3-1.

Extent of Site-Related COCs Exceeding RGs

Groundwater isoconcentration contours for TCE and RDX are presented in Figure 3-1 and Figure 3-2. Contours are drawn to the RGs to the greatest extent possible. The laboratory detection limit for both VC and TCE was 10 µg/L, which is greater than the RGs for these constituents (2 µg/L and 5 µg/L, respectively). Available data for TCE were still sufficient to estimate the extent of the plume at levels greater than the RGs. However, sufficient data are not available to contour VC to the RGs because this chemical was not detected at 10 of the 12 shallow monitoring wells. The VC isoconcentration contours are assumed to be the same as TCE for evaluation within this report since the TCE plume extends across the entire length of the site and VC is a degradation product of TCE. Figure 3-3 displays the combined isoconcentration contours for TCE and RDX contoured to the RG for both constituents showing the total surface area (approximately 3.3 acres) exceeding RGs. This area exceeding RGs will be addressed in Section 4.1 with the assembly of remedial technologies into remedial action alternatives that achieve all remedial action goals.

TABLE 3-1
Groundwater Remedial Goals Exceedances
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Station ID	**RGs-Groundwater**	YS22-GW01		YS22-GW01A	YS22-GW02	YS22-GW03	YS22-GW04	YS22-GW05
Sample ID		YS22-GW01-1007	YS22-GW01P-1007	YS22-GW01A-1007	YS22-GW02-1007	YS22-GW03-1007	YS22-GW04-1007	YS22-GW05-1007
Sample Date		10/25/07	10/25/07	10/30/07	10/26/07	10/26/07	10/25/07	10/25/07
Chemical Name								
Volatile Organic Compounds (µg/L)								
Trichloroethene	5	10 U	10 U	19	1.1 J	10 U	69	0.67 J
Vinyl chloride	2	10 U	10 U	10 U	10 U	10 U	10 U	10 U
Explosives (µg/L)								
RDX	6	15	15	1.2 J	1.9	4	150	14

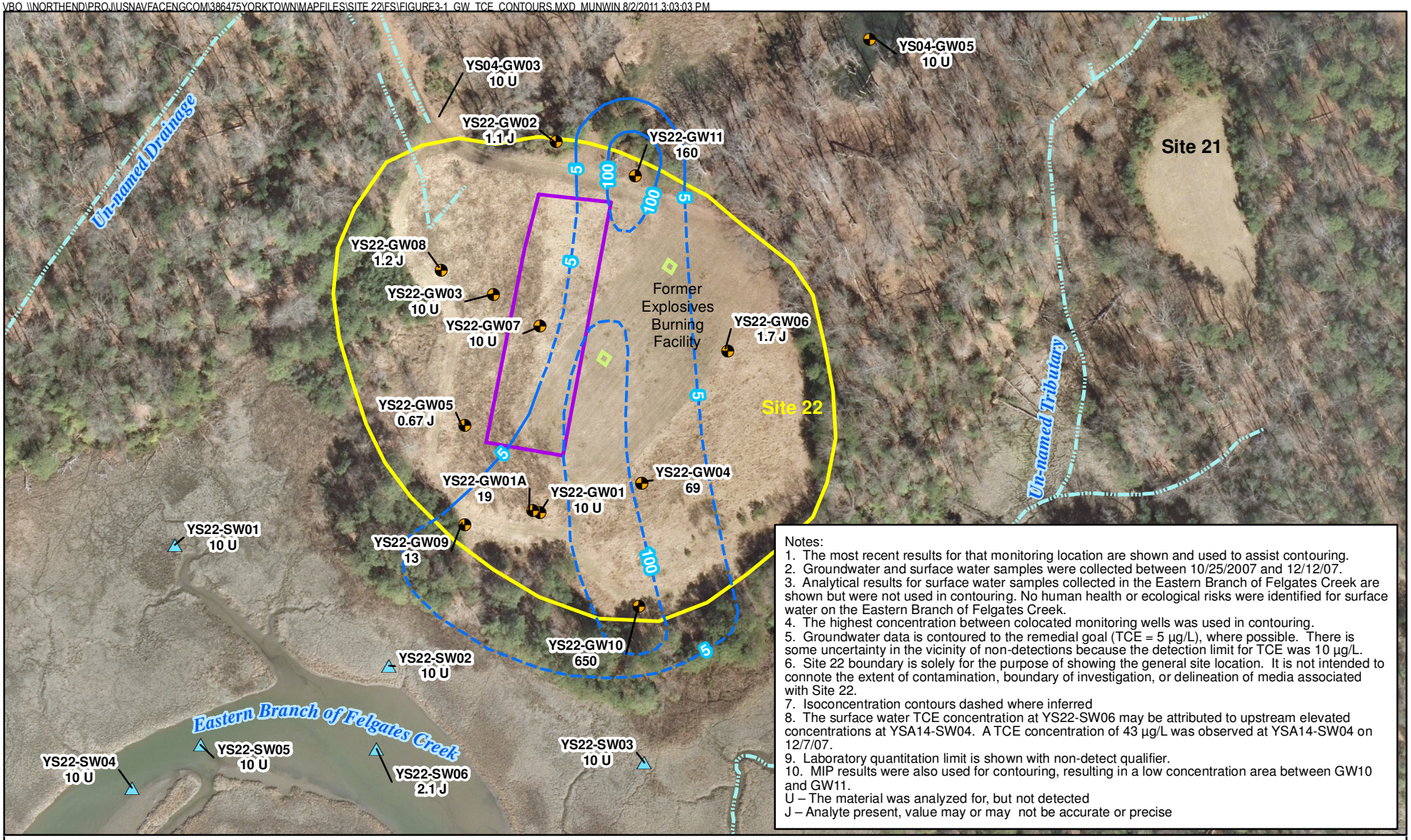
Station ID	**RGs-Groundwater**	YS22-GW06		YS22-GW07	YS22-GW08	YS22-GW09	YS22-GW10	YS22-GW11
Sample ID		YS22-GW06-1007	YS22-GW06P-1007	YS22-GW07-1207	YS22-GW08-1007	YS22-GW09-1007	YS22-GW10-1007	YS22-GW11-1007
Sample Date		10/29/07	10/29/07	12/03/07	10/29/07	10/30/07	10/29/07	10/26/07
Chemical Name								
Volatile Organic Compounds (µg/L)								
Trichloroethene	5	1.7 J	1.4 J	10 U	1.2 J	13	650	160
Vinyl chloride	2	10 U	10 U	10 U	10 U	2.5 J	10 U	17
Explosives (µg/L)								
RDX	6	2 J	2.2 J	2.4 J	0.24 U	15	3.9	0.25 U

Notes:

1. Shading indicates exceedance of Remedial Goals (RGs)
2. Maximum Contaminant Levels (MCLs) were established as the RGs for Trichloroethene and Vinyl Chloride.
3. Detailed RG calulations for RDX can be found in Appendix B.

J - Analyte present, value may or may not be accurate or precise
U - The material was analyed for, but not detected
µg/L - Micrograms per liter

VBO \\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE3-1_GW_TCE_CONTOURS.MXD MUNWIN 8/2/2011 3:03:03 PM



Notes:
1. The most recent results for that monitoring location are shown and used to assist contouring.
2. Groundwater and surface water samples were collected between 10/25/2007 and 12/12/07.
3. Analytical results for surface water samples collected in the Eastern Branch of Felgates Creek are shown but were not used in contouring. No human health or ecological risks were identified for surface water on the Eastern Branch of Felgates Creek.
4. The highest concentration between colocated monitoring wells was used in contouring.
5. Groundwater data is contoured to the remedial goal (TCE = 5 µg/L), where possible. There is some uncertainty in the vicinity of non-detections because the detection limit for TCE was 10 µg/L.
6. Site 22 boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
7. Isoconcentration contours dashed where inferred
8. The surface water TCE concentration at YS22-SW06 may be attributed to upstream elevated concentrations at YSA14-SW04. A TCE concentration of 43 µg/L was observed at YSA14-SW04 on 12/7/07.
9. Laboratory quantitation limit is shown with non-detect qualifier.
10. MIP results were also used for contouring, resulting in a low concentration area between GW10 and GW11.
U – The material was analyzed for, but not detected
J – Analyte present, value may or may not be accurate or precise

Legend

- Shallow Monitoring Well
- Surface Water Sample Locations
- Study Area
- Drainage
- TCE-Groundwater Isoconcentration Contour (µg/L)
- Excavation Areas
- Former Biocell Location

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Figure 3-1
TCE-Groundwater Isoconcentration Contours
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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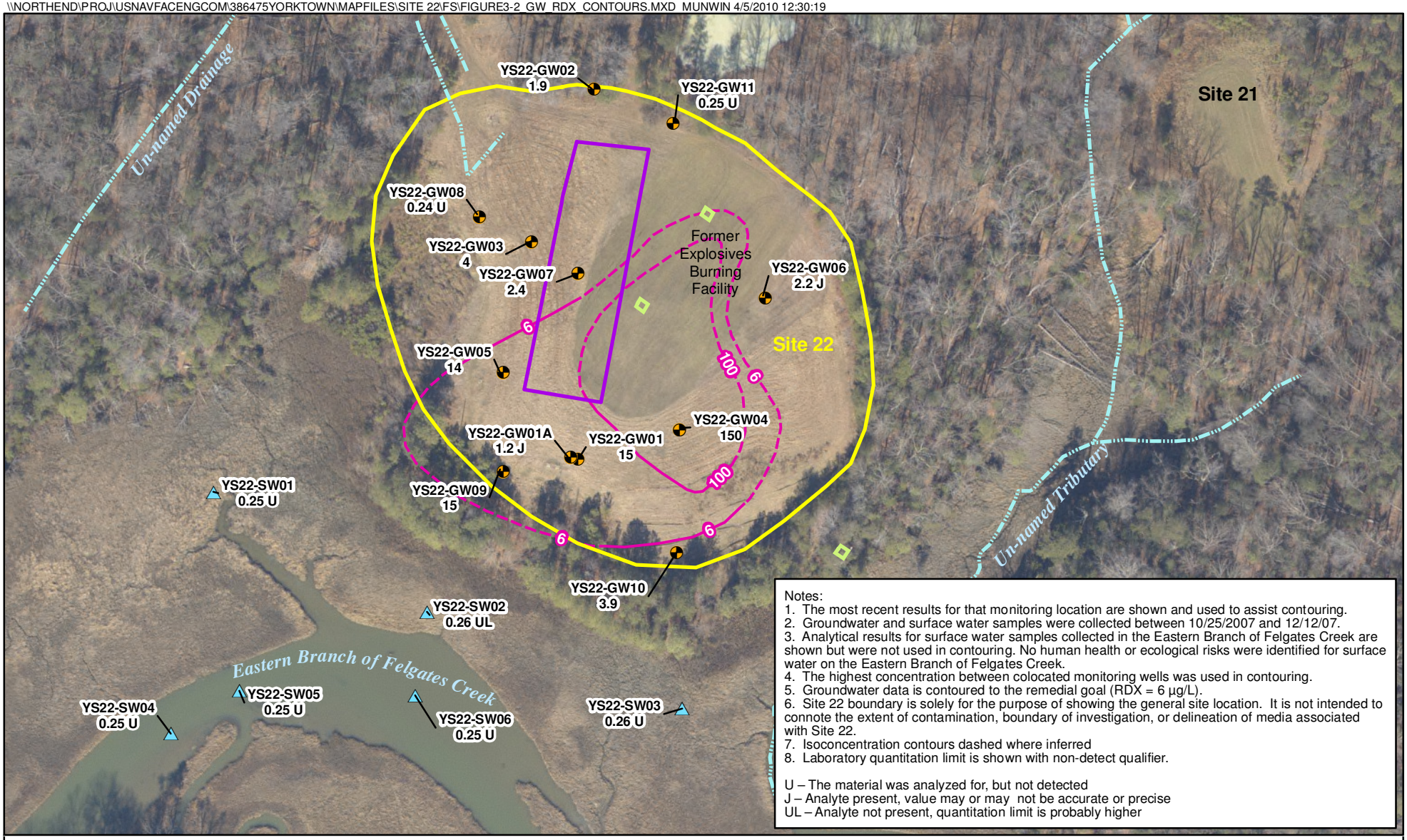
\\NORTHEND\PROJ\USNAVFACENGCOM\386475YORKTOWN\MAPFILES\SITE 22\FS\FIGURE3-2_GW_RDX_CONTOURS.MXD MUNWIN 4/5/2010 12:30:19



Notes:
1. The most recent results for that monitoring location are shown and used to assist contouring.
2. Groundwater and surface water samples were collected between 10/25/2007 and 12/12/07.
3. Analytical results for surface water samples collected in the Eastern Branch of Felgates Creek are shown but were not used in contouring. No human health or ecological risks were identified for surface water on the Eastern Branch of Felgates Creek.
4. The highest concentration between colocated monitoring wells was used in contouring.
5. Groundwater data is contoured to the remedial goal (RDX = 6 µg/L).
6. Site 22 boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
7. Isoconcentration contours dashed where inferred
8. Laboratory quantitation limit is shown with non-detect qualifier.

U – The material was analyzed for, but not detected
J – Analyte present, value may or may not be accurate or precise
UL – Analyte not present, quantitation limit is probably higher

Legend

- Shallow Monitoring Well
- Surface Water Sample Locations
- Study Area
- Drainage
- RDX-Groundwater Isoconcentration Contour (µg/L)
- Excavation Areas
- Former Biocell Location

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0 75 150 Feet

Figure 3-2
RDX-Groundwater Isoconcentration Contours
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

CH2MHILL

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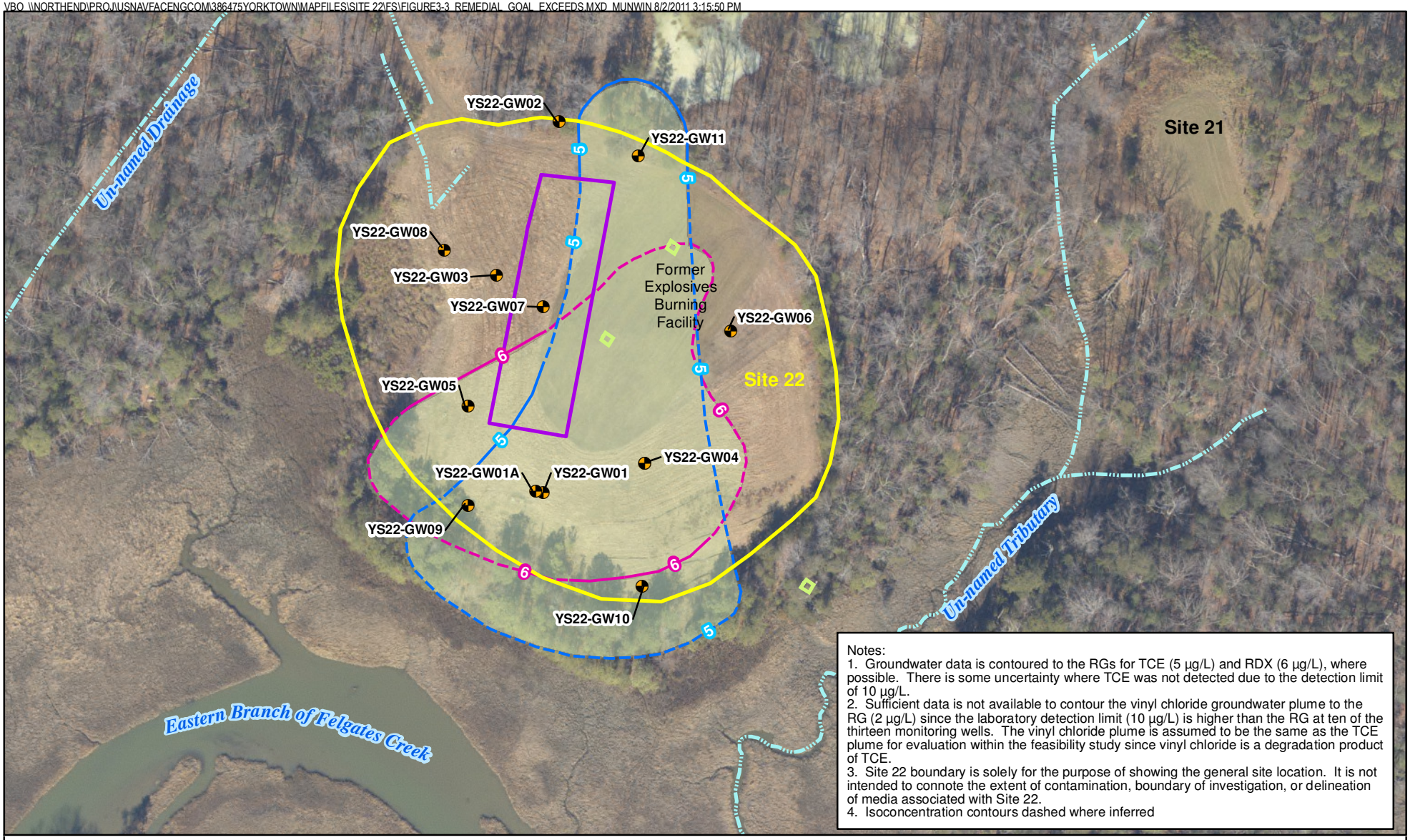

Notes:
1. Groundwater data is contoured to the RGs for TCE (5 µg/L) and RDX (6 µg/L), where possible. There is some uncertainty where TCE was not detected due to the detection limit of 10 µg/L.
2. Sufficient data is not available to contour the vinyl chloride groundwater plume to the RG (2 µg/L) since the laboratory detection limit (10 µg/L) is higher than the RG at ten of the thirteen monitoring wells. The vinyl chloride plume is assumed to be the same as the TCE plume for evaluation within the feasibility study since vinyl chloride is a degradation product of TCE.
3. Site 22 boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
4. Isoconcentration contours dashed where inferred

Legend

- Shallow Monitoring Well
- Study Area
- Drainage
- Excavation Areas
- Former Biocell Location
- TCE-Groundwater Isoconcentration Contour (5 ug/L)
- RDX-Groundwater Isoconcentration Contour (6 ug/L)
- Preliminary Remediation Goal Exceedances

N
W E
S

0 75 150
Feet

Figure 3-3
Remedial Goal Exceedances
Feasibility Study Report for Groundwater
at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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SECTION 4

Screening of Remedial Technologies and Development of Remedial Alternatives

To identify which technologies were best suited for use at Site 22 and to create remedial alternatives, all applicable technologies were evaluated. The evaluation process began by evaluating whether technologies can treat the site-related COCs and then screening candidate remedial technologies against three criteria: effectiveness, implementability, and relative cost. The technologies retained are used to develop a reasonable number of remedial alternatives. A remedial alternative may include a combination of technologies. Finally, the alternatives are assessed though a detailed comparative evaluation against the NCP criteria.

4.1 Screening of Remedial Technologies

Prior to developing potential remedial alternatives to address groundwater contamination at Site 22, potentially applicable groundwater remediation technologies were first screened.

The screening process incorporated the Navy's preference to select a remedy that would minimize impacts to current land use, meet proposed RAOs, and minimize the timeframes during which the treatment technology would have to be operated and maintained. The recent initiative by USEPA for consideration of sustainable environmental practices in remediation, which favors remedies with lower carbon footprints, was also incorporated. Technologies were divided into process options and screened based on their effectiveness, implementability, and cost. Table 4-1 summarizes the screening process and is color-coded for which technologies were not retained following screening. Technologies are placed through a two-phased screening process. The first phase assesses whether the technology is applicable for the contaminants and has the potential to work at the site. If a technology passes the primary screening, it is then evaluated for effectiveness, implementability and relative cost.

Only technologies that were retained following the secondary screening were brought forward to use in remedial alternatives. Technologies retained for use in remedial alternatives at Site 22 fall into several general response action categories. The general response actions listed below have been identified for Site 22:

- No Action
- In situ Treatment
- Monitoring

The No Action response is included in accordance with the NCP to serve as a baseline for evaluation of the remedial actions.

In situ treatment response actions are in situ methods of reducing the toxicity, mobility, volume, or mass of contaminants in groundwater. Treatment technologies include biological, chemical, or physical processes.

The Monitoring response action includes a groundwater sampling and analysis program to assess the behavior of contaminants over time, natural processes attenuating the contaminants, and performance of an active remediation.

Technologies retained for further consideration included those that have the potential to significantly reduce contaminant concentrations or complement the naturally occurring biodegradation of site-related COCs. Such technologies are cost-effective given the area exceeding RGs and the levels of contamination. The No Action response was retained as a baseline comparison of alternatives. The following technologies were retained:

- **In Situ Chemical Oxidation (ISCO) –** Retained based on effectiveness to treating site-related COCs in the target treatment area.
- **Enhanced In Situ Bioremediation (EISB) -** Retained based on effectiveness with site-related COCs. Additionally, site data suggests that reductive dechlorination of chlorinated VOCs may already be occurring. The addition of substrate will act to stimulate biodegradation of VOCs and RDX and maintain it in areas of elevated concentrations.
- **LUCs –** Retained based on relatively low cost and effectiveness in preventing direct contact between contaminants and potential receptors, provided controls are properly maintained.
- **Monitored Natural Attenuation (MNA) –** Retained based on its potential effectiveness from naturally occurring processes and resulting low capital and operations and maintenance (O&M) costs.

4.2 Development of Remedial Alternatives

Remedial alternatives were developed by combining technologies retained following the screening process presented in Table 4-1. To avoid evaluating an unmanageable number of alternatives, only the most logistically and technically sensible combinations for the given site conditions were carried forward. Four remedial alternative combinations were developed, providing a range of less-to-more aggressive technologies. All alternatives, with the exception of No Action, meet Site 22 RAOs. The alternatives are as follows:

4.2.1 Alternative 1 – No Action

Alternative 1 is the No Action alternative. Under this scenario, no remedial action would be undertaken at Site 22, and contaminants in groundwater would remain in place. Alternative 1 is required as a baseline for comparison of alternatives.

4.2.2 Alternative 2 – Hot Spot Removal of RDX using EISB and Associated Performance Monitoring; MNA of TCE, VC and RDX; and LUCs

Alternative 2 consists of a pre-design investigation to refine the CSM and the following remedial technology components which are described in further detail below.

- Implementing EISB of RDX using emulsified vegetable oil (EVO) bio-barriers perpendicular to groundwater flow in the target treatment area with RDX above 100 µg/L (Figure 4-1) to accelerate the total time for achieving RGs
- Using MNA for the dissolved TCE and VC plumes and the remaining dissolved RDX plume (< 100 µg/L) following active treatment
- Conducting periodic groundwater monitoring and synoptic groundwater level measurements
- Enforcing LUCs in the form of land and groundwater use restrictions until RGs are met

Based on the observed effectiveness of EISB at NSWC White Oak (CH2M HILL, 2011 and 2005) and the Iowa Army Ammunition Plant (Tetra Tech, 2010), no laboratory treatability studies or field pilot studies are assumed prior to full-scale implementation of Alternative 2.

Pre-Design Investigation

Prior to the final design of Alternative 2, a pre-design investigation is recommended to refine the lateral and vertical extent of RDX to identify the precise areas, depths, and lithologic units requiring treatment. The pre-design investigation is intended to reduce the target treatment area depicted in Figure 4-1. The only monitoring well with RDX concentrations above 100 µg/L in groundwater is YS22-GW04 (at 150 µg/L in 2007). Therefore, the target area shown in Figure 4-1 is likely conservatively drawn. By implementing a carefully designed field investigation, it may be possible to reduce by 50 percent the actual area and volume requiring EISB treatment.

For cost estimating purposes, the pre-design investigation is assumed to use 2-inch-diameter DPT rods to a maximum depth of 50 feet bgs. As many as four groundwater samples will be collected at each DPT location and sent offsite for RDX analysis to confirm the contaminant distribution. For this FS, it is assumed that the investigation would start with four DPT transects using 30-foot horizontal spacing, over the area of the 100 µg/L concentration contour, for a total of 30 locations. Additional transects may be needed if RDX concentrations along the perimeter of transects exceed 100 µg/L. A contingency of 20 percent was used in the costs for additional COC exceedances during delineation activities. Additionally, up to two soil samples will be collected during the pre-design investigation and analyzed for pH by titration to evaluate the buffering capacity and amount of sodium bicarbonate needed to adequately adjust the pH to optimize EISB injection performance.

Evaluation of EISB Substrates

Biodegradation of RDX can be enhanced by adding a suitable substrate to the subsurface. Under the anaerobic denitration pathway, a carbon source, other than the explosive compound on which the microorganisms can grow is required. EISB involves injecting insoluble or soluble substrates into the groundwater to facilitate biodegradation. The

description and evaluation of potential reagents for use at the site is provided in Appendix D where EVO was selected as the preferred substrate.

New Monitoring Well Installation and Surveying

Following the pre-design investigation, it is anticipated that additional wells will need to be installed to fill spatial data gaps at the site. For the purpose of this FS, it is assumed that three new wells will be required. Preliminary locations are shown on Figure 4-1, but may be modified based on the results of the pre-design investigation. Following installation, this alternative will likely require surveying of the new monitoring wells, as well as six existing shallow monitoring wells that were installed prior to 2007 and for which survey data appear to be slightly inaccurate.

Baseline Sampling

Prior to EISB treatment, a baseline sampling round will be performed for site groundwater. Three new and 12 existing shallow groundwater monitoring wells as well as one existing deep monitoring well will be monitored during this sampling round. Analytes will include site-related COCs and their degradation products (TCE, 1,1-VC, cis-dichloroethene [cis-DCE] and trans 1,2-DCE, VC, RDX, and ammonia) as well as geochemical parameters and sensitive metals (alkalinity, total organic carbon [TOC], nitrate, nitrite, sulfate, sulfide, methane, ethane, ethene, Fe, and Mn), and field water quality parameters (DO, ORP, pH, salinity, specific conductivity, temperature and turbidity). Sensitive metals are involved in biological redox reactions and include Fe and Mn. The presence of these metals in reduced form is an indication of iron- and manganese-reduction bioactivity and the overall redox conditions of the aquifer.

Full-scale EVO Injection and Performance Monitoring

EISB of RDX will be implemented in the target treatment area (Figure 4-1) by adding a suitable insoluble substrate to the subsurface. The substrate serves multiple purposes, including production of an electron donor source for biodegradation. Additionally, a pH buffer (either as a pre-buffered substrate, such as sodium bicarbonate, or as an additional injection) may be required to raise the existing groundwater pH, which ranges between 4.03 and 6.99 at shallow monitoring wells. This pH buffer would need to be applied locally only where bioactivity is being stimulated.

Upon completion of the pre-design investigation, a cost-effective and technically sufficient injection method will be determined (pneumatic fracturing, direct push, or permanent injection wells). For cost estimating purposes, it is assumed that EVO injection will be conducted by the installation of permanent injection wells. As previously stated, the target treatment area is considered to be conservatively drawn and the only monitoring well with RDX concentrations above 100 μg/L is YS22-GW04. Therefore, one bio-barrier would be placed directly upgradient of this monitoring well. Due to the uncertainty of the actual extent of the RDX high concentration area, two additional bio-barriers are assumed; one to the north and one to the south of this primary line. The southernmost bio-barrier would also help prevent further migration of the RDX plume. Within each bio-barrier, or transect line, the injection wells would be spaced approximately 20 feet apart. The radius of influence (ROI) of each injection point is assumed to be 10 feet. As shown on Figure 4-1, approximately 15 permanent injection locations are estimated for the target treatment area. The vertical target interval is assumed to be approximately 20 feet and extends from 20 to

40 feet bgs in the northern portion of the site and 30 to 50 feet bgs in the southern portion of the site. It is assumed that each location will have two co-located permanent injection wells, each with 10-foot screens to more effectively distribute the EVO to units with lower permeability across a 20-foot depth interval. Following installation of the injection well, each location will be surveyed by handheld geographic positioning system (GPS) units.

EVO injection pressure, flow rates, and injection solution concentration will be measured during EISB injection. Water levels, DO, conductivity, and ORP will be measured periodically in surrounding monitoring wells. It is assumed that approximately 7,880 lbs of EVO substrate would be injected into the treatment area during the first injection round. EVO would be diluted to an approximate 2 percent solution before injection to minimize impact to the hydraulic conductivity of the lithology. Performance monitoring within and surrounding the EISB injection area is important to ensure that effective and optimal conditions are established for the microorganisms. Because access to adequate water is not available, water associated with injection solution would likely be delivered to Site 22.

The FS conceptual design assumes that only one re-injection would occur based on the low concentrations of RDX observed at the site, although further injections may be required. The second injection would occur 2 years following the initial injection. For cost estimating purposes, it is assumed that the re-injection would only require treatment in 50 percent of the initial injection area. It is assumed that seven rounds of quarterly monitoring would be completed following the first injection and eight rounds of quarterly performance monitoring would be completed following the second round of injection, for a total of 16 rounds of performance monitoring (including baseline). Sample parameters will be the same as those described for the baseline sampling round, with the addition of volatile fatty acids (VFAs). It is assumed that all shallow site wells (new and existing) would be monitored during performance monitoring. Additionally, one existing deep site well would be monitored once every 2 years following the baseline sampling event, for a total of two sampling rounds during performance monitoring. Following the second injection performance monitoring, Alternative 2 would rely solely on MNA.

Monitored Natural Attenuation of VOCs and RDX

MNA refers to the reliance on natural processes to achieve RGs. Natural attenuation processes include a variety of physical, chemical, or biological processes that under favorable conditions act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in groundwater. These processes include biodegradation; dispersion; dilution; sorption; volatilization; and chemical or biological stabilization, transformation, or destruction of contaminants. Biodegradation pathways for chlorinated VOCs were discussed in Section 2.2.3.

Alternative 2 relies on natural and enhanced attenuation processes to achieve the RGs for TCE, VC, and RDX (< 100 µg/L). Reducing conditions predominantly present at the site are favorable for biologically mediated degradation of the chlorinated COCs and RDX. In addition, the RDX target treatment area may overlap with a portion of the TCE and VC plumes, resulting in enhanced biodegradation of these constituents within this area. Natural attenuation will continue under this alternative until the COC concentrations decline to below RGs.

Using site-specific TCE concentrations in 1996 and 2007, first-order decay rates were calculated for select monitoring wells and are summarized on Table 4-2. These site-specific decay rates were compared to theoretical rates to facilitate professional judgment in evaluating the timeframe to achieve the RAOs. Based on these assumptions, the estimated remediation timeframe to achieve the remediation goals for TCE under MNA is 34 years (Table 4-2). This is considered an order of magnitude estimate; because of uncertainties in the biodegradation rates, it may take more or less time than this to achieve the RGs.

The monitoring duration for Alternative 2 is planned for 34 years. The program would consist of monitoring the performance of EISB injections and MNA for the first 4 years as described above and only MNA for the remaining 30 years.

For this FS, it is assumed that all 12 existing shallow monitoring wells and the three proposed monitoring wells will be sampled annually. As part of the MNA program, downgradient monitoring wells will be evaluated to ensure that concentrations in these wells do not increase beyond the levels present during the RI and exceed Biological Technical Assistance Group (BTAG) screening values, which are protective of surface water and sediment. One existing deep monitoring well, located within the footprint of the contaminant plumes, will be sampled biennially to confirm that contaminants have not vertically migrated. Groundwater at each of the shallow and deep monitoring wells will be analyzed for site-related COCs and their degradation products (TCE, 1,1-DCE, cis 1,2-DCE and trans 1,2-DCE, VC, RDX, and ammonia). Groundwater from shallow monitoring wells will also be analyzed for geochemical parameters and sensitive metals (alkalinity, TOC, nitrate, nitrite, sulfate, sulfide, methane, ethane, and ethene), and field water quality parameters (DO, ORP, pH, salinity, specific conductivity, temperature, and turbidity). Six of the shallow monitoring wells located within the EISB target treatment area for RDX will additionally be analyzed for VFAs. The geochemical parameters and sensitive metals list will be evaluated based on sampling results after four years and may be reduced if site geochemical conditions are well understood. For cost estimating purposes it is assumed that geochemical parameters and sensitive metals will not be analyzed after 4 years.

Land Use Controls

Under Alternative 2, the site would be designated as a “restricted use” area in the base geographic information system (GIS). This designation would place controls on intrusive activities, such as excavation, residential development, or groundwater use. LUCs will also include language surrounding future evaluation of the vapor intrusion pathway if a building were constructed at the site. A Land Use Control Remedial Design (LUC RD) would be developed for the site. Records of the groundwater contamination would be kept in the base GIS/environmental database, if required. The restricted use designation would remain in place until groundwater monitoring indicates that RGs have been met. Since contaminants will remain in place, 5-year reviews would need to be completed.

4.2.3 Alternative 3 – Hot Spot Removal of RDX, TCE and VC using ISCO with Performance Monitoring; MNA of RDX, TCE and VC; and LUCs

Alternative 3 consists of a pre-design investigation to refine the CSM and the following remedial technology components and are described in further detail below:

- Implementing ISCO using permanganate (MnO4) in the active target treatment area with TCE and RDX above 100 µg/L (Figure 4-2) to accelerate the total time for achieving RGs
- Using MNA for the remaining dissolved plume (< 100 µg/L of TCE and RDX) and the target treatment area following active treatment
- Conducting periodic groundwater monitoring and water level measurements
- Enforcing LUCs in the form of land and groundwater use restrictions until RGs are met

No laboratory treatability studies or field pilot studies are assumed prior to full-scale implementation of Alternative 3.

Pre-Design Investigation

Prior to final design of Alternative 3, a pre-design investigation is recommended to refine the lateral and vertical extent of site-related groundwater COCs and to identify the precise areas, depths, and lithologic units requiring full-scale treatment. The pre-design investigation will be conducted similar to the method described in Section 4.2.3. However, since Alternative 3 will actively treat VOCs in groundwater, in addition to RDX, the investigation area is larger. For cost estimating purposes, it is assumed that the investigation will include four DPT transects using a 30-foot horizontal spacing, starting at YS22-GW11 and extending to YS22-GW10, for a total of 64 locations. Additional transects may be needed if TCE, RDX, or VC concentrations along the perimeter of transects exceed 100 µg/L. A contingency of 20 percent was used in the costs for additional COC exceedances during delineation activities. As many as four groundwater samples will be collected at each DPT location and sent offsite for TCE, VC, and RDX analysis to confirm the contaminant distribution.

Evaluation of Oxidants

ISCO is an aggressive technology used for the rapid treatment of a variety of organic contaminants in groundwater. It is based on the delivery of a chemical oxidant to contaminated media in order to oxidize chlorinated VOCs to innocuous compounds (carbon dioxide [CO_2], chloride ions, and hydrogen ions). Due to potentially high chemical cost, ISCO is typically implemented for the treatment of contaminated source areas. Generally, this technology may not be cost effective for large plumes with low contaminant concentrations because of the inherent limitations, challenges, and cost of delivering reagents to the subsurface over large areas. Common oxidants are catalyzed hydrogen peroxide (catalyzed hydrogen peroxide [CHP], which includes hydrogen peroxide-based Fenton's reagent), potassium or sodium permanganate, sodium persulfate, and ozone. The success of an ISCO remedy is a function of effective delivery, efficacious oxidants, and direct contact of the oxidant with the organics to be treated. The evaluation of potential oxidants

for use at the site is presented in Appendix D where permanganate was determined to be the preferred oxidant.

New Monitoring Well Installation and Surveying

Following the pre-design investigation, it is anticipated that additional wells will need to be installed to fill spatial data gaps at the site. For the purpose of this FS, it is assumed that three new wells will be required. Preliminary locations are shown on Figure 4-2, but may be modified based on the results of the pre-design investigation. Following installation, this alternative will likely require surveying of the new monitoring wells, as well as the six existing shallow wells that were installed prior to 2007 and for which data appear to be slightly inaccurate.

Baseline Sampling

Prior to ISCO injections, a baseline sampling round will be performed for site groundwater. Three new and twelve existing shallow groundwater monitoring wells as well as one existing deep monitoring well will be monitored during this sampling round. Analytes will include site-related COCs and their degradation products (TCE, 1,1-DCE, cis-DCE and trans 1,2-DCE, VC, RDX, and ammonia) as well as MnO_4 (colorimeter/ spectrophotometer field kit), sensitive inorganic constituents (alkalinity, TOC, nitrate, nitrite, sulfate, sulfide, methane, ethane, ethene, Fe, and Mn) and field water quality parameters (DO, ORP, pH, salinity, specific conductivity, temperature, and turbidity).

Full-scale Permanganate Injection

ISCO will be implemented in the target treatment area (Figure 4-2) by injection of permanganate. This target treatment area is estimated for treatment costing purposes and will be refined following the pre-design investigation. The results from a laboratory treatability test for permanganate was included in the Final RI Report for Site 22 (CH2M HILL, 2009).

Following the pre-design investigation, a cost-effective and technically sufficient injection method will be selected (pneumatic fracturing, direct push or permanent injection wells). For cost estimating purposes, it is assumed that direct push injections would be spaced approximately 15 feet apart in an off-set pattern for a full coverage of the target treatment area (including an approximate 20 percent overlap), which is assumed to be 24,655 square feet (ft^2) following the pre-design investigation. The ROI of each injection point is assumed to be 8 feet and will result in approximately 123 injection points. The target treatment area prior to the pre-design investigation is shown in Figure 4-2.

The vertical target interval is assumed to be 20 feet thick and extends from approximately 20 to 40 feet bgs in the northern portion of the target treatment area (near YS22-GW11) to 30 to 50 feet bgs in the southern portion of the target treatment area (near YS22-GW10). Previous investigations indicate contamination is deeper in the southern portion of the target treatment area than in the northern portion. The total mass of saturated soil and groundwater requiring treatment is approximately 493,100 cubic feet (ft^3). During the ISCO application, oxidant injection pressure, flow rates, and injection solution concentration will be measured. Water levels, color, permanganate (MnO_4) concentration, DO, conductivity, and ORP will be measured periodically in surrounding monitoring wells. Permanganate will be delivered at four 5-foot injection depths to cover the vertical treatment interval.

Assuming a 2 percent by weight $KMnO_4$ (potassium permanganate) solution, 299,269 gallons of oxidant solution would be delivered to the subsurface through 123 points. Following the ISCO application, each point will be surveyed by handheld GPS units. Water needed to produce the 2 percent $KMnO_4$ solution would be delivered, because access to adequate water for injection is not available onsite.

The FS conceptual design assumes that re-injection would occur once approximately 2 years after the first event for a total of two injections; however further injections may be required. For cost estimating purposes one re-injection round of ISCO (25,000 pounds) will treat 50 percent of initial injection area.

It is assumed that seven rounds of quarterly monitoring would be completed following the first injection and eight rounds of quarterly performance monitoring would be completed following the second round of injection, for a total of 16 rounds of performance monitoring (including baseline). Sample parameters will be the same as those described for the baseline sampling round. To monitor the performance of ISCO, MnO_4 (colorimeter/spectrophotometer field kit) and sensitive inorganic constituents will also be analyzed at the same frequency as the other sampling parameters. It is assumed that all shallow site wells (new and existing) would be monitored during performance monitoring. Additionally, one existing deep site well would be monitored once every two years following the baseline sampling event, for a total of two sampling rounds during performance monitoring. Following the second injection performance monitoring, Alternative 3 would rely solely on MNA.

Monitored Natural Attenuation

Alternative 3 relies on natural attenuation to achieve the RGs for TCE, VC, and RDX in areas where these COCs exhibit concentrations are above their RG and below 100 µg/L. Using site-specific TCE concentrations in 1996 and 2007, first-order decay rates were calculated for select monitoring wells (Table 4-2). These site-specific decay rates were compared to theoretical rates to facilitate professional judgment in determining the timeframe to achieve the RAOs. The alternative assumes that active remediation could reduce the concentrations of TCE and RDX within the target treatment area to below 100 µg/L, (VC is already below this concentration), within 4 years based on existing site conditions and professional experience. MNA will take an additional 21 years to achieve the closure criteria within the delineated plume. The estimated remediation timeframe to achieve the remediation goals and the proposed groundwater monitoring duration is 25 years based on these assumptions. This is considered an order of magnitude estimate; due to uncertainties in the biodegradation rates, it may take more or less time than this to achieve the RGs.

The monitoring duration for evaluating the remedy performance under Alternative 3 is planned for 25 years. The program would consist of ISCO performance monitoring during the first 4 years and MNA for the remaining 21 years. Monitoring during the 21 years of MNA will be completed annually for the same parameters and wells described for the baseline round of monitoring. For cost estimating purposes it is assumed that MnO_4 and sensitive inorganic constituents will not be analyzed after 4 years. The monitoring assumptions, including frequency, duration, and analyte list, are also included in the cost estimates (Appendix C).

Land Use Controls

For Alternative 3, it is also assumed that all LUC components of Alternative 2, as described in detail in Section 4.2.2, would be maintained to be protective of human health and the environment.

4.2.4 Alternative 4 – Hot Spot Removal of TCE, VC and RDX using EISB and Associated Performance Monitoring; MNA of TCE, RDX and VC; and LUCs

Alternative 4 consists of the following remedial technology components and are described in further detail below.

- Implementing EISB of RDX and VOCs using EVO bio-barriers perpendicular to groundwater flow in the target treatment area with TCE and RDX above 100 µg/L (Figure 4-3) to accelerate the total time for achieving RGs
- Using MNA for the remaining dissolved plume (< 100 µg/L of TCE and RDX) and the target treatment area following active treatment
- Conducting periodic groundwater monitoring and synoptic groundwater level measurements
- Enforcing LUCs in the form of land and groundwater use restrictions until RGs are met

No laboratory treatability studies or field pilot studies are assumed prior to full-scale implementation of Alternative 4.

Pre-Design Investigation

As described in Section 4.2.3, the identical pre-design investigation to Alternative 3 will refine the lateral and vertical extent of site-related groundwater COCs in the vicinity of the target treatment areas to identify the precise areas, depths, and lithologic units requiring full-scale treatment. Up to two soil samples will be collected during the pre-design investigation and analyzed for pH by titration to evaluate the buffering capacity and amount of sodium bicarbonate needed to adequately adjust the pH to optimize injection performance.

Evaluation of EISB Substrates

EISB involves injecting insoluble or soluble substrates into the groundwater to facilitate reductive chlorination. EISB of RDX will be implemented as presented in Section 4.2.2. For chlorinated VOCs, biodegradation via the reductive dechlorination pathway will be enhanced. Reductive dechlorination is a naturally occurring, microbially mediated, anaerobic process in which chlorine atoms on a parent VOC molecule are sequentially replaced with hydrogen. In the reductive dechlorination process, electrons are transferred from an electron donor source to the VOC 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 reductive dechlorination of many VOCs, and competing electron acceptors such as DO, nitrate, manganese (IV), and sulfate must be depleted.

EISB of chlorinated VOCs can be implemented via biostimulation and/or bioaugmentation. Biostimulation involves adding a suitable substrate (soluble or insoluble) to the subsurface. The introduced substrate serves multiple purposes, such as depletion of competing electron acceptors, creating strongly reducing conditions, and providing an electron donor source for reductive dechlorination. The substrate may also include nutrients, such as B12, which are used by the dechlorinating bacteria. Bioaugmentation is conducted using a microbial culture capable of reductively dechlorinating TCE and its daughter products, thereby preventing the accumulation of DCE or VC. Bioaugmentation is not necessary if a suitable population of the appropriate dechlorinating microbes is present.

The description and evaluation of potential substrates for use at the site is provided in Appendix D where EVO was selected as the preferred substrate.

New Monitoring Well Installation and Surveying

Following the pre-design investigation, it is anticipated that additional wells will need to be installed to fill spatial data gaps at the site. For the purpose of this FS, it is assumed that three new wells will be required. Preliminary locations are shown on Figure 4-3, but may be modified based on the results of the pre-design investigation. Following installation, this alternative will likely require surveying of the new monitoring wells, as well as the six existing shallow wells that were installed prior to 2007 and for which data appear to be slightly inaccurate.

Baseline Sampling

Prior to injections, a baseline sampling round will be performed for site groundwater. Three new and twelve existing shallow groundwater monitoring wells as well as one existing deep monitoring well will be monitored during this sampling round. Analytes will include site-related COCs and their degradation products (TCE, 1,1-DCE, cis-DCE and trans 1,2-DCE, VC, RDX, and ammonia) as well as geochemical parameters and sensitive metals (alkalinity, TOC, nitrate, nitrite, sulfate, sulfide, methane, ethane, ethane, Fe, Mn, and ammonia), and field water quality parameters (DO, ORP pH, salinity, specific conductivity, temperature and turbidity).

Full-scale EVO Injection and Performance Monitoring

Following the pre-design investigation, a cost-effective and technically sufficient injection method will be determined (pneumatic fracturing, direct push, or permanent injection wells). For cost estimating purposes, it is assumed that EVO injection will be conducted by the installation of permanent injection wells. Additionally, a pH buffer (either as a pre-buffered substrate, such as sodium bicarbonate, or as an additional injection) may be required to raise the existing groundwater pH, which ranges between 4.03 and 6.99 at shallow monitoring wells. This pH buffer would need to be applied locally only where bioactivity is being stimulated. The injection wells would be spaced approximately 20 feet apart along three transects in the target treatment area with TCE and RDX above 100 µg/L and perpendicular to groundwater flow for a full coverage of the target treatment area as shown in Figure 4-3. The vertical target interval is assumed to be approximately 20 feet, extends from 20 to 40 feet bgs in the northern-most bio barrier (near YS22-GW11), and plunges to 30 to 50 feet bgs in the southern-most bio barrier (near YS22-GW10). Based on the data collected during the RI, contamination is deeper in the southern portion of the site. The ROI of each injection point is assumed to be 10 feet. As shown on Figure 4-3, approximately

17 permanent injection locations are estimated for the target treatment area. It is assumed that each location will have two co-located permanent injection wells, each with 10-foot screens to more effectively distribute the EVO to units with lower permeability across a 20-foot depth interval. Following installation of the injection well, each location will be surveyed by handheld GPS units.

EVO injection pressure, flow rates, and injection solution concentration will be measured during EISB injection. Water levels, DO, conductivity, and ORP will be measured periodically in surrounding monitoring wells. It is assumed that approximately 8,930 pounds of EVO substrate would be injected into the treatment area during the first injection round. EVO would be diluted to an approximate 2 percent solution before injection to minimize impact to the hydraulic conductivity of the lithology. Because access to adequate water is not available, water associated with injection solution would likely be delivered to Site 22.

The FS conceptual design assumes that re-injection would occur approximately three times due to the level of TCE concentrations observed at the site. Injections would occur 2 years apart for a total of four injections, although further injections may be required. For cost estimating purposes, it is assumed that all re-injection rounds will require treatment in 50 percent of the initial injection area since concentrations of TCE and RDX within this area would not be below 100 µg/L.

The performance of EVO injections for the target treatment area would be monitored by sampling groundwater from the shallow site wells before, during, and after the injections. The monitoring events would consist of quarterly post-injection events for 24 months following each injection event. Additionally, one existing deep site well would be monitored once every 2 years following the baseline sampling event, for a total of two sampling rounds during performance monitoring. All constituents and parameters monitored during baseline monitoring will be analyzed at the same frequency with the addition of VFAs during the first 8 years to monitor the performance of EISB. Following active treatment and performance monitoring, Alternative 4 would rely solely on MNA.

Monitored Natural Attenuation

Alternative 4 relies on natural attenuation processes to achieve the RGs for TCE, VC, and RDX in areas where these exhibit concentrations are above their RG and below 100 µg/L. Using site-specific TCE concentrations in 1996 and 2007, first-order decay rates were calculated for select monitoring wells (Table 4-2). These site-specific decay rates were compared to theoretical rates to facilitate professional judgment in calculating the timeframe for achieving the RAOs. It is assumed that active remediation would reduce the concentrations of TCE and RDX within the target treatment area to below 100 µg/L (VC is already below this concentration) within 8 years based on existing site conditions and professional experience. Then MNA processes will take an additional 21 years to achieve the closure criteria within the delineated plume. The estimated remediation timeframe to achieve the RGs and the proposed groundwater monitoring duration is 29 years based on these assumptions. This is considered an order of magnitude estimate; as a result of uncertainties in the biodegradation rates, the time for achieving the RGs may be more than 29 years or less.

The monitoring duration for evaluating the remedy performance under Alternative 4 is planned for 29 years. The program would consist of monitoring the performance of EISB injections for the first 8 years and MNA for the remaining 21 years. Monitoring during the 21 years of MNA will be completed annually for the same parameters and wells described for the baseline round of monitoring. The geochemical parameters and sensitive metals list will be evaluated based on sampling results after four years and may be reduced if site geochemical conditions are well understood. For cost estimating purposes it is assumed that geochemical parameters and sensitive metals will not be analyzed after 8 years. Detailed monitoring assumptions are included in Appendix C.

Land Use Controls, Performance Monitoring, and Monitored Natural Attenuation

For Alternative 4, it is assumed that all LUC components of Alternative 2, as described in detail in Section 4.2.2, would be maintained to be protective of human health and the environment.

TABLE 4-1
Screening of Remedial Technologies
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening			Secondary Screening					
				Retain	Reject	Primary Screening Comments	Effectiveness	Implementability	Relative Cost	Retain	Reject	Secondary Screening Comments
No Action	None	N/A	No action provided.			Retained as baseline comparison.						Retained as baseline comparison
Institutional Control	Administrative Restrictions	Land Use Controls	Notices to prevent installation of wells in area exceeding MCLs. May also include restriction of future land use.	X		Although there are currently no groundwater uses onsite, a Land Use Control (LUC) will be required until the RGs are achieved.	Moderate to high. Can be effective in protecting human health and ecological receptors given consistent implementation.	Moderate to High. Requires working with the regulators and the base to establish well prohibition within and adjacent to the plume. Legal aspects can require extended timeframe.	Very low.	X		Retained for use site-wide.
Groundwater Containment	Physical Barriers	Slurry wall, sheet piling, vibrating barrier wall, etc.	Physical and/or chemical mechanism to create subsurface hydraulic barrier to prevent contaminated groundwater flow either horizontally or vertically.	X		Retained for use on downgradient edge of plume to prevent migration to off-site receptors	Moderate to high. Barriers are generally effective in protecting downgradient receptors for over 30 years.	Low. The downgradient edge of plume would require at least an 80 foot depth physical barrier and would require construction along steep slope in a marsh. Confining unit has not been encountered during prior drilling activities at the site.	Moderate. To achieve containment, the physical barrier system would also require a pump and treat system to maintain hydraulic control.		X	Rejected because topography at the site will not allow for a cost effective installation downgradient of the plume and contaminant concentrations are nominal for physical barriers to be an effective technology. No COCs were identified for surface water or sediment exposures and no further action was recommended for ecological receptors at Site 22.
	Hydraulic Barriers	Pump and Treat	A groundwater extraction/injection system that alters the natural hydraulic gradient to prevent contaminated groundwater flow either horizontally or vertically.	X		Retained for use on downgradient edge of plume to prevent migration to off-site receptors	Moderate to high. Although well, pump, or treatment system fouling can shut the system down, these barriers are typically very effective in protecting downgradient receptors.	Moderate. Construction considerations include supplying power to the site through the Explosive Safety Quantity Distance (ESQD) restricted area. Common construction technology(ies) may not be appropriate.	Moderate to high. No power at site. Would require long term operation. Requires treatment system for discharge to surface water or reinjection.		X	Rejected because constituent concentrations are nominal and hydraulic barriers would not be a cost effective technology at the site. No COCs were identified for surface water or sediment exposures and no further action was recommended for ecological receptors at Site 22.

TABLE 4-1
Screening of Remedial Technologies
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening			Secondary Screening					
				Retain	Reject	Primary Screening Comments	Effectiveness	Implementability	Relative Cost	Retain	Reject	Secondary Screening Comments
Groundwater Removal	Groundwater Extraction	Extraction Wells	Series of wells to extract contaminated groundwater.	X		Technically feasible. Requires little space for construction. Can also serve as hydraulic containment.	Moderate to high. Effective at hydraulic containment, but less effective for aquifer treatment. Likely to require a long timeframe to meet RGs in aquifer.	High. Easily implemented in area with moderate to high permeability.	Low to moderate. Requires treatment system for discharge to surface water or reinjection.		X	Rejected because contaminant concentrations are nominal for extractions wells to be an effective technology.
		Collection Trenches	Perforated pipe in trenches backfilled with porous media to collect water.	X		Retained because, though more expensive than wells, they offer greater assurance of hydraulic containment.	Moderate to high. More effective than wells for hydraulic containment in areas of very low or variable permeability. Likely to require a long timeframe to meet RGs in aquifer.	Low to high. Implementable at sites with shallow groundwater.	Moderate. Requires treatment system for discharge to surface water or reinjection.		X	Rejected because topography at the site will not allow for a cost effective installation downgradient of the plume and contaminant concentrations are nominal for collection trenches to be an effective technology.
		Skimmer Wells and Pumps	Mobile LNAPLs floating on top of the water table are extracted via pump. Mobile DNAPLs are extracted by pumps at the bottom of the well. Dual-pump systems may allow extraction of water and NAPLs.		X	Rejected because no mobile NAPL was identified.						
Groundwater Treatment (In-situ)	Chemical	Chemical Oxidation	Oxidant such as hydrogen peroxide, permanganate, or ozone is injected, which chemically oxidizes organic contaminants to less harmful compounds such as CO2 and H2O.	X		Potentially feasible but is highly site-specific.	Moderate. Theoretically effective, but requires good contact between contaminant and reagent. Aquifer heterogeneity would make uniform distribution difficult and would limit effectiveness. Natural oxidant demand was high (high oxidant dosage required) based on bench scale testing of potassium permanganate.	Moderate. Injection methodologies are improving, difficult to achieve good mixing in situ.	Moderate. Cost-effectiveness in proper situations. Oxidation not cost-effective on dilute dissolved VOC plumes.	X		Retained for use in the target treatment zones.
		Surfactant Flushing	Chemical injection, e.g. surfactant, to dissolve residual DNAPL pool into aqueous solution. Series of wells screened in the lower part of the water-bearing unit to extract localized residual DNAPLs in the groundwater.		X	Rejected because no DNAPL was identified.						

TABLE 4-1
Screening of Remedial Technologies
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening			Secondary Screening					
				Retain	Reject	Primary Screening Comments	Effectiveness	Implementability	Relative Cost	Retain	Reject	Secondary Screening Comments
Groundwater Treatment (In-situ) (continued)		Reactive Barrier	Treats groundwater plume as it passes through a permeable reactive zone. Reactive zone may be a combination of physical, chemical, and biological processes. May also include measures, such as low-permeability barriers, to channel groundwater towards treatment zone. Zero valent iron, for chemical reductive dechlorination, is the most commonly applied reactive media.	X		Can be effective in treating VOCs and metals insitu.	Moderate to high. Effective in treating VOCs and metals. Iron media may foul after some time (10 to 30 years) and require replacement.	Moderate to low. Required depth of installation makes impllementation more difficult at site. In addiiton, site topography will make downgradient installation difficult.	Moderate to high. Costs include wall construction, iron media purchase, trench soils disposal and periodic media replacement.		X	Rejected because topography at the site will not allow for a cost effective installation downgradient of the plume and contaminant concentrations are nominal for physical barriers to be an effective technology. No COCs were identified for surface water or sediment exposures and no further action was recommended for ecological receptors at Site 22.
	Physical Treatment	Air Sparging/Soil Vapor Extraction (AS/SVE)	Air injected into groundwater through a system of wells or horizontal perforated pipes to remove volatile compounds. May be combined with soil-vapor extraction to collect VOCs in the vadose zone.		X	Proven for treatment of VOCs but not expected to be effective for RDX.						
	Physical Treatment	Heating	The subsurface is heated using hot water/steam injection or six phase/radio frequency to enhance volatilization of contaminants. The volatilized contaminants rise to the unsaturated zone and are removed by vacuum extraction and treated. Used for NAPL source zones.		X	Rejected due to lack of NAPL at site and potential presence of explosive compounds and the site location within an Explosive Safety Quantity Distance (ESQD) restricted area.						
		Dual Phase Extraction	A groundwater collection system is used to lower the water table to expose contaminated soil. Soil vapor extraction is then used to removed absorbed or trapped contaminants. Used for NAPL source zones.		X	Rejected due to lack of NAPL.						
	Biological Treatment	Enhanced Aerobic Bioremediation	Stimulation of indigenous microorganism to degrade the contamination by injecting nutrient, oxygen, substrates, or engineered microorganisms.		X	Rejected because aerobic degradation of TCE is inefficient compared to anaerobic means. Also not applicable to RDX.						

TABLE 4-1
Screening of Remedial Technologies
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

General Response Action	Remedial Technology	Process Options	Description	Primary Screening			Secondary Screening					
				Retain	Reject	Primary Screening Comments	Effectiveness	Implementability	Relative Cost	Retain	Reject	Secondary Screening Comments
Groundwater Treatment (In-situ) (continued)		Enhanced In Situ Bioremediation (anaerobic bioremediation)	Use of a substrate such as Hydrogen Releasing Compound (HRC), vegetable oil, or molasses to promote biodegradation of organic compounds . Also may involve the use of nutrients or engineered microorganisms to promote biodegradation.	X		Effective in expediting remediation of chlorinated VOCs and RDX over natural attenuation.	Moderate to high. Proven to be effective for chlorinated ethenes and RDX. Less effective in soils of variable permeability because it is difficult to obtain even distribution of substrate.	Moderate to high. Easily implemented, but challenging to obtain good distribution of amendment into the contaminated aquifer. May also require pH buffering.	Low to moderate. It is typically considered a cost-effective alternative, but depends greatly upon the amount of substrate required. Bench-scale tests are not typically required or performed.	X		Retained for treatment of groundwater. Although the current groundwater data suggests that reductive dechlorination of chlorinated VOCs is occurring, addition of substrate will act to stimulate it and induce biodegradation of RDX.
		Monitored Natural Attenuation	Natural attenuation processes such as dilution, biotransformation, volatilization, adsorption, and dispersion coupled with regular monitoring for chemicals of concern as well as a range of indicators of biodegradation.	X		Natural attenuation may be occurring in the groundwater and may be sufficient to continue to remediate the plume and prevent risks from occurring.	Low to moderate. Effective for sites such as this where there are no unacceptable current risks and future risks are minimal.	High. Easily implemented, only monitoring would be required to monitor the progress.	Low. Costs would only include any additional monitoring locations and annual events.	X		Retained. May be used as a remedial alternative or as a long term option following treatment of targeted zones.
		Phytoremediation	Use of plants to remove, stabilize, or destroy contaminants in shallow soil or groundwater.		X	Rejected because depth of contaminated groundwater is greater than the maximum rooting depth for most plants.						

Notes:
Technologies in darker areas are rejected in primary or secondary screening.
RGs - Remedial Goals
COC - constituent of concern
N/A - not applicable

TABLE 4-2
Site-Specific TCE Decay Rates and Estimated Remediation Timeframes
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Monitoring Well ID	TCE Concentration (μg/L) 1996	TCE Concentration (μg/L) 2007	TCE Rate Constant (μg/L per day)	Alternative	Time to Achieve RAOs (Years)
YS22-GW01	14 J	10 U	-8.00E-05		
YS22-GW01A	27	19	-9.00E-05		
YS22-GW02	10 U	1.1 J	-6.00E-04		
YS22-GW03	10 U	10 U	Non-detect		
YS22-GW04	1200	69	-7.00E-04		
YS22-GW05	25 U	0.67 J	-9.00E-04		
		Average Detected*	3.95E-04		
				Alternative 2	34
				Alternative 3	25
				Alternative 4	29

Notes:
1. The average detected TCE decay rate is the average value calculated for monitoring wells YS22-GW01A and -GW04.
2. Alternative 2 includes MNA of TCE, Alternative 3 includes ISCO of TCE, and Alternative 4 includes EISB of TCE.
3. The time to achieve RAOs is based on a PRG of 5 μg/L, the average detected decay rate, and the current highest TCE concentration at the site (650 μg/L). Alternative 2 assumes no additional decay of TCE while Alternatives 3 and 4 assume TCE will be degraded to a concentration of 100 μg/L after 4 and 8 years, respectively.

EISB - enhanced in situ bioremediation
ISCO - in situ chemical oxidation
μg/L - micrograms per liter
MNA - monitored natural attenuation
PRG - preliminary remedial goal
RAO - remedial action objective
TCE - trichloroethene

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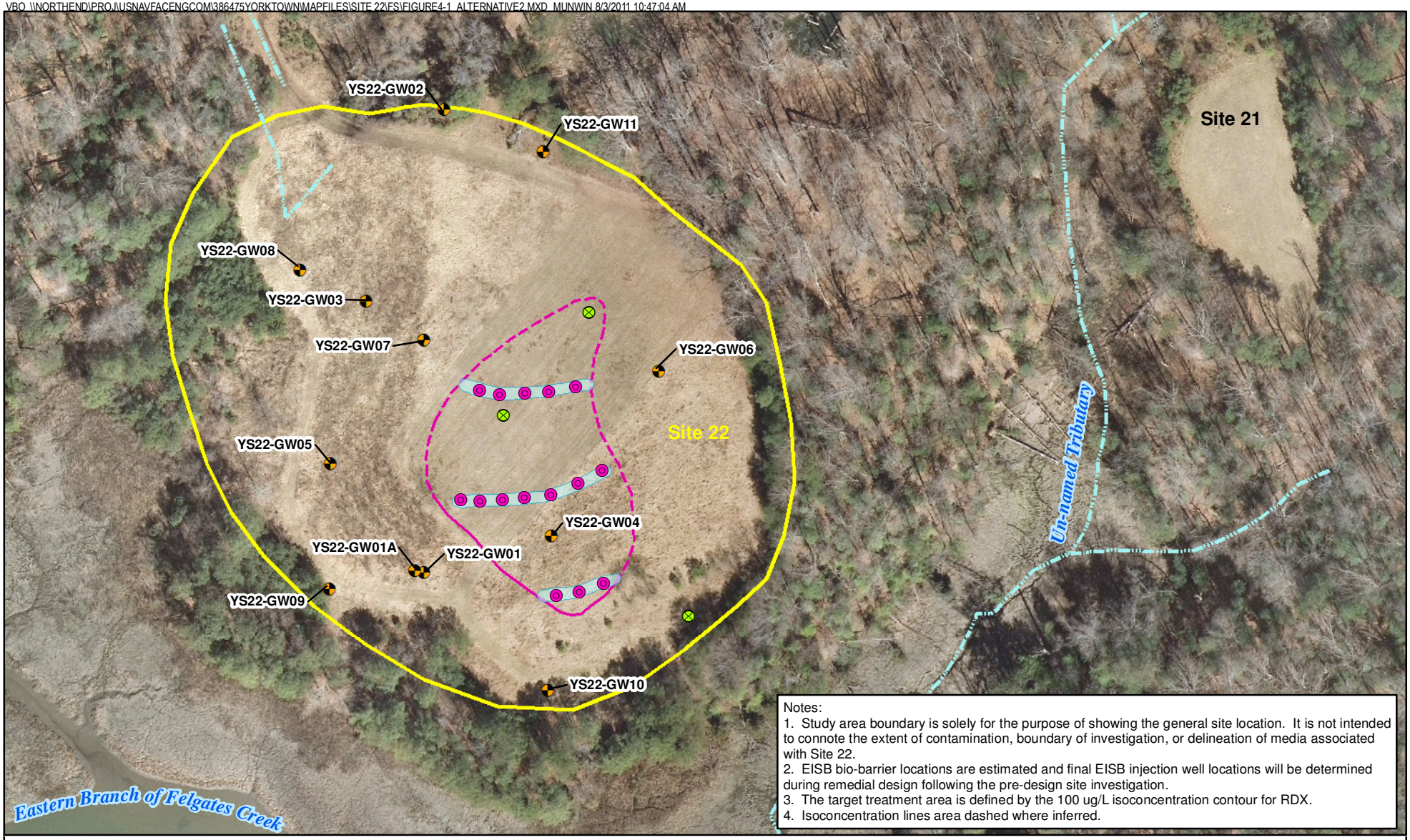

Notes:
1. Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
2. EISB bio-barrier locations are estimated and final EISB injection well locations will be determined during remedial design following the pre-design site investigation.
3. The target treatment area is defined by the 100 ug/L isoconcentration contour for RDX.
4. Isoconcentration lines area dashed where inferred.

Legend

- Shallow Monitoring Well
- Proposed Monitoring Well (Locations may be changed following the Pre-Design Investigation)
- Injection Locations
- Study Area
- EISB Biobarrier
- Drainage
- RDX-Groundwater Isoconcentration Contour (100 µg/L)

N
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S

0 60 120
Feet

Figure 4-1
Alternative 2 - Hot Spot Removal of RDX using EISB and Associated Performance Monitoring; MNA of TCE, VC, and RDX; and LUCs
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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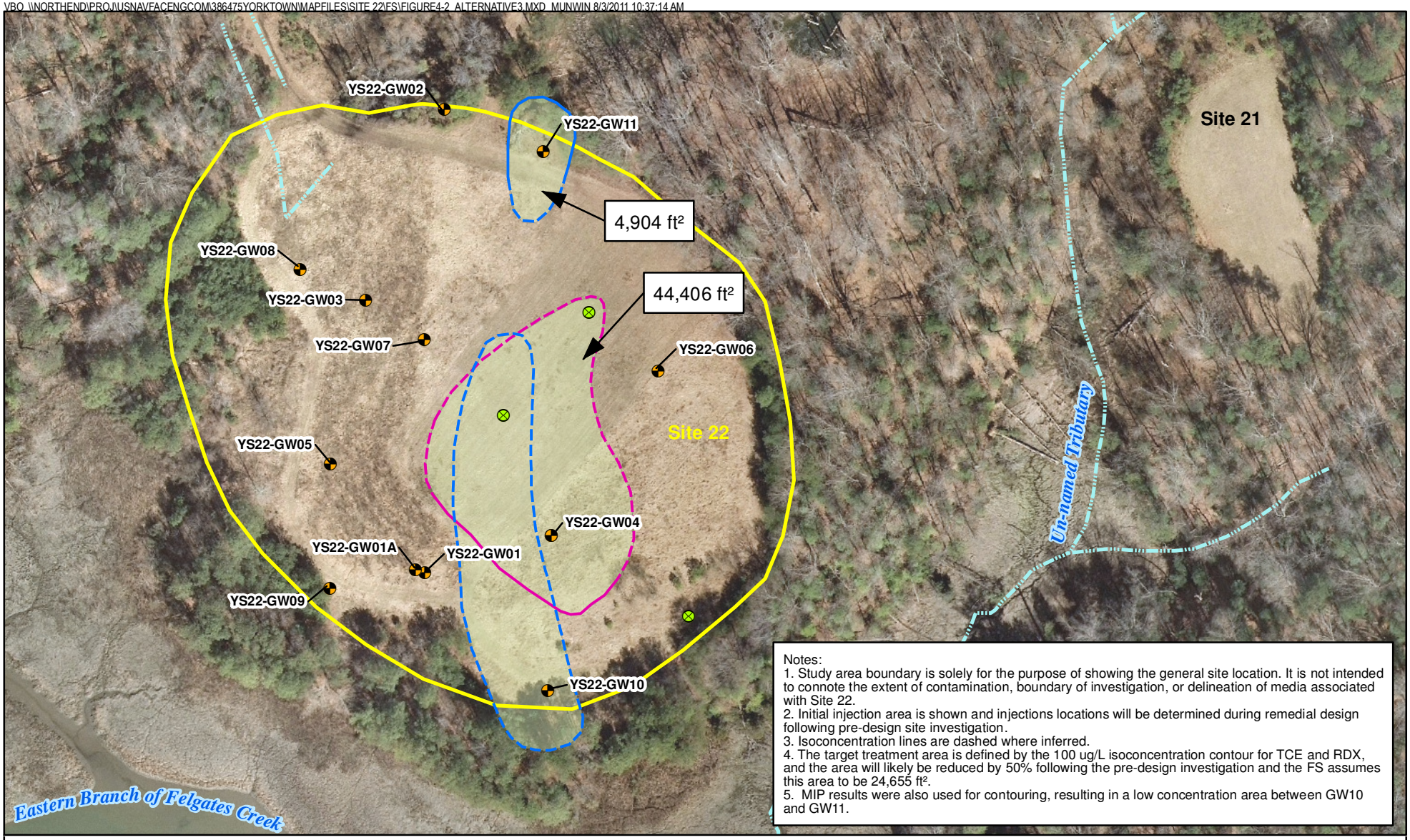

Notes:
1. Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
2. Initial injection area is shown and injections locations will be determined during remedial design following pre-design site investigation.
3. Isoconcentration lines are dashed where inferred.
4. The target treatment area is defined by the 100 ug/L isoconcentration contour for TCE and RDX, and the area will likely be reduced by 50% following the pre-design investigation and the FS assumes this area to be 24,655 ft².
5. MIP results were also used for contouring, resulting in a low concentration area between GW10 and GW11.

Legend

- Shallow Monitoring Well
- Proposed Monitoring Well (Locations may be changed following the Pre-Design Investigation)
- Study Area
- Drainage
- RDX-Groundwater Isoconcentration Contour (100 µg/L)
- TCE-Groundwater Isoconcentration Contour (100 µg/L)
- Target Treatment Area (Initial Injection)

N
W E
S

0 60 120
Feet

Figure 4-2
Alternative 3 – Hot Spot Removal of RDX, TCE, and VC using ISCO with Performance Monitoring; MNA of RDX, TCE, and VC; and LUCs
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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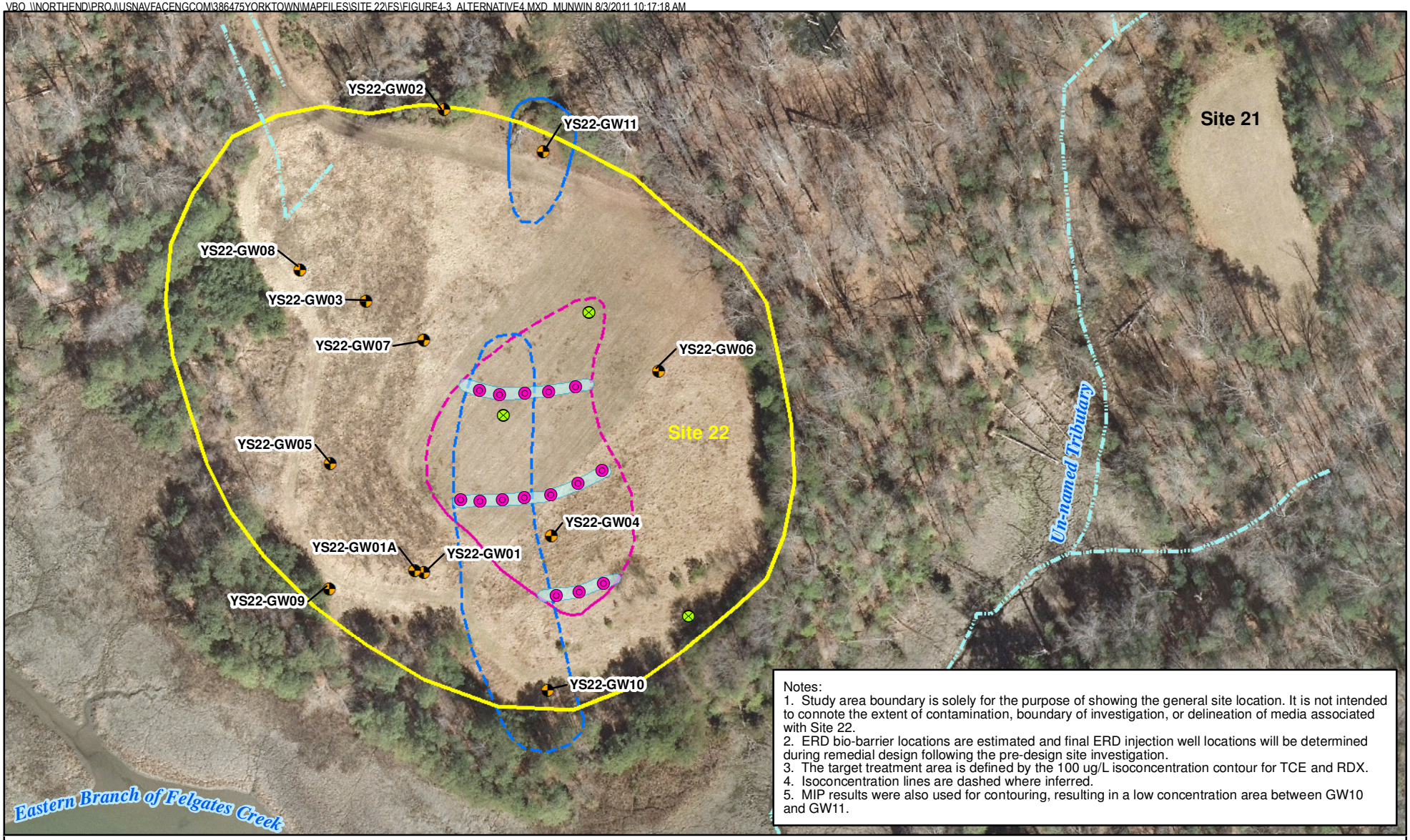

Notes:
1. Study area boundary is solely for the purpose of showing the general site location. It is not intended to connote the extent of contamination, boundary of investigation, or delineation of media associated with Site 22.
2. ERD bio-barrier locations are estimated and final ERD injection well locations will be determined during remedial design following the pre-design site investigation.
3. The target treatment area is defined by the 100 ug/L isoconcentration contour for TCE and RDX.
4. Isoconcentration lines are dashed where inferred.
5. MIP results were also used for contouring, resulting in a low concentration area between GW10 and GW11.

Legend

- Shallow Monitoring Well
- Proposed Monitoring Well (Locations may be changed following the Pre-Design Investigation)
- Injection Locations
- Study Area
- ERD Biobarrier
- Drainage
- RDX-Groundwater Isoconcentration Contour (100 µg/L)
- TCE-Groundwater Isoconcentration Contour (100 µg/L)

N W E S

0 60 120 Feet

Figure 4-3
Alternative 4 – Hot Spot Removal of RDX, TCE, and VC using ERD with Performance Monitoring; MNA of RDX, TCE, and VC; and LUCs
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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SECTION 5

Detailed Evaluation of Alternatives

In this section, the evaluation of alternatives developed in the previous section is discussed to provide a basis for selecting a remedy. Section 5.1 discusses the NCP criteria used to evaluate the alternatives. Section 5.2 discusses the sustainability guidance and metrics that are incorporated into each NCP criterion. Section 5.3 includes a comparative analysis of the remedial alternatives.

5.1 Evaluation Criteria for Remedial Alternatives

The remedial alternatives were evaluated against a common set of criteria. Each alternative was developed to address risk to human health and/or the environment posed by contamination at Site 22. The NCP requires evaluation of the remedial alternatives against the following nine criteria:

- Overall protection of human health and the environment
- Compliance with ARARs
- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, and volume through treatment
- Short-term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

The first two criteria are threshold criteria, which must be achieved by alternatives at a minimum, and the next five are considered primary balancing criteria. These first seven criteria form the basis of the detailed evaluation of alternatives. The last two criteria, state and community acceptance, are modifying criteria, and would be addressed in the Proposed Plan and ROD for Site 22.

The detailed alternatives analysis is the means for assembling and evaluating technical and policy considerations to develop the rationale for selecting a remedy. Each of the nine criteria is described below.

5.1.1 Overall Protection of Human Health and the Environment

This criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment. The overall assessment of protection draws on the assessments conducted under other evaluation criteria, especially long-term effectiveness, performance, and short-term effectiveness. This evaluation focuses on whether each alternative achieves adequate protection and describes how site risks are eliminated, reduced, or controlled. Also, the criterion allows for consideration of whether an alternative poses any unacceptable short-term or cross-media impacts.

5.1.2 Compliance with Applicable and Relevant and Appropriate Requirements

This criterion is used to evaluate whether each alternative will meet all of the federal and state ARARs identified, the ARARs were discussed in Section 3.3. The following factors were considered as each alternative was evaluated for this criterion on state and federal levels:

- Compliance with chemical-specific ARARs: Health- or risk-based numerical values or methodologies that when applied to site-specific conditions establish the amount or concentration of a chemical that may remain in or discharged to the environment.
- Compliance with location-specific ARARs: Restrict the concentration of hazardous substances or the conduct of activities solely because they are in specific locations, such as floodplains, wetlands, historical areas, and sensitive ecosystems or habitats.
- Compliance with action-specific ARARs: technology- or activity-based requirements that set controls or restrictions on design performance of remedial actions or management of hazardous constituents.

5.1.3 Long-term Effectiveness and Permanence

This criterion addresses the results of the remedial action in terms of risk remaining at the site after response objectives have been met. The primary focus of this evaluation is the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes. The following factors were considered as each alternative was evaluated for this criterion:

- Magnitude of estimated residual risk: An assessment of the risk remaining from untreated waste or treatment residuals after the response objectives have been met
- Adequacy and reliability of controls: An evaluation of the controls that can be used to manage treatment residuals or untreated wastes that remain at the facility, including the assessment of institutional controls, to assess whether they are sufficient to ensure that any exposure to human and ecological receptors is within protective levels.

5.1.4 Reduction in Toxicity, Mobility, and Volume

This criterion addresses the statutory preference for selecting remedial actions that employ treatment technologies that permanently and significantly reduce toxicity, mobility, or volume of hazardous substances and thereby reduce the principal threats at a site. The following factors were considered as each alternative was evaluated for this criterion:

- Treatment processes used and materials treated
- Amount of hazardous material destroyed or treated
- Degree of expected reduction in toxicity, mobility, or volume
- Degree to which treatment is irreversible
- Type and quantity of residuals remaining after treatment
- Satisfaction of the statutory preference for treatment as a principal element

5.1.5 Short-term Effectiveness

This criterion addresses the effects of the alternative on human health and the environment during the construction and implementation phases until RAOs are met. The following factors were considered as each alternative was evaluated for this criterion:

- Protection of community during remedial actions: Risk that results from implementation of the proposed remedial action, such as dust, increased traffic, odor or air-quality impacts from the remediation
- Protection of workers during remedial actions: Threats that may be posed to workers (heavy equipment, machinery and transportation) and the effectiveness and reliability of protective measures that could be taken
- Environmental impacts: Potential adverse environmental (ecological, water, or resource) impacts that may result from the implementation of an alternative such as greenhouse gas (GHG) emission, criteria pollutant emissions, destruction of habitats, and consumption of resources
- Time to achieve the RAOs: Estimate of the time required to achieve protection for either the entire site or individual elements associated with specific site areas or threats

5.1.6 Implementability

The evaluation of implementability includes the technical and administrative feasibility of implementing each alternative, as well as the availability of services and materials required for implementation. The following factors were considered as each alternative was evaluated for this criterion:

- Technical feasibility
  - Ability to construct and operate the technology
  - Reliability of the technology
  - Ease of undertaking additional remedial action, if necessary
  - Ability to monitor effectiveness of the remedy
- Administrative feasibility
  - Ability to coordinate with and obtain approvals from other agencies
  - Availability of offsite treatment, storage, and disposal services and capacity
  - Availability of necessary equipment and specialists
  - Availability of prospective technologies

5.1.7 Cost

This criterion evaluates alternatives based on the associated capital cost and O&M cost to achieve the RAOs. The estimated cost of each remedial option is expressed as present value based on an assumed discount rate of 4.9 percent over a 25 to 35-year operation period. The discount rate was selected on the basis of the Federal Office of Management and Budget (Accessed via Internet April 6, 2010). The O&M period is estimated for evaluation purposes only; the actual O&M period could be much longer in some cases, but would have minimal

impact to the cost estimate based on the discount rate. Total costs are expressed over a plus 50 to minus 30 percent range.

State Acceptance

This criterion evaluates concerns the state may have regarding each of the alternatives. This criterion is not discussed in this report but will be addressed in the ROD.

Community Acceptance

Typically, community comment and acceptance is noted in the ROD and is a result of the community review of the proposed plan.

5.2 Sustainability Metrics and Evaluation Criteria

Consideration of sustainable practices is becoming increasingly important throughout the remediation community and this emphasis is now being reflected in policy and guidance.

Executive Order (EO) 13423, released on January 26, 2007, mandated all federal agencies to conduct their environmental, transportation, and energy activities in an environmentally, economically, fiscally sound, integrated, continuously improving, efficient, and sustainable manner. In April 2008, the USEPA issued a guidance document, Green Remediation: Incorporating Sustainable Environmental Practices into the Remediation of Contaminated Sites, which is dedicated to developing and promoting innovative cleanup strategies that restore contaminated sites to productive use and reduce associated costs while promoting environmental stewardship.

The Department of the Navy (DON) Environmental Strategy lays out a vision for Sustaining our Environment, Protecting our Freedom, which links accomplishing the Navy's defense mission with its responsibility to safeguard the natural systems upon which the nation's quality of life depends. The Department of Defense (DOD) issued a Green and Sustainable Remediation Policy on August 10, 2009, encouraging services to use strategies that consider all environmental effects of a remedy implementation and operation and incorporate options to maximize the overall benefit of cleanup actions. EO 13514, released on October 5, 2009, sets sustainability goals for federal agencies and focuses on making improvements in their environmental, energy, and economic performance. The EO requires federal agencies to set a 2020 GHG emissions reduction target within 90 days; increase energy efficiency; reduce fleet petroleum consumption; conserve water; reduce waste; support sustainable communities; and leverage federal purchasing power to promote environmentally responsible products and technologies. NAVFAC (2009) prepared a Sustainable Environmental Remediation Fact Sheet, which outlines the Navy's guidance on incorporating sustainable remediation into the environmental remediation process. Furthermore, regulatory agencies are beginning to request that sustainability be considered during remedy implementation.

Using the approach described in the NAVFAC (2009), Sustainable Environmental Remediation (SER) was evaluated under each of the NCP Criteria for Site 22. The eight sustainability metrics discussed in the NAVFAC (2009) Fact Sheet include:

- Energy Consumption
- GHG Emissions

- Criteria Pollutant Emissions
- Water Impacts
- Ecological Impacts
- Resource Consumption
- Worker Safety
- Community Impacts

Table 5-1 summarizes how each of NAVFAC's sustainability metrics can be addressed under the existing NCP criteria. Based on the evaluation completed, the sustainability metrics are most effectively addressed in the two NCP criteria of (1) long-term effectiveness and permanence and (2) short-term effectiveness. The Air Force Center for Engineering and the Environment Sustainable Remediation Tool (SRT) (AFCEE, 2009) was used to quantify values for the sustainability metrics included in Table 5-1. The inputs parameters and results from the SRT are associated with the assumptions linked with the alternative descriptions included in Section 4.2, Appendix C, Preliminary Cost Estimates, and Appendix E, Sustainability Evaluation. The results of the SRT are incorporated into the balancing criteria discussion in Section 5.4 where a comparative analysis of remedial alternatives is performed.

5.3 Individual Analysis of Alternatives

The detailed analysis of remedial alternatives comprises individual and comparative evaluation of the remedial alternatives. During the individual evaluation, each alternative was assessed against the first seven NCP criteria described in Section 5.1. The results were then arrayed to compare the alternatives and identify the key tradeoffs among them. This approach provides decision makers with sufficient information to adequately compare the alternatives, select an appropriate remedy for the site, and demonstrate satisfaction of the remedy selection requirements in the ROD. The individual evaluation for each alternative is presented in the following narrative and is summarized in Table 5-2.

5.3.1 Alternative 1 – No Action

The no action alternative is required by CERCLA to be considered as the baseline remedial action. This alternative allows natural attenuation to reduce the contaminant plumes, but does not provide measures to prevent exposure to site-related COCs. Therefore, it is not considered protective of either human health or the environment. Currently, concentrations of COCs in groundwater exceed PRGs with no means to monitor future risks and therefore, this alternative does not meet ARARs. Likewise, long-term effectiveness is unacceptable because the plume will not be monitored, and there would be no mechanism for limiting future exposure to contaminated groundwater. There is uncertainty if RAOs would be achieved. This alternative does not include active treatment. Natural biodegradation will occur, but at unmonitored rates and at unknown locations. Therefore, we must assume that no contaminants are treated or destroyed under this alternative. Short-term risks are considered moderate. Although there would be no remedial construction and no immediate environmental impacts of this remedy, COC concentrations in the plumes would not be reduced to PRGs within the short-term. This alternative is easy to implement and the cost is essentially zero.

5.3.2 Alternative 2 – Hot Spot Removal of RDX using EISB and Associated Performance Monitoring; MNA of TCE, VC and RDX; and LUCs

Alternative 2 enhances the biodegradation in the RDX target treatment area and allows natural attenuation to reduce the VOC contaminant plumes. This alternative is considered protective of human health and the environment because site-related COCs would degrade over time from targeted EISB and natural processes and LUCs and groundwater monitoring would be maintained until RAOs are achieved. Monitoring during implementation will provide warning if the plume begins migrating into surface water or sediment or into the deeper portion of the aquifer. This remedy would comply with ARARs, and is considered effective and permanent. However, if an unacceptable risk was indicated during monitoring and 5-year reviews, a contingency plan for additional plume treatment would need to be developed. Emissions from reagent production, transportation, and heavy machinery would persist for an extended period after RAOs are achieved.

This alternative employs enhanced biodegradation for treatment of RDX. Although no active treatment process would be employed specifically for VOCs, natural biodegradation and other attenuation processes would be occurring. Therefore, reduction of toxicity, mobility, or volume of the plumes is acceptable, but assumed to be slow. However, some active treatment of TCE and VC would occur where the VOC plumes overlap with the RDX target treatment area. If natural attenuation processes are not effective at reducing the toxicity, mobility, or volume of the plumes within an acceptable timeframe, then additional treatment may be required. The short-term effectiveness is considered moderately high because this alternative has optimal sustainability metrics achieved with fewer environmental impacts (due to the limited extent of the treatment area). There would be minimal risk to workers and the community during implementation. The short-term effectiveness would be less effectives if the substrate daylights or a spill occurs during transport or injection activities.

This alternative employs a reliable technology that is technically feasible for the site and could be easily implemented with available labor, materials, and equipment. The costs of this alternative are split between capital cost (43 percent), present worth of O&M cost (47 percent), and present worth periodic costs (10 percent). These costs could increase if monitoring indicates that more extensive EISB injections are needed to achieve RAOs and/or prevent plume migration. Costs could also increase if the actual injection ROI is lower than assumed for this FS and the number of injection points need to be increased.

5.3.3 Alternative 3 – Hot Spot Removal of RDX, TCE and VC using ISCO and Associated Performance Monitoring; MNA of TCE, VC and RDX; and LUCs

Alternative 3 chemically oxidizes RDX and VOCs in the target treatment areas and allows natural attenuation to reduce concentrations within the remainder of the plumes. This alternative is considered protective of human health and the environment because site-related COCs would degrade over time from targeted ISCO and natural processes and LUCs and groundwater monitoring would be maintained until RAOs are achieved. Monitoring during implementation will provide warning if the plume begins migrating into surface water or sediment or into deeper aquifers. This remedy would comply with ARARs, and is considered effective and permanent. However, if an unacceptable risk was indicated during monitoring and 5-year reviews, a contingency plan for additional plume treatment

would need to be developed. Emissions from reagent production, transportation, and heavy machinery would persist for an extended period after RAOs are achieved.

This alternative employs ISCO as a treatment technology and natural attenuation processes would continue to occur outside of the treatment area. Therefore, reduction of toxicity, mobility, or volume of the plume is acceptable. If natural attenuation processes are not effective at reducing the toxicity, mobility, or volume of the plumes within a reasonable timeframe, then additional treatment may be required.

The short-term effectiveness is considered moderate because minimal sustainability metrics are achieved with moderate environmental impacts. Although the remedial timeframe is estimated at less than 30 years, there is some risk to workers, the community, and the environment from the handling and transportation of oxidants and potential spills or ground surfacing during the injection work. This alternative also has high carbon dioxide and SOx emissions associated with oxidant and polyvinyl chloride (PVC) manufacturing.

This alternative employs a reliable technology that is technically feasible for the site and could be easily implemented with available labor, materials, and equipment. However, there are limited case studies for RDX oxidation in the field. The costs of this alternative are split between capital cost (54 percent), present worth of O&M cost (29 percent), and present worth periodic costs (17 percent). These costs could increase if monitoring indicates that more extensive ISCO injections are needed to achieve RAOs and/or prevent plume migration. Costs could also increase if the actual injection ROI is lower than assumed for this FS and the number of injection points need to be increased.

5.3.4 Alternative 4 – Hot Spot Removal of TCE, VC, and RDX using EISB and Associated Performance Monitoring; MNA of TCE, RDX and VC; and LUCs

Alternative 4 enhances the biodegradation of RDX and VOCs in the target treatment areas and allows natural attenuation to reduce concentrations within the remainder of the plumes. This alternative is considered protective of human health and the environment because site-related COCs would degrade over time from targeted EISB and natural processes and LUCs and groundwater monitoring would be maintained until RAOs are achieved. Monitoring during implementation will provide warning if the plume begins migrating into surface water or sediment or into deeper aquifers. This remedy would comply with ARARs, and is considered effective and permanent. However, if an unacceptable risk was indicated during monitoring and 5-year reviews, a contingency plan for additional plume treatment would need to be developed. Emissions from reagent production, transportation, and heavy machinery would persist for an extended period after RAOs are achieved.

This alternative employs EISB as a treatment technology and natural attenuation processes would continue to occur outside of the treatment area. Therefore, reduction of toxicity, mobility, or volume of the plume is acceptable. If natural attenuation processes are not effective at reducing the toxicity, mobility, or volume of the plumes within a reasonable timeframe, then additional treatment may be required.

The short-term effectiveness is considered moderate because minimal sustainability metrics are achieved with moderate environmental impacts. Although the remedial timeframe is estimated at less than 30 years, there is some risk to workers, the community, and the environment from the handling and transportation of carbon substrates and potential spills

or ground surfacing during the injection work. This alternative also has high energy consumption, NOx, and PM10 due to fuel consumption.

This alternative employs a reliable technology that is technically feasible for the site and could be easily implemented with available labor, materials, and equipment. The costs of this alternative are split between capital cost (42 percent), present worth of O&M cost (32 percent), and present worth periodic costs (26 percent). These costs could increase if monitoring indicates that more extensive EISB injections are needed to achieve RAOs and/or prevent plume migration. Costs could also increase if the actual injection ROI is lower than assumed for this FS and the number of injection points need to be increased.

5.4 Comparative Analysis of Remedial Alternatives

The comparative evaluation is described in the following sections. Each of the criteria was divided into its sub-criteria. A quantitative comparative analysis for each sub-criterion was employed using a ranking system of 1 to 10, with 1 being the lowest valued metric and 10 being the highest. A score of 1 indicates the alternative does not meet any of the attributes of the criteria. A score of 10 indicates the alternative meets all attributes of the criteria. The scores between 1 and 10 reflect the degree to which an alternative meets all attributes of the criteria. Table 5-3 provides a detailed breakdown, including the scoring of the individual sub-criteria, and the results of the ranking for each alternative.

5.4.1 Overall Protection of Human Health and the Environment

All alternatives, with the exception of the Alternative 1, are protective of human health and the environment. Performance monitoring will be conducted and LUCs will be maintained to provide adequate protection of human health and the environment by controlling exposure to contaminated site media until the RAOs are met.

5.4.2 Compliance with ARARs

All alternatives, with the exception of Alternative 1, are expected to comply with ARARs. Alternatives 2, 3, and 4 would all require measures to be taken to comply with performance monitoring and LUCs. All alternatives would also require additional measures to ensure compliance with ARARs related to the injections of reagents into the subsurface. The ARARs are presented in Appendix A.

5.4.3 Long-term Effectiveness and Permanence

Magnitude of Residual Risk

Once RAOs are achieved, all alternatives, except Alternative 1, are expected to have residual risks of the same magnitude. Some residual risk will be apparent because Alternatives 2, 3, and 4 rely on monitoring and LUCs. Some emissions (NO_x [nitrogen oxide], PM10 [particulate matter less than 10 micrometers in aerodynamic diameter], and CO_2 associated with GHG and criteria pollutants) from reagent production, transportation, and heavy machinery use may persist for an extended period after RAOs are achieved. The nominal residual risk associated with these emissions would affect the general population and would not be specific to Site 22 receptors. Alternative 1 scored the lowest because it would not achieve the RAOs.

Adequacy and Reliability of Controls

With proper engineering, planning, and implementation, controls can be put in place to effectively monitor all of the alternatives to verify continued compliance with RAOs. A monitoring plan needs to be implemented to provide for an adequate frequency of monitoring to detect any indications of contaminant rebound or migration that could threaten human or ecologic receptors, or threaten compliance with ARARs. LUCs need to be continually enforced until the RAOs are achieved and while COCs exceed their RGs.

Alternatives 2, 3, and 4 received the same scores because their controls are all reliable. Alternative 1 scored the lowest because no controls would be in place to monitor.

5.4.4 Reduction of Toxicity, Mobility, and Volume through Treatment

Treatment Process Used and Materials Treated

Alternative 3 received the highest score because it employs an active treatment in the entire target treatment area. Alternatives 2 and 4 received lower scores because they will be used for treatment barriers and will not directly treat as much material. Alternative 1 received the lowest score because treatment is not a component of this alternative.

Amount of Hazardous Materials Destroyed or Treated

The relative differences in scores and the rationale for the scores for this sub-criterion mirror those for the Treatment Process Used and Materials Treated sub-criteria. The larger the area and the higher the concentrations are within the area in which active treatment is employed, the higher the amount of hazardous materials are destroyed or treated and the higher the score. Alternative 1 received the lowest score because treatment is not a component of this alternative.

Degree of Expected Reductions in Toxicity, Mobility, or Volume

The relative differences in scores and the rationale for the scores for this sub-criterion mirror those for the Treatment Process Used and Materials Treated sub-criteria. The larger the area and the higher the concentrations are within the area in which active treatment is employed, the higher the degree of expected reductions and the higher the score. Alternative 1 received the lowest score because active treatment is not a component of this alternative.

Degree to which Treatment is Irreversible

The relative differences in scores and the rationale for the scores for this sub-criterion mirror those for the Treatment Process Used and Materials Treated sub-criteria. The larger the area and the higher the concentrations are within the area in which active treatment is employed, the higher the degree to which treatment is irreversible and the higher the score. Alternative 1 received the lowest score because active treatment is not a component of this alternative.

Type and Quantity of Residual Remaining After Treatment

The relative differences in scores and the rationale for the scores for this sub-criterion mirror those for the Treatment Process Used and Materials Treated sub-criteria. The larger the area and the higher the concentrations are within the area in which active treatment is employed, the lower the type and quantity of residual remaining after treatment and the higher the

score. Alternative 1 received the lowest score because active treatment is not a component of this alternative.

5.4.5 Short-term Effectiveness

Protection of Community during Remedial Actions

Alternative 1 received the highest score because it would not involve any activities that would affect the community. Alternative 2 received the next highest score based on the minimal impacts to the community during implementation due to fewer EISB injections. Alternative 2 also had the least risk of accident and lost time quantified using the SRT (Appendix E). Compared to Alternative 2, Alternative 4 scored lower because of the greater number of injection points and EISB injections, higher volume of heavy machinery traffic, and frequency of site visits. Alternative 3 received the lowest score because of the high heavy machinery use and the transportation of chemical oxidant on public roads and highways.

Protection of Workers during Remedial Actions

All workers can be protected during completion of remedial actions through implementation of health and safety programs. However, the relationship is apparent between the scale of construction and potential injury or exposure to hazards associated with remedial activities—the more intensive the construction project, the greater the probability of injury.

Alternative 1 scored the highest because it would not include any activities involving workers. Alternatives 2 and 4 pose a slightly higher risk to workers during implementation because of a slightly higher chance of encountering site-related constituents due to additional intrusive activities. Alternative 3 has the lowest score since it has the highest risk of accident and lost time primarily due to working with oxidants and quantified using the SRT (Appendix E). EVO exposure is not considered as significant a concern compared to a chemical oxidant.

Environmental Impacts

With the exception of Alternative 1, all alternatives would have some level of negative impact to the environment. Long-term monitoring requires years of trips to the site with the creation of purge water and emission of GHG due to transportation. Natural resources and energy consumption will occur with the use of fuel and the processing of oxidant. GHG and criteria pollutant emissions can occur through use of fossil fuels. Potential impacts to wildlife include noise, construction activities, materials brought onsite, and footprint disturbed during remedial construction.

Alternative 1 received the highest score because it would not include any activities that would impact the environment. Alternative 2 scored the next highest because it includes the least amount of construction or intrusive activities and environmental impacts.

Alternative 4 scored low because of the high level of intrusive activities and it would likely result in high GHG with transportation and heavy machinery use. Alternative 4 has a slightly higher NO_x and PM10 compared to Alternative 3, which is primarily due to the total fuel consumption estimated for completion of each alternative. In addition, the total energy

consumption for Alternative 4 is slightly higher than for Alternatives 2 or 3 as a result of the fuel consumption estimated to complete each alternative.

Alternative 3 scored the lowest because it included environmental impacts related to the production of the chemical oxidant in addition to the higher impact discussed with Alternative 4. Alternative 3 has notably higher CO_2 emissions due to the emission factor associated with the oxidant manufacturing. Additionally, Alternative 3 has the highest sulfur oxide (SO_x) emissions primarily due to the total length of PVC required for the temporary injection locations.

These scores were influenced by the Sustainability Evaluation discussed in Appendix E.

Time Until Remedial Action Objectives Are Achieved

The timeframe associated with achieving the RAOs associated with each remedial technology is uncertain. Alternative 1 has the greatest risk of an extended timeframe because no treatment and no monitoring exist to evaluate when RAOs are achieved. Alternative 2 received the next lowest ranking because it would be the longest active alternative to achieve RAOs. Alternatives 3 and 4 are estimated to achieve RAOs in a similar timeframe; however, Alternative 3 is ranked a little higher because it treats a larger area and will most likely reach RAOs first.

5.4.6 Implementability

Ability to Construct and Operate the Technology

Alternative 1 received the highest score because it requires no action. Alternatives 2 through 4 scored relatively high because the engineering and construction services required for each of the remedial technologies are readily available. Alternatives 2, 3, and 4 would implement EISB or ISCO, increasing the construction and operation component of the alternative.

Reliability of the Technology

Alternative 1 scored the lowest because it would be the most unreliable alternative and because it is not expected to achieve RAOs. Alternatives 2 through 4 are reliable provided they are designed and implemented appropriately. All alternatives would require thorough monitoring to verify they continue to operate on a path toward achieving RAOs. Alternative 4 scored the highest as the treatment barrier would remediate the RDX and VOC target treatment areas and EISB is a reliable treatment technology. Alternative 2 would also employ treatment barriers using EISB but only over the RDX target treatment area, relying more on natural attenuation processes. Alternative 3 would completely treat the RDX and VOC target treatment areas by a reliable and readily used technology however it has inherent limitations and challenges for delivering reagents over large areas to the subsurface.

Ease of Undertaking Additional Remedial Actions, If Necessary

Additional remedial actions can be undertaken with all of the alternatives, if necessary.

Ability to Monitor Effectiveness of Remedy

Alternative 1 does not entail monitoring. Alternatives 2 through 4 are designed with effective monitoring programs, therefore they all received high scores.

Ability to Coordinate and Obtain Approvals From Other Agencies

It is anticipated that Alternatives 2 through 4 would be able to obtain the required approvals from the necessary agencies, therefore they all received high scores. Alternative 1 received the lowest score because it is not expected to receive approval from the necessary agencies.

Availability of Offsite Treatment, Storage, and Disposal Services and Capacity

Adequate treatment, storage capacity, and disposal services are available for all alternatives.

Availability of Necessary Equipment and Specialists

Adequate equipment and specialists to implement all alternatives are available.

Availability of Prospective Technologies

The prospective technologies for all alternatives are available.

5.4.7 Cost

An order of magnitude (OOM) cost for each alternative has been estimated based on a variety of key assumptions, including an assumed 35-year project life. The timeframe required to achieve the RGs may vary by alternative. Significant uncertainty is associated with the timeframes. However, costs beyond 35 years will have minimal impact to the overall evaluation based on the present worth estimate. OOM cost estimates have been prepared in accordance with USEPA (2000) guidance and represent a minus 30 to plus 50 percent range of accuracy.

Appendix C includes a summary table that shows the estimated capital, O&M, periodic, and total present value of each alternative. The least expensive alternative is Alternative 2, with an estimated total present value of $1,907,000. Alternatives 3 and 4 have estimated present value costs of $2,482,000 and $2,718,000, respectively. Alternative 2 also has the lowest total capital cost, estimated at $708,026. Alternatives 3 and 4 have estimated capital costs of $1,228,931 and $1,024,061, respectively.

TABLE 5-1
Sustainabiliy Metrics and NCP Criteria
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

NCP Criteria	Subcriteria	Sustainability Metrics							
		Energy Consumption	GHG Emissions	Criteria Pollutant Emissions	Water Impacts	Ecological Impacts	Resources Consumption	Worker Safety	Community Impacts
Protection of Human Health and the Environment	Protection of Human Health and Environment								
Compliance with ARARs	Compliance with Chemical Specific ARARs								
	Compliance with Action Specific ARARs								
	Compliance with Location Specific ARARs								
	Compliance with other criteria, advisories, and guidance								
Long-Term Effectiveness and Permanence	Magnitude of Residual Risk		E	E					
	Adequacy and reliability of controls								
Reduction in Toxicity, Mobility, and Volume	Treatment Process used and materials treated								
	Amount of Hazardous materials destroyed or treated								
	Degree of Expected Reductions in Toxicity, Mobility, and Volume								
	Degree of which treatment is irreversible								
	Type and Quantity of Residual Remaining After Remedial Action								
Short-Term Effectiveness	Protection of Community During Remedial Action								A
	Protection of Workers During Remedial Actions							B	
	Environmental Impacts	F	E	D			C		
	Time until RAOs are achieved								
Implementability	Ability to construct and operate the Technology								
	Reliability of the Technology								
	Ease of undertaking additional remedial actions, if necessary								
	Ability to Monitor effectiveness of Remedy								
	Ability to obtain approvals from other agencies								
	Coordination with other agencies								
	Availability of offsite treatment, storage, and disposal services and capacity								
	Availability of necessary equipment and specialists								
	Availability of Prospective Technologies								
Cost	Capital Costs								
	Operating and Maintenance Costs								
	Present Worth Costs								
State Acceptance	State Acceptance								
Community Acceptance	Community Acceptance								

Legend:
A - Compliments NCP criteria but also addresses risks to community in terms of potential for injury or fatality associated with traffic
B - Compliments NCP criteria but also addresses potential for injury or fatality associated with total hours worked
C - Use of non-renewable energy (coal for power requirements [fuel])
D - Impacts associated with release of VOCs to the atmosphere
E - Some emissions persist only in the short term, others last for decades and may persist after RAO's have been achieved
F - Environmental impacts associated with energy extraction from earth resources
Note: F, E, D, and C could potentially be mapped to NCP Criteria "Protection of Human Health and The Environment" - but this would be a more difficult fit since the main focus of that criteria is risk based exposure.

TABLE 5-2
Detailed Evaluation of Remedial Alternatives
Site 22 Feasibility Study Report
Naval Weapons Station Yorktown
Yorktown, Virginia

Evaluation Criteria	Alternative 1 No Action	Alternative 2 Enhanced In Situ Bioremediation and Performance Monitoring of RDX with MNA of VOCs and LUCs	Alternative 3 In Situ Chemical Oxidation and Performance Monitoring or RDX and VOCs with MNA and LUCs	Alternative 4 Enhanced In Situ Bioremediation and Performance Monitoring of RDX and VOCs with MNA and LUCs
Overall Protection of Human Health and the Environment	**Not Protective.** • Does not prevent exposure to site-related COCs or provide measures to reduce site-related COC concentrations to achieve RAOs.	**Protective.** • Targeted chemical treatment of RDX and biodegradation over time; • Site-related VOCs will degrade over time; • LUCs and groundwater monitoring implemented and maintained until RAOs are achieved.	**Protective.** • Targeted chemical treatment of site-related COCs and biodegradation over time; • LUCs and groundwater monitoring implemented and maintained until RAOs are achieved.	**Protective.** • Targeted chemical treatment of site-related COCs and biodegradation over time; • LUCs and groundwater monitoring implemented and maintained until RAOs are achieved.
Compliance with ARARs	**Does not meet.** • Not in compliance; • Groundwater concentrations currently exceed MCLs; • Risks to contaminated groundwater above MCLs remain.	**Meets.** • In compliance; • Moderate to extended timeframe; • Land use controls would prevent groundwater use.	**Meets.** • In compliance; • Moderate timeframe; • Land use controls would prevent groundwater use.	**Meets.** • In compliance; • Moderate timeframe; • Land use controls would prevent groundwater use.
Long-Term Effectiveness and Permanence	**Ineffective.** • No treatment or monitoring, uncertain if RAOs would be achieved.	**Effective.** • Risks once active remediation is completed are expected to be reduced; • Low level of residual risk, since monitoring would determine if site-related COCs exist above criteria requiring additional treatment; • Emissions (NO_x, PM10, and carbon dioxide associated with GHG and criteria pollutants) from reagent production, transportation and heavy machinery use persist for an extended period after RAOs are achieved; • Monitoring, LUCs, and 5-year reviews needed until levels allow for unrestricted use.	**Effective.** • Risks once active remediation is completed are expected to be reduced; • Low level of residual risk, since monitoring would determine if site-related COCs exist above criteria requiring additional treatment; • Emissions (NO_x, PM10, and carbon dioxide associated with GHG and criteria pollutants) from reagent production, transportation and heavy machinery use persist for an extended period after RAOs are achieved; • Monitoring, LUCs, and 5-year reviews needed until levels allow for unrestricted use.	**Effective.** • Risks once active remediation is completed are expected to be reduced; • Low level of residual risk, since monitoring would determine if site-related COCs exist above criteria requiring additional treatment; • Emissions (NO_x, PM10, and carbon dioxide associated with GHG and criteria pollutants) from reagent production, transportation and heavy machinery use persist for an extended period after RAOs are achieved; • Monitoring, LUCs, and 5-year reviews needed until levels allow for unrestricted use.
Reduction of Toxicity, Mobility, and Volume Through Treatment	**No Treatment.** • Reduction of TMV would only gradually occur as a result of natural processes; • Reduction and mobility of site-related COCs would remain unknown and undocumented.	**Limited Treatment.** • EISB used in RDX target treatment area; • No active treatment of VOCs included, however, components of the alternative would reduce TMV; • Reduction in toxicity and volume would gradually occur as a result of natural processes; • Monitoring to assess toxicity, mobility, and volume of site-related COCs in groundwater would be performed.	**Treatment.** • ISCO used in RDX and VOC target treatment areas; • Continued reduction in toxicity and volume would gradually occur as a result of natural processes; • Monitoring to assess toxicity, mobility, and volume of site-related COCs in groundwater would be performed.	**Treatment.** • EISB used in RDX and VOC target treatment areas; • Continued reduction in toxicity and volume would gradually occur as a result of natural processes; • Monitoring to assess toxicity, mobility, and volume of site-related COCs in groundwater would be performed.
Short-Term Effectiveness	**Moderate.** • Construction and implementation phases do not present risk to the community, workers, or environment; • Achievement of RAOs is not expected.	**Moderately High.** • Minimal loss time and risk of accident to workers and community from transportation and handling or substrate; • Risk for migration of substrate and potential spills during transportation; • Minimal sustainability metrics achieved with moderate environmental impacts; • Moderate sustainability metrics achieved with fewer environmental impacts; • Achieve RAOs in estimated 34 years.	**Moderate.** • Some loss time and risk of accident to workers and community from handling and transportation of oxidants; • Risk for migration of oxidant and potential spills during transportation; • Minimal sustainability metrics achieved with moderate environmental impacts; • Highest carbon dioxide emissions and energy consumption primary due to oxidant and PVC manufacturing; • Achieve RAOs in estimated 25 years.	**Moderate.** • Minimal loss time and risk of accident to workers and community from transportation and handling or substrate; • Risk for migration of substrate and potential spills during transportation; • Minimal sustainability metrics achieved with moderate environmental impacts; • Highest SOx, NO_x and PM10 emissions due to fuel consumption; • Achieve RAOs in estimated 29 years.
Implementability	**Low Feasibility.** • No action is easy to operate; • Not a reliable technology; • No way to monitor its effectiveness.	**High Feasibility.** • Easy to operate and construct; • Reliable technology; • Able to monitor effectiveness.	**High Feasibility** • Commonly used chemicals and delivery equipment • Reliable technology; • Able to monitor effectiveness.	**High Feasibility** • Able to operate and construct; • Reliable technology; • Able to monitor effectiveness.
Cost	**No Cost**	**Total Present Value: $ 1,907,000** Present Value – Capital Costs: $ 708026 Present Value – O&M Costs: $1,028,565 Present Value – Periodic Costs: $170,101	**Total Present Value: $ 2,482,000** Present Value – Capital Costs: $ 1,228,931 Present Value – O&M Costs: $833,902 Present Value – Periodic Costs: $418.999	**Total Present Value: $ 2,718,000** Present Value – Capital Costs: $ 1,024,061 Present Value – O&M Costs: $994,759 Present Value – Periodic Costs: $698,898

Notes:

The costs included in this table come from the cost estimate, which has been prepared in accordance with EPA 540-R-00-002 and represents a -30 to +50 percent range of accuracy. The cost estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions may affect the accuracy of the estimate. CH2M HILL is not responsible for any variance from the estimate or actual prices and conditions obtained.

TABLE 5-3
Detailed Comparative Analysis of Remedial Alternatives
Site 22 Feasibility Study Report
Naval Weapsons Station Yorktown
Yorktown, Virginia

Evaluation Criteria	Alternative 1 - No Action	Alternative 2 - EISB and Performance Monitoring of RDX with MNA of VOCs and LUCs	Alternative 3 - ISCO and Performance Monitoring of RDX and VOCs with MNA and LUCs	Alternative 4 - EISB and Performance Monitoring of RDX and VOCs with MNA and LUCs
Overall Protection of Human Health and the Environment	**1**	**10**	**10**	**10**
Compliance with ARARs	**1**	**10**	**10**	**10**
Compliance with Chemical-Specific ARARs	1	10	10	10
Compliance with Action-Specific ARARs	1	10	10	10
Compliance with Location-Specific ARARs	1	10	10	10
Compliance with Other Criteria, Advisories, and Guidances	1	10	10	10
Long-Term Effectiveness and Permanence	**1.0**	**8.5**	**8.5**	**8.5**
Magnitude of Residual Risk	1	8	8	8
Adequacy and Reliability of Controls	1	9	9	9
Reduction of Toxicity, Mobility, and Volume Through Treatment	**1.0**	**5.0**	**9.0**	**7.0**
Treatment Process Used and Materials Treated	1	5	9	7
Amount of Hazardous Materials Destroyed or Treated	1	5	9	7
Degree of Expected Reductions in Toxicity, Mobility, and Volume	1	5	9	7
Degree to Which Treatment is Irreversible	1	5	9	7
Type and Quantity of Residual Remaining After Treatment	1	5	9	7
Short-Term Effectiveness	**7.8**	**6.8**	**6.0**	**6.5**
Protection of Community During Remedial Actions	10	7	5	6
Protection of Workers During Remedial Actions	10	8	7	8
Environmental Impacts	10	6	4	5
Time Until Remedial Action Objectives are Achieved	1	6	8	7
Implementability	**6.6**	**9.3**	**9.3**	**9.4**
Ability to Construct and Operate the Technology	10	7	7	7
Reliability of the Technology	1	7	7	8
Ease of Undertaking Additional Remedial Actions, if Necessary	10	10	10	10
Ability to Monitor Effectiveness of Remedy	1	10	10	10
Ability to Coordinate and Obtain Approvals From Other Agencies	1	10	10	10
Availability of Offsite Treatment, Storage, and Disposal Services and Capacity	10	10	10	10
Availability of Necessary Equipment and Specialists	10	10	10	10
Availability of Prospective Technologies	10	10	10	10
Total Benefit	**18.4**	**49.5**	**52.8**	**51.4**
Total Present Value Cost	**$ -**	**$ 1,577,000**	**$ 2,268,000**	**$ 2,411,000**
Cost ($1,000/benefit unit) -30% to +50% range	**-**	**22.3 - 47.8**	**32.1 - 68.7**	**34.1 - 73.1**

Note: Qualitative comparative analysis of alternatives using a rating scale of 1 through 10 (1 = lowest score, 10 = highest score)

SECTION 6

Summary and Conclusions

Based on the comparison of alternatives utilizing the NCP criteria, Alternatives 2 through 4 performed very similarly. All are capable of achieving clean up goals. The time estimated for each of the three remedial alternatives (not including the No Action alternative) to reach RAOs ranges from 25 to 34 years. Alternative 2 employs EISB to reduce treatment time in the RDX target area, Alternative 3 employs ISCO to reduce treatment time in the RDX and VOC target areas, and Alternative 4 uses EISB to reduce treatment time in the RDX and VOC target areas. All alternatives (Alternatives 2 through 4) rely to some degree on MNA to reduce the concentrations of site-related COCs plus LUCs to maintain protectiveness of human health and the environment.

Alternatives 3 and 4 are similar in cost while Alternative 2 is the most cost effective. The rankings in the sustainability evaluation for Alternatives 2, 3, and 4 were similar. Alternative 2 had the lowest CO_2 emissions and safety risk, Alternative 3 had the lowest NO_x, SO_x, and PM10 air emissions since it requires less fuel consumption to complete the alternative, and Alternative 4 had the lowest energy consumption. Although Alternative 2 is expected to take up to 9 years longer to achieve RAOs compared to Alternative 3, this additional time is not expected to be consequential given that this site is not currently used and there are no existing buildings or planned construction in the future. The cost versus benefit (such as length of time, sustainability) comparison indicates that although Alternative 2 takes longer to reach RAOs, it is more cost effective and results in less disruptions to the environment and injury risk to humans than the other alternatives presented. Therefore, Alternative 2 is the preferred alternative for remediation of groundwater contamination at Site 22.

SECTION 7

References

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Appendix A
ARARs and TBCs

APPENDIX A

Applicable or Relevant and Appropriate Requirements

Feasibility Study Report for Groundwater at Site 22

Naval Weapons Station Yorktown

Yorktown, Virginia

Classification	Media	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment
Federal-Chemical Specific	***Safe Drinking Water Act***						
	Groundwater	SDWA standards serve to protect public water systems. Primary drinking water standards consist of federally enforceable MCLs. MCLs are the highest level of a contaminant that is allowed in drinking water.	Groundwater contamination exceeds MCLs. Cleanup to MCLs for the contaminants presenting Human Health Risk is being considered in order to meet the state's expectations for beneficial use.	40 CFR 141.61 (a) (1), (5), (7) and (9)	2, 3, 4	Relevant and Appropriate	These alternatives would be implemented with a target goal of achieving MCLs. However, the aquifer is not currently, nor reasonably anticipated in the future to be used as a potable water supply.
	Groundwater	SDWA standards serve to protect public water systems. The MCLG is the level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.	Cleanup standards for on-site ground or surface waters that are current or potential sources of drinking water.	40 CFR 141.50 to 141.55	2, 3, 4	TBC	MCLGs are non-enforceable standards. This remedial action is being implemented with a target goal of achieving MCLs. The aquifer is not currently, nor reasonably anticipated in the future to be used as a potable water supply.
	Groundwater	National Secondary Drinking Water Regulations (NSDWRs or secondary standards) are non-enforceable guidelines regulating contaminants that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.	Cleanup standards for on-site groundwater that are potential sources of drinking water.	40 CFR 143	2, 3, 4	TBC	Secondary MCLs are non-enforceable standards. This remedial action is being implemented with a target goal of achieving MCLs. The aquifer is not currently, nor reasonably anticipated in the future to be used as a potable water supply.
	Clean Water Act						
		Spill, Prevention, Control, and Countermeasures standards require that adequate precautions be taken to prevent discharges of oil to waters of the United States.	The total possible capacity of oil storage at the site is equal to or greater than 1,320 gallons. Capacity is determined by summing the total capacity of containers and oil filled equipment at the site having a volume of 55 gallons or greater.	40 CFR 112, Subparts A and C	2, 4	Applicable	Applies if any other oil based substance is present at any time at the site and the prerequisite is met.
	USEPA RSL Tables						
	Water, air, fish tissue, soil	Chemical concentrations corresponding to fixed levels of human health risk (i.e., a hazard quotient of 1, or lifetime cancer risk of 10^{-6}, whichever occurs at a lower concentration).	Assessment of potential human health risks.	USEPA RSL Tables	2, 3, 4	TBC	The RSLs present generic chemical concentrations for individual contaminants to determine the need for further investigation or site cleanup. A baseline HHRA has been performed to calculate site specific risks and was used in the development of PRGs. This remedial action is being implemented to achieve concentrations to meet the
Virginia-Chemical Specific	***State Water Control Law*** **[VA Code Ann. §§ 62.1-44.2 to 62.1-44.34:28 (2003)]**						
	Groundwater	Establishes groundwater quality standards to protect the public health or welfare and enhance the quality of water.	Groundwater is addressed in the remedy	*Groundwater Quality Standards* , 9 VAC 25-280-30	2,3,4	Applicable	These alternatives would be implemented with a target goal of achieving MCLs. A baseline HHRA has been performed to calculate site specific risks and was used in the development of PRGs in the event that MCLs were not available for a constituent of concern. The aquifer is not currently, or reasonably anticipated to be used as a potable water supply.

APPENDIX A

Applicable or Relevant and Appropriate Requirements

Feasibility Study Report for Groundwater at Site 22

Naval Weapons Station Yorktown

Yorktown, Virginia

Classification	Media	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment
Virginia-Chemical Specific	***Environmental Health Services [VA Code Ann. §§ 32.1-163 to 248.2]***						
	Groundwater	SMCLs are guidelines pertaining to aesthetic qualities of drinking water (i.e., color, odor, and taste).	Potential drinking water source.	*Waterworks Regulations* , 12 VAC 5-590-10 to 1280	2,3,4	TBC	SMCLs are non-enforceable guidelines. The aquifer is not currently, nor reasonably anticipated in the future to be used as a potable water supply. The remedial action is being implemented with a target goal of achieving MCLs.
Federal-Location Specific	***Migratory Bird Treaty Act***						
	Native bird area	Protects almost all species of native birds in the United States from unregulated taking.	Presence of migratory birds.	*Migratory Bird Treaty Act* , 16 USC 703	2,3,4	Applicable	Site 22 is located in the Atlantic Migratory Flyway. If migratory birds, or their nests or eggs, are identified at Site 22, operations will not destroy the birds, nests or eggs.
	Coastal Zone Management Act						
	Coastal zone or area that will affect the coastal zone	Federal activities must be consistent with, to the maximum extent practicable, state coastal zone management programs. Federal agencies must comply with the consistency requriements of 15 CFR 930.	Performing an activity that would have any reasonablly forseeable affect on the coastal zone as defined by the state of Virginia.	*Coastal Zone Management Act* , 16USC1456(c), 15 CFR 930.30 to 33, .36(a), .39(b-d)	2,3,4	Relevant and Appropriate	Site 22 is excluded from the coastal zone as lands held in trust by the Federal Government are exempt. However, if any activity performed will likely affect lands that are not exempt from the coastal zone the consistency equirements of 15 CFR 930 apply.
Federal-Action Specific	***Safe Drinking Water Act***						
	Underground injection	Regulates the subsurface emplacement of liquids through the Underground Injection Control program, which governs the design and operation of five classes of injection wells in order to prevent contamination of underground sources of drinking water. The Underground Injection Control program regulates well construction, well operation, and monitoring.	Any dug hole or well that is deeper than its largest surface dimension, where the principal function of the hole is in subsurface placement of fluids.	40 CFR 144.1(g), 144.6, 144.12(a), 144.24(a), 144.82, 144.83, 146.8, 146.10(c)	2,3,4	Applicable	These alternatives will include substrate injections. Permits are not applicable to on-site CERCLA injection wells; however, these alternatives will comply with the substantive requirements of the regulation.
Virginia-Action Specific	***Erosion and Sediment Control Law*** **[VA Code Ann. §§ 10.1-560 to 573 (2010)]**						
	Construction activities that that disturb at least 10,000 sq ft of land.	Regulations for the effective control of soil erosion, sediment deposition and nonagricultural runoff which must be met in any control program to prevent the unreasonable degradation of properties, stream channels, waters and other natural resources.	Construction activities that disturb at least 10,000 sq ft of land.	Erosion and Sediment Control Regulations, 4 VAC 50-30-40, 60.A	2,3,4	Applicable	Erosion and sediment control measures will be followed for the implementation of remedial activities if needed. However, because site activities will disturb less than 10,000 sq ft, the work to be completed at the site may be eligible for a waiver.

APPENDIX A
Applicable or Relevant and Appropriate Requirements
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Classification	Media	Requirement	Prerequisite	Citation	Alternative	ARAR Determination	Comment
Virginia-Action Specific	***Virginia Waste Management Act* [VA Code Ann. §§ 10.1-1400 to 1457 (2009)]**						
	Handling, storage, treatment, disposal, and/or transportation of hazardous waste	Regulates the management, transportation, and disposal of wastes. Requires that generators properly characterize wastes generated and manage them appropriately.	Management of wastes that meet the definition of solid waste.	*Hazardous Waste Regulations* , 9 VAC 20-60-261 (hazardous waste identification incorporating all of 40 CFR 261); 9 VAC 20-60-262 (incorporating 40 CFR Parts 262.11 and 262.34 (generator requirements); Solid Waste Management Regulations, 9 VAC 20-80-140, to 170 150, 240.(c)	2,3,4	Applicable	These alternatives will generate water and soil wastes which will be characterized for off site disposal. Based on site history, waste will likely not be characterized as hazardous waste. If characterization results indicate this material is hazardous, it will be disposed of accordingly.

Notes:

Alt 1 - No Action (Note: none of the ARARs or TBC criteria apply to Alternative 1)
Alt 2 - Enhanced In Situ Bioremediation and Performance Monitoring of RDX, Monitored Natural Attenuation of VOCs and Land Use Controls
Alt 3 - In Situ Chemical Oxidation and Performance Monitoring of RDX and VOCs with Monitored Natural Attenuation and Land Use Controls
Alt 4 - Enhanced In Situ Bioremediation and Performance Monitoring of RDX and VOCs with Monitored Natural Attenuation and Land Use Controls

ARARs were not identified with the classification of Virginia-Location Specific.

Acronyms and Abbreviations

ARAR	Applicable or relevant and appropriate requirement	RCRA	Resource Conservation and Recovery Act
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act	SDWA	Safe Drinking Water Act
CFR	Code of Federal Regulations	TCLP	Toxicity Characteristic Leaching Procedure
HHRA	Human Health Risk Assessment	USC	United States Code
MCL	Maximum Contaminant Level	VA	Virginia
PRG	Preliminary Remedation Goal	VAC	Virginia Administrative Code
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine	VAC	Volatile Organic Compound

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Appendix B
Calculation of Groundwater RGOs for RDX

TABLE B-1

Values Used for Daily Intake Calculations for RDX: Reasonable Maximum Exposure

Feasibility Study Report for Groundwater at Site 22

Naval Weapons Station Yorktown

Yorktown, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Resident	Adult	Yorktown Aquifer - Tap Water and Water in Excavation Pit	CW	Chemical Concentration in Water	95% UCL	µg/l	95% UCL	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR-W	Ingestion Rate of Water	2	liters/day	EPA, 1997	CW x IR-W x EF x ED x CF2 x 1/BW x 1/AT
				EF	Exposure Frequency	350	days/year	EPA, 1991	
				ED	Exposure Duration	24	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW	Body Weight	70	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	8,760	days	EPA, 1989	
		Child	Yorktown Aquifer - Tap Water and Water in Excavation Pit	CW	Chemical Concentration in Water	95% UCL	µg/l	95% UCL	CDI (mg/kg-day) =
				IR-W	Ingestion Rate of Water	1	liters/day	EPA, 1997	CW x IR-W x EF x ED x CF2 x 1/BW x 1/AT
				EF	Exposure Frequency	350	days/year	EPA, 1991	
				ED	Exposure Duration	6	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW	Body Weight	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
		Child/Adult	Yorktown Aquifer - Tap Water and Water in Excavation Pit	CW	Chemical Concentration in Water	95% UCL	µg/l	95% UCL	CDI (mg/kg-day) =
				IR-W-A	Ingestion Rate of Water, Adult	2	liters/day	EPA, 1997	CW x IR-W-Adj x EF x CF2 x 1/AT
				IR-W-C	Ingestion Rate of Water, Child	1	liters/day	EPA, 1997	
				IR-W-Adj	Ingestion Rate of Water, Age-adjusted	1.09	liter-year/kg-day	calculated	IR-W-Adj (liter-year/kd-day) =
				EF	Exposure Frequency	350	days/year	EPA, 1991	(ED-C x IR-W-C / BW-C) +
				ED-A	Exposure Duration, Adult	24	years	EPA, 1991	(ED-A x IR-W-A / BW-A)
				ED-C	Exposure Duration, Child	6	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				BW-A	Body Weight , Adult	70	kg	EPA, 1991	
				BW-C	Body Weight, Child	15	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
Dermal	Resident	Adult	Yorktown Aquifer - Tap Water and Water in Excavation Pit	CW	Chemical Concentration in Water	95% UCL	µg/l	95% UCL	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	
				t_{event}	Event Time	0.58	hr/event	EPA, 2004	Organics :
				SA	Skin Surface Area Available for Contact	18,000	cm^2	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				EV	Event Frequency	1	events/day	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EF	Exposure Frequency	350	days/year	EPA, 2004	x CF2 x CF3
				ED	Exposure Duration	24	years	EPA, 2004	
				BW	Body Weight	70	kg	EPA, 1991	t_{event}>t*: DAevent (mg/cm^2-event) =
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-N	Averaging Time (Non-Cancer)	8,760	days	EPA, 1989	((1 + 3B + $3B^2$)/(1+B)^2)) x CF2 x CF3
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	
		Child	Yorktown Aquifer - Tap Water and Water in Excavation Pit	CW	Chemical Concentration in Water	95% UCL	µg/l	95% UCL	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm^2-event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t_{event}	Event Time	1.0	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA	Skin Surface Area Available for Contact	6,600	cm^2	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	6	years	EPA, 2004	t_{event}>t*: DAevent (mg/cm^2-event) =
				BW	Body Weight	15	kg	EPA, 1991	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + $3B^2$)/(1+B)^2)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	
Dermal	Resident	Child/Adult	Yorktown Aquifer - Tap Water and Water in Excavation Pit	CW	Chemical Concentration in Water	95% UCL	µg/l	95% UCL	CDI (mg/kg-day) = DA-Adj x EF x 1/AT
				DAevent-A	Dermally Absorbed Dose per Event, Adult	calculated	mg/cm^2-event	calculated	
				DAevent-C	Dermally Absorbed Dose per Event, Child	calculated	mg/cm^2-event	calculated	DA-Adj = (Daevent-A x SA-A x ED-A x 1/BW-A)
				DA-Adj	Dermally Absorbed Dose, Age-adjusted	calculated	mg-year/event-kg	calculated	+ (Daevent-C x SA-C x ED-C x 1/BW-C)
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K_p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm^2-event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t_{event} x CF2 x CF3
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	
				t_{event}-A	Event Time, Adult	0.58	hr/event	EPA, 2004	Organics :
				t_{event}-C	Event Time, Child	1.0	hr/event	EPA, 2004	t_{event}<t*: DAevent (mg/cm^2-event) =
				SA-A	Skin Surface Area, Adult	18,000	cm^2	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t_{event})/π))
				SA-C	Skin Surface Area, Child	6,600	cm^2	EPA, 2004	x CF2 x CF3
				EV	Event Frequency	1	events/day	EPA, 2004	
				EF	Exposure Frequency	350	days/year	EPA, 2004	t_{event}>t*: DAevent (mg/cm^2-event) =
				ED-A	Exposure Duration, Adult	24	years	EPA, 2004	FA x Kp x CW x (t_{event}/(1+B) + 2 x τ x
				ED-C	Exposure Duration, Child	6	years	EPA, 2004	((1 + 3B + $3B^2$)/(1+B)^2)) x CF2 x CF3
				BW-A	Body Weight, Adult	70	kg	EPA, 1991	
				BW-C	Body Weight, Child	15	ke	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	- -	
				CF3	Conversion Factor 3	0.001	l/cm^3	- -	

(1) Professional Judgement based on construction activities that would occur 8 hrs per day for the RME.

(2) Assumed contact with groundwater during construction project would be 125 days/year.

(3) Skin surface area in contact with groundwater assumed to be hands, forearms, lower legs, and feet.

Sources:

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TABLE B-2

Calculation of Chemical Cancer Risks and Non-Cancer Hazards for RDX: Reasonable Maximum Exposure

Feasibility Study Report for Groundwater at Site 22

Naval Weapons Station Yorktown

Yorktown, Virginia

Receptor	Exposure Medium	Exposure Point	Exposure Route	Exposure Point Concentration (µg/L)	DAevent (mg/cm2-event)	Non-Cancer Hazard Calculations			
						Intake/Exposure Concentration (mg/kg/day)	RfD (mg/kg/day)	Sources of RfD:	Hazard Quotient
Residential Adult	Groundwater	Yorktown Aquifer-Tap Water	Ingestion	9.4E+01	N/A	2.6E-03	3.0E-03	IRIS (Chronic) HEAST (Subchronic)	8.6E-01
			Dermal Absorption	9.4E+01	9.4E-08	2.3E-05	3.0E-03	IRIS (Chronic) HEAST (Subchronic)	7.7E-03
Residential Child	Groundwater	Yorktown Aquifer-Tap Water	Ingestion	9.4E+01	N/A	6.0E-03	3.0E-03	IRIS (Chronic) HEAST (Subchronic)	2.0E+00
			Dermal Absorption	9.4E+01	1E-07	5.2E-05	3.0E-03	IRIS (Chronic) HEAST (Subchronic)	1.7E-02

Receptor	Exposure Medium	Exposure Point	Exposure Route	Exposure Point Concentration (µg/L)	DAevent (mg/cm2-event)	Cancer Risk Calculations			
						Intake/Exposure Concentration (mg/kg/day)	CSF (1/mg/kg/day)	Source	Cancer Risk
Residential Child/Adult	Groundwater	Yorktown Aquifer-Tap Water	Ingestion	9.4E+01	---	1.4E-03	1.1E-01	IRIS	1.5E-04
			Dermal Absorption	9.4E+01	9.4E-08	1.24023E-05	1.1E-01	IRIS	1.4E-06

Notes:

1. The medium-specific and exposure scenario–specific intake equations used in this assessment are provided in the RAGS Part D Table 4 (USEPA, 2001a).
2. Risk values obtained from Final RI Report for Groundwater at Site 22: Appendix J- Human Health Risk Assessment Tables (CH2M HILL, 2009)

CSF - Cancer Slope Factor
HEAST - Health Effects Assessment Summary Tables
IRIS - Integrated Risk Information System Database
N/A - not applicable
RfD - Reference Dose
µg/L - micrograms per liter

TABLE B-3

Calculation of Groundwater Remedial Goal Options for RDX

Feasibility Study Report for Groundwater at Site 22

Naval Weapons Station Yorktown

Yorktown, Virginia

Residential Adult

Chemical	Exposure Point Concentration (µg/L)	Hazard Quotient				RGO - 0.1 (µg/L)	RGO - 1.0 (µg/L)	RGO - 3.0 (µg/L)
		Inh	Ing	Der	Total			
RDX	9.4E+01	--	8.6E-01	7.7E-03	8.7E-01	1.1E+01	1.1E+02	3.3E+02

Residential Child

Chemical	Exposure Point Concentration (µg/L)	Hazard Quotient				RGO - 0.1 (µg/L)	RGO - 1.0 (µg/L)	RGO - 3.0 (µg/L)
		Inh	Ing	Der	Total			
RDX	9.4E+01	--	2.0E+00	1.7E-02	2.0E+00	4.7E+00	4.7E+01	1.4E+02

Residential Child/Adult

Chemical	Exposure Point Concentration (µg/L)	Carcinogenic Risk				RGO - 10^{-6} (µg/L)	RGO - 10^{-5} (µg/L)	RGO - 10^{-4} (µg/L)
		Inh	Ing	Der	Total			
RDX	9.4E+01	--	1.5E-04	1.4E-06	1.6E-04	6.0E-01	6.0E+00	6.0E+01

Notes:

1. For carcinogens: RGO = (Exposure Point Concentration x Target Risk Level)/ Total Cancer Risk
2. For noncarcinogens: RGO = (Exposure Point Concentration x Target Hazard Level)/ Total Hazard Quotient
3. Remedial Goal Options (RGOs)
4. Hazard quotient, carcinogenic risk, and exposure point concentration values obtained from Final RI Report for Groundwater at Site 22: Appendix J-Human Health Risk Assessment Tables (CH2M HILL, 2009)

µg/L - micrograms per liter

Appendix C
Preliminary Cost Estimates

APPENDIX C
Preliminary Cost Estimates
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Remedial Action Cost Estimate Summary

Site: Naval Weapons Stations Yorktown
Location: Site 22 - Yorktown, Virginia
Phase: Draft FS
Base Year: 2010

	Alternative 2: EISB for RDX, MNA for VOCs, and LUCs	Alternative 3: ISCO and Performance Monitoring for RDX and VOCS with MNA and LUCs	Alternative 4: EISB and Performance Monitoring for RDX and VOCs with MNA and LUCs
Total Project Duration (Years)	34	25	29
Present Value - Capital Costs	$708,026	$1,228,931	$1,024,061
Present Value - O&M Costs	$1,028,565	$833,902	$994,759
Present Value - Periodic Costs	$170,100	$418,999	$698,698
Total Present Value Cost	**$1,907,000**	**$2,482,000**	**$2,718,000**
Total Present Value Cost (+50%)	$2,861,000	$3,723,000	$4,077,000
Total Present Value Cost (-30%)	$1,335,000	$1,738,000	$1,903,000

Disclaimer:

1. The information in this cost estimate is based on the best available information regarding the anticipated scope of the remedial alternatives. Changes in the cost elements are likely to occur as a result of new information and data collected.

2. This cost estimate has been prepared in accordance with EPA 540-R-00-002 and represents a -30 to +50 percent range of accuracy. This estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions such as, but not limited to: local labor or contractor availability, wages, other work, material market fluctuations, price escalations, force majeure events, and developing bidding conditions, may affect the accuracy of this estimate. CH2M HILL is not responsible for any variance from this estimate or actual prices and conditions obtained.

3. Estimates are presented in current dollars without escalation.

APPENDIX C
Preliminary Cost Estimates
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Alternative 2: EISB for RDX, MNA for VOCs, and LUCs

Site: Naval Weapons Stations Yorktown
Location: Site 22 - Yorktown, Virginia
Phase: Draft FS
Base Year: 2010

KEY ASSUMPTIONS

1. 3 new shallow groundwater monitoring well(s) will be installed.
2. New monitoring well construction will be consistent with existing monitoring wells.
3. Monitoring well installation will take 3 (10-hr) days.
4. Utility clearance and surveyor will take 1 (10-hr) day total.
5. 3 new and 12 existing shallow groundwater monitoring wells will be monitored during all sampling events. 1 existing deep monitoring well will be monitored during the baseline sampling event and once every 2 years following the baseline sampling event.
6. Sampling event preparation will take 10 hours (Geologist) for laboratory and data validation procurement, equipment ordering and planning.
7. Each sampling event will take 2 Geologists 3 (10-hr) days.
8. Monitoring will be conducted quarterly for the first 4 years and annually thereafter until RAOs are achieved (34 years).
9. Analysis: Site-related COCs and their degradation products (TCE, 1,1-dicholoroethene, cis and trans 1,2-dicholoroethene, vinyl chloride, RDX, and ammonia) as well as geochemical parameters and sensitive metals (alkalinity, TOC, nitrate, nitrite, sulfate, sulfide, methane, ethane, ethene, Fe, Mn), and field water quality parameters (dissolved oxygen, oxidation-reduction potential, pH, salinity, specific conductivity, temperature and turbidity). The geochemical parameters and sensitive metals list will be evaluated based on sampling results after four years and may be reduced if site geochemical conditions are well understood. For cost estimating purposes it is assumed that geochemical parameters and sensitive metals will not be analyzed after 4 years.
10. Pre-design investigation includes 30 DPT locations (plus 20% contingency) with up to 4 groundwater samples analyzed for site related COCs and their degradation products.
11. Assuming a soil bulk density of 110 lbs per ft^3 within the biobarriers (treatment zone).
12. Assuming a porosity of 22% (0.22).
13. The EVO solution volume estimates are based on maximum oil retention by aquifer material of 0.002 kilograms (kg) of oil per kg of soil.
14. 7,880 lbs of EVO (with pH buffer) would be injected into 30 permanent injection wells over a 8 day period.
15. 3,940 lbs of EVO (with pH buffer) would be re-injected into 30 permanent injection wells over a 4 day period at 2 years after the initial injection.
16. Assumes an average injection rate of 4.5 gallons per minute (gpm) with 8 hours of injection per day, simultaneous injection into three locations, and 2 percent dilution of EVO.
17. Assumes field activities for 10 hours per day, with 8 of the 10 days for injection.
18. Quarterly performance monitoring is assumed for 24 months after each injection and includes monitoring volatile fatty acids in addition to the laboratory analyses shown above.
19. Injection water would be delivered to the site and stored since a potable water source is not available on-site.
20. All laboratory data is assumed to be validated.
21. Design details are conceptual in nature and presented in this FS to develop costs for alternative comparison.

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
CAPITAL COSTS					
Land Use Controls					
Signs	4	EACH	$319	$1,275	RS Means 10400-200-2200
Deed Notifications	1	LS	$10,000	$10,000	Engineer's Estimate
SUBTOTAL				**$11,275**	
Pre-Design Investigation					
Private Utility Locator	1	LS	$3,800	$3,800	Engineer's Estimate
DPT Rate (3 locations/day)	12	DAYS	$2,500	$30,000	Engineer's Estimate
Driller Per diem (2 drillers)	12	DAYS	$290	$3,480	DOD Travel Per Diem Allowance, FY2009
Geologist (10-hr days)	120	HR	$66	$7,968	Navy CLEAN Rate
Geologist (Transportation)	12	DAYS	$80	$960	Engineer's Estimate
Laboratory (Site-Related COCs)	1	LS	$51,600	$51,600	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$8,109	$8,109	Navy CLEAN BOA Rates (Site-Related COC's)
SUBTOTAL				**$105,917**	
Utility Locator and Surveyor					
Private Utility Locator	1	LS	$2,000	$2,000	Engineers Estimate
Surveyor	1	LS	$3,500	$3,500	
Geologist	10	HR	$66	$660	Navy CLEAN Rate
Geologist (Transportation)	1	DAY	$80	$80	Engineers Estimate
SUBTOTAL				**$6,240**	
Proposed Monitoring Well Installation (Subcontractor)					
Driller Per diem (2 drillers)	3	DAY	$290	$870	DOD Travel Per Diem Allowance, FY2009
Drilling (4.25-in HSA)	126	LF	$20	$2,520	WDC Estimate (drilling and decon)
Well Materials	126	LF	$8	$1,008	Riser/Screen, 2-inch sched 40 PVC
Annular Materials	126	LF	$14	$1,764	sand/bentonite/concrete (8.25"auger)
Well Completion	3	EA	$450	$1,350	well pad, manhole casing/well caps
Well Development Labor	3	PER WELL	$165	$495	WDC Est., 2 hr per screen
Disposal of Generated Wastes	3	PER WELL	$1,000	$3,000	Recent similar project
Geologist	30	HR	$66	$1,980	Navy CLEAN Rate
Geologist (Transportation)	3	DAY	$80	$240	Engineer's Estimate
SUBTOTAL				**$13,227**	
Proposed Injection Well Installation (Subcontractor)					
Driller Per diem (2 drillers)	18	DAY	$290	$5,220	DOD Travel Per Diem Allowance, FY2009
Drilling (4.25-in HSA)	1200	LF	$20	$24,000	WDC Estimate (drilling and decon)
Well Materials	1200	LF	$8	$9,600	Riser/Screen, 2-inch sched 40 PVC
Annular Materials	1200	LF	$14	$16,800	sand/bentonite/concrete (8.25"auger)
Well Completion	30	EA	$450	$13,500	well pad, manhole casing/well caps
Well Development Labor	30	PER WELL	$165	$4,950	WDC Est., 2 hr per screen
Disposal of Generated Wastes	30	PER WELL	$1,000	$30,000	Recent similar project
Geologist	180	HR	$66	$11,880	Navy CLEAN P2 Rate
Geologist (Transportation)	18	DAYS	$25	$450	Engineer's Estimate
SUBTOTAL				**$116,400**	
Proposed Monitoring & Injection Well Installation (Insurance)					
Pollution and Liability Insurance	3%	of	$129,627	$3,889	
Payment & Performance Bond	3%	of	$129,627	$3,889	
General Requirements	12%	of	$129,627	$15,555	
SUBTOTAL				**$23,333**	
Baseline Groundwater Sampling Event					
Field Preparation	10	HR	$66	$660	Navy CLEAN P2 Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,960	Navy CLEAN P2 Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$7,011	$7,011	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs)	1	LS	$1,004	$1,004	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
SUBTOTAL				**$24,072**	
EISB Pre-Implementation Activities					
Project Manager	80	HR	$87	$6,961	Navy CLEAN Rate
Engineer/Hydrogeologist	80	HR	$104	$8,356	Navy CLEAN Rate
Sr. Engineer/Hydrogeologist	10	HR	$128	$1,281	Navy CLEAN Rate
Project Delivery Engineer	10	HR	$128	$1,281	Navy CLEAN Rate

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Project Procurement	10	HR	$87	$870	Navy CLEAN Rate
Utility Location	1	LS	$4,000	$4,000	Navy CLEAN Rate
SUBTOTAL				**$22,750**	
EISB Initial EVO Injection					
EVO with pH Buffer (Including Delivery)	7,880	LBS	$4	$31,520	Dajak - Characterization and Remediation Techologies
Water Delivery and Storage	52.0	1,000 GAL	$71	$3,714	Bruce & Son Water Works, Richmond VA
Mixing Equipment and Material	1	LS	$20,000	$20,000	Engineer's Estimate
Equipment Setup	20	HR	$100	$2,000	Navy CLEAN Rate
Driller Per diem (2 drillers)	8	DAYS	$290	$2,320	DOD Travel Per Diem Allowance, FY2009
Engineer/Hydrogeologist	160	HR	$87	$13,922	2 people, 10-hr days
Engineer (Transportation)	10	DAYS	$66	$660	Engineer's Estimate
Project Manager	24	HR	$87	$2,088	Navy CLEAN Rate - 3 hr per inj. day
Sr. Engineer/Hydrogeologist	28	HR	$128	$3,588	Navy CLEAN Rate - 3.5 hr per inj. Day
Project Delivery Engineer	8	HR	$128	$1,025	Navy CLEAN Rate - 1 hr per inj. day
Project Procurement	8	HR	$87	$696	Navy CLEAN Rate - 1 hr per inj. day
SUBTOTAL				**$81,533**	
Performance Monitoring - Groundwater Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (2 days - 2 Geologist)	40	HR	$66	$2,656	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	2	DAYS	$80	$160	Engineer's Estimate
Analytical (Site-Related COCs and Volatile Fatty Acids)	1	LS	$3,114	$3,114	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$2,722	$2,722	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs and Volatile Fatty Acids)	1	LS	$373	$373	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$463	$463	Navy CLEAN BOA Rates (Geochemistry)
SUBTOTAL				**$11,736**	
Annual Performance Monitoring - Groundwater Sampling	3	Events	$11,736	**$35,208**	Fourth event is included as part of annual O&M costs.
EISB Initial EVO Injection Reporting					
Project Manager	25	HR	$87	$2,175	Navy CLEAN Rate
Engineer/Hydrogeologist	80	HR	$104	$8,356	Navy CLEAN Rate
Sr. Engineer/Hydrogeologist	30	HR	$128	$3,844	Navy CLEAN Rate
Labor - Editor	20	HR	$87	$1,740	Navy CLEAN Rate
Labor - CAD Technician	25	HR	$87	$2,175	Navy CLEAN Rate
SUBTOTAL				**$18,291**	
COMBINED SUBTOTAL				**$469,981**	
Contingency	15%	of	$469,981	$70,497	
SUBTOTAL				**$540,478**	
Project Management	10%	of	$540,478	$54,048	
Remedial Design	6%	of	$540,478	$32,429	
Construction Management	15%	of	$540,478	$81,072	
TOTAL CAPITAL COSTS				**$708,026**	
OPERATION AND MAINTENANCE COSTS					
OPERATION AND MAINTENANCE COSTS (Years 1 through 4)					
Cost per Performance Monitoring and MNA Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs and VFAs)	1	LS	$10,355	$10,355	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs and VFAs)	1	LS	$1,250	$1,250	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$43,690**	
Land Use Controls Inspection					
Quarterly Inspection (Engineer)	56	HR	$104	$5,849	Navy CLEAN Rate
SUBTOTAL				**$5,849**	
COMBINED SUBTOTAL				**$49,539**	
Contingency	15%	of	$49,539	$7,431	
SUBTOTAL				**$56,970**	
Project Management	10%	of	$56,970	$5,697	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 1 through 4)				**$62,666**	
OPERATION AND MAINTENANCE COSTS (Year 5)					
Cost per MNA Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$165	$495	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$7,011	$7,011	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$1,004	$1,004	Navy CLEAN BOA Rates (Site-Related COC's)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$30,742**	
Land Use Controls Inspection					
Quarterly Inspection (Engineer)	56	HR	$104	$5,849	Navy CLEAN Rate
SUBTOTAL				**$5,849**	
COMBINED SUBTOTAL				**$36,591**	
Contingency	15%	of	$36,591	$5,489	
SUBTOTAL				**$42,080**	
Project Management	10%	of	$42,080	$4,208	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Year 5)				**$46,288**	
OPERATION AND MAINTENANCE COSTS (Years 6 through 34)					
Cost per MNA Sampling Event					

APPENDIX C
Preliminary Cost Estimates
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$6,871	$6,871	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$985	$985	Navy CLEAN BOA Rates (Site-Related COC's)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$30,328**	
Land Use Controls Inspection					
Annual Inspection (Engineer)	14	HR	$104	$1,462	Navy CLEAN Rate
SUBTOTAL				**$1,462**	
COMBINED SUBTOTAL				**$31,790**	
Contingency	15%	of	$31,790	$4,768	
SUBTOTAL				**$36,558**	
Project Management	10%	of	$36,558	$3,656	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 5 through 34)				**$40,214**	
PERIODIC COSTS					
Periodic Reviews (Years 5, 10, 15, 20, 25, and 30)					
5 Year Review	1	LS	$5,000	$5,000	
SUBTOTAL				**$5,000**	
EISB EVO Injection (Re-Injection and Performance Monitoring) (Year 3)					
ERD EVO Injection - Field Work	50%	LS	$81,533	$40,766	50% of Cost of Initial Injection
Annual Performance Sampling (Quarterly Events)	1	LS	$35,208	$35,208	Fourth event is included as part of annual O&M costs.
ERD EVO Injection - Reporting	75%	LS	$18,291	$13,718	75% of Cost of Initial Reporting
SUBTOTAL				**$89,692**	
EISB EVO Injection (Performance Monitoring) (Year 2 and 4)					
Quarterly Performance Sampling	1	LS	$35,208	$35,208	Fourth event is included as part of annual O&M costs.
SUBTOTAL				**$35,208**	

PRESENT VALUE ANALYSIS

Discount Rate : 2.3%
Years of O&M : 34

Federal Office of Management and Budget Circular A-94

END YEAR	DESCRIPTION	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE
1	Total Capital Costs	$708,026	$708,026	1	$708,026
4	Total Annual O&M Costs (Years 1 - 4)	$250,666	$62,666	0.945	$236,813
5	Total Annual O&M Costs (Year 5)	$46,288	$46,288	0.934	$43,235
34	Total Annual O&M Costs (Years 6 - 34)	$1,166,209	$40,214	0.642	$748,517
2	Periodic Costs	$35,208	$35,208	0.956	$33,643
3	Periodic Costs	$89,692	$89,692	0.934	$83,778
4	Periodic Costs	$35,208	$35,208	0.913	$32,147
5	Periodic Costs	$5,000	$5,000	0.893	$4,463
10	Periodic Costs	$5,000	$5,000	0.797	$3,983
15	Periodic Costs	$5,000	$5,000	0.711	$3,555
20	Periodic Costs	$5,000	$5,000	0.635	$3,173
25	Periodic Costs	$5,000	$5,000	0.566	$2,832
30	Periodic Costs	$5,000	$5,000	0.506	$2,528
	SUBTOTAL				**$1,906,692**

TOTAL PRESENT VALUE OF ALTERNATIVE 2	**$1,907,000**
TOTAL PRESENT VALUE OF ALTERNATIVE 2 (+50%)	**$2,861,000**
TOTAL PRESENT VALUE OF ALTERNATIVE 2 (-30%)	**$1,335,000**

This cost estimate has been prepared in accordance with EPA 540-R-00-002 and represents a -30 to +50 percent range of accuracy. This estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions such as, but not limited to: local labor or contractor availability, wages, other work, material market fluctuations, price escalations, force majeure events, and developing bidding conditions, may affect the accuracy of this estimate. CH2M HILL is not responsible for any variance from this estimate or actual prices and conditions obtained.

Alternative 3: ISCO and Performance Monitoring for RDX and VOCS with MNA and LUCs

Site: Naval Weapons Stations Yorktown
Location: Site 22 - Yorktown, Virginia
Phase: Draft FS
Base Year: 2010

KEY ASSUMPTIONS

1. 3 new shallow groundwater monitoring well(s) will be installed.
2. New monitoring well construction will be consistent with existing monitoring wells.
3. Monitoring well installation will take 3 (10-hr) days.
4. Utility clearance and surveyor will take 1 (10-hr) day total.

5. 3 new and 12 existing shallow groundwater monitoring wells will be monitored during all sampling events. 1 existing deep monitoring well will be monitored during the baseline sampling event and once every 2 years following the baseline sampling event.
6. Sampling event preparation will take 10 hours (Geologist) for laboratory and data validation procurement, equipment ordering and planning.
7. Each sampling event will take 2 Geologists 3 (10-hr) days.
8. Monitoring will be conducted quarterly for the first 4 years and annually thereafter until RAOs are achieved (25 years).

9. Analysis: Site-related COCs and their degradation products (TCE, 1,1-dicholoroethene, cis and trans 1,2-dicholoroethene, vinyl chloride, RDX, and ammonia) as well as MnO4 (colorimeter/ spectrophotometer field kit) and sensitive inorganic constituents (alkalinity, total organic carbon [TOC], nitrate, nitrite, sulfate, sulfide, methane, ethane, ethene, iron [Fe], manganese [Mn]) and field water quality parameters (dissolved oxygen, oxidation-reduction potential, pH, salinity, specific conductivity, temperature and turbidity). MnO4 and and sensitive inorganic constituents will be evaluated based on sampling results after four years and may be reduced if site conditions are well understood. For cost estimating purposes it is assumed that MnO4 and and sensitive inorganic constituents will not be analyzed after 4 years.
10. Pre-design investigation includes 64 DPT locations (plus 20% contingency) with up to 4 groundwater samples analyzed for site related COCs and their degradation products.
11. Assuming a soil bulk density of 110 lbs per ft^3, 54,241,000 lbs (or 246,500 kg) of soil are within the treatment zone.
12. Assuming a porosity of 22% (0.22), 811,446 gallons of water will require treatment.
13. Assuming a stoichiometric demand of the dissolved phase site-related COCs is 33.2 lbs of KMnO4, since the maximum concentrations are below 1 mg/L.
14. Based on the bench-scale studies, the permanganate oxidant demand of soil ranges from 1.5 g/kg for sandy soils to 9.3 g/kg for clayey soils at Site 22 (CH2M HILL, 2009).
15. Assuming an average soil demand of 5.4 g/kg, an efficiency contact of 10%, and a 50% safety factor.
16. 50,000 lbs of potassium permanganate would be injected into 123 temporary injection wells over a 21 day period , during the initial injection round.
17. 25,000 lbs of potassium permanganate would be injected into 62 temporary injection wells over a 11 day period, during re-injection in year 2.
18. Assumes an average injection rate of 10 gallons per minute (gpm) with 8 hours of injection per day and simultaneous injection into three locations.
19. Assumes field activities for 10 hours per day, with 8 of the 10 days for injection.
20. Quarterly performance monitoring is assumed for 24 months after each injection.
21. Injection water would be delivered to the site and stored since a potable water source is not available on-site.
22. All laboratory data is assumed to be validated.
23. Design details are conceptual in nature and presented in this FS to develop costs for alternative comparison.

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
CAPITAL COSTS					
Land Use Controls					
Signs	4	EACH	$319	$1,275	RS Means 10400-200-2200
Deed Notifications	1	LS	$10,000	$10,000	Engineer's Estimate
SUBTOTAL				**$11,275**	
Pre-Design Investigation					
Private Utility Locator	1	LS	$3,800	$3,800	Engineer's Estimate
DPT Rate (3 locations/day)	25	DAYS	$2,500	$62,500	Engineer's Estimate
Driller Per diem (2 drillers)	25	DAYS	$290	$7,250	DOD Travel Per Diem Allowance, FY2009
Geologist (10-hr days)	250	HR	$66	$16,600	Navy CLEAN Rate
Geologist (Transportation)	25	DAYS	$80	$2,000	Engineer's Estimate
Laboratory (Site-Related COCs)	1	LS	$110,491	$110,491	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$17,363	$17,363	Navy CLEAN BOA Rates (Site-Related COC's)
SUBTOTAL				**$220,004**	
Utility Locator and Surveyor (Well Installation)					
Private Utility Locator	1	LS	$2,000	$2,000	Engineers Estimate
Surveyor	1	LS	$3,500	$3,500	Engineer's Estimate
Geologist	10	HR	$66	$664	Navy CLEAN Rate
Geologist (Transportation)	1	DAYS	$80	$80	Engineer's Estimate
SUBTOTAL				**$6,244**	
Proposed Monitoring Well Installation (Subcontractor)					
Driller Per diem (2 drillers)	3	DAY	$290	$870	DOD Travel Per Diem Allowance, FY2009
Drilling (4.25-in HSA)	126	LF	$20	$2,520	WDC Estimate (drilling and decon)
Well Materials	126	LF	$8	$1,008	Riser/Screen, 2-inch sched 40 PVC
Annular Materials	126	LF	$14	$1,764	sand/bentonite/concrete (8.25"auger)
Well Completion	3	EA	$450	$1,350	well pad, manhole casing/well caps
Well Development Labor	3	PER WELL	$165	$495	WDC Est., 2 hr per screen
Disposal of Generated Wastes	3	PER WELL	$1,000	$3,000	Recent similar project
Geologist	30	HR	$66	$1,992	Navy CLEAN Rate
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
SUBTOTAL				**$13,239**	
Proposed Monitoring Well Installation (Insurance)					
Pollution and Liability Insurance	3%	of	$13,239	$397	
Payment & Performance Bond	3%	of	$13,239	$397	
General Requirements	12%	of	$13,239	$1,589	
SUBTOTAL				**$2,383**	
Baseline Groundwater Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$7,011	$7,011	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Sensitive Inorganic Constituents and MnO4)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs)	1	LS	$1,004	$1,004	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Sensitive Inorganic Constituents)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
SUBTOTAL				**$24,100**	
ISCO Pre-Implementation Activities					
Project Manager	80	HR	$87	$6,961	Navy CLEAN Rate
Engineer/Hydrogeologist	80	HR	$104	$8,356	Navy CLEAN Rate
Sr. Engineer/Hydrogeologist	10	HR	$128	$1,281	Navy CLEAN Rate
Project Delivery Engineer	10	HR	$128	$1,281	Navy CLEAN Rate
Project Procurement	10	HR	$87	$870	Navy CLEAN Rate
Utility Location	1	LS	$4,000	$4,000	Engineer's Estimate
SUBTOTAL				**$22,750**	
ISCO Initial Permanganate Injection					
DPT Day Rental	21	Days	$5,900	$123,900	Vironex
Vendor Cost Potassium Permanganate	50,000	LBS	$3	$125,000	Vironex
Shipping - Potassium Permanganate	50,000	LBS	$0.11	$5,500	Carus (11/08)
Water Delivery and Storage	299	1000 GAL	$71.43	$21,376	Bruce & Son Water Works, Richmond VA
Mixing Equipment and Material	1	EA	$50,000	$50,000	Engineer's Estimate
Equipment Setup	80	HR	$66	$5,312	Navy CLEAN Rate
Driller Per diem (2 drillers)	21	DAY	$290	$6,090	DOD Travel Per Diem Allowance, FY2009
Engineer/Hydrogeologist	420	HR	$104	$43,869	Navy CLEAN Rate - 2 people, 10-hr days
Engineer (Transportation)	21	DAYS	$80	$1,680	Engineer's Estimate
Project Manager	63	HR	$87	$5,482	Navy CLEAN Rate - 3 hr per inj. day
Sr. Engineer/Hydrogeologist	73.5	HR	$128	$9,418	Navy CLEAN Rate - 3.5 hour per inj. day
Project Delivery Engineer	21	HR	$128	$2,691	Navy CLEAN Rate - 1 hour per inj. day
Project Procurement	21	HR	$87	$1,827	Navy CLEAN Rate - 1 hour per inj. day
SUBTOTAL				**$402,144**	
Performance Monitoring - Groundwater Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs and Mn Reagent)	1	LS	$6,780	$6,780	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Sensitive Inorganic Constituents and MnO4)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs)	1	LS	$966	$966	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Sensitive Inorganic Constituents)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
SUBTOTAL				**$23,831**	
Annual Performance Monitoring - Groundwater Sampling	3	Events	$23,831	**$71,492**	Fourth event is included as part of annual O&M costs.
ISCO Initial Permanganate Injection Reporting					
Project Manager	25	HR	$87	$2,175	Navy CLEAN Rate
Engineer/Hydrogeologist	80	HR	$104	$8,356	Navy CLEAN Rate
Sr. Engineer/Hydrogeologist	30	HR	$128	$3,844	Navy CLEAN Rate
Labor - Editor	20	HR	$87	$1,740	Navy CLEAN Rate
Labor - CAD Technician	25	HR	$87	$2,175	Navy CLEAN Rate
SUBTOTAL				**$18,291**	
COMBINED SUBTOTAL				**$815,752**	
Contingency	15%	of	$815,752	$122,363	
SUBTOTAL				**$938,115**	
Project Management	10%	of	$938,115	$93,812	
Remedial Design	6%	of	$938,115	$56,287	
Construction Management	15%	of	$938,115	$140,717	
TOTAL CAPITAL COSTS				**$1,228,931**	
OPERATION AND MAINTENANCE COSTS					
OPERATION AND MAINTENANCE COSTS (Years 1 through 4)					
Cost per Performance Monitoring Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs and Mn Reagent)	1	LS	$6,920	$6,920	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Sensitive Inorganic Constituents and MnO4)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
Data Validation (Site-Related COCs)	1	LS	$985	$985	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Sensitive Inorganic Constituents)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$39,990**	
Land Use Controls Inspection					
Quarterly Inspection (Engineer)	56	HR	$104	$5,849	Navy CLEAN Rate
SUBTOTAL				**$5,849**	
COMBINED SUBTOTAL				**$45,839**	
Contingency	15%	of	$45,839	$6,876	
SUBTOTAL				**$52,715**	
Project Management	10%	of	$52,715	$5,272	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 1 through 4)				**$57,987**	
OPERATION AND MAINTENANCE COSTS (Year 5)					
Cost per Performance Monitoring Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$7,011	$7,011	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$1,004	$1,004	Navy CLEAN BOA Rates (Site-Related COC's)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$30,487**	
Land Use Controls Inspection					
Quarterly Inspection (Engineer)	56	HR	$104	$5,849	Navy CLEAN Rate
SUBTOTAL				**$5,849**	
COMBINED SUBTOTAL				**$36,336**	
Contingency	15%	of	$36,336	$5,450	
SUBTOTAL				**$41,787**	
Project Management	10%	of	$41,787	$4,179	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Year 5)				**$45,965**	
OPERATION AND MAINTENANCE COSTS (Years 6 through 25)					
Cost per Performance Monitoring Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$6,871	$6,871	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$985	$985	Navy CLEAN BOA Rates (Site-Related COC's)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$30,328**	
Land Use Controls Inspection					
Annual Inspection (Engineer)	14	HR	$104	$1,462	Navy CLEAN Rate
SUBTOTAL				**$1,462**	
COMBINED SUBTOTAL				**$31,790**	
Contingency	15%	of	$31,790	$4,768	
SUBTOTAL				**$36,558**	
Project Management	10%	of	$36,558	$3,656	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 6 through 25)				**$40,214**	
PERIODIC COSTS					
Periodic Reviews (Years 5, 10, 15, 20, 25)					
5 Year Review	1	LS	$5,000	$5,000	
SUBTOTAL				**$5,000**	
ISCO Permanganate Injection (Re-Injection and Performance Monitoring) (Year 3)					
ISCO Permanganate Injection - Field Work	50%	LS	$402,144	$201,072	50% of Cost of Initial Injection
Annual Performance Sampling (Quarterly Events)	1	LS	$71,492	$71,492	Fourth event is included as part of annual O&M costs.
ISCO Permanganate Injection - Reporting	75%	LS	$18,291	$13,718	
SUBTOTAL				**$286,282**	
ISCO Permanganate Injection (Performance Monitoring) (Year 2 and 4)					
Quarterly Performance Sampling	1	LS	$71,492	$71,492	Fourth event is included as part of annual O&M costs.
SUBTOTAL				**$71,492**	

PRESENT VALUE ANALYSIS

Discount Rate : 2.3%
Years of O&M : 25

Federal Office of Management and Budget Circular A-94

END YEAR	DESCRIPTION	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE
1	Total Capital Costs	$1,228,931	$1,228,931	1	$1,228,931
4	Total Annual O&M Costs (Years 1 - 4)	$231,947	$57,987	0.945	$219,129
5	Total Annual O&M Costs (Year 5)	$45,965	$45,965	0.934	$42,934
25	Total Annual O&M Costs (Years 6 - 25)	$804,282	$40,214	0.711	$571,839
2	Periodic Costs	$71,492	$71,492	0.956	$68,313
3	Periodic Costs	$286,282	$286,282	0.934	$267,404
4	Periodic Costs	$71,492	$71,492	0.913	$65,276
5	Periodic Costs	$5,000	$5,000	0.893	$4,463
10	Periodic Costs	$5,000	$5,000	0.797	$3,983
15	Periodic Costs	$5,000	$5,000	0.711	$3,555
20	Periodic Costs	$5,000	$5,000	0.635	$3,173
25	Periodic Costs	$5,000	$5,000	0.566	$2,832
	SUBTOTAL				**$2,481,832**

TOTAL PRESENT VALUE OF ALTERNATIVE 3 **$2,482,000**

TOTAL PRESENT VALUE OF ALTERNATIVE 3 (+50%) **$3,723,000**

TOTAL PRESENT VALUE OF ALTERNATIVE 3 (-30%) **$1,738,000**

This cost estimate has been prepared in accordance with EPA 540-R-00-002 and represents a -30 to +50 percent range of accuracy. This estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions such as, but not limited to: local labor or contractor availability, wages, other work, material market fluctuations, price escalations, force majeure events, and developing bidding conditions, may affect the accuracy of this estimate. CH2M HILL is not responsible for any variance from this estimate or actual prices and conditions obtained.

Alternative 4: EISB and Performance Monitoring for RDX and VOCs with MNA and LUCs

Site: Naval Weapons Stations Yorktown
Location: Site 22 - Yorktown, Virginia
Phase: Draft FS
Base Year: 2010

KEY ASSUMPTIONS

1. 3 new shallow groundwater monitoring well(s) will be installed.
2. New monitoring well construction will be consistent with existing monitoring wells.
3. Monitoring well installation will take 3 (10-hr) days.
4. Utility clearance and surveyor will take 1 (10-hr) day total.
5. 3 new and 12 existing shallow groundwater monitoring wells will be monitored during all sampling events. 1 existing deep monitoring well will be monitored during the baseline sampling event and once every 2 years following the baseline sampling event.
6. Sampling event preparation will take 10 hours (Geologist) for procurements, equipment, etc.
7. Each sampling event will take 2 Geologists 3 (10-hr) days.
8. Monitoring will be conducted quarterly for the first 8 years and annually thereafter until RAOs are achieved (29 years).
9. Analysis: Site-related COCs and their degradation products (TCE, 1,1-dicholoroethene, cis and trans 1,2-dicholoroethene, vinyl chloride, RDX, and ammonia) as well as geochemical parameters and sensitive metals (alkalinity, TOC, nitrate, nitrite, sulfate, sulfide, methane, ethane, ethane, Fe, Mn, Ammonia), and field water quality parameters (dissolved oxygen, oxidation-reduction potential, pH, salinity, specific conductivity, temperature and turbidity). The geochemical parameters and sensitive metals list will be evaluated based on sampling results after four years and may be reduced if site geochemical conditions are well understood. For cost estimating purposes it is assumed that geochemical parameters and sensitive metals will not be analyzed after 8 years.
10. Pre-design investigation includes 64 DPT locations (plus 20% contingency) with up to 4 groundwater samples analyzed for site related COCs and their degradation products.
11. Assuming a soil bulk density of 110 lbs per ft^3 within the biobarriers (treatment zone).
12. Assuming a porosity of 22% (0.22).
13. The EVO solution volume estimates are based on maximum oil retention by aquifer material of 0.002 kilograms (kg) of oil per kg of soil.
14. 8,930 lbs of EVO (with pH buffer) would be injected into 34 permanent injection wells over a 10 day period.
15. 4,465 lbs of EVO (with pH buffer) would be re-injected into 34 permanent injection wells over a 5 day period at 2, 4, and 6 years after the initial injection.
16. Assumes an average injection rate of 4.5 gallons per minute (gpm) with 8 hours of injection per day, simultaneous injection into three locations, and 2 percent dilution of EVO.
17. Assumes field activities for 10 hours per day, with 8 of the 10 for injection.
18. Quarterly performance monitoring is assumed for 24 months after each injection and includes monitoring volatile fatty acids in addition to the laboratory analyses shown above.
19. Injection water would be delivered to the site and stored since a potable water source is not available on-site.
20. All laboratory data is assumed to be validated.
21. Design details are conceptual in nature and presented in this FS to develop costs for alternative comparison.

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
CAPITAL COSTS					
Land Use Controls					
Signs	4	EACH	$319	$1,275	RS Means 10400-200-2200
Deed Notifications	1	LS	$10,000	$10,000	Engineer's Estimate
SUBTOTAL				**$11,275**	
Pre-Design Investigation					
Private Utility Locator	1	LS	$3,800	$3,800	Engineer's Estimate
DPT Rate (3 locations/day)	25	DAYS	$2,500	$62,500	Engineer's Estimate
Driller Per diem (2 drillers)	25	DAYS	$290	$7,250	DOD Travel Per Diem Allowance, FY2009
Geologist (10-hr days)	250	HR	$66	$16,600	Navy CLEAN Rate
Geologist (Transportation)	25	DAYS	$66	$1,660	Engineer's Estimate
Laboratory (Site-Related COCs)	1	LS	$110,491	$110,491	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$17,363	$17,363	Navy CLEAN BOA Rates (Site-Related COC's)
SUBTOTAL				**$219,664**	
Utility Locator and Surveyor (Well Installation)					
Private Utility Locator	1	LS	$2,000	$2,000	Engineer's Estimate
Surveyor	1	LS	$3,500	$3,500	
Geologist	10	HR	$66	$664	Navy CLEAN Rate
Geologist (Transportation)	1	DAYS	$80	$80	Engineer's Estimate
SUBTOTAL				**$6,244**	
Proposed Monitoring Well Installation (Subcontractor)					
Driller Per diem (2 drillers)	3	DAY	$290	$870	DOD Travel Per Diem Allowance, FY2009
Drilling (4.25-in HSA)	126	LF	$20	$2,520	WDC Estimate (drilling and decon)
Well Materials	126	LF	$8	$1,008	Riser/Screen, 2-inch sched 40 PVC
Annular Materials	126	LF	$14	$1,764	sand/bentonite/concrete (8.25"auger)
Well Completion	3	EA	$450	$1,350	well pad, manhole casing/well caps
Well Development Labor	3	PER WELL	$165	$495	WDC Est., 2 hr per screen
Disposal of Generated Wastes	3	PER WELL	$1,000	$3,000	Recent similar project
Geologist	30	HR	$66	$1,992	Navy CLEAN P2 Rate
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
SUBTOTAL				**$13,239**	
Proposed Injection Well Installation (Subcontractor)					
Driller Per diem (2 drillers)	20	DAY	$290	$5,800	DOD Travel Per Diem Allowance, FY2009
Drilling (4.25-in HSA)	1360	LF	$20	$27,200	WDC Estimate (drilling and decon)
Well Materials	1360	LF	$8	$10,880	Riser/Screen, 2-inch sched 40 PVC
Annular Materials	1360	LF	$14	$19,040	sand/bentonite/concrete (8.25"auger)
Well Completion	34	EA	$450	$15,300	well pad, manhole casing/well caps
Well Development Labor	34	PER WELL	$165	$5,610	WDC Est., 2 hr per screen
Disposal of Generated Wastes	34	PER WELL	$1,000	$34,000	Recent similar project
Geologist	200	HR	$66	$13,280	Navy CLEAN P2 Rate
Geologist (Transportation)	20	DAYS	$80	$1,600	Engineer's Estimate
SUBTOTAL				**$132,710**	
Proposed Monitoring & Injection Well Installation (Insurance)					
Pollution and Liability Insurance	3%	of	$145,949	$4,378	
Payment & Performance Bond	3%	of	$145,949	$4,378	
General Requirements	12%	of	$145,949	$17,514	
SUBTOTAL				**$26,271**	
Baseline Groundwater Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN P2 Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN P2 Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$7,011	$7,011	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs)	1	LS	$1,004	$1,004	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
SUBTOTAL				**$24,100**	
EISB Pre-Implementation Activities					
Project Manager	80	HR	$87	$6,961	Navy CLEAN Rate
Engineer/Hydrogeologist	80	HR	$104	$8,356	Navy CLEAN Rate
Sr. Engineer/Hydrogeologist	10	HR	$128	$1,281	Navy CLEAN Rate
Project Delivery Engineer	10	HR	$128	$1,281	Navy CLEAN Rate
Project Procurement	10	HR	$87	$870	Navy CLEAN Rate
Utility Location	1	LS	$4,000	$4,000	Navy CLEAN Rate
SUBTOTAL				**$22,750**	
EISB Initial EVO Injection					
EVO with pH Buffer (Including Delivery)	8,930	LBS	$4	$35,720	Dajak - Characterization and Remediation Techologies
Water Delivery and Storage	59.0	1,000 GAL	$71	$4,214	Bruce & Son Water Works, Richmond VA
Mixing Equipment and Material	1	LS	$20,000	$20,000	Engineer's Estimate
Equipment Setup	20	HR	$66	$1,328	Navy CLEAN Rate
Driller Per diem (2 drillers)	10	DAYS	$290	$2,900	DOD Travel Per Diem Allowance, FY2009
Engineer/Hydrogeologist	200	HR	$104	$20,890	2 people, 10-hr days
Engineer (Transportation)	10	DAYS	$80	$800	Engineer's Estimate
Project Manager	30	HR	$87	$2,610	Navy CLEAN Rate - 3 hr per inj. day
Sr. Engineer/Hydrogeologist	35	HR	$128	$4,485	Navy CLEAN Rate - 3.5 hr per inj. Day
Project Delivery Engineer	10	HR	$128	$1,281	Navy CLEAN Rate - 1 hr per inj. day
Project Procurement	10	HR	$87	$870	Navy CLEAN Rate - 1 hr per inj. day
SUBTOTAL				**$95,099**	
Performance Monitoring - Groundwater Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs and VFAs)	1	LS	$10,214	$10,214	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs and VFAs)	1	LS	$1,231	$1,231	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
SUBTOTAL				**$27,530**	
Annual Performance Monitoring - Groundwater Sampling	3	Events	$27,530	**$82,590**	Fourth event is included as part of annual O&M costs.
EISB Initial EVO Injection Reporting					
Project Manager	25	HR	$87	$2,175	Navy CLEAN Rate
Engineer/Hydrogeologist	80	HR	$104	$8,356	Navy CLEAN Rate
Sr. Engineer/Hydrogeologist	30	HR	$128	$3,844	Navy CLEAN Rate
Labor - Editor	20	HR	$87	$1,740	Navy CLEAN Rate
Labor - CAD Technician	25	HR	$87	$2,175	Navy CLEAN Rate
SUBTOTAL				**$18,291**	
COMBINED SUBTOTAL				**$679,762**	
Contingency	15%	of	$679,762	$101,964	
SUBTOTAL				**$781,726**	
Project Management	10%	of	$781,726	$78,173	
Remedial Design	6%	of	$781,726	$46,904	
Construction Management	15%	of	$781,726	$117,259	
TOTAL CAPITAL COSTS				**$1,024,061**	

APPENDIX C
Preliminary Cost Estimates
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

DESCRIPTION	QTY	UNIT	UNIT COST	TOTAL	NOTES
OPERATION AND MAINTENANCE COSTS					
OPERATION AND MAINTENANCE COSTS (Years 1 through 5)					
Cost per Performance Monitoring Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs and VFAs)	1	LS	$10,355	$10,355	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs and VFAs)	1	LS	$1,250	$1,250	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$43,690**	
Land Use Controls Inspection					
Quarterly Inspection (Engineer)	56	HR	$104	$5,849	Navy CLEAN Rate
SUBTOTAL				**$5,849**	
COMBINED SUBTOTAL				**$49,539**	
Contingency	15%	of	$49,539	$7,431	
SUBTOTAL				**$56,970**	
Project Management	10%	of	$56,970	$5,697	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 1 through 5)				**$62,666**	
OPERATION AND MAINTENANCE COSTS (Years 6 through 8)					
Cost per Performance Monitoring Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$0	$0	Engineer's Estimate
Analytical (Site-Related COCs and VFAs)	1	LS	$10,355	$10,355	Navy CLEAN BOA Rates (Site-Related COC's)
Analytical (Geochemical Parameters)	1	LS	$8,165	$8,165	Navy CLEAN BOA Rates (Geochemistry)
Data Validation (Site-Related COCs and VFAs)	1	LS	$1,250	$1,250	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Geochemical Parameters)	1	LS	$1,448	$1,448	Navy CLEAN BOA Rates (Geochemistry)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$43,450**	
Land Use Controls Inspection					
Annual Inspection (Engineer)	14	HR	$104	$1,462	Navy CLEAN Rate
SUBTOTAL				**$1,462**	
COMBINED SUBTOTAL				**$44,912**	
Contingency	15%	of	$44,912	$6,737	
SUBTOTAL				**$51,649**	
Project Management	10%	of	$51,649	$5,165	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 6 through 8)				**$56,813**	
OPERATION AND MAINTENANCE COSTS (Years 9 through 29)					
Cost per Performance Monitoring Sampling Event					
Field Preparation	10	HR	$66	$664	Navy CLEAN P2 Rate
Field Work (3 days - 2 Geologist)	60	HR	$66	$3,984	Navy CLEAN P2 Rate
Field Equipment	1	LS	$1,584	$1,584	Pine Environmental
Geologist (Transportation)	3	DAYS	$80	$240	Engineer's Estimate
Analytical (Site-Related COCs)	1	LS	$6,871	$6,871	Navy CLEAN BOA Rates (Site-Related COC's)
Data Validation (Site-Related COCs)	1	LS	$985	$985	Navy CLEAN BOA Rates (Site-Related COC's)
Annual Report	1	LS	$16,000	$16,000	Engineer's Estimate
SUBTOTAL				**$30,328**	
Land Use Controls Inspection					
Annual Inspection (Engineer)	14	HR	$104	$1,462	Engineers Estimate
SUBTOTAL				**$1,462**	
COMBINED SUBTOTAL				**$31,790**	
Contingency	15%	of	$31,790	$4,768	
SUBTOTAL				**$36,558**	
Project Management	10%	of	$36,558	$3,656	
TOTAL ANNUAL OPERATION AND MAINTENANCE COSTS (Years 9 through 29)				**$40,214**	
PERIODIC COSTS					
Periodic Reviews (Years 5, 10, 15, 20, 25)					
5 Year Review	1	LS	$5,000	$5,000	
SUBTOTAL				**$5,000**	
EISB EVO Injection (Re-Injection and Performance Monitoring) (Year 3, 5 and 7)					
EISB EVO Injection - Field Work	50%	LS	$95,099	$47,549	50% of Cost of Initial Injection
Annual Performance Sampling (Quarterly Events)	1	LS	$82,590	$82,590	Fourth event is included as part of annual O&M costs.
EISB EVO Injection - Reporting	75%	LS	$18,291	$13,718	75% of Cost of Initial Reporting
SUBTOTAL				**$143,857**	
EISB EVO Injection (Performance Monitoring) (Year 2, 4, 6, and 8)					
Quarterly Performance Sampling	1	LS	$82,590	$82,590	Fourth event is included as part of annual O&M costs.
SUBTOTAL				**$82,590**	

PRESENT VALUE ANALYSIS

Discount Rate : 2.3%
Years of O&M : 29

Federal Office of Management and Budget Circular A-94

END YEAR	DESCRIPTION	TOTAL COST	TOTAL COST PER YEAR	DISCOUNT FACTOR	PRESENT VALUE	
1	Total Capital Costs	$1,024,061	$1,024,061	1	$1,024,061	
5	Total Annual O&M Costs (Years 1 - 5)	$313,332	$62,666	0.934	$292,670	89.3%
8	Total Annual O&M Costs (Years 6 - 8)	$170,440	$56,813	0.903	$153,862	
29	Total Annual O&M Costs (Year 9 - 29)	$844,496	$40,214	0.649	$548,227	
2	Periodic Costs	$82,590	$82,590	0.956	$78,918	
3	Periodic Costs	$143,857	$143,857	0.934	$134,371	
4	Periodic Costs	$82,590	$82,590	0.913	$75,409	
5	Periodic Costs	$148,857	$148,857	0.893	$132,859	
6	Periodic Costs	$82,590	$82,590	0.872	$72,057	
7	Periodic Costs	$143,857	$143,857	0.853	$122,688	
8	Periodic Costs	$82,590	$82,590	0.834	$68,853	
10	Periodic Costs	$5,000	$5,000	0.797	$3,983	
15	Periodic Costs	$5,000	$5,000	0.711	$3,555	
20	Periodic Costs	$5,000	$5,000	0.635	$3,173	
25	Periodic Costs	$5,000	$5,000	0.566	$2,832	
	SUBTOTAL				**$2,717,518**	

TOTAL PRESENT VALUE OF ALTERNATIVE 4	**$2,718,000**
TOTAL PRESENT VALUE OF ALTERNATIVE 4 (+50%)	**$4,077,000**
TOTAL PRESENT VALUE OF ALTERNATIVE 4 (-30%)	**$1,903,000**

This cost estimate has been prepared in accordance with EPA 540-R-00-002 and represents a -30 to +50 percent range of accuracy. This estimate is limited to the conditions existing at its issuance and is not a guaranty of actual price or cost. Uncertain market conditions such as, but not limited to: local labor or contractor availability, wages, other work, material market fluctuations, price escalations, force majeure events, and developing bidding conditions, may affect the accuracy of this estimate. CH2M HILL is not responsible for any variance from this estimate or actual prices and conditions obtained.

Appendix D
Reagent Evaluation: ISCO and EISB

APPENDIX D

Reagent Evaluation: ISCO and EISB

In Situ Chemical Oxidation

Catalyzed Hydrogen Peroxide. Hydrogen peroxide alone is an oxidant, but at low concentrations (<0.1 percent), it is not kinetically fast enough to degrade many organic contaminants before decomposition occurs. As discovered by H.J.H. Fenton, addition of a ferrous salt or iron (II) dramatically increases the reaction kinetics. The reactive hydroxyl radicals that form are very short-lived (hours), although stabilizers such as citrate have extended the time for the radicals to form to several days. Catalyzed hydrogen peroxide (CHP) is typically applied in the field by adding an iron catalyst to a hydrogen peroxide solution. Up to a 15 percent solution of hydrogen peroxide is common for this application. An amendment for pH adjustment may be needed, as CHP is more effective under acidic pH (2 to 4) conditions. Some catalysts, however, can be used with H_2O_2 in the neutral pH setting. The oxidation reaction by H_2O_2 is highly exothermic in nature. While CHP is effective for treating trichloroethene (TCE) and vinyl chloride (VC), no published literature was found for CHP treating hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX). The nature of organic energetics, however, suggest that these would readily be oxidizable. The short-lived reaction rates of the hydroxyl radical is not advantageous when applying In Situ Chemical Oxidation (ISCO) in a heterogeneous formation where back-diffusion is expected from silty clay units into the more permeable sandy units. In addition, shell fragments observed in the subsurface at Site 22 will serve as an oxidant sink consuming radicals and thus limiting the effectiveness of the site-related constituent of concern (COC) decreases. Therefore, CHP is not considered further at Site 22.

Permanganate. Permanganate is the mildest oxidant compared to other oxidants considered for Site 22. It oxidizes chlorinated ethenes through the following general reaction:

$$C_2H_YCl_X + 2KMnO_4 \rightarrow 2CO_{2(g)} + 2K^+ + YH^+ + 2MnO_{2(s)} + XCl^-$$

In this reaction, the chlorinated ethenes are destroyed, producing carbon dioxide (CO_2) gas, solid manganese dioxide, and several dissolved ions. CO_2 exists naturally in subsurface zones from biological processes and bicarbonate partitioning in the groundwater. Manganese dioxide (MnO_2) is a mineral naturally present in many soils. Excessive precipitation of MnO_2 in soil pores can reduce the permeability of the soil, thereby inhibiting injection of the oxidant. Permanganate may also oxidize natural organic matter (NOM) to which metals are sorbed, or the hydrogen cation generated may decrease groundwater pH if not buffered, leading to potential mobilization of redox-sensitive and exchangeable sorbed metals and biological perturbation.

Permanganate demand is stoichiometric, based on (COC) concentrations and natural soil oxidant demand from organic matter and reduced minerals. When delivered in stoichiometric excess, permanganate is relatively stable and persistent in the subsurface for months to a few years, allowing migration by diffusive processes. Field applications typically use a 0.5 to 4 percent solution prepared onsite from potassium permanganate

crystals. Alternatively, a liquid 40 percent sodium permanganate solution is diluted to the desired injection concentration. K-permanganate crystals often contain trace amounts of metallic impurities, such as chromium and lead.

Permanganate is very effective at oxidizing chlorinated ethenes (TCE and VC). A pilot study at the Nebraska Ordinance Plant (Albano, et al., 2010) and an onsite treatability study at the United States Department of Energy's Pantex Plant in Texas (IT and Stoller, 2000) demonstrated the effectiveness of permanganate as a treatment technology for RDX. Therefore, it is considered further for the groundwater at Site 22.

Ozone. Ozone gas can oxidize contaminants directly or through the formation of hydroxyl radicals. Like peroxide, ozone reactions are most effective in systems with acidic pH. The oxidation reaction proceeds with extremely fast, pseudo-first order kinetics. Ozone oxidation reactions occur in gas phase inside the "bubble" following the Criegee mechanism. As such, ozone oxidation may be rate-limited by aqueous phase diffusion and volatilization. Due to ozone's high reactivity and instability, ozone is produced onsite, and requires closely spaced delivery points (e.g., air sparging wells). As a result, the process requires high capital investment. For these reasons and due to the heterogeneity of the lithology at the site, ozone is not considered further as an oxidant at Site 22.

Persulfate. Sodium persulfate is a stable and strong oxidant. However, activation of persulfate to form sulfate radicals is required and can be conducted by heat (steam injection, low H_2O_2 concentration), catalysis by transition metals such as iron (II), copper, silver, and manganese, or by alkaline conditions (ph > 10.5). The addition of heat or a ferrous salt or iron (II) dramatically increases the oxidative strength of persulfate. This increase is attributed to the production of sulfate-free radicals, a strong oxidant roughly equivalent to the hydroxyl radical generated by CHP or ozone.

$$Na_2S_2O_8 \text{ (heat or catalyst activation)} \rightarrow 2SO_4^{-}{}_{(radicals)}$$

$$SO_4^{-}{}_{(radicals)} + e^- \rightarrow SO_4^{-2} \qquad E^o{}^1 = 2.6 \text{ volts}$$

The persulfate anion itself is a strong oxidizer:

$$S_2O_8^{-2} + 2H^+ + 2\,e^- \rightarrow 2HSO_4^{-2} \qquad E^o = 2.1 \text{ volts}$$

Under acidic conditions, persulfate also reacts with water to produce hydrogen peroxide, a kinetically faster oxidant than persulfate (FMC, 2001). Similar to the other oxidants, pH will decrease following the application due to acid anion generation. However, the decrease in pH can be mitigated by adding sodium carbonate (approximately 20 percent of persulfate loading on a mole basis) or other substances to effectively buffer the aquifer pH. Carbonate also appears to provide better stability to and increase activity of persulfate. Another advantage compared to other oxidants, persulfate does not appear to react readily with NOM, resulting in lower loading (total oxidant demand) compared to the other oxidants.

While activated persulfate is effective for treating TCE and VC, no published literature was found for full-scale applications of activated persulfate for treating RDX (although lab studies have been conducted for other energetics). However, given the nature of energetics, RDX should be amenable to oxidation by persulfate. Persulfate typically remains active in

the subsurface for 3 to 6 weeks, which may treat some COCs that will diffuse from the lower permeability zones back into the sandy layers in the heterogeneous formation with time. However, permanganate –when dosed appropriately – can remain in the subsurface for longer periods of time (up to 2 years), and is thus better suited for Site 22 than persulfate. Therefore, persulfate is not considered further at Site 22.

Enhanced In Situ Bioremediation

Enhanced in situ bioremediation (EISB) is considered at a treatment technology for this Feasibility study (FS). EISB of TCE and VC in groundwater has been implemented at numerous sites and is well documented. EISB of RDX is less common but has been shown to be effective at Sites 7 and 9 at the Former Naval Surface Warfare Center (NSWC) - White Oak, Silver Spring, Maryland (CH2M HILL, 2011 and 2005) and the Iowa Army Ammunition Plant (Tetra Tech, 2010). The most commonly used insoluble EISB substrates are Hydrogen Release Compound® (HRC®) and vegetable oil (emulsified and non-emulsified). Emulsified vegetable oil (EVO) is a food-grade, emulsified vegetable oil. The oil droplets are small enough to pass through most pores in the soil. Linoleic and other long-chain fatty acids in the vegetable oil slowly dissolve in water over time and are broken down by native microorganisms to lower molecular weight fatty acids such as pyruvate and propionate. Ultimately, the oil degrades to form acetic acid and hydrogen. The hydrogen and dissolved organic carbon from the acetic acid are then available to support reductive dechlorination of chlorinated solvents. Both EVO and HRC® can last several weeks to years. The benefit of the long-lasting donors is that operation and maintenance is minimized.

Soluble ERD substrates include benzoate, lactate, acetate, propionate, butyrate, methanol, ethanol, sucrose, molasses, and hydrogen. These substrates are water soluble, degrade rapidly, and are transported with groundwater flow. Because these substrates degrade rapidly, they require more frequent injections than insoluble substrates. They are typically injected as aqueous solutions into an aquifer using injection wells or direct push technology (DPT) methods. Soluble EISB is not considered for this FS due to the possibility of frequent injections.

For the purpose of this FS conceptual design and cost estimate, the use of EVO substrate is assumed, although another substrate may later be selected.

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Appendix E
Sustainability Evaluation

APPENDIX E

Sustainability Impact Analysis

Sustainable design in remediation projects is a systematic, balanced planning and management of risk concept. Sustainability includes many aspects of environmental, social, economic, and health developments. This sustainability evaluation quantifies environmental footprints for three remedial alternatives developed in the Yorktown Naval Weapons Station, Site 22 Feasibility Study (FS) and is not considered a full life-cycle analysis. This sustainability evaluation is only a small subsection of sustainability. The remedial alternatives include the following:

- Alternative 2- Enhanced In Situ Bioremediation (EISB) and Performance Monitoring of hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), Monitored Natural Attenuation (MNA) of Volatile Organic Compounds (VOCs), and Land Use Controls (LUCs)
- Alternative 3 – In Situ Chemical Oxidation (ISCO) and Performance Monitoring of RDX and VOCs with Monitored Natural Attenuation and Land Use Controls
- Alternative 4 – Enhanced In Situ Bioremediation and Performance Monitoring of RDX and VOCs with Monitored Natural Attenuation and Land Use Controls

The sustainability evaluation was completed using the Sustainable Remediation Tool (SRT) Version 2.1. The SRT was developed for the Air Force Center for Engineering and the Environment (AFCEE) to help incorporate sustainability concepts into a remediation decision making process for:

- Planning future remediation implementation
- Optimizing operating remediation systems
- Comparing remediation technologies

The SRT quantifies select sustainability metrics for comparing the environmental footprints of specific technologies and remediation alternatives. The current technologies in the SRT are: 1) Excavation, 2) Soil Vapor Extraction, 3) Thermal Treatment, 4) Pump and Treat, 5) Enhanced Bioremediation, 6) In situ Chemical Oxidation, 7) Permeable Reactive Barrier, and 8) Monitored Natural Attenuation/Long-Term Monitoring.

The SRT is an advanced technology screening tool but does not perform a full life-cycle analysis. The SRT is designed to evaluate particular remediation technologies on the basis of their environmental footprints by estimating the emissions of various parameters, such as greenhouse gases and energy resources (fuel and electricity). Other footprint analysis efforts might also consider additional, fewer, or different environmental parameters than those considered for this study. Other parameters such as air toxics, water usage, generation of waste, and effects to ecosystems were not part of this evaluation.

The SRT is structured into Risk-Based Corrective Action (RBCA) Tool Kit-type Tiers. This allows the user to choose the level of effort and detail appropriate for the project at hand. Tier 1 (simplest tier) calculations are based on rules-of-thumb that are widely used in the

environmental remediation industry. Tier 2 calculations are more detailed and incorporate site-specific factors and for projects that have advanced to the Feasibility Study (FS) stage. Since this project has advanced to the FS stage, a Tier 2 evaluation using Capital and Operating and Maintenance (O&M) metrics was used. Key assumptions and user inputs used to calculate the environmental footprints for each alternative are presented in subsequent tables associated with this Appendix (**Table 1** through **Table 7**) and were obtained from detailed descriptions of each remedial alternative presented in Section 4.2 and further explained in Appendix C – Preliminary Cost Estimates.

Air Emissions

For the air emissions analysis, metrics associated with the production of carbon dioxide (CO_2), sulfur oxides (SO_x), nitrogen oxides (NO_x), and particle matter (PM10) were considered. The following four components were evaluated for their air emission impacts:

- Vehicle Use for Capital and O&M Activities
- Drill Rig Use for Capital Activities
- Polyvinyl Chloride (PVC) Consumption for Capital Activities
- Injection Substrate/Oxidant Consumption for Capital Activities

Sustainability metrics for vehicle use for Capital and O&M activities were calculated assuming 100 miles per round trip, for each visit to the site. This corresponds to the round-trip distance from the CH2M HILL Virginia Beach office to the Yorktown Naval Weapons Station. The number of site visits varied between each alternative but assumptions are presented in subsequent tables within this Appendix. Air emissions were calculated by multiplying the vehicle emission factors by the total number of miles driven.

Sustainability metrics for drill rig use for Capital activities including monitoring well installation, temporary and permanent injection wells, and direct push technology (DPT) locations associated with the pre-design investigation. The quantity of locations and depth intervals varied between each alternative but assumptions are presented in subsequent tables within this Appendix. Air emissions were calculated by multiplying the diesel emission factors by the total number of gallons required.

Sustainability metrics for polyvinyl chloride (PVC) consumption for Capital activities associated with monitoring well installation, temporary and permanent injection wells.. The total linear feet of drilling varied between each alternative but assumptions are presented in subsequent tables within this Appendix. Air emissions were calculated by multiplying emission factors for PVC manufacturing by the total linear feet of drilling.

Sustainability metrics for injection substrate/oxidant consumption for Capital activities associated with ISCO and ERD injection. The total weight of ERD substrate and ISCO oxidant were assumed based on remedial objectives and the associated assumptions are presented in subsequent tables within this Appendix. Air emissions were calculated by multiplying emission factors for substrate and oxidant manufacturing by the total weight.

Risk of Accident and Lost Time

Impacts associated with the potential for injuries and lost time were evaluated for each alternative. Sustainability metrics for lost time resulting from hours worked and travel hours for vehicle use during Capital and O&M activities were based on the assumed total

APPENDIX E
Table 1 - Sustainability Evaluation - Main Screen Data Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

SRT Main Screen Data Inputs

Project Information

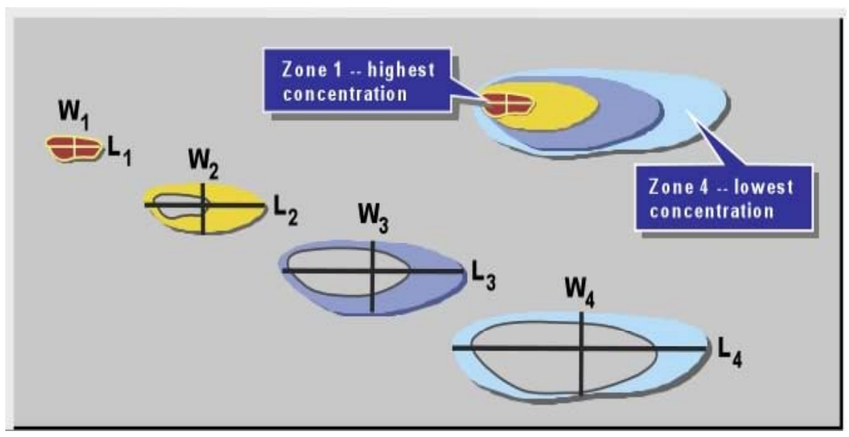
Site Name	Site 22	
Location	Naval Station Yorktown, Yorktown VA	
Analysis	Capital and O&M	#1) Capital and O&M, #2) Capital Only, or #3) O&M Only

Environmental Media

Groundwater Inputs

	Zone 1	Zone 2	Zone 3	Zone 4	
width (ft)	222.1	381.6			see embedded figure below
length (ft)	222.1	381.6			see embedded figure below
Concentration low (ug/L)	100	5			
Concentration high (ug/L)	650				

Contaminant class	CVOC	#1) CVOC, #2) BTEX
Depth to groundwater (ft bgs)	5.5	
Depth to top of formation (ft)	25	
Thickness of water bearing media (ft)	20	average bottom depth of CVOC contamination = 45 (thickness = 20 ft)
Aquifer media	silt	#1) sandy gravel, #2) sand (well graded), #3) sand (poorly graded), #4) silt, #5) clay
Hydraulic gradient	0.01	



Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
Highlight indicates minimum required user inputs

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APPENDIX E
Table 2 - Sustainability Evaluation - Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Sustainable Remediation Tool

Alternative 2 - Enhanced In Situ Bioremediation Component

Required	Optional			User Inputs
		Design for Managing Groundwater		
X			Airline miles flown by project team (total miles for all travelers)	0
X			Average Distance Traveled by Site Workers per one-way trip (miles)	50
X			Trips by Site Workers during construction	52
X			Trips by Site Workers after construction	10
X			Number of monitoring wells	
X			Length of PVC piping, per well (ft)	40
X			Number of samples collected per sampling event	15
X			Plume Calculation Method	ks
X			Source zone point decay rate constant (k_s = 1/yr)	0.144
		Materials and Consumable Amounts Used for Metrics		
	X		PVC (lbs)	2400
	X		Diesel (gallons)	384
	X		Donor/substrate (lbs)	20000
	X		Gasoline (gallons)	410
		Technology Cost		
	X		Capital	NU
	X		O&M	NU
		Project-specific Metrics (Add & Subtract/Offsets)		
	X		Additional Technology Cost	0
	X		Total Energy Consumed	60000
	X		CO_2 Emissions to Atmosphere	8
	X		Safety/Accident Risk	0
		Materials and Consumable Calculations - MNA/LTM		
	2		Length of PVC per well (entered above) (ft)	40
	2		Conversion factor (lbs/ft)	2.03
	2		PVC (lbs)	2400
	2		Linear feet for drilling	1200
	2		Drilling rate (ft/day)	100
	2		Drilling fuel consumption rate (gal/day)	32
	2		Fuel for drilling (diesel)	384
	2		Total fuel (diesel)	384
	2		Jet fuel use rate per passenger (gal/mile)	0.0000097
	2		Weight of passenger + luggage (lbs)	200
	2		Total air miles (all passenger; entered above)	0
	2		Jet fuel (Capital) (gallons)	0
	2		Vehicle miles per gallon (travel)	15
	2		Miles traveled (Capital)	6200
	2		Gasoline (Captal) (gallons)	410
	2		Total fuel (gasoline + jet fuel) Capital (gallons)	410
		Metrics Basic Calculations - Technology Cost		
	2		Technology Cost (Capital)	NU
	2		Technology Cost (O&M)	NU
		Metrics Basic Calculations - Safety/Accident Risk		
	2		Hours worked	690
	2		Vehicle speed (mph)	40
			Hours for travel (post construction/site visit)	130
			Total hours worked	820
	2		Injuries per hour	2.74E-09
	2		Total vehicle miles traveled	6,200
	2		Injuries per mile	9.10E-07
	2		Lost hours per injury	48
	2		Safety/Accident Risk (lost hours)	0.27

Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
X = Applicable for both Tier 1 and Tier 2
2 = Available and Optional Tier 2 Only
Highlight indicates minimum required user inputs
NU = not used

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APPENDIX E
Table 3 - Sustainability Evaluation - Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Sustainable Remediation Tool

Alternative 2 - Performance Monitoring and Monitored Natural Attenuation Components

Required	Optional			User Inputs Performance Monitoring	User Inputs MNA
		Design for Managing Groundwater			
X			Airline miles flown by project team (total miles for all travelers)	0	0
X			Average Distance Traveled by Site Workers per one-way trip (miles)	50	50
X			Trips by Site Workers during construction	3	0
X			Trips by Site Workers after construction	0	160
X			Number of monitoring wells	3	1
X			Length of PVC piping, per well (ft)	42	42
	X		Number of characterization (basline) sampling events	1	0
	X		Number of sampling events in the first year	5	16
	X		Number of sampling events per year in subsequent years	1	1
	X		Duration (years)	35	29
X			Number of samples collected per sampling event	15	15
X			Plume Calculation Method	ks	ks
X			Source zone point decay rate constant (k_s = 1/yr)	0.144	0.144
		Materials and Consumable Amounts Used for Metrics			
	X		PVC (lbs)	260	0
	X		Diesel (gallons)	41	0
	X		Gasoline (Capital) (gallons)	60	0
	X		Gasoline (O&M) (gallons)	230	1300
		Technology Cost			
	X		Capital	NU	NU
	X		O&M	NU	NU
		Project-specific Metrics (Add & Subtract/Offsets)			
	X		Additional Technology Cost	0	0
	X		Total Energy Consumed	0	0
	X		CO_2 Emissions to Atmosphere	0	0
	X		Safety/Accident Risk	0	0
		Materials and Consumable Calculations - MNA/LTM			
	2		Length of PVC per well (entered above) (ft)	42	42
	2		Conversion factor (lbs/ft)	2.03	2.03
	2		PVC (lbs)	260	-
	2		Linear feet for drilling	127	-
	2		Drilling rate (ft/day)	100	-
	2		Drilling fuel consumption rate (gal/day)	32	-
	2		Fuel for drilling (diesel)	40.6	-
	2		Total fuel (diesel)	40.6	-
	2		Jet fuel use rate per passenger (gal/mile)	0.0000097	0.0000097
	2		Weight of passenger + luggage (lbs)	200	200
	2		Total air miles (all passenger; entered above)	-	-
	2		Jet fuel (Capital) (gallons)	-	-
	2		Jet fuel (O&M) (gallons)	-	-
	2		Vehicle miles per gallon (travel)	15	15
	2		Miles traveled (Capital)	900	-
	2		Miles traveled (O&M)	3,400	19,000
	2		Gasoline (Captal) (gallons)	60	-
	2		Gasoline (O&M) (gallons)	230	1,300
	2		Total fuel (gasoline + jet fuel) Capital (gallons)	60	-
	2		Total fuel (gasoline + jet fuel) O&M (gallons)	230	1,300
		Metrics Basic Calculations - Technology Cost			
	2		Technology Cost (Capital)	NU	NU
	2		Technology Cost (O&M)	NU	NU
		Metrics Basic Calculations - Safety/Accident Risk			
	2		Hours worked (Capital)	74	-
	2		Hours worked (O&M)	200	2,100
	2		Total hours worked	274	2,100
	2		Vehicle speed (mph)	40	40
	2		Injuries per hour	2.74E-09	2.74E-09
	2		Vehicle miles traveled (Capital)	900	-
	2		Vehicle miles traveled (O&M)	3,400	19,000
	2		Total vehicle miles traveled	4,300	19,000
	2		Injuries per mile	9.10E-07	9.10E-07
	2		Lost hours per injury	48	48
	2		Safety/Accident Risk (lost hours)	0.19	0.83

Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
Tasks included in "Capital Tasks" include re-injection.
X = Applicable for both Tier 1 and Tier 2
2 = Available and Optional Tier 2 Only
Highlight indicates minimum required user inputs
NU = not used

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APPENDIX E
Table 4 - Sustainability Evaluation - Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Sustainable Remediation Tool

Alternative 3 - In Situ Chemical Oxidation Component

Required	Optional			User Inputs
		Design for Managing Groundwater		
X			Airline miles flown by project team (total miles for all travelers)	0
X			Average Distance Traveled by Site Workers per one-way trip (miles)	50
X			Trips by Site Workers during construction	32
X			Trips by Site Workers after construction	20
X			Treat Source Only or Source + Plume?	Source Only
X			Treatment frequency	One re-injection
X			Length of pipe, per well	35
	X		Number of injection points	200
X			Natural Oxygen Demand (g/kg)	average
		Materials and Consumable Amounts Used for Metrics		
	X		PVC (lbs)	-
	X		Oxidant (lbs)	75,000
	X		Gasoline (Capital) (gallons)	347
	X		Diesel (gallons)	280
		Technology Cost		
	X		Capital	NU
		Project-specific Metrics (Add & Subtract/Offsets)		
	X		Additional Technology Cost	0
	X		Total Energy Consumed	0
	X		CO_2 Emissions to Atmosphere	0
	X		Safety/Accident Risk	0
		Materials and Consumable Calculations - In Situ Chemical Oxidation		
	2		Length of PVC per well (feet)	35
	2		Number of injection points	200
	2		Conversion factor (lbs/ft)	2.03
	2		PVC (Capital) (lbs)	-
	2		Linear feet for drilling	7,000
	2		Drilling rate (ft/day)	300
	2		Drilling fuel consumption rate (gal/day)	10
	2		Fuel for drilling (diesel)	233
	2		Oxidant load delivery capacity (lbs/load)	10,000
	2		Number of loads for oxidant	8
	2		Distance to oxidant supplier (miles)	50
	2		Total miles driven for oxidant	800
	2		Vehicle mileage (transportation for oxidant delivery)	17.6
	2		Fuel for heavy trucks (transportation; diesel) (gallons)	45
	2		Fuel for drilling + bringing oxidant to site (diesel)	280
	2		Jet fuel use rate per passenger	0.0000097
	2		Weight of passenger + luggage	200
	2		Total air miles (all passengers; input above)	-
	2		Total jet fuel	-
	2		Vehicle mileage (travel)	15
	2		Miles traveled (Capital)	5,200
	2		Gasoline	347
	2		Total fuel (gasoline + jet fuel)	347
		Metrics Baseline Calculations - Technology Cost		
	2		Volume for treatment	NU
	2		Unit cost	NU
	2		Cost	NU
		Metrics Baseline Calculations - Safety/Accident Risk		
			Hours worked	700
	2		Injuries per hour	2.74E-09
	2		Additional injuries per hour due to oxidant risk	1.65E-05
	2		Vehicle speed (mph)	40
	2		Hours for travel (post-construction/site visit)	250
	2		Total vehicle miles traveled	5,200
	2		Injuries per mile	9.10E-07
	2		Lost hours per injury	48
	2		Safety/Accident Risk (lost hours)	0.78

Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
Pre-Design Investigation Hours, Mileage, and PVC are included.
Tasks included in "Capital Tasks" include re-injection.
X = Applicable for both Tier 1 and Tier 2
2 = Available and Optional Tier 2 Only
Highlight indicates minimum required user inputs
NU = not used

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APPENDIX E
Table 5 - Sustainability Evaluation - Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Sustainable Remediation Tool

Alternative 3 - Performance Monitoring and Monitored Natural Attenuation Components

Required	Optional			User Inputs Performance Monitoring	User Inputs MNA
		Design for Managing Groundwater			
X			Airline miles flown by project team (total miles for all travelers)	0	0
X			Average Distance Traveled by Site Workers per one-way trip (miles)	50	50
X			Trips by Site Workers during construction	0	0
X			Trips by Site Workers after construction	23	125
X			Number of monitoring wells	3	1
X			Length of PVC piping, per well (ft)	30	42
	X		Number of characterization (basline) sampling events	0	0
	X		Number of sampling events in the first year	11	16
	X		Number of sampling events per year in subsequent years	3	1
	X		Duration (years)	15	21
X			Number of samples collected per sampling event	15	15
X			Plume Calculation Method	ks	ks
X			Source zone point decay rate constant (k_s = 1/yr)	0.144	0.144
		Materials and Consumable Amounts Used for Metrics			
	X		PVC (lbs)	0	0
	X		Diesel (gallons)	0	0
	X		Gasoline (Capital) (gallons)	0	0
	X		Gasoline (O&M) (gallons)	210	1000
		Technology Cost			
	X		Capital	NU	NU
	X		O&M	NU	NU
		Project-specific Metrics (Add & Subtract/Offsets)			
	X		Additional Technology Cost	0	0
	X		Total Energy Consumed	0	0
	X		CO_2 Emissions to Atmosphere	0	0
	X		Safety/Accident Risk	0	0
		Materials and Consumable Calculations - MNA/LTM			
	2		Length of PVC per well (entered above) (ft)	42	42
	2		Conversion factor (lbs/ft)	2.03	2.03
	2		PVC (lbs)	-	-
	2		Linear feet for drilling	-	-
	2		Drilling rate (ft/day)	-	-
	2		Drilling fuel consumption rate (gal/day)	-	-
	2		Fuel for drilling (diesel)	-	-
	2		Total fuel (diesel)	-	-
	2		Jet fuel use rate per passenger (gal/mile)	0.0000097	0.0000097
	2		Weight of passenger + luggage (lbs)	200	200
	2		Total air miles (all passenger; entered above)	-	-
	2		Jet fuel (Capital) (gallons)	-	-
	2		Jet fuel (O&M) (gallons)	-	-
	2		Vehicle miles per gallon (travel)	15	15
	2		Miles traveled (Capital)	-	-
	2		Miles traveled (O&M)	3,100	15,000
	2		Gasoline (Captal) (gallons)	-	-
	2		Gasoline (O&M) (gallons)	210	1,000
	2		Total fuel (gasoline + jet fuel) Capital (gallons)	-	-
	2		Total fuel (gasoline + jet fuel) O&M (gallons)	210	1,000
		Metrics Basic Calculations - Technology Cost			
	2		Technology Cost (Capital)	NU	NU
	2		Technology Cost (O&M)	NU	NU
		Metrics Basic Calculations - Safety/Accident Risk			
	2		Hours worked (Capital)	-	-
	2		Hours worked (O&M)	310	1,600
	2		Total hours worked	310	1,600
	2		Vehicle speed (mph)	40	40
	2		Injuries per hour	2.74E-09	2.74E-09
	2		Vehicle miles traveled (Capital)	-	-
	2		Vehicle miles traveled (O&M)	3,100	15,000
	2		Total vehicle miles traveled	3,100	15,000
	2		Injuries per mile	9.10E-07	9.10E-07
	2		Lost hours per injury	48	48
	2		Safety/Accident Risk (lost hours)	0.14	0.66

Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
Tasks included in "Capital Tasks" include re-injection.
X = Applicable for both Tier 1 and Tier 2
2 = Available and Optional Tier 2 Only
Highlight indicates minimum required user inputs
NU = not used

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APPENDIX E
Table 6 - Sustainability Evaluation - Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Sustainable Remediation Tool

Alternative 4 - Enhanced In Situ Bioremediation Component

Required	Optional		User Inputs
		Design for Managing Groundwater	
X		Airline miles flown by project team (total miles for all travelers)	0
X		Average Distance Traveled by Site Workers per one-way trip	50
X		Trips by Site Workers during construction	52
X		Trips by Site Workers after construction	20
X		How efficient is the biodegradation project	High
X		Treat Source Only or Source + Plume	Source Only
X		Length of piping, per well	45.33
	X	Number of Wells (Permanent Injection)	34
	X	Oxygen additive (if BTEX)	NU
	X	Substrate/Donor (if CVOCs)	EVO
		Materials and Consumable Amounts Used for Metrics	
	X	PVC	3,100
	X	Substrate/Donor (lbs)	23,000
	X	Diesel	493
	X	Gasoline	480
		Technology Cost	
	X	Capital	NU
		Project-specific Metrics (Add & Subtract/Offsets)	
	X	Additional Technology Cost	0
	X	Total Energy Consumed	150000
	X	CO_2 Emissions to Atmosphere	17
	X	Safety/Accident Risk	0.08
		Materials and Consumable Calculations - Enhanced Bioremediation	
	2	Length of PVC per well (entered above) (ft)	45.33
	2	PVC Conversion Factor (lbs/ft)	2.03
	2	PVC (lbs)	3,100
	2	Donor Conversion Factor (lbs/gal)	7.89
	2	Donor or Oxygen Additive (if applicable) (lbs)	23,000
	2	Linear Feet for Drilling	1,541
	2	Drilling rate (ft/day)	100
	2	Drilling fuel consumption rate (gal/day)	32
	2	Total Fuel (Diesel)	493
	2	Jet Fuel Use Rate per Passenger (gal/mile)	0.0000097
	2	Weight of Passenger + Luggage	200
	2	Jet Fuel	0
	2	Vehicle Mileage (Travel) (miles/gallon)	15
	2	Miles Traveled	7,200
	2	Gasoline	480
		Metrics Basic Calculations - Technology Cost	
	2	Volume Treated	NU
	2	Technology Cost (Capital Phase)	NU
		Metrics Basic Calculations - Safety/Accident Risk	
	2	Hours Worked	810
	2	Vehicle speed (mph)	40
	2	Hours for Travel (Post-construction/site visit)	250
	2	Total Hours Worked	1,060
	2	Injuries per Hour	2.74E-09
	2	Total Vehicle Miles Traveled	7,200
	2	Injuries per Mile	9.10E-07
	2	Lost hours per injury	48
	2	Safety/Accident Risk (lost hours)	0.31

Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
Pre-Design Investigation Hours, Mileage, and PVC are included.
Tasks included in "Capital Tasks" include re-injection.
X = Applicable for both Tier 1 and Tier 2
2 = Available and Optional Tier 2 Only
Highlight indicates minimum required user inputs
NU = not used
EVO = emulsified vegetable oil

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APPENDIX E
Table 7 - Sustainability Evaluation - Input Parameters
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Sustainable Remediation Tool

Alternative 4 - Performance Monitoring and Monitored Natural Attenuation Components

Required	Optional			User Inputs Performance Monitoring	User Inputs MNA
		Design for Managing Groundwater			
X			Airline miles flown by project team (total miles for all travelers)	0	0
X			Average Distance Traveled by Site Workers per one-way trip (miles)	50	50
X			Trips by Site Workers during construction	3	0
X			Trips by Site Workers after construction	10	135
X			Number of monitoring wells	3	1
X			Length of PVC piping, per well (ft)	42	42
	X		Number of characterization (basline) sampling events	1	0
	X		Number of sampling events in the first year	5	32
	X		Number of sampling events per year in subsequent years	1	1
	X		Duration (years)	35	21
X			Number of samples collected per sampling event	15	15
X			Plume Calculation Method	ks	ks
X			Source zone point decay rate constant (k_s = 1/yr)	0.144	0.144
		Materials and Consumable Amounts Used for Metrics			
	X		PVC (lbs)	260	0
	X		Diesel (gallons)	41	0
	X		Gasoline (Capital) (gallons)	60	0
	X		Gasoline (O&M) (gallons)	290	1100
		Technology Cost			
	X		Capital	NU	NU
	X		O&M	NU	NU
		Project-specific Metrics (Add & Subtract/Offsets)			
	X		Additional Technology Cost	0	0
	X		Total Energy Consumed	0	0
	X		CO_2 Emissions to Atmosphere	0	0
	X		Safety/Accident Risk	0	0
		Materials and Consumable Calculations - MNA/LTM			
	2		Length of PVC per well (entered above) (ft)	42	42
	2		Conversion factor (lbs/ft)	2.03	2.03
	2		PVC (lbs)	260	-
	2		Linear feet for drilling	127	-
	2		Drilling rate (ft/day)	100	-
	2		Drilling fuel consumption rate (gal/day)	32	-
	2		Fuel for drilling (diesel)	40.6	-
	2		Total fuel (diesel)	40.6	-
	2		Jet fuel use rate per passenger (gal/mile)	0.0000097	0.0000097
	2		Weight of passenger + luggage (lbs)	200	200
	2		Total air miles (all passenger; entered above)	-	-
	2		Jet fuel (Capital) (gallons)	-	-
	2		Jet fuel (O&M) (gallons)	-	-
	2		Vehicle miles per gallon (travel)	15	15
	2		Miles traveled (Capital)	900	-
	2		Miles traveled (O&M)	4,400	16,000
	2		Gasoline (Captal) (gallons)	60	-
	2		Gasoline (O&M) (gallons)	290	1,100
	2		Total fuel (gasoline + jet fuel) Capital (gallons)	60	-
	2		Total fuel (gasoline + jet fuel) O&M (gallons)	290	1,100
		Metrics Basic Calculations - Technology Cost			
	2		Technology Cost (Capital)	NU	NU
	2		Technology Cost (O&M)	NU	NU
		Metrics Basic Calculations - Safety/Accident Risk			
	2		Hours worked (Capital)	74	-
	2		Hours worked (O&M)	330	1,700
	2		Total hours worked	404	1,700
	2		Vehicle speed (mph)	40	40
	2		Injuries per hour	2.74E-09	2.74E-09
	2		Vehicle miles traveled (Capital)	900	-
	2		Vehicle miles traveled (O&M)	4,400	16,000
	2		Total vehicle miles traveled	5,300	16,000
	2		Injuries per mile	9.10E-07	9.10E-07
	2		Lost hours per injury	48	48
	2		Safety/Accident Risk (lost hours)	0.23	0.70

Notes:
Assumptions included are described in the detailed cost estimate appendix and within the body of the Feasibility Study.
Tasks included in "Capital Tasks" include re-injection.
X = Applicable for both Tier 1 and Tier 2
2 = Available and Optional Tier 2 Only
Highlight indicates minimum required user inputs
NU = not used

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APPENDIX E
Table 8 - Sustainability Evaluation - Summary of Results
Feasibility Study Report for Groundwater at Site 22
Naval Weapons Station Yorktown
Yorktown, Virginia

Alternative	Air Emissions				Safety/Accident Risk		Non Renewable Resource Use		Technologies Evaluated with SRT
	CO2 (tons)[1]	NOx (tons)	SOx (tons)	PM10 (tons)	Lost Hours[2] (/yr)	Injury Risk[3] (/yr)	Total Energy Consumption[4] (kWh)	Equivalent to Average Annual Power Consumption for U.S. Households[5] (households)	
Alternative 2: EISB and Performance Monitoring with MNA and LUCs	13	0.0098	0.0001	0.0008	0.83	1.7E-02	56,000	5.3	MNA/LTM
	51	0.0539	0.0144	0.0028	0.46	9.6E-03	67,000	6.3	Pre-Design/EISB and Performance Monitoring
	64	0.0637	0.0145	0.0036	1.3	2.7E-02	123,000	11.5	Total of Alternative 2
Alternative 3: ISCO and Performance Monitoring with MNA and LUCs	10	0.0075	0.0001	0.0007	0.66	1.4E-02	91,000	8.5	MNA/LTM
	162	0.0336	0.0001	0.0017	0.92	1.9E-02	36,900	3.5	Pre-Design/ISCO and Performance Monitoring
	172	0.0411	0.0002	0.0024	1.6	3.3E-02	127,900	12.0	Total of Alternative 3
Alternative 4: EISB and Performance Monitoring with MNA and LUCs	11	0.0083	0.0001	0.0007	0.70	1.5E-02	47,000	4.4	MNA/LTM
	67	0.0673	0.0174	0.0035	0.62	1.3E-02	55,000	5.2	Pre-Design/EISB and Performance Monitoring
	78	0.0756	0.0175	0.0042	1.3	2.8E-02	102,000	9.6	Total of Alternative 4

Notes:
CO_2 = carbon dioxide
kWh = kilowatt-hour
LTM = long term monitoring
SOx = sulfur oxides
NOx = nitrogen oxides
PM10 = Particulate Matter (inhalable coarse particles smaller than 10 micrometers)
yr = year
-- = not applicable

MNA = Monitored Natural Attenuation
LUC = Land Use Controls
ISCO = In Situ Chemical Oxidation
EISB = Enhanced In Situ Bioremediation

Notes:
[1]The use of tons indicates American or short tons. 1 American or short ton = 2,000 pounds.
[2]Lost hours represents the number of hours lost time due to injuries resulting from hours worked at the site and travel hours.
[3]The risk of non-fatal injuries derived from the United States Bureau of Labor, 2006.
[4]Energy consumption for each technology evaluated with SRT takes into consideration all the sources of energy consumed during lifecycle of the technology. Energy sources include gasoline, diesel, electricity and natural gas.
[5]Residental Energy Consumption of 10,656 kWh/single-family home-year reported by the U.S. Department of Energy in 2006.

number of miles driven to reach remedial action objectives for each alternative. The risk of non-fatal injuries was derived from United States Bureau of Labor statistics.

Additional risk associated with handling of oxidant associated with the ISCO alternative was accounted for using the United States Bureau of Labor statistics for chemical manufacturing workers, and is a variable within the SRT.

Non-Renewable Resource Use

The different remediation technologies being proposed for each alternative result in the use of varying amounts of non-renewable resources (such as fuel and/or electricity). The annual non-renewable fuel use and power consumption were calculated for each alternative. Possible renewable resources (such as water) were not factored in as part of the analysis.

Alternative 3 will use a considerable amount of water. It is estimated that 299,000 gallons of water would be required during the activities be meet the remedial objectives. This is approximately 80% more water usage than Alternatives 2 and 4 which use 52,000 and 59,000 gallons, respectively.

Results of Analysis

The associated impacts calculated for each remedial alternative using the SRT are included in **Table 8** within this Appendix. Since the activities associated with Alternative 2 and 4 are so similar, overall the environmental footprints are also very similar. Alternative 2 has the lowest environmental footprint for CO_2 when compared to both the short- and long-term environmental outcomes of the other alternatives evaluated. Alternative 3 has notably higher CO_2 emissions due to the emission factor associated with the oxidant manufacturing, the amount of oxidant required for treatment, andsize of the target treatment area. The substrate is being strategically injected into the subsurface for Alternative 2 and 4 with much smaller target treatment areas than the ISCO alternative. The other air emissions for Alternatives 2 and 4 are slightly higher compared to Alternative 3. This is primarily due to the total fuel consumption estimated to complete each alternative. In addition, Alternative 3 has the highest risk of accident and lost time primarily due to working with oxidants. The total energy consumption for Alternatives 2 and 4 are once again very similar and lower than Alternative 3. The total energy consumption for Alternative 2 is slightly higher than Alternative 4 but slightly lower than Alternative 3. This is primarily due to the fuel consumption estimated to complete each alternative.

References

AFCEE, *Sustainable Remediation Tool Version 2.1*, Microsoft Excel based platform, December 2009.

Appendix F
Responses to Comments Letters

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February 28, 2011
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Mr. Moshood Odewole
Federal Facility Remediation (3HS11)
United States Environmental Protection Agency
Region 3
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Subject: Response to Comments *Draft Feasibility Study Report for Groundwater at Site 22*
WPNSTA Yorktown
Yorktown, Virginia

Dear Mr. Thomson,

This letter presents responses to your comments on the subject document submitted on September 27, 2010. Comments are presented below followed by responses in italics.

GENERAL COMMENTS

1. Three of the four remedial alternatives evaluated in detail for the site include monitored natural attenuation (MNA) as a component of the alternative. The draft FS Report has not, however, presented sufficient evidence to show that MNA is a viable alternative for site groundwater, capable of remediating both chlorinated volatile organic compounds (VOCs) as well as hexahydro-1, 3, 5-trinitro-1, 3, 5-triazine (RDX) to remedial goals (RGs). Section 4.2.2, Alternative 2-Monitored Natural Attenuation and Land Use Controls, on Page 4-3, states, "Reducing conditions predominantly present at the site are favorable for biologically mediated degradation of the chlorinated [contaminants of concern] COCs and RDX." The FS Report has not, however, presented sufficient data to show that the reducing conditions are actually degrading site contaminants over times. While the presence of vinyl chloride in site groundwater is one of line of evidence to support degradation of trichloroethylene (TCE), EPA's Final Office of Solid Waste and Emergency Response (OSWER) Directive "Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites" (OSWER Directive Number 9200.4-17P) indicates that a three-tiered approach should be us used to evaluate the potential efficacy of MNA as a remedial alternative. The three tiers, or lines of evidence, are as follows:

    (1) Historical groundwater data that demonstrate a "clear and meaningful trend" of decreasing contaminant mass and /or concentration over time at appropriate monitoring or sampling points.

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(2) Hydro geologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels . A decrease in parent products (such as TCE) coupled with an increase in daughter products (such as cis-1,2,-dichloroethene and vinyl chloride) could be used to demonstrate biodegradation.

(3) Data from field or microcosm studies which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern (typically used to demonstrate biological degradation processes only).

The OSWER Directive further states, "Unless EPA or the implementing state agency determines that historical data (Number 1 above) are of sufficient quality and duration to support a decision to use monitored natural attenuation, EPA expects that data characterizing the nature and rates of natural attenuation processes at the site (Number 2above) should be provided. Where the latter are also inadequate or inconclusive, data from microcosm studies (Number 3 above) may also be necessary." Since limited historical data have been presented to show a clear and meaningful trend of decreasing concentration over time, additional lines of evidence are necessary. Please review the FS Report to provide supporting documentation and an evaluation of the efficacy of using MNA as a remedial alternative at the site. EPA's Technical Protocol for Evaluation Natural Attenuation of Chlorinated Solvents in Groundwater (September 1998) should be consulted for this evaluation. Additional discussions should also focus on degradation processes applicable to RDX as the FS Report currently does not provide sufficient evaluation of the degradation processes applicable to this constituent. RDX metabolites and breakdown products should be identified and quantified.

Response 1: *It is the respondents understanding that EPA requests additional lines of evidence [(1) decreasing concentrations over time, (2) hydrogeologic and geochemical data, (3) data from field or microcosm studies] to support Monitored Natural Attenuation presented as the preferred alternative for Site 22 Groundwater. Substantial decreases in TCE concentrations, the presence of TCE degradation products in groundwater at the site, geochemical conditions appropriate for degradation of TCE and the presence of Dehalococcoides sp., the microbe capable of degrading TCE completely to ethene, support the viability of a MNA approach for the chlorinated VOCs at the site. However, it is acknowledged that the available data for RDX do not support the required lines of evidence for this chemical. Consequently, the recommended alternative in the FS will be modified to include an active component to address RDX at the site.*

2. No laboratory treatability studies or field pilot studies are proposed for Alternative 3, In Situ Chemical Oxidation (ISCO) and Performance Monitoring with Monitored Natural Attenuation and Land Use Controls, or Alternative 4, Enhanced Reductive Dechlorination (ERD) and Performance Monitoring with Monitored Natural Attenuation and Land Use Controls. Although neither of these alternatives is selected as the preferred alternative, all relevant technology agencies and options for a given alternatives is selected as the preferred alternative, all relevant technology and options for a given alternative should be presented so the regulatory

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agencies and the public can make a decision on the selection of an alternative. Pilot tests would likely better determine the effectiveness of ISCO and ERD, particularly with respect to remediating RDX, and to determine optimal spacing for injection locations and optimal quantities needed for substrate addition. Appendix D, Reagent Evaluation: ISCO and ERD, acknowledges that "case studies exist that show permanganate can also be effective for treating RDX", but information regarding whether or not ISCO has reported success with full-scale implementation is not provided. The section on ERD in Appendix D does not address RDX at all, so it cannot be determined whether RDX could successfully be remediated with this technology. Given the uncertainties associated with these technologies for remediating RDX, it is recommended that pilot studies be included for Alternatives 3 and 4. The cost comparison of the alternatives should take cost of pilot tests into account.

Response 2: *A laboratory treatability test for permanganate was included in the Final RI Report for Site 22 and the results of the test are included within Section 6.3.5 (CH2M HILL, 2009) and the selection of permanganate as the preferred oxidant is included within Appendix D of the FS Report. References associated with case studies using permanganate as an effective oxidant for RDX will be included in Appendix D. Because existing information is available, a treatability or pilot study is not recommended for Alternative 3.*

A recent remedy completed at Naval Research Laboratory, White Oak reduced RDX concentrations to level as high as 380 ug/L to below detection levels using an ERD approach. Based on these data, ERD is believed to be a viable remedy for RDX and no pilot test is recommended.

SPECIFIC COMMENTS

3. **Section2.2.1 Nature and Extent of Contamination Page 2-2 and 2-3:** The Analytical Results subsection states that no VOCs were detected in the four deep monitoring wells screened in the bottom 10 feet of the Yorktown-Eastover aquifer, but the FS Report does not indicate whether no not RDX was detected in the deep monitoring wells. Figure 2-1, Site-Related COCs-Detected in Groundwater, does not show any detected results for the deep wells. For clarity and to support the evaluation of remedial alternatives, please revise the FS Report to indicate whether any site COCs, including RDX, were detected in the deep monitoring wells.

Response 3: *The four deep wells at Site 22 were installed to meet the objectives of decision logic included in the Groundwater RI Work Plan for Site 22, which required collection of DPT VOC groundwater samples at the depths of the deepest membrane interface probe (MIP) electron capture device (ECD) response. ECD responses were noted at depths of approximately 85 ft bgs, which is too deep to collect DPT groundwater samples. Consequently, the deep monitoring wells were installed. No VOCs were detected in these wells and the response on the MIP was believed to be an equipment error resulting from the depths at which the MIP data were collected, which were at the limits of the functionality of the equipment. The sampling approach in the work plan did not specify collection of samples for other analytes for the DPT samples. Consequently, the wells were never sampled for explosives. Explosives are particulates and are not expected to migrate readily though the finer grained soils which lie between 20 and 40 ft bgs at the site. Because the approach taken was consistent with the sampling approach outlined in the work plan, the results are believed*

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to be acceptable to support the Feasibility Study. However, the text will be clarified to specify that no contamination was noted in the deep wells at Site 22, so the remedy is limited to the shallower intervals.

4. **Section 2.2.2. Risk Assessment, Page 2-3** Heptachlor epoxide and arsenic were identified as constituents of concern (COCs) in the human health risk assessment (HHRA), but these chemicals " were determined to be unrelated to site activities" and "no additional action is required" for these chemicals. Please revise the FS Report to provide a summary on how it was determined that heptachlor epoxide and arsenic are unrelated to site activities and require no further action (i.e., provide data that nullified the HHRA determination).

Response 4: *Section 11.3 (Conclusions and Recommendations – Site 22) of the Final Remedial Investigation Report for Groundwater, Sites 4, 21 and 22, Naval Weapons Station Yorktown, Yorktown, Virginia (CH2M HILL, 2009) summarizes the conclusions of the RI and the basis of heptachlor epoxide and arsenic requiring no additional action. A summary is presented below and a reference to the Final RI Report will be added to the FS Report.*

TCE, heptachlor epoxide, vinyl chloride, RDX, and arsenic were identified as human health COCs at Site 22. Even though arsenic was considered a human health COC under the RME exposure scenario, concentrations of arsenic did not pose risk under the CTE exposure scenario, and dissolved concentrations did not exceed the MCL. Therefore, no additional action is recommended for arsenic. Heptachlor epoxide was detected in a number of samples, but only one sample concentration (YS22-GW03 at 0.21 µg/L) slightly exceeded the MCL (0.2 µg/L). Concentrations of heptachlor epoxide at Site 22 suggest their presence is attributable to normal pesticide use and not a CERLCA-related release. Pesticides and herbicides were commonly applied to the soil at Department of Defense facilities to control pests and weeds, which may have resulted in pesticides and herbicides accumulating in environmental media. The legal application of pesticides and herbicides are not CERCLA-related releases and are, therefore, not subject to regulation under CERCLA. These details will be added to the FS Report.

The WPNSTA Yorktown Partnering Team agreed to the conclusions of the Remedial Investigation Report for Groundwater (CH2M HILL, 2009). Consequently, only TCE, vinyl chloride and RDX were carried forward to the FS, but arsenic and heptachlor epoxide were not.

5. **Section 2.2.2:** The second sentence of the first paragraph should indicate that the pathway not quantitatively evaluated in the risk assessment was vapor intrusion.

Response 5: *This edit will be made as requested.*

6**. Section 2.2.3, Conceptual Site Model, Page 2-4**: The source of groundwater contamination in the northern portion of the site, in the vicinity of wells YS22-GW02 and YS 22-GW11, is not defined. In the Sources of Contamination and Migration subsection, it is noted that "the most highly contaminated soils at Site 22 have been previously removed" and "contaminant concentrations in the groundwater…at Site 22 are likely to decrease in the future because no source is present…" Excavation areas and detected concentrations in groundwater are shown on Figure 2-1, Site-Related COCs – Detected in Groundwater; however wells YS22-GW02 and YS22-GW11, which reported concentrations of TCE, vinyl chloride, and RDX above

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screening criteria, are located north/northwest and up gradient of the closest excavation area. Based on the limited data and evaluation provided in the FS Report, it is not apparent that the source of the groundwater contamination in the northern portion of the sited has been removed. Please revise the FS Report to identify the likely source of groundwater contamination in the northern portion of the site, and indicate whether any soil contamination was identified in this area of the site.

Response 6: *All source material associated with groundwater contamination at Site 22 was removed. No additional contaminant source areas were identified upgradient of wells YS22-GW02 and YS22-GW11 during the MIP study. The RI associated with Site 4 (see FS Figure 1-2), located directly upgradient of Site 22, recommended that no additional action is necessary to address groundwater at that Site. VOCs were not detected in Site 4 monitoring wells at levels of concern during the Site 4 evaluation and the landfill has been removed and either backfilled with clean fill or restored as ponds. It should be noted that Site 4 is considered the upgradient boundary of contamination identified at Site 22 because wells screened at comparable depths at Site 4 did not contain VOCs at levels of concern. Site 4 organic detections and removal action areas are shown on attached* ***Figure 4-4*** *from the Groundwater RI Report for your review.*

7. 2.2.3, Conceptual Site Model, Page 2-5: In the discussion of the fate and transport of RDX, the FS Report states, "available literature indicates that RDX may degrade slowly under reducing conditions through intermediate degradation products." The literature sources referenced in this statement have not been cited in the FS Report. Please revise the FS Report proper citations for any documents or literature referenced.

Response 7: *The literature sources referenced in the document as well as the new information obtained from the White Oak site described in response 2 will be included in the FS.*

8. **Section 2.2.4**: The draft FS concludes that TCE, VC and RDX are considered site-related COCs because they are "present at the site."However, per Section 2.2.2., arsenic and heptachlor epoxide were "determined to be unrelated to site activities." This contradicts the rationale provided in Section 2.2.4 for identifying COCs. The draft FS should be revised so that the language explaining COC selection is consistent.

Response 8: *Please see the response to Comment 4. The text in Section 2.2.4 will be modified to read, "TCE and VC posed risk under future exposure scenarios and exceed MCLs. No MCL exists for RDX, but the concentrations pose risk under future exposure scenarios. Based on the conclusions of the Final Remedial Investigation Report for Groundwater at Sites 4, 21 and 22 (CH2M HILL, 2009), additional remedial action is necessary to address TCE, VC and RDX only. Remedial alternatives to address these three COCs are addressed in subsequent sections of this report."*

9. **Figure 2-1, Site-Related COCs-Detected in Groundwater**: Figure 2-1 shows that concentrations of TCE, vinyl chloride, and RDX were detected above screening criteria in the northernmost up gradient shallow wells (YS22-GW02 and YS22-GW11). It is not apparent from this figure that the upgradient extent of contamination in groundwater has been defined. If wells from Site 4, located

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immediately north of the Site 22, are being used to define the up gradient extent of contamination in groundwater and show that it is adequately bounded. If there are no Site 4 wells screened at appropriate depths and locations to serve as upgradient boundary wells, additional monitoring wells north of Site 22 may be necessary.

Response 9: *Please see the response to Comment 6. The text of the FS will be modified to clarify that Site 4 is considered the upgradient boundary of contamination identified at Site 22. Monitoring wells installed at Site 4 at comparable depths than at Site 22 did not contain VOCs at levels of concern, MIP data does not identify source areas upgradient of existing well data at Site 22, and the Site 4 landfill has been removed.*

10. **Figure 2-1, Site-Related COCs-Detected in Groundwater**: A note on this figure indicates that concentrations shaded in green exceed regional screening levels (RSLs); however, this approach was not consistently applied. For example, TCE concentrations in wells YS22-GW08, YS22-GW05, and YS22-GW02 are shaded green; however all detected concentrations in these wells are below the TCE RSL of 1.7 ug/1 provided on the figure. Please revise Figure 2-1 to address these discrepancies. In addition, provide the source of the TCE RSL of 1.7 micrograms per liter (ug/1) as the published TCE RSL is 2.0 ug/1.

Response 10: *The figure will be modified as requested. The screening values shown on the figure are from the RI report and will be modified to reflect current RSLs in the FS.*

11. **Figure 2-2, Field Parameters and Geochemistry Results**: Dissolved oxygen (DO) measurements were not collected at two of the shallow wells (i.e., YS22-GW10, YS22-GW02). Please revise Figure 2-2 to include a note to explain why DO measurements were not collected at wells YS22-GW10 and YS22-GW02.

Response 11: *The following footnote will be added to the subject figure: "Readings were not collected by the field team at these locations due to improper readings from the DO meter."*

12. **Section 2.2**: On page 2-2 state that Trichloroethene (TCE) was detected in samples from 9 of the 12 shallow monitoring wells (maximum concentration of 650 micrograms per liter from YS22-GW-10). Figure 1-4 aquifer potentiometric surface map shows well YS22-GW-10 as the most down gradient well from site 22. There is no data to delineate the TCE plume at the south of Site 22.

Response 12: *YS22-GW10 was installed as far downgradient as was permissible by drilling equipment. There is a 20 ft drop in elevation between this well and the wetland area to the south. Consequently, the downgradient edge of the plume is considered the surface water, where concentrations of TCE were either non-detect or low detections (2.1 µg/L was the only detection). In addition, groundwater concentrations of site-related COCs do not exceed BTAG screening values. See response to Comment #13.*

13. **Section 2.2.2**: On page 2-4 states that no contaminants of concern (COC) for ecological receptors were identified for surface water or sediment at Site 22. Similarly, no COCs were identified for food web exposures. Thus, risks to ecological receptors were considered acceptable. No further action was recommended for ecological receptors at Site 22. It is unclear from this statement if potential future risk from discharging groundwater was addressed as part of the ecological risk assessment (ERA). Figure 2-1 shows that groundwater from wells 04, 10, and 11 have

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trichlorethene (TCE) concentrations of 69 micrograms/liter (ug/1), 650 ug/1, and 160 ug/1, respectively, in excess of EPA BTAG screening levels for freshwater (21 ug/1) indicating that ecological risk is possible should this groundwater discharge into adjacent creeks. If this migration pathway was not addressed as part of the ERA, it will need to be addressed as part of the FS.

Response 13: *The ecological risk assessment does not directly evaluate the potential future risk from discharging groundwater but it does incorporate seep samples and evaluates the downgradient water body (Felgates Creek) to which groundwater would discharge. The maximum concentration of TCE observed in seep samples was 1.0 ug/L, which is well below both the freshwater (21.0 ug/L) and marine (1,940 ug/L) BTAG surface water screening values. In addition, it should be noted that surface water flow within the Eastern Branch of Felgates Creek reverses because of tidal fluctuation and the BTAG screening value for TCE discussed within Comment #13 is associated with freshwater; the BTAG marine-based screening value for TCE in water is 1,940 ug/L, which was the value used in the ERA. Based upon the data in Table 9-1 of the final RI, the salinity of Felgates Creek in the vicinity of the site is 15 ppt or greater, which indicates that the water in any potential discharge areas to the creek is marine (10 ppt or greater salinity is generally considered the cutoff between brackish and marine waters). As a result, concentrations of TCE, vinyl chloride, and RDX in Site 22 groundwater do not exceed the screening values used within Table 9-10 of the Site 22 Final RI (November, 2009) and concentrations directly measured within surface water are also less than the applicable screening values (all of these chemicals were also not detected in creek sediment, where any groundwater discharge would first occur). Consequently, there are currently no unacceptable risks to ecological receptors resulting from groundwater discharges. However, an RAO will be added to the FS to ensure groundwater concentrations are not increasing to levels that may pose unacceptable risk to ecological receptors in adjacent surface water bodies.*

14**. Figure 2-3 Conceptual Site Model (CSM**): This figure shows the approximate extent of TCE and RDX in groundwater exceeding their applicable remedial goals (RG)s, but the figure does not show the extent of vinyl chloride (VC) exceeding its remedial goal. Section 3.3.1 explains that the laboratory detection limit of 10 ug/L was higher than the VC RG (2ug/L). Since vinyl chloride is also a site COC, it should be included on the figure to show extent of VC exceeding laboratory detection limit. In addition, a note explaining why VC exceeding its RG cannot be depicted should be included on the figure. Please revise Figure 2-3 accordingly.

Response 14: *The suggested edits to Figure 2-3 will be made as requested. However, it should be noted that the concentration of vinyl chloride exceeded the MCL and laboratory detection limit in only one location (YS22-GW11). Consequently, the area of the exceedance will possibly underestimate actual concentration exceeding the MCL. The footnote suggested will clarify that the reporting limit was higher than the RG.*

15. **Section 3.2, Remedial Action Objectives, Page 3-2**: The Remedial Action Objectives (RAOs) for the site are too general. EPA's RI/FS Guidance states that RAOs should be as specific as possible without limiting the range of potential alternatives. RAOs should also specify the following: the contaminant(s) of concern, exposure routes and receptors, and an acceptable contaminant level or range of levels for each exposure route (i.e., RGs). Revise the FS Report to develop more

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specific RAOs for the site which include the above-noted items. The RAOs should reduce contaminant concentrations in groundwater to site-specific RGs, rather than "to the maximum extent practicable."

Response 15*: In order to address this comment in consideration of the Navy's Guidance for Optimizing Remedy Evaluation, Selection and Design, and in consideration of Comment 15, the RAOs will be modified as follows:*

- *To reduce contaminant concentrations in groundwater to established remedial goals (RGs) for TCE, VC, and RDX*
- *To maintain land use controls to prevent human (residential and construction worker) exposure to groundwater until risk-based RGs are met*
- *To ensure groundwater concentrations are not increasing to levels that may pose unacceptable risk to ecological receptors in adjacent surface water bodies*

16. **Section 3.2** on page 3-2 states that the remedial action objectives (RAO) for the protection of human health and the environment for groundwater are to reduce contaminant concentrations in groundwater to the maximum extent practicable and maintain land use controls until contaminant concentrations in groundwater allow for unlimited use and unrestricted exposure at Site 22. An additional RAO should be to prevent the migration of contaminated groundwater to adjacent surface water bodies to prevent exposure and potential risk to ecological receptors. The development of preliminary remedial goals discussed in Section 3.3.1 will also need to address this issue to protect ecological receptors in adjacent surface water bodies. As discussed above, an additional RAO is warranted since TCE concentrations in three groundwater wells exceed EPA BTAG screening levels for freshwater.

Response 16: *Please see response to comment 13 and15.*

17.**Section 3.3, Applicable or Relevant and Appropriate Requirements (ARARs), Pages 3-2 and 3-3:** This section includes a discussion of ARARs but it does not mention whether there is an guidance or other recommended federal, state, or local criteria that should be identified as "to be considered" (TBC) criteria in the development of remedial action alternatives. TBCs are not generally enforceable but are advisory. An example of a TBC would be us of EPA RSLs or Health Advisories for specific chemicals in determining action or cleanup levels. Please revise the FS Report to identify and include a discussion of potential TBCs.

Response 17: *The FS ARARs tables will be revised to include To Be Considereds (TBCs).*

18.**Section 3.3.1, Development of Risk-Based Preliminary Remedial Goals, Page 3-4**: The second paragraph under the Human Health Remedial Goals subsection notes that "the same exposure assumptions used in the HHRA to estimate intake via ingestion, dermal contact, and inhalation from groundwater were used for the risk-based cleanup goal calculations" for RDX. Please revise the FS Report to document the exposure assumptions used so that the PRG calculations for RDX can be verified, and to assure that the most up-to-date and adequately protective exposure parameters were used.

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Response 18: *Further detail will be provided on the calculation of the risk-based cleanup goal for RDX. Since the hazards and risks calculated in the HHRA included in the RI were used to derive the risk-based cleanup goal for RDX (as shown in Appendix B), the exposure factors and toxicity values used in the HHRA to calculate the hazards and risks will be added to Appendix B.*

19. **Section 3.3.1, Developments of Risk-Based Preliminary Remedial Goals, Page 3-4:** Under the Extent of Site-Related COCs Exceeding RGs subsection, the statement "Couldn't we at least show where VC exceeded 10?" should be removed from the FS Report since it appears to be an artifact of the internal review. Please revise the FS Report.

Response 19: *The suggested edit will be made as requested.*

20. **Section 3.3.1**: Contrary to the first sentence, risk-based PRGs were not developed for TCE and VC in groundwater because MCLs are available. (Refer to the second paragraph in this section.) The first paragraph should be modified to reflect this.

Regarding the paragraph describing the extent of site-related CoCs exceeding RGs, the following points should be noted:

- The analytical detection limit for VC should be low enough to ensure the remediation goal (2ug/L) is met. A detection limit of 10 ug/L is not sufficient.
- Because of high detection limits for VC, the draft FS assumes that the VC isoconcentration contours are similar to TCE. However, VC is much lighter than TCE and, presumably, has the potential to move faster than TCE in groundwater.

Response 20: *The first sentence of the section will be clarified to indicate that a risk-based PRG was calculated for RDX while MCLs were selected as RGs for TCE and vinyl chloride. It is noted that the analytical detection limit for vinyl chloride in future rounds of sampling must be low enough to ensure that the RGs are met (<2 ug/L). While it is acknowledged that VC is lighter than TCE and may migrate faster, given the low detected concentrations of TCE in the one location in which it was detected and the extent of the TCE plume which is assumed all the way to the Eastern Branch of Felgates Creek, it is believed that making the assumption that VC is present throughout the extent of the TCE plume is sufficiently conservative to adequately evaluate remedial alternatives.*

21**. Section 4.2.2, Alternative 2- Monitored Natural Attenuation and Land Use Controls, Page 4-3**: The third full paragraph on this page describes calculations first-order decay rates, and the estimated time frame to achieve remedial goals under Alternative 2. No supporting documentation of these calculations has been provided. The FS Report has not provided the 1997 or 2006 data nor has it described exactly which decay rates were used to calculate the estimated time frame to achieve remedial goals (i.e., the site-specific decay rates or theoretical rates). Additionally, the estimated time frame for achieving RGs is a factor in selecting a remedial alternative, it is imperative that all COCs be considered when estimating a time frame for cleanup. Please revise the FS Report to calculate decay rates and time frame estimates for all COCs, including RDX and vinyl chloride, and provide supporting documentation for all calculations. This comment also applies to clean up estimates for Alternatives 3 and 4.

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Response 21: *Analytical data was collected in 1996 and 2007 not 1997 and 2006 respectively, as stated within the FS Report. The 2007 data was included in the Final RI Report for Groundwater at Site 22 (CH2M HILL, 2009) and the 1996 data was included in the Round 2 RI Report – Site 22 (Baker, 2001a). Using Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies (EPA, 2002), the site-specific decay rate for TCE and RDX was calculated using monitoring wells that displayed a decreasing detected concentration between the two events. Vinyl chloride was non-detect in 2007 so degradation rates and time to achieve RAOs durations were not calculated but were assumed to be comparable to TCE. These site-specific decay rates were compared to theoretical decay rate ranges (EPA, 2002) to facilitate professional judgment in evaluating the timeframe to achieve the RAOs for each alternative. The site-specific decay rates for TCE were within theoretical decay rate ranges while the site specific decay rate for RDX was slightly slower than theoretical ranges.*

Using professional judgment and existing site conditions, it was assumed that Alternative 3 and 4 would take 4 and 8 years, respectively, to reduce the site-related COC concentrations below100 ug/L utilizing active treatment. Following, active treatment of ISCO or ERD, monitored natural attenuation would take an additional 21 years to achieve the RAOs using the same assumptions and professional judgment as discussed above.

A summary table which includes the site-specific decay rates and time to achieve RAOs for TCE will be included within the Draft Final FS Report. Calculations for RDX will be removed from the report, because RDX concentrations did not decrease consistently across the site based on available data. The conclusions of the report will be updated to reflect these modifications and in accordance with Comment 1, an additional alternative will be added that will allow for MNA of chlorinated VOCs and active treatment of RDX.

22**. Section 4.2.2, Alternative 2- Monitored Natural Attenuation and Land Use Controls, Page 4-3:** The last paragraph on this page discusses the proposed monitoring associated with Alternative 2. The FS is not proposing to monitor groundwater in the deep wells onsite nor is it proposing to monitor surface water concentrations. Although no VOCs were detected in the deep wells during the previous investigation as noted on Page 2-2, it is recommended that at least a subset of the deep wells be included in the monitoring program, possibly on a reduced sampling schedule, to verify that contamination is not migrating vertically and beyond its current configuration. Additionally, it is recommended that surface water samples be collected at the leading edge of the plume to verify that groundwater is not discharging to surface water at potentially unacceptable levels. Further, no degradation products of RDX have been proposed for analysis. Therefore, it is unclear how the degradation of RDX will be monitored. Please revise the FS Report to incorporate sampling of deep wells and surface water into the monitoring plan, or provide adequate justification for not including this sampling. Additionally, please propose to monitor RDX degradation products in an effort to better monitor its degradation, or provide justification for not doing so. This comment also applies to Alternatives 3 and 4 since periodic monitoring has also been proposed for these alternatives.

Response 22: *A subset of the deep wells will be included in the monitoring program associated with each alternative, on a reduced sampling schedule, to verify that contamination is not migrating vertically and beyond its current configuration.*

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Based on the conclusions of the Final Remedial Investigation Report for Groundwater, Sites 4, 21 and 22, the WPNSTA Yorktown Partnering Team agreed to no further action to address surface water and sediment at Sites 4, 21 and 22. There were no unacceptable risks for surface water and sediment in adjacent water bodies at the sites. However, consistent with the proposed modification to the RAOs in the response to comment 15 above, it is recommended that groundwater monitoring of the most downgradient wells include evaluation to ensure that concentrations in these wells do not increase beyond the levels present during the RI and exceed BTAG screening values. If concentrations in these wells do increase or exceed BTAG screening values, it is recommended that further evaluation of surface water and sediment be completed.

RDX degradation intermediates such as nitroso-dinitro-hexahydro-1,3,5-triazine (MNX), dinitroso-hexahydro-1,3,5-triazine (DNX), and tri-nitroso-hexahydro-1,3,5-triazine (TNX) are transient in groundwater (Larese-Casanova and Scherer, 2007). Consequently, monitoring of these chemicals is not proposed. However, monitoring of ammonia, a less transient byproduct of RDX degradation, will be included in the monitoring strategies for all alternatives included in the FS.

23. **4.2.2** Page 4-3, Iron and manganese are identified as "…sensitive metals." The reasons iron and manganese are sensitive metals need to be provided.

Response 23: *Iron and manganese are considered "sensitive metals" due to their role in the microbiological redox sequence (see attached). Bioavailable forms of oxidized species of these metals (such as ferric oxyhydroxide minerals and manganese oxides) are readily used as electron acceptors by groundwater bacteria. The presence of these metals in reduced form is good indicators of the occurrence of iron- and manganese-reduction bioactivity in an aquifer and useful in helping gauge the overall redox conditions in an aquifer. Additional clarification will be added to the text.*

24. **Section 4.2.2:** Alternative 2 MNA states that reducing conditions predominantly present at the site are favorable for biological remediation of the chlorinated COCs and RDX, however, the draft FS fails to present a technical course of action that allows converging lines of evidence to be used to scientifically document the occurrence of natural attenuation and to quantify the rate in which it is according. As mentioned above, the EPA OSWER Directive 9200.4-17 (1997) identify 3 lines of evidence that can be used to estimate natural attenuation of chlorinated hydrocarbons, including:

a) Historical ground water and/or soul chemistry data demonstrate a clear and meaningful trend of decreasing contaminant mass and/or concentration over time at appropriate monitoring or sampling points. (in the case of groundwater plume, decreasing concentration should not be solely the result of plume migration.)

b) Hydro geologic and geochemical data that can be used to demonstrate indirectly the type(s) of natural attenuation process active at the site, and the rate at which those processes will reduce contaminant concentrations to require levels. For example, characterization data may be used to quantify the rates of contaminants sorption, dilution or volatilization or to demonstrate and quantify the rates of biological degradation processes occurring at the site.

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c) Data from field or microcosm studies (conducted in or with actual contaminated site media) which directly demonstrate the occurrence of a particular natural attenuation process at the site and its ability to degrade the contaminants of concern.

Unless EPA or the implementing state agency determines that historical data (paragraph (a) above are of sufficient quality and duration to support a decision to use MNA, EPA expects that data characterizing the nature and rates of natural attenuation processes at the site (paragraph (b) above) should be provided. Where the latter are also inadequate or inconclusive, data from microcosm studies (paragraph (c) above) may also be necessary.

Response 24: *See response to comment 1.*

25**. Section 4.2.3, Alternative 3- In Situ Chemical Oxidation and Performance Monitoring with Monitored Natural Attenuation and Land Us Controls, Page 4-5:** A pre-design investigation to refine the extent of contamination in groundwater had been proposed as part of Alternative 3. This investigation would include collecting groundwater samples at 64 locations along four transects. The proposed sample locations have not been shown on a site figure that show the proposed boring locations and transects in relation to the existing contamination.

Response 25: *The pre-design investigation would include a total of four north-to-south transects. Transects would be located parallel and approximately 15-ft and 45ft west and east of an imaginary line between YS22-GW10 and YS22-GW11. Further locations and or transects may be required following the initial four transects to identify TCE, RDX, or VC concentrations along the perimeter of transects which exceed 100 µg/L.*

Assumptions associated with the pre-design investigations included within the FS Report are included to facilitate alternative cost comparison. A separate pre-design investigation work plan would be submitted for agency approval following a ROD for Site 22 groundwater where a figure would be prepared of the proposed boring locations and transects in relation to the existing contamination.

26. **Section 4.2.3**: Alternative 3 ISCO states that prior to design of the ISCO alternative, a pre-design investigation is recommended to refine the lateral and vertical extent of site related groundwater COCs in the vicinity of the target treatment areas. Please not that this pre-design investigation must be performed irrespective of the remedy selected.

Response 26: *A pre-design investigation is included within Alternative 3 and 4 to facilitate design and refine the target treatment area requiring active treatment associated with these remedial alternatives. Since Alternative 2 does not include a target treatment area, a pre-design investigation is not required since sufficient data exists to implement remedial alternative.*

27. **Section 5, Detailed Evaluation of Alternatives, Pages 5-1 through 5-10**: The FS Report has not included a detailed discussion of the individual alternatives with respect to the first seven of nine evaluation criteria. Only a summary table has been presented (Table 5-2, Detailed Evaluation of Remedial Alternatives). EPA's RI/FS

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Guidance states, "The analysis of individual alternatives with respect to the specified criteria should be presented in the FS report as a narrative discussion accompanied by a summary table…This discussion should focus on how and to what extent, the various factors within each of the criteria are addressed. The uncertainties associated with specific alternatives should be included when changes in assumptions or unknown conditions could affect the analysis." Please revise the FS Report to present a narrative discussion of the alternatives against the evaluation criteria in consideration of the factors described in the RI/FS Guidance.

Response 27: *The narrative discussion will be added to the Draft Final FS as requested.*

28. **Section 5.2**: Page 5-5, eight sustainability metrics for NAVFAC are bulleted and include ecological impacts. According to Table 5-1, ecological impacts are only associated with short-term effectiveness. It is uncertain why ecological impacts are not included under long-term effectiveness and permanence. Protection of ecological receptors is equivalent to environmental protectiveness and is a threshold criterion and cannot only be considered over just the short term. This apparent deficiency must be addressed.

Response 28: *EPAs comment is unclear to the respondents. One of the eight Navy sustainability metrics, ecological impacts, is listed through all nine NCP criteria. The "Environmental Impacts" which may include a much broader range than just ecological receptors, is listed only as subcriteria to the NCP criteria "short-term effectiveness". In addition, environmental impacts are not subcriteria of long-term effectiveness and permanence but only subcriteria of short-term effectiveness. Furthermore, Sustainable Remediation Tool (SRT) does not evaluate ecological impacts so another tool or mechanism would need to be used to quantify this metric.*

29. **Section 6** on page 6-1 states that the cost versus benefit (such as length of time, sustainability) comparison indicated that although Alternative 2 takes longer to reach RAOs, it is more cost effective and more sustainable than the other alternatives presented. Therefore, Alternative 2 is the preferred alternative for remediation of groundwater contamination at Site 22. EPA BTAG agrees with the selection of this alternative provided the short term risk to ecological receptors from discharging groundwater in excess of BTAG screening levels is addressed.

Response 29: *Please see responses to comments 1, 13, 15 and 16.*

30. **Appendix A, ARARs**: The site is located adjacent to the Eastern Branch of Felgates Creek and its unnamed tributary, yet Appendix A has not identified ARARs specific to wetlands and floodplains. Please revise the FS Report to clarify whether ARARs for wetlands or floodplains would apply to the site, and identify specific ARARs.

Response 30: *The wetland areas adjacent to the site will remain undisturbed during remedies discussed in all evaluated alternatives. Consequently, no ARARs associated with wetlands or floodplains apply. A statement in regards to this will be added to the FS Report.*

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31**. Appendix C, Preliminary Cost Estimates, Alternative 2: MNA and LUCs**: The following comments were generated with respect to Alternative 2's cost estimate:

- For Operation and Maintenance Costs (Years 1 through 4), 14 annual land use control inspections are estimated. It appears that only four annual inspections would be needed for Years 1 through 4. Please address this discrepancy and revise the cost estimate as appropriate.
- For Operation and Maintenance Costs (Years 5 through 34), 14 annual land use control inspections are estimated. It appears that several additional annual inspections would be needed since Years 5 through 34 spans 30 years. Please address this discrepancy and revise the cost estimate as appropriate.

Please note that Alternatives 3 and 4 also include the incorrect number of annual land use control inspections and should be corrected as well.

Response 31: *Assumptions for inspections will be modified to assume quarterly inspections for the first 5 years and annual inspections for the remainder of the performance monitoring period.*

32. Appendix C, Preliminary Cost Estimates, Alternative 3: ISCO and Performance Monitoring with MNA and LUCs: The following comments were generated with respect to Alternative 3's cost estimate:

- Item Number 8 under "Key Assumptions" indicates that monitoring will be conducted until RAOs are achieved (34 years). According to Section 4.2.3, RAOs for Alternative 3 should be achieved within 25 years, not 34. Please address this discrepancy and revise the cost estimate as appropriate.
- Item Number 9 under "Key Assumptions" states that "sensitive inorganic constituents" would be analyzed, but the specific constituents to be analyzed have not been defined. Please define the sensitive inorganic constituents that will be analyzed.
- Item Number 14 under "Key Assumptions" references bench-scale studies for information pertaining to the permanganate oxidant demand, but it is unclear to which specific bench-scale studies this comment refers. Please provide further information on the bench-scale studies.

Response 32:

- *Item Number 8 under "Key Assumptions" will be revised to "Monitoring will be conducted annually until RAOs are achieved (25 years)."*
- *Item Number 9 under "Key Assumptions" will state the sensitive inorganic constituents include alkalinity, total organic carbon [TOC], nitrate, nitrite, sulfate, sulfide, methane, ethane, ethene, iron [Fe], manganese [Mn].*
- *A bench-scale study permanganate oxidant demand was included in the Final RI Report for Site 22 and the results of the test are included within Section 6.3.5 (CH2M HILL, 2009).*

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Please feel free to contact me should you have any additional questions.

Sincerely,

CH2M HILL

William J. Friedmann Jr.

William J. Friedmann, Jr.
Activity Manager

cc: Mr. Wade Smith/VDEQ
Mr. Tom Kowalski/NAVFAC Midlant
Mr. Adam Forshey/CH2M HILL
Mr. Robert Thomson/USEPA Region 3

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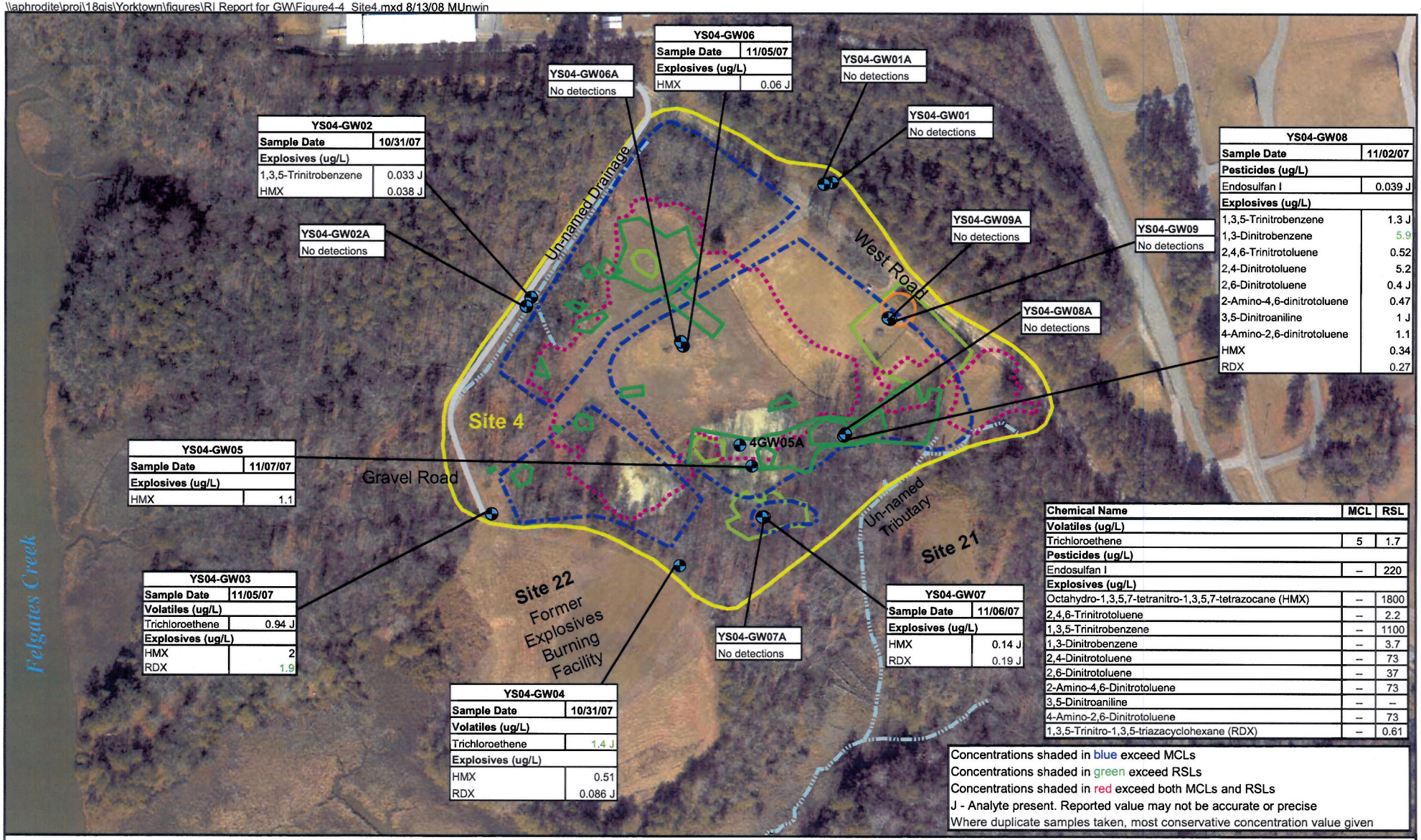

Chemical Name	MCL	RSL
Volatiles (ug/L)		
Trichloroethene	5	1.7
Pesticides (ug/L)		
Endosulfan I	--	220
Explosives (ug/L)		
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocane (HMX)	--	1800
2,4,6-Trinitrotoluene	--	2.2
1,3,5-Trinitrobenzene	--	1100
1,3-Dinitrobenzene	--	3.7
2,4-Dinitrotoluene	--	73
2,6-Dinitrotoluene	--	37
2-Amino-4,6-Dinitrotoluene	--	73
3,5-Dinitroaniline	--	--
4-Amino-2,6-Dinitrotoluene	--	73
1,3,5-Trinitro-1,3,5-triazacyclohexane (RDX)	--	0.61

Concentrations shaded in blue exceed MCLs
Concentrations shaded in green exceed RSLs
Concentrations shaded in red exceed both MCLs and RSLs
J - Analyte present. Reported value may not be accurate or precise
Where duplicate samples taken, most conservative concentration value given

Legend

- Study Area
- Location of Former Ash Pile
- Drainage
- Gravel Access Road
- Monitoring Wells
- Approximate Waste Boundary (1992)
- 1994 NTCRA Surface Battery/Soil and Surface Debris Removal Area
- 1994 NTCRA Removal Areas
- 2005 NTCRA Removal Areas

N

0 125 250 Feet

Figure 4-4
Site 4 Organic Detections in Groundwater
Remedial Investigation Report for Groundwater
at Sites 4, 21, and 22
Naval Weapons Station Yorktown
Yorktown, Virginia

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September 13, 2010

377124.TS.PT.01

Mr. Wade Smith
Remedial Project Manager
Virginia Department of Environmental Quality
629 East Main Street, 4th Floor
Richmond, VA 23219

Subject: Response to Comments *Draft Feasibility Study Report for Groundwater, Site 22,* WPNSTA Yorktown
Yorktown, Virginia

Dear Mr. Smith

This letter is in response to your comments on the subject document provided in your comment letter dated 25 August 2010. All requested editorial comments will be incorporated as requested.

Comment 1: Section 3.2 (Page 3-2) states that one of the RAOs for groundwater is to maintain LUCs until contaminant concentrations in groundwater allow for unlimited use and unrestricted exposure. However, Section 1.4 states that Site 22 is located inside an area encumbered by the ESQD and cannot be developed for real estate purposes. Please include a discussion of if/how the ESQD affects the RAOs.

Response 1: The following text will be added to Section 3.2: "The ESQD arc does not impact the overall RAOs for the site. The ESQD arc will be in effect as long as ordnance and munitions activities are being conducted at WPNSTA Yorktown. However, the RAO to maintain LUCs is necessary in the event that ordnance activities and development restrictions posed by the ESQD arc are discontinued at the base."

Comment 2: Please include a discussion in Section 3.3 (Page 3-4) on why the inferred 100 ug/L TCE groundwater isoconcentration contours on Figure 3-1 (and subsequently on Figures 4-2 and 4-3) are not adjoining.

Response 2: The isoconcentration contours are not shown as adjoining on the basis of the MIP data which identified a clean area between the two areas of higher concentration (see attached Figure 6-3 from the RI Report. A footnote will be added to Figure 3-1 and subsequent figures to provide clarification.

Comment 3: In Virginia, both MCLs and SMCLs are contained in the Department of Health's *Waterworks Regulations*: 12 VAC 5-590-10 to 1280. The statutory basis for the

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Waterworks Regulations is found in Chapter 6 of Title 32.1 of the Virginia Code, *Environmental Health Services*: Va. Code Ann.§§ 32.1-163 to 248.2. In the absence of MCLs/SMCLs, other health-based standards or criteria, or best professional judgment based on risk assessment, may be employed. Where groundwater that is a potential drinking water source discharges to surface water, the cleanup level at the discharge point would be the more stringent of either the MCL/SMCL or a discharge limit based on the *Water Quality Standards*: 9 VAC 25-260-5 to 550. Please add *Waterworks Regulations*: 12 VAC 5-590-10 and 440.

Response 3: 12VAC 5-590-440 specifies analytical methods to be employed by a waterworks operation and therefore they are not applicable or relevant and appropriate to activities that would be conducted at Site 22 based on the alternatives presented in the FS. Additionally, the criteria specified are not more stringent than Federal MCLs which have been included as applicable chemical-specific ARARs for the constituents of concern at Site 22. As per 40 CFR 300.400 (g)(4), only state regulations that are more stringent than federal requirements may be considered applicable or relevant and appropriate.

Comment 4: Please add the Erosion and Sediment Control Regulations: 4 VAC 50-30-10 to 110, to the Virginia Action-specific ARARs for those alternatives that may require monitoring well installation or land disturbing activities.

Response 4: The Erosion and Sediment Control Regulations, VA Code Ann. §§ 10.1-562 - 573 will be added to the ARARs table as requested. However, because site activities will disturb less than 10,000 sq ft, the work to be completed at the site may be eligible for a waiver. Surface disturbance activities will result in negligible impact to surface runoff characteristics. None of the remedial activities proposed in the FS at Site 22 will result in land development. Consequently, it is believed that the substantive requirements of the Erosion and Sediment Control Regulations only need to be attained.

Please feel free to contact me should you have any additional questions.

Sincerely,

CH2M HILL

William J Friedmann, Jr.

William Friedmann
Project Manager

cc: Mr. Tom Kowalski/NAVFAC
Mr. Robert Thomson/USEPA
Ms. Laura Cook/CH2M HILL

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