DRAFT-FINAL

SITE-WIDE REMEDIAL INVESTIGATION REPORT
SPRING VALLEY FORMERLY USED DEFENSE SITE

SPRING VALLEY, WASHINGTON, DC

Contract No.: W912DR-09-D-0061, Delivery Order 0011
DERP FUDS MMRP/CWM Project No. C03DC091801 and
DERP FUDS HTRW Project No. C03DC091802

US ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT

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APRIL 06, 2015

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Site-Wide Remedial Investigation Report Summary and Next Steps

Overview:

The Spring Valley Formerly Used Defense Site (FUDS) consists of approximately 661 acres in Northwest Washington, D.C. During the World War I-era, the site was known as the American University Experiment Station (AUES) and Camp Leach. It was used by the U.S. government for engineer troop training, research and testing of chemical agents, equipment, and munitions. Between 1993 and 2014, the U.S. Army Corps of Engineers performed investigations to gather the data necessary to determine the nature and extent of known contamination, assess risk to human health and the environment, and establish criteria for possible cleanup actions associated with past Department of Defense (DoD) activities. During the investigations, the Corps of Engineers also removed munitions related items and arsenic contaminated soil.

Munitions testing at the American University Experiment Station

Due to the location of the FUDS in a residential community and the nature of the early burial pit findings, the Corps of Engineers took a multi-pronged approach to investigate previously identified areas while concurrently analyzing historical records to plan investigations in additional areas.

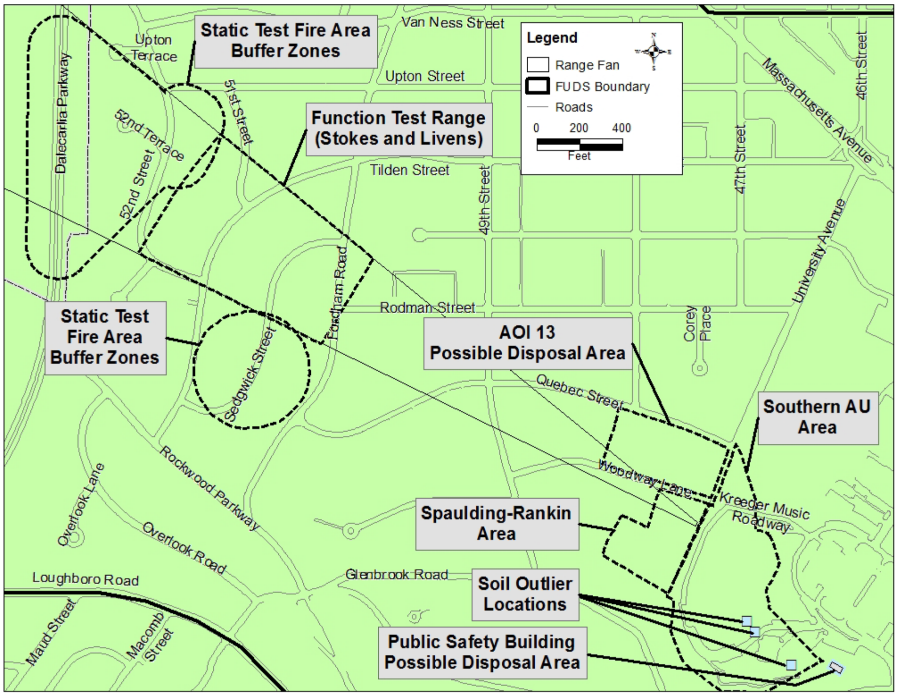
What is the Remedial Investigation (RI) Report?

The Site-Wide RI Report summarizes the results of completed field activities performed to characterize the nature and extent of any potential contamination resulting from past DoD activities in the Spring Valley FUDS. It reviews past DoD activities in the area now designated as the Spring Valley FUDS. The report describes various ways the area was defined based on historical and anecdotal information during the course of the RI to plan focused investigations. It then includes assessments based on the cumulative results of the RI field efforts to evaluate hazards posed by munitions and risks posed by chemical contaminants. Human health risk assessments, as well as an ecological risk assessment, were developed to evaluate possible chemical contaminants. Munitions hazard assessments are documented in the report to evaluate potential munitions hazards at different areas throughout the Spring Valley FUDS. Finally, the report describes areas identified through the risk and hazard assessment processes, where the Army Corps of Engineers recommends a Feasibility Study (FS) to address potential remaining concerns.

What are the RI Recommendations?

- Conduct a FS to address chemical risks in soil:
  - At a few locations on the American University campus/Spaulding Captain Rankin Area.
- Conduct a FS to address potential explosive hazards associated with:
  - Munitions related items possibly remaining within the impact areas of the ballistic test ranges (*See map: Function Test Range*).
  - Munitions burial pits within the static test fire areas and their surrounding buffer zones (*See map: Static Test Fire Areas*).
  - Possible munitions disposal pits associated with the identified possible disposal areas (*See map: Possible Disposal Area*).

See map (below) for additional information regarding the areas to be further evaluated in the FS.



What's Next?

The Army Corps of Engineers will perform a FS focusing on the areas recommended for further evaluation in the Remedial Investigation Report. The FS will outline how the Corps of Engineers plans to address any potential unacceptable risks and hazards. After the FS the Corps of Engineers will prepare a Proposed Plan, which will identify a preferred clean-up action to address remaining risks and hazards. The public will be invited to review and provide comments on the Proposed Plan during a formal public comment period, which will include a public meeting.

The Corps of Engineers remains committed to implementing a measured and comprehensive path forward at the Spring Valley Formerly Used Defense Site — the objective being a thorough and complete cleanup, with the safety of the surrounding neighborhood, university community, and site workers as the number one priority.

Where can I learn more?

The Site-Wide RI Report will be posted on USACE's Spring Valley website: **http://www.nab.usace.army.mil/Home/SpringValley.aspx**. Additional fact sheets and information regarding the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) process — the regulatory process followed for the Spring Valley FUDS — are also available on the website. To learn more, please call our Community Outreach Office at 410-962-2210.

U.S. ARMY CORPS OF ENGINEERS – BALTIMORE DISTRICT
10 SOUTH HOWARD STREET, BALTIMORE, MD 21201
http://www.nab.usace.army.mil/Home/SpringValley/SiteWide.aspx

April 06, 2015

Attn: Lan Reeser
CENAB-EN-HN
10 S. Howard Street
Baltimore, MD 21201-1715

Dear Mr. Reeser,

ERT, Inc., is pleased to present the Draft-Final Site-Wide Remedial Investigation report for the Spring Valley FUDS Integrated Site-Wide Remedial Investigation/Feasibility Study, Washington, DC. This version, which is being made available for public comment, incorporates revisions based on USEPA, DCDOE, RAB TAPP, American University, and CENAB back check comments on the December 2014 Draft-Final version of the document.

Electronic and hard copy distribution will be made as shown below. Please do not hesitate to call me at 301-323-1442 if you need anything more.

Sincerely,

ELECTRONIC SIGNATURE

Thomas J. Bachovchin, P.G.
Project Manager

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DRAFT-FINAL
SITE-WIDE REMEDIAL INVESTIGATION REPORT

Integrated Site-Wide
Remedial Investigation/Feasibility Study Project
Spring Valley Formerly Used Defense Site (SVFUDS)
Washington, D.C.

Contract: W912DR-09-D-0061, Delivery Order 0011
DERP FUDS MMRP/CWM Project No. C03DC091801 and
HTRW Project No. C03DC091802

U.S. Army Corps of Engineers
Baltimore District

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DRAFT-FINAL

Site-Wide Remedial Investigation Report

Integrated Site-Wide Remedial Investigation/Feasibility Study Project

Spring Valley Formerly Used Defense Site (SVFUDS)

Washington, D.C.

Prepared for:

U.S. Army Corps of Engineers

Baltimore District

Contract W912DR-09-D-0061

Delivery Order 0011

Prepared by:

ERT, Inc.

Laurel, Maryland 20707

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4/06/15

Thomas Bachovchin, PG
Project Manager

Date

07/29/14

Jennifer Harlan, PMP
Program Manager

Date

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COMPLETION OF SENIOR TECHNICAL REVIEW

This document has been produced within the framework of the ERT, Inc. (ERT) quality management system. As such, a senior technical review has been conducted. This included review of all elements addressed within the document, proposed or utilized technologies and alternatives and their applications with respect to project objectives and framework of U.S. Army Corps of Engineers regulatory constraints under the current project, within which this work has been completed.

07/29/14

Jennifer Harlan, PMP Date
Senior Technical Reviewer

COMPLETION OF INDEPENDENT TECHNICAL REVIEW

This document has been produced within the framework of ERT's quality management system. As such, an independent technical review, appropriate to the level of risk and complexity inherent in the project, has been conducted. This included a review of assumptions; alternatives evaluated; the appropriateness of data used and level of data obtained; and reasonableness of the results, including whether the product meets the project objectives. Comments and concerns resulting from review of the document have been addressed and corrected as necessary.

03/25/14

Barry Millman, PE Date
Independent Technical Reviewer

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ACRONYMS AND ABBREVIATIONS

ABP	agent breakdown products
ALM	Adult Lead Model
AOI	area of interest
AOITF	Areas of Interest Task Force
ARB	Anomaly Review Board
ATSDR	Agency for Toxic Substances and Disease Registry
AU	American University
AUES	American University Experiment Station
BCF	bioconcentration factor
bgs	below ground surface
CA	chemical agent
CCA	copper chromated arsenate
CDC	Child Development Center
CDI	chronic daily intake
CENAB	U.S. Army Corps of Engineers, Baltimore District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
COC	chemical of concern
COPC	chemical of potential concern
COPEC	chemical of potential ecological concern
CSF	cancer slope factor
CSA	Comprehensive Sampling Area
CSM	conceptual site model
CTA	Central Testing Area
CTE	central tendency evaluation
CWA	chemical warfare agent
CWM	chemical warfare materiel
CWS	Chemical Warfare Service
DA	Department of the Army
DC	District of Columbia
DDOE	District Department of the Environment
DC DOH	District of Columbia Department of Health
DCRA	Department of Consumer and Regulatory Affairs
DC WASA	DC Water and Sewer Authority
DERP	Defense Environmental Restoration Program
DGM	digital geophysical mapping
DMM	discarded military munitions

DNT	dinitrotoluene
DoD	Department of Defense
DQO	data quality objective
DVD	digital versatile disc
ECBC	Edgewood Chemical Biological Center
ECS	Engineering Control Structure
EDS	Explosive Destruction System
EE/CA	Engineering Evaluation/Cost Analysis
EPC	exposure point concentration
EPIC	Environmental Photographic Interpretation Center
ERDC	Engineering Research Development and Engineering Center
ERT	ERT, Inc.
EU	exposure units
FS	Feasibility Study
ft	feet
FUDS	Formerly Used Defense Site
GIS	geographic information system
GPO	geophysical prove out
GPR	ground penetrating radar
GPS	global positioning system
HA	hazard assessment
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
HTW	hazardous and toxic waste
IDW	investigation derived waste
IEUBK	integrated exposure biokinetic uptake
INPR	Inventory Project Report
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
kg	kilogram
Koc	organic carbon partition coefficient
Kow	octanol-water partition coefficient
LUC	land use control
MC	munitions constituents
MEC	munitions and explosives of concern
MD	munitions debris
mg/kg	milligram per kilogram
mm	millimeters
MMRP	Military Munitions Response Program
MRA	Munitions Response Area
MRS	Munitions Response Site
MRSPP	Munitions Response Site Prioritization Protocol
NA	not applicable
Navy	Department of the Navy
NCP	National Contingency Plan

NTCRA	non-time critical removal action
NFA	no further action
NGS	National Geodetic Survey
OE	ordnance and explosives
OSWER	Office of Solid Waste and Emergency Response
OSR	Operation Safe Removal
OU	Operable Unit
PAH	polycyclic aromatic hydrocarbons
POI	point of interest
PEF	particulate emission factor
PPRTV	Provisional Peer Reviewed Toxicity Values
ppb	parts per billion
ppm	parts per million
PSB	Public Safety Building
QAPP	Quality Assurance Project Plan
QC	quality control
RA	Remedial Action
RAB	Restoration Advisory Board
RAGS	Risk Assessment Guidance for Superfund
RAO	remedial action objective
RCRA	Resource Conservation and Recovery Act
RfC	reference concentration
RfD	reference dose
RI	Remedial Investigation
RME	reasonable maximum exposure
RSL	regional or risk-based screening level
RTS	Robotic Total Station
SDA	Small Disposal Area
SLERA	screening level ecological risk assessment
SVOC	semi-volatile organic compounds
SVFUDS	Spring Valley Formerly Used Defense Site
TAL	target analyte list
TAPP	Technical Assistance for Public Participation
TCL	target compound list
TCRA	time critical removal action
TBD	to be determined
TCLP	Toxicity Characteristic Leaching Procedure
TIC	tentatively identified compound
TNT	trinitrotoluene
TP	test pits
UCL	upper confidence level
USACE	U.S. Army Corps of Engineers
USACHPPM	U.S. Army Center for Health Promotion and Preventive Medicine
USAEC	U.S. Army Environmental Command
USAESCH	U.S. Army Engineering and Support Center, Huntsville
USATHAMA	U.S. Army Toxic and Hazardous Materials Agency

U.S.C.	United States Code
USDA	United States Department of Agriculture
USEPA	U.S. Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	U.S. Geological Survey
UXO	unexploded ordnance
VOC	volatile organic compounds
WA	Washington Aqueduct
WWI	World War I

GLOSSARY OF TERMS

Anomaly Avoidance – Techniques employed on property known or suspected to contain unexploded ordnance (UXO), other munitions that may have experienced abnormal environments (e.g., discarded military munition (DMM)), munitions constituents in high enough concentrations to pose an explosive hazard, or CA, regardless of configuration, to avoid contact with potential surface or subsurface explosive or CA hazards, to allow entry to the area for the performance of required operations (DoD 6055.09-M-V8 [DoD, 2012]).

CERCLA - The Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a 1980 law commonly known as Superfund, authorizes EPA to respond to releases, or threatened releases, of hazardous substances that may endanger public health, welfare, or the environment. CERCLA also enables EPA to force parties responsible for environmental contamination to clean it up or to reimburse the Superfund for response or remediation costs incurred by EPA.

Cultural Debris – Debris that is not related to munitions or range operations. Such debris includes, but is not limited to, rebar, household items (refrigerators, washing machines, etc.), automobile parts and automobiles that were not associated with range targets, fence posts, and fence wire. Cultural debris does not refer to items of cultural or historical significance.

Chemical Agents (CA) and Agent Breakdown Products (ABPs) – CAs are chemical compounds (to include experimental compounds) that, through its chemical properties, produces lethal or other damaging effects on human beings, and is intended for use in military operations to kill, seriously injure, or incapacitate persons through its physiological effects. Excluded are research, development, test, and evaluation solutions; riot control agents; chemical defoliants and herbicides; smoke and other obscuration materials; flame and incendiary materials; and industrial chemicals (DoD, 2012). ABPs are formed by decomposition, hydrolysis, microbial degradation, oxidation, photolysis, and decontamination of CAs.

Chemical Warfare Materiel (CWM) – Items generally configured as a munition containing a chemical compound that is intended to kill, seriously injure, or incapacitate a person through its physiological effects. CWM includes V- and G-series nerve agents or H-series (mustard) and L-series (lewisite) blister agents in other-than-munition configurations; and certain industrial chemicals (e.g., hydrogen cyanide (AC), cyanogen chloride (CK), or carbonyl dichloride (called phosgene or CG)) configured as a military munition. Due to their hazards, prevalence, and military-unique application, CA identification sets are also considered CWM. CWM does not include: riot control devices; chemical defoliants and herbicides; industrial chemicals (e.g., AC, CK, or CG) not configured as a munition; smoke and other obscuration producing items; flame and incendiary producing items; or soil, water, debris or other media contaminated with low concentrations of chemical agents where no CA hazards exist (DoD, 2012).

Decision Document (DD) – The Department of Defense has adopted the term Decision Document for the documentation of remedial action (RA) decisions at non-National Priorities List (NPL) FUDS Properties. The decision document shall address the following: Purpose, Site Risk, Remedial Alternatives, Public/Community Involvement, Declaration, and Approval and Signature. A Decision Document for sites not covered by an interagency agreement or Federal facility agreement is still required to follow a CERCLA response. All Decision Documents will be maintained in the FUDS Property/Project Administrative Record file. An Action Memorandum is the decision document for a removal response action. (USACE, 2004d).

Discarded Military Munitions (DMM) – Military munitions that have been abandoned without proper disposal or removed from storage in a military magazine or other storage area for the purpose of disposal. The term does not include UXO, military munitions that are being held for future use or planned disposal, or military munitions that have been properly disposed of, consistent with applicable environmental laws and regulations. (10 United States Code [USC] 2710(e)(2)).

Explosive Hazard – A condition where danger exists because explosives are present that may react (e.g., detonate, deflagrate) in a mishap with potential unacceptable effects (e.g., death, injury, damage) to people, property, operational capability, or the environment (DoD, 2012).

Exposure Unit – Used in risk assessment to define the geographical area in which a receptor is randomly exposed to a contaminated medium for a relevant exposure duration. Environmental sampling provides information about the contamination within and around an EU. Multiple EUs may be defined at a site based on the choice of a receptor, the exposure medium, and the nature of contact with the medium. Site-specific information regarding the activities of receptors should guide assumptions about the receptor's contact with exposure media. (USEPA RAGS Volume 3 Part A, Appendix C).

Formerly Used Defense Sites (FUDS) Property – A facility or site (property) that was under the jurisdiction of the Secretary of Defense and owned by, leased to, or otherwise possessed by the United States at the time of actions leading to contamination by hazardous substances. The FUDS program is limited to those real properties that were transferred from DoD control prior to October 17, 1986. Properties must be located within the United States (DodM 4715.20 [DoD, 2012a]).

Military Munitions – Military munitions means all ammunition products and components produced for or used by the armed forces for national defense and security, including ammunition products or components under the control of the DoD, the Coast Guard, the Department of Energy, and the National Guard. The term includes confined gaseous, liquid, and solid propellants; explosives, pyrotechnics, chemical and riot control agents, smokes, and incendiaries, including bulk explosives, and chemical warfare agents; chemical munitions, rockets, guided and ballistic missiles, bombs, warheads, mortar rounds, artillery ammunition, small arms ammunition, grenades, mines, torpedoes, depth charges, cluster munitions and dispensers, demolition charges; and devices and components thereof. The term does not include wholly inert items; improvised explosive devices; and nuclear weapons, nuclear devices, and nuclear components, other than nonnuclear components of nuclear devices that are managed under the nuclear weapons program of the Department of Energy after all required sanitization operations under the Atomic Energy Act of 1954 (42 U.S.C. 201 1 et seq.) have been completed. (10 U.S.C. 101(e)(4)(A) through (C)).

Munitions and Explosives of Concern (MEC) – This term, which distinguishes specific categories of military munitions that may pose unique explosives safety risks means (A) UXO, as defined in 10 U.S.C. 101(e)(5); (B) DMM, as defined in 10 U.S.C. 2710(e)(2); or (C) MC (e.g., Trinitrotoluene [TNT], Cyclotrimethylenetrinitramine [RDX]), as defined in 10 U.S.C. 2710(e)(3), present in high enough concentrations to pose an explosive hazard.

Munitions Constituents (MC) – Any materials originating from UXO, DMM, or other military munitions, including explosive and nonexplosive materials, and emission, degradation, or breakdown elements of such ordnance or munitions. (10 U.S.C. 2710(e)(3)) **.**

Munitions Debris (MD) – Remnants of munitions (e.g., fragments, penetrators, projectiles, shell casings, links, fins) remaining after munitions use, demilitarization, or disposal (DoD, 2012).

Munitions Response – Response actions, including investigation, removal actions and remedial actions to address the explosives safety, human health, or environmental risks presented by UXO, DMM, or MC, or to support a determination that no removal or remedial action is required (DoD, 2012).

Munitions Response Area (MRA) – Any area on a defense site that is known or suspected to contain UXO, DMM, or MC. Examples include former ranges and munitions burial areas. An MRA is composed of one or more MRSs (DoD, 2012).

Munitions Response Site (MRS) – A discrete location within an MRA that is known to require a munitions response (DoD, 2012).

Partners - The Partners for the SVFUDS included USACE, USEPA, and DDOE, with additional stakeholder participants including the RAB TAPP consultant, AU, and contractors involved in active SVFUDS investigations. The Partners provided agency-level coordination through formal regularly scheduled meetings, referred to as Partnering meetings, beginning in 2001.

Proposed Plan (PP) – In the first step in the remedy selection process, the lead agency identifies the alternative that best meets the requirements in CERCLA 300.430(f)(1) and presents that alternative to the public in a proposed plan. The purpose of the proposed plan is to supplement the Remedial Investigation/Feasibility Study (RI/FS) and provide the public with a reasonable opportunity to comment on the preferred alternative for remedial action, as well as alternative plans under consideration, and to participate in the selection of remedial action at a site. (USACE, 2004d).

Range – A designated land or water area that is set aside, managed, and used for range activities of the DoD. The term includes firing lines and positions, maneuver areas, firing lanes, test pads, detonation pads, impact areas, electronic scoring sites, buffer zones with restricted access, and exclusionary areas. The term also includes airspace areas designated for military use in accordance with regulations and procedures prescribed by the Administrator of the Federal Aviation Administration. (10 U.S.C. l0l (e)(l)(A) and (B)).

Remedial Action (RA) – Those actions consistent with permanent remedy taken instead of or in addition to removal actions in the event of a release or threatened release of a hazardous substance into the environment, to prevent or minimize the release of hazardous substances so that they do not migrate to cause substantial danger to present or future public health, welfare or the environment. The term includes, but is not limited to, such actions at the location of the release as storage; confinement; perimeter protection using dikes, trenches, or ditches; clay cover; neutralization; cleanup of released hazardous substances and associated contaminated materials; recycling or reuse; diversion; destruction; segregation of reactive wastes; dredging or excavations; repair or replacement of leaking containers; collection of leachate and runoff; on-site treatment or incineration; provision of alternative water supplies; and any monitoring reasonably required to assure that such actions protect the public health, welfare, and the environment. The term includes the costs of permanent relocation of residents and businesses and community facilities where the President determines that, alone or in combination with other measures, such relocation is more cost-effective and environmentally preferable to the transportation, storage, treatment, destruction, or secure disposition off-site of hazardous substances, or may otherwise be necessary to protect the public health or welfare. The term includes off-site transport and off-site storage, treatment, destruction, or secure disposition of hazardous substances and associated contaminated materials (USACE, 2004d).

Remedial Investigation/Feasibility Study (RI/FS) – An in-depth study designed to gather the data necessary to determine the nature and extent of known contamination at a site, assess risk to human health and the environment, and establish criteria for cleaning up the site. During the FS, the RI data are analyzed and remedial alternatives are identified. The FS serves as the mechanism for the development, screening, and detailed evaluation of alternative remedial actions (USACE, 2004d).

Removal or Removal Action – The cleanup or removal of released hazardous substances from the environment. Such actions may be taken in the event of the threat of release of hazardous substances into the environment, such actions as may be necessary to monitor, assess, and evaluate the release or threat of release of hazardous substances, the disposal of removed material, or the taking of such other actions as may be necessary to prevent, minimize, or mitigate damage to the public health or welfare or to the environment, which may otherwise result from a release or threat of release. The term includes, in addition, without being limited to, security fencing or other measures to limit access, provision of alternative water supplies, temporary evacuation and housing of threatened individuals not otherwise provided for, action taken under section 9604(b) of this title, and any emergency assistance which may be provided under the Disaster Relief and Emergency Assistance Act [42 U.S.C. 5121 et seq.] The requirements for removal actions are addressed in 40 CFR §§300.410 and 330.415. The three types of removals are emergency, time-critical, and non time-critical removals.

Restoration Advisory Board (RAB) – A forum for the discussion and exchange of information between representatives of the Department of Defense (DoD), regulators, state and local governments, tribal governments, and the affected community. RABs provide an opportunity for stakeholders to have a voice and actively participate in the review of technical documents, to review restoration progress, and to provide individual advice to decision makers regarding restoration activities at FUDS Properties and Projects (USACE, 2004d).

Unexploded Ordnance (UXO) – Military munitions that (A) have been primed, fuzed, armed, or otherwise prepared for action; (B) have been fired, dropped, launched, projected, or placed in such a manner as to constitute a hazard to operations, installations, personnel, or material; and (C) remain unexploded whether by malfunction, design, or any other cause. (10 U.S.C. 101(e)(5)(A) through (C)).

EXECUTIVE SUMMARY

INTRODUCTION AND BACKGROUND

ERT, Inc., (ERT) was tasked with drafting an Integrated Site-Wide Remedial Investigation (RI) report for the U.S. Army Corps of Engineers (USACE), for the Spring Valley Formerly Used Defense Site (SVFUDS), located in Washington, D.C. The work was performed under the Munitions Response and Environmental Remediation Services Contract (W912DR-09-D-0061, Delivery Order 0011), which is administered by the Baltimore District (CENAB). The U.S. Army Engineering and Support Center, Huntsville (USAESCH) provides additional oversight for activities involving chemical warfare materiel (CWM). CENAB and USAESCH are referred to jointly as "USACE", unless specific district responsibilities are discussed.

This project falls under the Military Munitions Response Program (MMRP) of the Defense Environmental Restoration Program (DERP)/Formerly Used Defense Sites (FUDS). MMRP under the DERP includes munitions constituents (MC) and munitions and explosives of concern (MEC). Within DERP, the FUDS Program concerns eligible Department of Defense (DoD) contamination/hazards at properties transferred from DoD control prior to October 17, 1986, which – prior to that date – had been owned by, leased to, or otherwise possessed by the United States and under the jurisdiction of the DoD at the time of the actions leading to its contamination. USACE performs and has been performing response activities throughout the SVFUDS in accordance with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and its implementing regulations, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

The purpose of this RI is to adequately characterize the nature and extent of any potential hazardous and toxic waste (HTW), MC, and CWM contamination, and/or MEC hazards resulting from the past DoD activities at the SVFUDS. The SVFUDS RI spans more than two decades involving numerous investigation phases conducted simultaneously in a densely populated Washington, D.C. suburban neighborhood. Stakeholder coordination was performed at two major levels: the agency level with regulators, and the community level with community representatives and individual community members. The Spring Valley Partners were formed to provide agency-level coordination through formal regularly scheduled meetings, referred to as Partnering meetings, beginning in 2001. Prior to 2001, ad hoc meetings between the Partnering agencies were held periodically to discuss D.C.'s findings and requests. The Partners for the SVFUDS include USACE, the U.S. Environmental Protection Agency (USEPA) Region 3, and Washington, D.C.'s District Department of the Environment (DDOE). Additional stakeholder participants in Partnering meetings included the Restoration Advisory Board (RAB), Technical Assistance for Public Participation (TAPP) consultant, and American University (AU).

The nature of this RI is notably different from traditional RIs referencing a single set of objectives identified in a single RI work plan. While typical RIs follow the CERCLA sequence of activities, due to the location of SVFUDS in a suburban community and the nature of the early burial pit findings, USACE took a multi-pronged approach to investigate previously identified areas while concurrently analyzing historical records to plan investigations in additional areas.

Although each of these concurrent multiple activities, including different types of investigations of different discrete areas, and time-critical and non-time critical removal actions, resulted in completed standalone reports documenting all of the findings, the intention of this RI report is to present the rationale for each key event and summarize their findings to provide a more complete characterization of the SVFUDS. This RI report does not repeat the detail of these individual reports or change any of their conclusions (other than to provide an update or place them into a larger context, where appropriate); the primary key reports are contained in their entirety on digital versatile discs (DVDs) provided in the appendices.

Site Description and History

The SVFUDS comprises 661 acres in northwest Washington, D.C. This is a largely residential area with local shops and restaurants, surrounded by a cluster of dense apartment buildings and/or townhouses, and spreading out into single-family homes. The character of these areas is more suburban in nature, with a greater concentration of cul-de-sacs than anywhere else in the city. Land use in and around the SVFUDS is primarily low-density residential, with smaller portions zoned for commercial use. The campus of AU is considered institutional use. The Dalecarlia Woods area on the western edge of the SVFUDS is zoned as Federal or public use.

In 1917, the Bureau of Mines founded the American University Experiment Station (AUES) to do research and perform small-scale testing of chemical warfare items. AUES operations generally fell into one or more of the following categories: gas mask research, offensive and defensive toxic chemical investigations, medical research, pyrotechnic investigations, and mechanical investigations. Also starting in 1917, USACE set up Camp Leach to organize and train engineer officers and regiments. From 1917-18, about 100,000 troops trained at Camp Leach. The 195-acre site, located on the northeast portion of AU and adjacent properties, consisted primarily of tents and barracks along with staging and training areas for troops.

Site Delineation

The SVFUDS has been delineated in several ways over the years to plan focused investigations, incorporate newly identified historical information and analyses, or address updated MMRP requirements. The SVFUDS boundary line was established in January 1993 based on the known AUES and Camp Leach boundaries according to historical records, including the spatial orientation of Points of Interest (POIs) identified from a 1918 aerial photomosaic.

The SVFUDS consists of five Operable Units (OUs). USACE began defining OUs following the expansion of investigation activities in 1999. OU-1 was defined as the investigation area covered during Operation Safe Removal (OSR). The area investigated as part of the Spaulding and Captain Rankin Area RI became designated as OU-2. Following in sequence, OU-3 consists of 4801 Glenbrook Road, 4825 Glenbrook Road, and 4835 Glenbrook Road, and peripheral parts of AU, that were the first group of properties to undergo expanded investigations after the completion of OSR. Based on findings of the initial OU-3 investigations, an expanded area surrounding OU-3 was designated as OU-4. Through consultation with the regulators, USACE then defined the remaining portions of the SVFUDS outside OU-2, OU-3, and OU-4 as OU-5 to conduct further investigation and characterization of the remainder of the SVFUDS.

The SVFUDS includes 54 POIs or areas identified by historical archive screening where DoD activity involving training, testing, research and development may have taken place based on the historical records search conducted by the Army. POIs were established early during OSR at locations where the historical record indicated AUES testing or research activities occurred. During the course of RI activities, USACE has developed focused investigations for each of the

54 POIs to further characterize these areas based on the specific activities which may have occurred there.

The SVFUDS has 28 Areas of Interest (AOIs). AOIs were identified by a workgroup called the AOI Task Force (AOITF). The AOITF consisted of four members, including one representative from each of the three partnering agencies (USACE, USEPA, DDOE) and the SVFUDS RAB TAPP consultant. AOIs were identified and evaluated using all available sources of information, including historical documents and photographs, aerial photographs and photographic analysis, sampling and geophysical data, health-related data, and anecdotal information.

The Range Fan is a cone-shaped area defined by a firing point and potential impact areas down range. Historical records for the AUES suggest that Livens projectiles, and 3-inch and 4-inch Stokes mortars may have been fired from the Livens Battery Pit and Stokes Mortar Gun Placements near AU and Woodway Lane and, in turn, may have impacted downrange locations to the northwest towards the Dalecarlia Woods, a federally owned property.

The Army currently requires MMRP RIs to designate Munitions Response Sites (MRSs) as the areas of investigation and focus. An MRS is a discrete location within a Munitions Response Area (MRA) that is known to require a munitions response. For the SVFUDS, MRS 01 is a compilation of several test areas and burial pits and it consists of the areas where field testing is thought to have occurred, as well as associated burial pits and disposal areas. However, the SVFUDS investigation units were designated as POIs, AOIs, Operable Units, or other, prior to establishment of the MRS terminology, and therefore, MRS usage does not supersede those POI, AOI, or OU designations in this RI report.

<u>Previous Activities</u>

The SVFUDS is an extremely complex site involving several ongoing and concurrent activities over many years, focusing on different potential hazards and/or different investigation locations. In order to manage and track all of the site activities and present them in a cohesive manner, all previous activities were organized primarily by the following key types of activities completed for the SVFUDS: initial investigation and characterization, follow-on investigation and characterization, geophysical investigations, and removal actions. All of the activities conducted at the SVFUDS fall under one (or more) of these activity types.

In 1986, prior to the OSR FUDS, the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) conducted an historical records search in response to a request made by AU. AU researchers had prepared a study which noted that AU was used as a chemical warfare laboratory during World War I (WWI) and that munitions may have been buried in the vicinity of AU. AU requested assistance from the Army to determine what material was buried and the exact location of possible burials.

<u>Initial Investigation and Characterization</u>

On January 5, 1993, a contractor unearthed buried munition items while digging a utility trench on 52nd Court. Upon notice of the discovery, the U.S. Army Technical Escort Unit from the Chemical and Biological Defense Agency at Aberdeen Proving Ground, Maryland, initiated an emergency response, known as OSR FUDS Phase I, which was completed on February 2, 1993.

OSR FUDS Phase II was the start of the RI phase for the SVFUDS. Using historical documentation including reports, maps and photos, USACE established POIs and performed geophysical investigations at POIs considered to be potential munitions burial locations and conducted sampling of environmental media at 17 POIs. POIs and the findings were documented in the 1995 OSR FUDS RI report, which recommended no further action for the SVFUDS with the exception of the Spaulding and Captain Rankin Area (a single property that contained former shell pits/bunkers associated with AUES activities). The RI report was followed by a No Further Action Record of Decision in June 1995.

In June 1994, an Engineering Evaluation/Cost Analysis (EE/CA) was conducted for the Spaulding and Captain Rankin Areas. The EE/CA identified risk associated with the soil within the former shell pits (bunkers). Based on these findings, a Non-Time-Critical Removal Action (NTCRA) was conducted in this location to remove the soil debris found within the POI structures. A separate RI for the Spaulding and Captain Rankin Area, prepared in 1996, addressed exposures to subfloor soils and concrete and pipe drain termini at POIs 21, 22, and 23 for construction workers. In the June 1996 Spaulding and Captain Rankin RI Report, USACE recommended no further action for this area.

In 1999, the USEPA prepared a human health risk assessment (HHRA) for the SVFUDS, conducting an analysis of soil sampling data collected between 1993 and 1995 at 16 locations throughout Spring Valley and AU property (taking splits of the USACE OSR FUDS RI samples).

<u>Follow-on Investigation and Characterization</u>

The D.C. Department of Consumer and Regulatory Affairs (DCRA) prepared a report in 1996 that criticized USACE's No Further Action Record of Decision at the SVFUDS and recommended site-wide comprehensive geophysical investigations, soil sampling, and a health study. Following further USACE review of the issues, it was determined that the location of POI 24 (a possible mustard agent burial pit) was on the grounds of 4801 Glenbrook Road instead of AU property. Given the incorrect location of POI 24, USACE conducted field investigations in the vicinity of the revised POI 24 location, on 4801 Glenbrook Road, where two large burial pits (pits 1 and 2) were discovered and excavated.

To further address DCRA concerns, the USEPA collected soil samples in and around these OU-3 properties (4801, 4825, and 4835 Glenbrook Road) to supplement their HHRA and based on the interim results from the USEPA sampling, and historical information, it was determined that the soil of the three properties (4801, 4825, and 4835 Glenbrook Road) may have been impacted by AUES activities in the vicinity of the two burial pits.

Based on these findings, it was determined in 2000 that the area of investigation should be expanded beyond OU-3. The expanded area of investigation was designated as OU-4 and it included approximately 80 private residences and significant portions of the AU campus. This investigation was primarily intended to characterize these properties for arsenic in the soil.

In response to significant community concerns regarding possible soil contamination in the greater community, the USACE, in consultation with the USEPA and the DDOE, developed a comprehensive plan to conduct arsenic soil sampling on every property within the SVFUDS and conduct additional geophysical investigations focusing on identifying additional potential burial pits as well as individual buried munition items. The expanded area of investigation, some 577 acres, was designated as OU-5.

The soils of both OU-4 and OU-5 were characterized for arsenic and selected CWM compounds associated with AUES activities under an EE/CA, which addressed the findings of the OU-4 and OU-5 investigations. Under this EE/CA, more focused sampling of properties was conducted if the initial arsenic screening composite results were above 12.6 milligrams per kilogram (mg/kg), indicating the possible presence of arsenic above the 20 mg/kg arsenic removal goal. The 20 mg/kg arsenic removal goal was established through consensus of the Partners and supported by the independent Scientific Advisory Panel, established to assist the community in understanding the overall approach to technical issues affecting Spring Valley. A total of 151 properties were identified in the EE/CA with one or more 20 by 20 foot square grids with arsenic concentrations above this goal. On a case by case basis, some sites received tighter 10 by 10 foot square grid sampling. An additional 32 properties were identified post-EE/CA with one or more grids above the arsenic removal goal as a result of removal actions identifying 20 mg/kg arsenic extending onto adjacent properties or delayed property owner permission to sample for arsenic.

Additional follow-on investigations resulted from the findings of the previous ones, many of these focusing on discrete areas of AU within OU-4. Individual investigation efforts were conducted for these areas within AU:

- Child Development Center
- Small Disposal Area
- Athletic Fields
- Lot 18 Disposal Area
- Public Safety Building
- Bamboo Area
- Kreeger Hall Area
- AU Ground Scars

In addition, in 2000, the USEPA completed an HHRA specific to the southern portion of the AU campus. The focus of this HHRA was to evaluate the potential risk to human health from exposures to metals in the soil at AU.

Localized groundwater sampling was conducted as part of the OSR FUDS RI in 1993, but the groundwater data were not suggestive of contamination at that time. The plan for the comprehensive study of groundwater and the procedures to complete these characterization activities began in 2005. Since then, over 50 monitoring wells, including three deep bedrock wells, have been sampled at least once as part of the SVFUDS groundwater study.

Geophysical Investigations

In some areas, geophysical surveys were the only investigations performed. Therefore they are discussed separately in this RI report, where appropriate. However, for some of the larger areas such as AU, where multiple investigation activities were conducted concurrently, geophysical investigation activities are incorporated into those sections and there may be some overlap in the discussions.

Geophysical investigations were conducted on 99 residential properties between 1998 and 2011. Properties were prioritized for investigation using a complex classification scheme. The investigations were conducted in two phases: properties were first non-intrusively geophysically surveyed to identify buried metallic anomalies. Following analysis of the geophysical survey results by the Anomaly Review Board (ARB), intrusive investigations of metallic anomalies with characteristics of possible buried WWI munition items were conducted.

In addition to the investigations performed on residential properties, many geophysical investigation efforts were conducted on the discrete areas of AU described above. Geophysical investigations were also completed on approximately 60 acres of District of Columbia and federal property located in the western edge of the SVFUDS, just east of the Dalecarlia Reservoir, using the same geophysical survey approach employed for the residential and AU investigations.

Removal Actions

Concurrent with ongoing SVFUDS investigations, for specific areas, removal actions were determined to be warranted. Removal actions were completed as Time Critical Removal Action (TCRA) or NTCRAs. For the SVFUDS, these removals were primarily excavations of arsenic contaminated soil.

TCRAs were conducted on the AU Child Development Center and portions of the athletic fields. USACE determined that TCRAs were also needed for several residential properties. The prioritization of these properties was based on the results of the arsenic testing. This work, on 24 residential properties and one lot, began in July 2002 and concluded in September 2003. CENAB conducted NTCRAs on 100 properties and 9 lots during the period of 2004-2013.

While soil removal was the primary removal action method, for selected properties, USACE also used ferns that naturally extract arsenic from soil. This process, known as phytoremediation, was used to fully or partially address 21 residential properties and one municipal lot.

In August 2010, several agencies within the DoD as well as the Partners, agreed to separate the 4825 Glenbrook Road property from the remainder of the SVFUDS and place it on its own CERCLA process pathway. Accordingly, 4825 Glenbrook Road investigation activities are summarized in this RI to provide context for investigations conducted in the vicinity of 4825 Glenbrook Road.

CONCEPTUAL SITE MODEL

Conceptual Site Models (CSMs) were developed to plan each primary investigative effort. A CSM is used to communicate and describe the current state of knowledge and assumptions about risks at a project site. The CSM presents the exposure pathway analysis by integrating information on the HTW/MC/CWM and MEC source, receptors, and receptor interaction. For the SVFUDS, the CSM was compared with known activities at the AUES to focus HTW/MC/CWM investigations in the SVFUDS. The AUES was used for testing of chemical warfare materiel and was generally divided into two use areas: the area within the AU and Spaulding property bounded by a perimeter fence served as the research center where chemicals, gases, and munitions were developed and stored; and the area outside the AU and Spaulding property boundaries where chemicals and items developed at the research facilities were field tested. Different investigations were planned for discrete sites relative to where these previous past activities occurred.

A MEC CSM was also developed, with the source, interaction, and receptor pathway requirements basically the same as for HTW/MC/CWM contamination. The primary release mechanisms resulting in the occurrence of MEC are related to the type of military munition activity, or result from the improper functioning of the military munition. The MEC CSM for the SVFUDS is based on the historical AUES activities, where munitions were ballistically and statically fired. For the SVFUDS, the investigations of the sources of munitions were based around the past activities most likely to result in MEC.

AUES activities both inside and outside the research facility perimeter fence were considered to potentially result in MEC, although in different ways. The area within the perimeter fence served as a research center and it was considered that the past activities most likely to result in MEC were disposal and burial as indicated by the presence of POIs analyzed to be possible or probable pits, based on historical documentation and aerial photographs. AOIs and POIs associated with the field testing areas outside the fence were primarily assessed to be impacted by either ballistically fired testing or statically fired testing; in addition, some areas were identified as areas where potential disposal or burial took place.

RI FIELD ACTIVITIES

The SVFUDS required some special procedures for field activities to characterize the site. These included analytical parameters, geophysics, and intrusive investigation procedures that may not be required for most HTW sites.

Analytical Requirements

As a former experiment station, analytical plans for the SVFUDS required analyses for additional parameters, including CWM and CWM agent breakdown products (ABPs) that would not typically be present on HTW sites. For the SVFUDS, analysis for the non-routine parameters, mustard and its ABPs (dithiane, oxathiane, and thiodiglycol) and Lewisite, required special procedures. Long historical lists of chemicals documented to have been used at the AUES were compiled, and by 2004, a structured evaluation process was developed to integrate all the chemicals from all the lists into a formal comprehensive list of chemicals to be analyzed, by media, when sampling objectives required comprehensive characterization.

Geophysics

For the SVFUDS, geophysical surveys have been the primary initial tool used to investigate the presence of MEC or munitions debris (MD), as well as buried pits and trenches. A variety of geophysical instruments and procedures for interpreting the data have been used to obtain the best possible picture of site conditions at the time. A timeline of geophysical activities indicates that, based on performance, the EM61-MK2 and the G-858 instruments were the primary tools used for geophysical investigation of the SVFUDS.

With regard to the interpretation of the collected geophysical data, several classification schemes have been used at the SVFUDS to assess the nature of the anomalies. Anomaly classification schemes were used by the ARB to evaluate, prioritize and select anomalies for intrusive investigation. Some of the early classification systems resulted in excavation of anomalies that were not related to munitions, wasting time and resources, and a more formalized scheme for anomaly classification was developed by USACE, USEPA and DDOE that incorporated a detailed process to select and prioritize anomalies based on the attributes of the geophysical signature and correlation to other SVFUDS features, such as identified POIs or ground scars. USACE also developed a classification scheme to prioritize each residential property for geophysical investigations utilizing photogrammetry, a geographic information system (GIS) database, and an automated sorting algorithm to accurately prioritize the properties.

Intrusive Anomaly Investigations

After the ARB had established the list of anomalies to be further investigated, they were excavated in accordance with safety protocols determined by the site specific probability assessment prepared by USACE. The probability assessment determined the probability of encountering MEC/CWM during intrusive activities: sites were determined to be "non-MEC/CWM" or "MEC/CWM" sites. If the probability assessment determined that the probability of encountering MEC/CWM was "seldom" or "remotely possible" the site would be classified as a "non-MEC/CWM" site and referred to as a "low probability" site. At low probability sites, anomalies could be excavated in open air without evacuations of people in the vicinity of the dig.

When USACE determined that the probability of encountering MEC/CWM during the investigation was "frequent", "likely", or "occasional", the investigation procedures followed protocols for "MEC/CWM" sites, referred to as "high probability" sites. High probability sites required significantly more planning, resources, and equipment to ensure safety of workers and the community and the anomaly excavation team performed the intrusive investigation either using engineering controls or under evacuation.

RI RESULTS (NATURE AND EXTENT)

The determination of the nature and extent of contamination of HTW, MC, CWM, MEC, and MD, was assessed by the findings of each of the primary types of activities conducted at the SVFUDS (investigation/characterization, geophysical surveys, and removals).

Investigation and Characterization

The findings of the investigation and characterization activities define the nature and extent of HTW/MC/CWM contamination for the SVFUDS. Investigation and characterization activities were completed as standalone reports performed at discrete areas of the SVFUDS. The findings of each of those reports have been previously reviewed by stakeholders. Recommendations leading to additional soil sampling were made at the time those reports were reviewed, and any additional samples required to further define nature and extent of HTW/MC/CWM contamination were collected at that time. Several discrete areas of the SVFUDS have proceeded through quantitative HHRAs, prior to this RI report, and any conclusions indicating remaining risk have been addressed in follow-on investigations such that characterization of those discrete areas was considered to be complete.

The results of more recent supplemental sampling, assessed as part of the comprehensive risk screening process conducted to identify further areas requiring quantitative risk assessment, have been incorporated into the quantitative HHRAs included in this RI report. While the findings of these quantitative HHRAs could result in the need for additional sampling in the future (through the Feasibility Study [FS] process) to determine extent of contamination in smaller focused areas, no additional sampling is currently required for further nature and extent characterization of the SVFUDS.

The groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A Groundwater RI will be provided as a separate document at a later date.

Geophysical Investigations

For the OSR FUDS investigation, geophysical surveys were performed on some 492 properties, or portions thereof, within the 661 acres of the SVFUDS, with focus on the identified POIs with an objective to locate burial pits and trenches. However, regulatory agencies generally agree that it is not practical to geophysically survey 100% of a site the size of the SVFUDS. Therefore, sound rationale for the selection of properties was crucial to determining the nature and extent of MEC or MD contamination. Since 2001, a structured classification scheme to prioritize properties for geophysical investigations has been followed. While this process has provided high quality geophysical data of all key areas based on historical review of past practices and likelihood of MEC or MD being present, the presence of individual munitions-related items will remain a possibility.

Removal Actions

Removal actions at the SVFUDS have been concurrent with other investigations, being expedited through the TCRA and NTCRA processes. The nature and extent of contamination in the areas of removals has been bounded through the removal actions, with soil excavations continuing until clean confirmation samples were obtained.

Nature and Extent Summary

A significant amount of data was gathered over the course of the RI. The key activity types of investigation and characterization, geophysical investigations, and removals, all contributed to achieving the DQOs for the SVFUDS sites. Table ES-1 provides a summary of completed investigations at individual sites, focusing on the POIs and AOIs (numbered sequentially), and the Range Fan. The intention of the table is to present the findings of the many investigations performed in the SVFUDS in the context of how achievement of the investigation objectives determined the nature and extent of contamination on an individual site level.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 1 / Circular Trenches	AOI 9, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Soil sampling for full AUES list parameters also conducted as part of the 2003 EE/CA with NTCRAs completed on 3 of the 5 properties based on arsenic contamination. Geophysical investigations found and removed MD items on 2 properties; no MEC/MD found on the other 3 properties. Miscellaneous soil samples were collected during geophysical investigations. All soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 2 / Possible Pit	AOI 9, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA with NTCRA required based on arsenic contamination. Geophysically surveyed; a possible pit anomaly was identified. Site access has not been granted for intrusive follow-on actions.	Investigation objectives achieved. Nature and extent of contamination to be defined.
POI 3 / Small Crater Scars	AOI 9, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigations found and removed MD items on all 3 properties. Miscellaneous soil samples were collected during geophysical investigations. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 4 / Possible Pit	AOI 9, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed MD items. Miscellaneous soil sample collected during geophysical investigation. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 5 / Possible Pit	AOIs 9, 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed MD items. Miscellaneous soil samples collected during geophysical investigation. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 6 / Possible Target or Test Site	AOIs 9, 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed a Stokes Mortar MEC item and MD items. Miscellaneous soil samples collected during geophysical investigation. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 7 / Possible Test Area	AOIs 9, 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. POI specific sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA with arsenic based NTCRAs completed on 2 of the 8 properties. Geophysical investigations found and removed MD items on 2 of 3 properties investigated. Supplemental soil samples collected to address AOITF recommendations with results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 8 / Possible Target or Test Site	AOIs 9, 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA with NTCRA completed based on arsenic contamination. Partial (part of POI under street) geophysical investigation completed with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 9 / Possible Firing or Observation Stalls	AOI 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA with NTCRAs completed on the 2 properties based on arsenic contamination. Geophysical investigations found and removed MD items on both properties. Miscellaneous soil samples collected during geophysical investigations. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 10 / Possible Target or Test Site	POIs 11, 39; AOIs 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	POI specific soil sampling (surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Geophysical investigation completed with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 11 / Scattered Ground Scars	POIs 10, 39; AOIs 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Geophysical investigation completed with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 12 / Possible Graded Area	AOIs 8, 21	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria on the 4 properties. Geophysical investigations were conducted on 3 properties under the OSR FUDS; no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 13 / Circular Trenches	POI 14; AOIs 11, 21	Soil sampling, Geophysical investigations, Groundwater sampling	POI specific soil sampling (surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria on the 10 properties. Geophysical investigation completed on 3 properties with no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified. Multiple groundwater sampling events conducted at nearby MW-23 indicate no results exceeded comparison criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 14 / Pit	POI 13, AOIs 11, 21	Soil sampling, Geophysical investigations, Groundwater sampling	1993 excavation and remediation of munitions burial pit under the OSR FUDS. MEC/MD and CWM found and removed. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Subsequent geophysical investigation completed with no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified. Multiple groundwater sampling events conducted at nearby MW-23 indicate no results exceeded comparison criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 15 / Ground Scar	AOI 21	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS with no MEC/MD found. POI specific sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, and cyanide) conducted as part of the 2003 EE/CA on the 5 properties. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 16 / Chemical Persistency Test Area	AOI 21	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS with no MEC/MD found. Soil sampling conducted under the OSR FUDS. POI specific sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA with TCRAs and NTCRAs completed on 8 of the 63 properties based on arsenic contamination. Subsequent geophysical investigation of one property with no MEC/MD found. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 17 / Possible Pit	Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation conducted with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan				
AOI or POI Number	**Related Areas**	**Investigation Objectives**	**Investigation Summary**	**Nature and Extent Determination**
POI 18 / Small Crater Scars	Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. NTCRAs completed on 2 of the 3 properties based on arsenic contamination. Geophysical investigations found and removed a Thermite Grenade MEC item and MD items on one of 3 properties investigated. Soil sample collected during geophysical investigation identified mercury contamination on one property. Contaminated soil removed as part of the NTCRA. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 19 / Old Mustard Field	None	Soil sampling	Geophysical investigations conducted under the OSR FUDS with no MEC/MD found. Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, and cyanide) also conducted as part of the 2003 EE/CA with NTCRAs completed on 5 of 23 properties based on arsenic contamination. Remaining soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 20 / Ground Scar	AOIs 3, 24	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation conducted with no MEC/MD finds. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 21 / Two-chambered Shell Pit	POIs 22, 23; AOIs 22, 24; MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. NTCRA conducted to remove contaminated soil and debris from the shell pit. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted on the property containing POIs 21, 22, and 23 with MD items found and removed. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 22 / Shell Pit	POIs 21, 23; AOIs 22, 24; MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted on the property containing POIs 21, 22, and 23 with MD items found and removed. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 23 / Three-chambered Shell Pit	POIs 21, 22; AOIs 22, 24; MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. NTCRA conducted to remove contaminated soil and debris from the shell pit. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted on the property containing POIs 21, 22, and 23 with MD items found and removed. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results carried to HHRA for Spaulding - Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 24 / Probable Pit	POI 53, AOIs 5, 17; MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Current information locates this POI at 4825 Glenbrook where a separate remedial action is being conducted. Numerous MEC/ MD and CWM items have been found and removed from this property.	Work at 4825 Glenbrook Road is addressed in a separate RI/FS/RA.
POI 25 / Possible Trenches	AOI 3, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic conducted on the 4 properties as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigations conducted on all 4 properties with no MEC/MD items found. OSR FUDS RI mistakenly attributes Spaulding-Rankin Area samples to POI 25.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 26 / Small Crater Scars	POI 53, AOI 13, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed MD items. Miscellaneous soil samples collected during geophysical investigation. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 27 / Probable Ditch or Trench	None	Soil sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. This ground scar was investigated under the AU ground disturbance study; no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 28 / Probable Ditch or Trench	None	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS; no MEC/MD found. Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. One subsurface sample result exceeded screening criteria for arsenic, but left in place at request of property owner.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 29 / Ground Scar	AOI 14	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS; no MEC/MD found. Soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 30 - 36 / Training Trenches	AOI 25	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. NTCRAs completed on 17 of the 32 properties where arsenic contamination exceeded the screening criteria. Geophysical investigations conducted on 2 properties with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 37 / Mill Creek	None	Soil and Surface Water sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS with no MEC/MD found. Soil/surface water sampling also conducted under OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. NTCRAs completed on 6 of the 15 properties where arsenic contamination exceeded the screening criteria. Geophysical investigation conducted on one property; no MEC/MD found. Miscellaneous soil samples collected during geophysical investigations. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Surface water sample results did not indicate risk from arsenic, chemical agents/ABPs or explosives.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 38 / Bradley Field/Major Tolman's Field	AOI 18	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA with NTCRAs completed on 2 of the 7 properties based on arsenic contamination. Geophysical investigation conducted on one property; no MEC/MD found. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Subsequent evaluation by the AOITF determined that an accurate location of POI 38 (AOI 18) could not be identified.	Investigation objectives were not achieved for this POI. POI was not located.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 39 / Static Test Fire Area	POIs 10, 11; AOIs 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. NTCRA completed on one property where arsenic contamination exceeded the screening criteria. Geophysical investigations performed on three of the 5 residential and all four DC right-of-way properties located within this POI. One 75 mm projectile MEC item and several MD items were recovered from the DC right-of-way portion of the POI. Miscellaneous soil sample collected during geophysical investigations. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 40 / Ohio Hall	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 41 / History Building	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. One subsurface sample result exceeded screening criteria for arsenic, but left in place at request of property owner.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 42 / Physio-logical Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 43 / Gun Pit	POIs 21, 22, 23, 53; AOI 4, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted with MD items found and removed. Supplemental soil samples collected to address AOITF recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 44 / Chemical Research Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 45 / Explosives Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 46 / Canister Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 47 / Bacterio-logical Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 48 / Dispersoid Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 49 / Pharmaco-logical Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 50 / Concrete Gun Pit	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 51 / Fire and Flame Laboratory	POI 53	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS; no MEC/MD. Soil sampling conducted under the OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. A ground scar was investigated adjacent to POI 51 under the AU ground scar disturbance study with no MEC/MD found. All soil sample results carried to HHRA for Southern AU (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 52 / Electrolytic Laboratory	POI 53	Soil sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS; no MEC/MD found. Soil sampling conducted under OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. All soil sample results carried to HHRA for Southern AU (see Section7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 53 / Baker Valley	POIs 24, 26, 43, 51, 52, AU; AOIs 4, 5, 13, 17, 22, 24, 26; Range Fan, Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that contains many AOIs and POIs. Soil sampling conducted under the OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. TCRAs and NTCRAs completed based on arsenic contamination. Geophysical investigations conducted on properties within POI 53 with MEC, MD, and CWM items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results from the AU campus portion of POI 53 were carried to HHRA for Southern AU. Soil sample results from Spaulding-Rankin Area portion of POI 53 were carried to HHRA for Spaulding- Rankin Area (see Section 7). The remaining sample results within POI 53 were evaluated during the HHRA screening process; no risks identified. Multiple groundwater sampling events conducted within POI 53 have detected results exceeding comparison criteria (see Appendix G).	Characterization of nature and extent of groundwater contamination ongoing. Excluding the separate POI 24 RA, investigation objectives have been achieved, and nature and extent of contamination have been defined.
POI AU	POI 53; AOIs 17, 22, 24, 28; MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that contains many AOIs and POIs. Soil sampling conducted under the OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. TCRAs completed based on arsenic contamination. Geophysical investigations conducted on areas within POI AU with MEC, MD, and CWM items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results were carried to HHRA for Southern AU (see Section 7). Multiple groundwater sampling events conducted within POI AU have detected results exceeding comparison criteria (see Appendix G).	Characterization of nature and extent of groundwater contamination is ongoing. Soil sampling and geophysical investigations are completed to define the nature and extent of contamination at this POI.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 1 / "X" Feature	None	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide conducted as part of the 2003 EE/CA with NTCRAs completed on 3 of the 17 properties based on arsenic contamination. Soil sampling for full AUES list parameters also conducted as part of the 2003 EE/CA on one property. Geophysical investigation on 6 properties with no MEC/MD found. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 2 /Rick Woods Burial Pit	Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. Geophysical investigations found and removed MD items.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 3 / Gunpowder Magazine Area	POI 20	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation conducted with no MEC/MD found. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 4 / Livens Gun Pit	POIs 43, 53; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted with MD items found and removed. Supplemental soil samples collected to address AOITF recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 5 / 4825/4835 Glenbrook Road	POIs 24, 53, AU; AOI 17; Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	4835 Glenbrook Road has undergone significant soil removal through the NTCRA process and considerable geophysical anomaly intrusive investigation via test pitting. One Livens projectile classified as MD and AUES-related laboratory glassware were identified during investigations. No MEC or CWM was identified. An HHRA concluded that unacceptable cancer risks and non-carcinogenic health effects were not expected. 75 MEC items, 24 CWM items, and 413 MD items along with numerous AUES – related laboratory glassware items were recovered during investigations at 4825 Glenbrook Road. Multiple groundwater sampling events conducted down gradient of AOI 5 have detected results exceeding comparison criteria (see Appendix G).	Investigation objectives have been achieved to define the nature and extent of contamination 4835 Glenbrook Road. Work at 4825 Glenbrook Road is addressed in a separate RA.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 6 / Dalecarlia Impact Area	Range Fan, Partially within MRS 01	Geophysical investigations	Geophysical investigations conducted under the OSR FUDS. One MEC item, a partially filled Livens smoke round, and numerous MD items found. Soil sample associated with the MEC item conducted under OSR FUDS. Surface soil screening for arsenic conducted as part of the 2003 EE/CA with NTCRA completed on one lot based on arsenic contamination. Subsequent geophysical investigations found and removed additional MD items. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 7 / Rockwood Six	AOI 17	Soil sampling, Geophysical investigations, Groundwater investigations	Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA or NTCRA completed on 5 of the 6 properties based on arsenic contamination. Soil sampling for full AUES list parameters also conducted for 2003 EE/CA on two properties. Geophysical investigation on all 6 properties with no MEC/MD or CWM found except for that relating to the adjacent POI AU (AU Lot 18). Soil sample results evaluated during HHRA screening process; no risks identified. Multiple groundwater sampling events conducted at PZ-3 within AOI 7 indicate no unacceptable results.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 8 / Possible Graded Area	POI 12, AOI 21	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria on the 5 properties. Geophysical investigations were conducted on 3 properties under the OSR FUDS; no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 9 / Sedgwick Ground Scars	POIs 1-8; AOI 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Large area that includes many POIs, one AOI, and the Range Fan. Significant soil sampling conducted under OSR FUDS and the 2003 EE/CA. NTCRAs completed on 11 of the 52 properties based on arsenic contamination. Geophysical investigations were conducted on 29 properties within AOI 9; MEC/MD items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. All soil sample results were carried to HHRA for AOI 9 (see Section 7). See Related Areas for additional information.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 10 / Westmore-land Recreation Center	None	None	The AOITF found no documents, maps, sampling results, geophysics, or anecdotal evidence of any AUES contamination or activity at this AOI. Further, the area is greater than 2000 feet from the SVFUDS boundary, and additional investigations were determined not to be required for this AOI.	Investigation objectives were not developed for this AOI.
AOI 11 / 52nd Court Pit and Trenches	POIs 13, 14; AOI 21	Soil sampling, Geophysical investigations, Groundwater sampling	See POIs 13 and 14	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 12 / Livens Battery Impact Area	AOI 21, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with arsenic based NTCRA completed on 1 of 2 properties. Geophysical investigations conducted on both properties with MD items found and removed on one property.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 13 / Quebec / Woodway 13 Properties	POIs 26, 53; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with NTCRA completed on one property based on arsenic contamination. Soil sampling for full AUES list parameters also conducted as part of the 2003 EE/CA on one property. Geophysical investigation on 11 of 13 properties with MEC/MD found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. All soil sample results were evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 14 / Sharpe Bunker on Seminary	POI 29	Soil sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS with no MEC/MD found. Surface soil screening for arsenic conducted as part of the 2003 EE/CA; results did not exceed screening criteria. Further investigations were determined not to be required for this AOI.	Investigationobjectives achieved. Nature and extent of contamination defined.
AOI 15 / Dog Wallows	None	Soil sampling, Geophysical investigations	Surface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. A ground scar was investigated within AOI 15 under the AU ground scar disturbance study with no MEC/MD found. Further investigations were determined not to be required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 16 / Westmore-land Circle Impact Area	None	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide for 2003 EE/CA with NTCRA completed on 6 of the 77 properties based on arsenic contamination. Geophysical investigations conducted on 2 properties; no MEC/MD items found. Further investigations were determined not to be required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 17 / $800,000 Burial Site	POIs 24, 53, AU; AOIs 5, 26	Soil sampling, Geophysical investigations, Groundwater sampling	The AOITF did not identify a specific location for this AOI. The burial pit is likely one of the several burial pits identified and removed from 4801 and 4825 Glenbrook Road. The Partners concurred that no further actions are required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 18 / Major Tolman's Field	POI 38	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA with NTCRAs completed on 2 of the 7 properties based on arsenic contamination. Geophysical investigation conducted on one property; no MEC/MD found. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Subsequent evaluation by the AOITF determined that an accurate location of POI 38 (AOI 18) could not be identified. Subsequent evaluation by the AOITF determined that an accurate location of POI 38 (AOI 18) could not be identified.	Investigation objectives were not achieved for this AOI. AOI was not located.
AOI 19 / Tenleytown Station	None	Soil sampling	All 8 properties had previously been sampled for arsenic as part of the 2003 EE/CA and all sampling results were less than screening levels. No geophysical surveys were conducted. There is no historical evidence that AOI 19 was ever used by AUES or Camp Leach for disposal or storage activities and the Partners concluded that there is insufficient evidence to warrant further investigation.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 20 / Slonecker-Johnson Groundscars	None	Test trenching	An intrusive investigation of the linear ground scars was completed via trenching. No AUES-related material was found, no soil staining was observed, and there was no evidence to indicate this AOI was a burial area.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 21 / Weaver Farm	POIs 5-16, 39; AOIs 8, 9,11,12, 24; Range Fan, Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that includes many POIs, AOIs, and the Range Fan. Much soil sampling conducted under OSR FUDS and 2003 EE/CA. TCRA and NTCRA removals completed based on arsenic contamination. Geophysical investigations conducted; MEC, MD, and CWM items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF recommendations. All soil sample results were evaluated during the HHRA screening process; no unacceptable risks identified. Multiple groundwater sampling events at MW-23 and down-gradient wells. See Related Areas for additional information.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 22 / Mercury Detection Areas	POIs 21- 23, 24, 53, AU; Partially within MRS 01	Soil sampling	Inappropriate mercury analytical method used in the OSR FUDS RI was further investigated with more recent sampling and updated methodology for this RI. All mercury sample results were evaluated during the HHRA screening process. A small area of POI AU contains mercury above acceptable risk levels (see HHRA Section 7.3).	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 23 / Railroad Sidings	None	None	Research was conducted to determine when the railroad siding was constructed. While research was unable to identify a construction date, an analysis of records at the WA archives indicated that a railroad siding was not present at the WA prior to 1920 and therefore could not have been used as a distribution point for shipping supplies to the AUES and Camp Leach. Further investigations were determined not to be required.	Investigation objectives were not developed for this AOI.
AOI 24 / Antimony Detection Areas	POI 7, 10, 11, 20-23, 25, 39, 53, AU; AOI 3, 9, 21; Partially within MRS 01	Soil sampling	Antimony detections from the OSR FUDS RI were further investigated in accordance with the AOITF recommendations. Supplemental sampling for antimony in soils was completed as part of this RI. All antimony sample results were evaluated during the HHRA screening process; no unacceptable risks were identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 25 / Camp Leach Trenches	POIs 30-36	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. NTCRAs completed on 17 of the 32 properties where arsenic contamination exceeded the screening criteria. Geophysical investigations conducted on 2 properties with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.

Table ES-1. Completed Investigation Summary for POIs/AOIs/Range Fan				
AOI or POI Number	**Related Areas**	**Investigation Objectives**	**Investigation Summary**	**Nature and Extent Determination**
AOI 26 / 4801 Glenbrook Road	POI 53, AOI 17, Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Significant soil sampling and geophysical investigations conducted at this property. NTCRA activities removed arsenic contaminated soil. Intrusive investigations excavated and removed two large burial pits and a third burial pit on the property line shared with 4825 Glenbrook Road. Multiple groundwater sampling events conducted down gradient of AOI 26 have detected results exceeding comparison criteria (see Appendix G).	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 27 / Third Circular Trench	None	None	Research was conducted to determine whether documentation supported that a third circular trench was constructed off the grounds that were leased or used by the AUES. AOITF determined there was no evidence to support a third circular trench.	Investigation objectives were not developed for this AOI.
AOI 28 / Hamilton Hall Burial Pit	POI AU, Partially within MRS 01	Soil sampling, Geophysical investigations	Geophysical investigations associated with this AOI were conducted to address the AOITF recommendations. No MEC/MD or CWM items found. However, a soil sample associated with AUES-related debris was found to contain elevated arsenic. The arsenic contamination was removed under the AU TCRA. The Partners reviewed the findings from the intrusive activities in the vicinity of Hamilton Hall and concluded that no additional investigation of this AOI is necessary.	Investigation objectives achieved. Nature and extent of contamination defined.
Range Fan	POIs 3-11, 17, 18, 25, 39, 43, 53; AOIs 2, 4, 6, 9, 12, 13, 21, 22, 24; MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that includes many POIs and AOIs. Significant soil sampling conducted under OSR FUDS and the 2003 EE/CA. TCRAs and NTCRAs completed based on arsenic contamination. Geophysical investigations conducted; MEC/MD items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF recommendations. All soil sample results were evaluated during the HHRA screening process; no risks were identified. Multiple groundwater sampling events conducted at down-gradient monitoring wells. See Related Areas for additional information.	Investigation objectives achieved. Nature and extent of contamination defined.

1 See Tables 1-1 and 1-2 for descriptions of POIs and AOIs.

RISK ASSESSMENT

Risk assessment for the SVFUDS required integration of multiple risk-related issues on a site-wide basis to form a comprehensive understanding of risk remaining within the SVFUDS. These included various risk-related elements as well as quantitative HHRAs.

Risk-related Elements

In addition to quantitative HHRAs completed, other risk-related elements that contribute to understanding risk within the SVFUDS included:

- The derivation and protectiveness of 20 mg/kg arsenic as the soil cleanup goal;
- An evaluation of arsenic potentially remaining in soil beneath city streets;
- External health-related studies (prepared by others); and a
- Screening Level Ecological Risk Assessment (SLERA)

An evaluation of the 20 mg/kg arsenic removal goal for carcinogenic and non-carcinogenic risks posed to adult and child residents indicated that the risks for children and adults are within USEPA's acceptable range.

Cancer risk and non-cancer hazard levels were evaluated for a construction worker with exposure to arsenic contaminated soils beneath city streets. The evaluation concluded that arsenic concentrations up to 100 mg/kg in the soil could be encountered by the construction worker without exceeding the acceptable USEPA risk levels, and based on a review of the 68 properties where soil samples were collected adjacent to a city street, the highest arsenic concentration (out of 228 samples) was less than half of that level.

The Agency for Toxic Substance and Disease Registry (ATSDR) and Johns Hopkins Bloomberg School of Public Health (JHSPH), agencies and organizations external to USACE, conducted health consultations and exposure studies to evaluate possible past and present exposures to contamination associated with past SVFUDS activities. The primary health scoping study (conducted by JHSPH) noted that the overall health of Spring Valley residents continues to be very good and mortality rates continue to be below the U.S. average for most causes.

The potential for ecological hazards was assessed in the SLERA, which evaluated whether unacceptable adverse risks are or may be posed to ecological receptors as a result of hazardous substance releases. The SVFUDS area was characterized with respect to operational, physical, chemical, and ecological characteristics, and the current and anticipated future land uses. Based on the data presented, the SLERA concluded that ecological risks are negligible and that there is no need for additional ecological risk assessment or further action on the basis of ecological risks.

Quantitative HHRAs

The comprehensive risk screening process included review of the previous (pre-2005) HHRAs to assess whether they remain protective, supplemental additional soil sampling to address data gaps, and identification of specific areas where further risk assessment was warranted. This screening resulted in the quantitative HHRAs conducted on the AOI 9, Spaulding-Rankin, and Southern AU exposure units (EUs), which estimated the magnitude of exposure to COPCs, identified potential exposure pathways, and quantified exposures to estimate the risks posed to human receptors associated with exposure to the soil at each of the EUs.

Table ES-2 summarizes the key findings of the quantitative HHRAs for the three EUs.

For the residential AOI 9 EU, non-cancer HIs and incremental cancer risks are below a level of concern. Therefore, further assessment or action at the AOI 9 EU is not required.

For the residential Spaulding-Rankin EU, cobalt was determined to be a COC that poses unacceptable risks and follow-on actions are required to address it.

For the Southern AU EU (excluding outlier locations), cobalt was determined to be a COC that poses unacceptable risks and follow-on actions are required to address it.

For the much smaller outlier locations at the Southern AU EU, three locations are associated with risks: mercury (one location) and vanadium and cobalt (one location) in soil are associated with non-carcinogenic risks, and carcinogenic PAHs in soil (one location) are associated with carcinogenic risks that exceed USEPA's risk range. Thus, these chemicals in soil at these outlier locations are COCs that pose unacceptable risks and follow-on actions are required to address them.

In addition to these HHRAs addressing soil, a groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

Table ES-2. Summary of Risk Assessment Findings

Exposure Unit	Conclusion	Risk Driver (soil)
AOI 9	No Further Action	None
Spaulding-Rankin	Unacceptable non-carcinogenic risk	Cobalt
Southern American University (excluding outlier locations)	Unacceptable non-carcinogenic risk	Cobalt
Southern AU Outlier Locations	Unacceptable non-carcinogenic risk	Mercury, Vanadium, and Cobalt
	Unacceptable carcinogenic risk	Carcinogenic PAHs

Hazard Assessment

The MEC Hazard Assessment (HA) methodology was used to evaluate the 'explosive hazard' component of an HHRA, assessing potential explosive hazards to human receptors at the SVFUDS. At the SVFUDS, the MEC HA was organized around the past activities most likely to result in MEC at the Site. These include:

- Ballistically Fired Testing (e.g., Range Fan);
- Statically Fired Testing (e.g., Circular Trenches); and
- Disposal (e.g., 52nd Court, OU-4 AU Lot 18). This has been further divided into 'known' and 'possible' disposal areas

The SVFUDS Range Fan was developed based on ballistically fired testing activities at the AUES. A typical range fan comprises the Firing Point, the Range Safety Fan (or Safety Buffer), and the Function Test Range (or Impact Area). With the exception of the Firing Point, which was thoroughly investigated for MEC, these areas were evaluated in the MEC HA scoring.

Five areas of the SVFUDS were identified as static fire test areas. However, these areas would not typically represent MEC concerns in that the testing process would have monitored and controlled individual items, and any munition item not properly firing would be identified in real time. None of the items would be left behind, and therefore, no MEC HA scoring would be required.

Five areas were identified as ‘known’ disposal areas based on the findings of various investigations, but these have been thoroughly investigated and no MEC HA scoring was warranted. Three areas have been identified as ‘possible’ disposal areas based on a weight of evidence assessment, but it is not certain they contain buried munitions and there is little specific information upon which to run the MEC HA. Therefore, a generic MEC HA that conservatively assumed a worst case disposal area/burial pit scenario was completed.

Table ES-3 summarizes the SVFUDS MEC HA for current use conditions, indicating that three of the four activities scored resulted in a MEC HA hazard level category of 3 (moderate potential explosive hazard conditions). The MEC HA provides the basis for the evaluation and implementation of effective management response alternatives in an FS, but the scores are qualitative references only and should not be interpreted as quantitative measures of explosive hazard, or as the sole basis for determining whether or not further action is necessary at a site.

Table ES-3. Summary of MEC HA Findings

Area	***Current Use Conditions***	
	Hazard Level Category	**Associated Relative Explosive Hazard**
Safety Buffer for Livens	4	Low potential explosive hazard conditions
Function Test Range for Stokes	3	Moderate potential explosive hazard conditions
Function Test Range for Livens	3	Moderate potential explosive hazard conditions
Generic Disposal Area	3	Moderate potential explosive hazard conditions

Table ES-3 indicates that the Livens Range Safety Buffer scored a hazard level category of 4 (low potential explosive hazard conditions) based on current use activities. This reflects that few MEC items would be expected in a buffer area. The Function Test Ranges or impact areas for both the Livens and the Stokes mortars received a MEC HA score of 3 (moderate potential explosive hazard conditions) based on current use activities. The moderate potential explosive hazard conditions that this score represents for this documented impact area suggests that follow-on actions may be required to mitigate unacceptable explosive hazards that could exist on the properties within the impact areas.

The static test fire areas were not scored, but similar to the findings at the initial 52nd Court trenches (POI 13 disposal area), static testing activities may suggest the presence of munitions burial pits near the testing locations. The potential for remaining munitions burial pits suggests that follow-on actions may be required to mitigate unacceptable explosive hazards associated with possible munitions burial pits in the 150 ft investigation or buffer zones around the known static fire test areas.

The generic MEC HA scoring for the possible disposal areas was completed and the score was a 3. The unknowns associated with the three possible disposal areas and the moderate potential explosive hazard conditions they represent (using conservative assumptions) suggest that follow-on actions may be required to mitigate unacceptable explosive hazards that could exist in these three areas.

SUMMARY AND CONCLUSIONS

Recommendations focus on unacceptable risks posed by HTW/MC/CWM contaminated soil as determined by the quantitative HHRA, and unacceptable explosive hazards posed by potentially remaining MEC. The specific nature of the follow-on actions will be determined through the alternatives analysis conducted for the FS.

Regarding HTW/MC/CWM contamination, the following is recommended:

- **Conduct an FS to address unacceptable non-carcinogenic risks in soil in the Spaulding-Rankin EU.**
- **Conduct an FS to address unacceptable non-carcinogenic risks in soil at the Southern AU EU (excluding outlier locations), and carcinogenic and non-carcinogenic risks in soil in three outlier locations in the Southern AU EU.**

Regarding MEC contamination, the following is recommended:

- **Conduct an FS to address potential unacceptable explosive hazards associated with munitions possibly remaining within the impact areas of the Function Test Ranges for the 3” Stokes, 4” Stokes, and the 8” Livens.**
- **Conduct an FS to address potential unacceptable explosive hazards associated with possible munitions disposal burial pits in the buffer zones and test areas of the Static Test Fire areas.**
- **Conduct an FS to address potential unacceptable explosive hazards associated with possible munitions disposal burial pits associated with the Possible Disposal Areas (AU PSB, AOI 13, and POI 2 / Fordham Road area).**

Table ES-4 presents recommendations for each POI, AOI and the Range Fan, providing a comprehensive overview of the site-wide characterization and recommendations for the SVFUDS. The table incorporates the areas recommended above for follow-on actions into the appropriate POI, AOI, or Range Fan designation to further organize the site-wide RI findings by the delineated SVFUDS areas. Note that some recommendations are shown more than once, as areas such as AOI 9 and the Range Fan overlap.

Table ES-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
POI 1 / Circular Trenches	AOI 9, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with possible POI 1 munitions burial pits.**
POI 2 / Possible Pit	AOI 9, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with the POI 2 Possible Disposal Area.**
POI 3 / Small Crater Scars	AOI 9, Range Fan, Within MRS 01	Within POI 1 buffer zone **(see POI 1 recommendation)**.
POI 4 / Possible Pit	AOI 9, Range Fan, Within MRS 01	Within POI 1 buffer zone **(see POI 1 recommendation)**.
POI 5 / Possible Pit	AOIs 9, 21, Range Fan, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with the Function Test Ranges (Impact Areas) for the 3" Stokes, 4" Stokes, and the 8" Livens.**
POI 6 / Possible target or Test Site	AOIs 9, 21, Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
POI 7 / Possible Test Area	AOIs 9, 21, 24, Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
POI 8 / Possible target or Test Site	AOIs 9, 21, Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
POI 9 / Possible Firing or Observation Stalls	AOIs 21, Range Fan, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with possible POI 9 munitions burial pits.**
POI 10 / Possible Target or Test Site	POIs 11, 39, AOIs 21, 24, Range Fan, Within MRS 01	**Within POI 39. FS to address potential unacceptable explosive hazards associated with possible POI 10 munitions burial pits.**
POI 11 / Scattered Ground Scars	POIs 10, 39, AOIs 21, 24, Range Fan, Within MRS 01	Within POI 39 **(see POI 10 recommendation)**.
POI 12 / Possible Graded Area	AOIs 8, 21	No Further Action
POI 13 / Circular Trenches	POI 14, AOIs 11, 21	No Further Action
POI 14 / Pit	POI 13, AOIs 11, 21	No Further Action
POI 15 / Ground Scar	AOI 21	No Further Action
POI 16 / Chemical Persistency Test Area	AOI 21	No Further Action
POI 17 / Possible Pit	Range Fan, Within MRS 01	No Further Action
POI 18 / Small Crater Scars	Range Fan, Within MRS 01	No Further Action
POI 19 / Old Mustard Field	None	No Further Action
POI 20 / Ground Scar	AOIs 3, 22, 24	No Further Action
POI 21 / Two-chambered shell pit	POIs 22, 23, AOIs 22, 24, Within MRS 01	**FS to address the unacceptable non-carcinogenic risks associated with soil COC at the Spaulding-Rankin property**
POI 22 / Shell pit	POIs 21, 23, AOIs 22, 24, Within MRS 01	Within Spaulding-Rankin property **(see POI 21 recommendation)**

Table ES-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
POI 23 / Three chambered shell pit	POIs 21, 22, AOIs 22, 24, Within MRS 01	Within Spaulding-Rankin property **(see POI 21 recommendation)**
POI 24 / Probable Pit	POI 53, AOIs 5, 17, Within MRS 01	No Further Action for 4835 Glenbrook Road.
		Work at 4825 Glenbrook Road is being addressed in a separate RA.
POI 25 / Possible Trenches	AOI 3, Range Fan, Within MRS 01	No Further Action
POI 26 / Small Crater Scars	POI 53, AOI 13, Within MRS 01	**Within AOI 13. FS to address potential unacceptable explosive hazards associated with the AOI 13 Possible Disposal Area.**
POI 27 / Probable Ditch or Trench	None	No Further Action
POI 28 / Probable Ditch or Trench	None	No Further Action
POI 29 / Ground Scar	AOI 14	No Further Action
POI 30 - 36 / Training Trenches	AOI 25	No Further Action
POI 37 / Mill Creek	None	No Further Action
POI 38 / Bradley Field/Major Tolman's Field	AOI 18	No Further Action
POI 39 / Static Test Fire Area	POIs 10, 11, AOIs 21, 24, Within MRS 01	Contains POIs 10 and 11 **(see recommendations for those areas).**
POI 40 / Ohio Hall	None	No Further Action
POI 41 / History Building	None	No Further Action
POI 42 Physiological Laboratory	None	No Further Action
POI 43 / Gun Pit	POIs 21, 22, 23, 53, AOI 4, Range Fan, Within MRS 01	No Further Action
POI 44 / Chemical Research Laboratory	None	No Further Action
POI 45 / Explosives Laboratory	None	No Further Action
POI 46 / Canister Laboratory	None	No Further Action
POI 47 / Bacteriological Laboratory	None	No Further Action
POI 48 / Dispersoid Laboratory	None	No Further Action
POI 49 / Pharmacological Laboratory	None	No Further Action
POI 50 / Concrete Gun Pit	None	No Further Action
POI 51 / Fire and Flame Laboratory	POI 53	No Further Action
POI 52 / Electrolytic Laboratory	POI 53	No Further Action
POI 53 /Baker Valley	POIs 24, 26, 43, 51, 52, AU, AOIs 4, 5, 13,17, 22,24, 26, Range Fan, Partially within MRS 01	No Further Action except for overlap of POI AU and AOI 13, and Spaulding-Rankin property **(see recommendations for those areas)**.

Table ES-4. Recommendations for POIs/AOIs/Range Fan		
AOI or POI Number	**Related Areas**	**Recommendations**
POI AU	POI 53, AOIs 17, 22, 24, 28, Within MRS 01	**FS to address unacceptable non-carcinogenic risks in soil at POI AU, and carcinogenic and non-carcinogenic risks in soil in the three outlier locations within POI AU.** **FS to address potential unacceptable explosive hazards associated with the Public Safety Building Possible Disposal Area.**
AOI 1 / "X" Feature	Range Fan, Within MRS 01	No Further Action
AOI 2 / Rick Woods Burial Pit	POI 20	No Further Action
AOI 3 / Gunpowder Magazine Area	POIs 43, 53, Range Fan, Within MRS 01	No Further Action
AOI 4 / Livens Gun Pit	POI 53, AOIs 17, 22, 24, 28, Within MRS 01	Within Spaulding-Rankin property **(see POI 21 recommendation)**
AOI 5 / 4825/4835 Glenbrook Road	POI 24, AOI 17, Range Fan, Partially within MRS 01	No Further Action for 4835 Glenbrook Road. Work at 4825 Glenbrook Road is being addressed in a separate RA.
AOI 6 / Dalecarlia Impact Area	AOI 17	No Further Action
AOI 7 / The Rockwood Six	POI 12, AOI 21	No Further Action
AOI 8 / Possible Graded Area	POIs 1-8 AOI 24, Range Fan, Within MRS 01	No Further Action
AOI 9 / Sedgwick Ground Scars	POI 24, AOI 17, Partially within MRS 01	**See POI 1 and POI 5 recommendations.**
AOI 10 / Westmoreland Recreation Center	None	No Further Action
AOI 11 / 52nd Court Pit and Trenches	POIs 13, 14, AOI 21	No Further Action
AOI 12 / Livens Battery Impact Area	Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
AOI 13 / Quebec / Woodway 13 Properties	POIs 26, 53, Range Fan, Within MRS 01	**See POI 26 recommendation.**
AOI 14 / Sharpe Bunker on Seminary	POI 29	No Further Action
AOI 15 / Dog Wallows	None	No Further Action
AOI 16 / Westmoreland Circle Impact Area	None	No Further Action
AOI 17 / $800,000 Burial Site	POIs 24, 53, AU, AOIs 5, 26	No Further Action
AOI 18 / Major Tolman's Field	POI 38	No Further Action
AOI 19 / Tenleytown Station	None	No Further Action
AOI 20 / Slonecker-Johnson Ground Scars	None	No Further Action
AOI 21 / Weaver Farm	POIs 5-16, 39, AOIs 8, 9,11,12, 24, Range Fan, Partially within MRS 01	No Further Action except for overlap of POIs 9, 39, and AOI 12 **(see recommendations for those areas)**.

Table ES-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
AOI 22 / Mercury Detection Areas	POIs 20- 23, 25, 53, AU, Partially within MRS 01	No Further Action for this HTW-only AOI except for overlap of POI AU **(see POI AU recommendation)**.
AOI 23 / Railroad Sidings	None	No Further Action
AOI 24 / Antimony Detection Areas	POI 7, 10, 11, , 20-23 25, 39, 53, AU, AOI 9, Partially within MRS 01	No Further Action except for overlap of POI 7, 39, AU, and AOI 13 **(see recommendations for those areas)**.
AOI 25 / Camp Leach Trenches	POIs 30-36	No Further Action
AOI 26 / 4801 Glenbrook Road	POI 53, AOI 17, Partially within MRS 01	No Further Action
AOI 27 / Third Circular Trench	None	No Further Action
AOI 28 / Hamilton Hall Burial Pit	POI AU, Partially within MRS 01	No Further Action
Range Fan	POIs 3-11, 17, 18, 25, 39, 43, 53, AOIs 2, 4, 5, 6, 9, 12, 13, 22, 24, Within MRS 01	For the Function Test Ranges (Impact Areas) for the 3” Stokes, 4” Stokes, and the 8” Livens, **see recommendations for POIs 5, 6, 7, 8, and AOI 12.**
		No Further Action for the Firing Point and the Range Safety Buffers for the 3” Stokes, 4” Stokes, and 8” Livens, except for the overlap of POIs 9, 39, AOI 13, and the Spaulding-Rankin property **(see recommendations for those areas)**.

<u>Notes</u>: Bold text with shading indicates recommendations to conduct an FS. Bold text without shading indicates a reference back to a related area (i.e., area is covered under a previous recommendation to conduct an FS).

1.0 INTRODUCTION AND BACKGROUND

ERT, Inc., (ERT) was tasked with drafting an Integrated Site-Wide Remedial Investigation (RI) report for the U.S. Army Corps of Engineers (USACE), at the Spring Valley Formerly Used Defense Site (SVFUDS), located in Washington, D.C. The work was performed under the Munitions Response and Environmental Remediation Services Contract (W912DR-09-D-0061, Delivery Order 0011), which is administered by the Baltimore District (CENAB). The U.S. Army Engineering and Support Center, Huntsville (USAESCH) provides additional oversight for activities involving chemical warfare materiel (CWM). For purposes of this RI report CENAB and USAESCH are referred to jointly as “USACE”, unless specific district responsibilities are discussed.

This project falls under the Military Munitions Response Program (MMRP) of the Defense Environmental Restoration Program (DERP)/Formerly Used Defense Sites (FUDS). The Department of Defense (DoD) established the MMRP under the DERP to address munitions constituents (MC), and munitions and explosives of concern (MEC) (comprising unexploded ordnance [UXO], discarded military munitions [DMM], and MC in high enough concentrations to pose an explosive threat) that are located on certain properties – including FUDS.

Under the DERP, the U.S. Army is the DoD’s lead Agent for FUDS, and USACE executes FUDS for the Army. USACE performs (and has been performing) its response activities throughout SVFUDS (including 4825 Glenbrook Road) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). FUDS is administered pursuant to the DERP statute, the CERCLA, Executive Orders 12580 and 13016, the NCP, and DoD and Army policies in managing and executing the FUDS program. (The NCP constitutes the regulations that implement CERCLA.) USACE is the lead agency for carrying out the response action at this CERCLA site.

Advanced and consistent coordination with project stakeholders was essential to achieve consensus and make progress, as the SVFUDS RI spans more than two decades involving numerous investigation phases conducted simultaneously in a densely populated Washington, D.C. suburban neighborhood. The level of stakeholder involvement and coordination evolved throughout the course of the project. Stakeholder coordination was performed at two major levels: the agency level with regulators, and community level with community representatives and individual community members.

USACE began meeting with regulators and stakeholders in 1998 and initiated monthly meetings in 2001. Agency-level coordination through formal regularly scheduled meetings, referred to as Partnering meetings, began in 2001. The Partners for the SVFUDS included USACE, the USEPA Region 3, and Washington, D.C.’s District Department of the Environment (DDOE) (formerly known as the District of Columbia Department of Health (DC DOH) and Department of Consumer and Regulatory Affairs (DCRA)). Additional stakeholder participants in Partnering meetings included the Restoration Advisory Board (RAB) Technical Assistance for Public Participation (TAPP) consultant, American University (AU), and contractors involved in active SVFUDS investigations. Monthly deliberative, consensus-driven meetings were established to ensure early consultation with and oversight by regulators and early involvement of stakeholder participants. USACE formalized its agency-level coordination through obtaining consensus on the Partnering process and mission, “to evaluate information with a goal of protecting human health and the environment by identifying and mitigating risks resulting from past U.S. Army activities within the Spring Valley Formerly Used Defense Site" (USACE, USEPA and DDOE, 2004). Partnering meetings were not open to the public; however, meeting minute summaries were made publicly available following meetings and elected officials and RAB members were invited to attend Partnering meetings to facilitate added transparency with the Partnering and technical planning process.

The RAB was established in 2001 to provide a mechanism for interested community members to review progress and maintain a collaborative dialogue between the local community, USACE, USEPA, and DDOE. The RAB, through TAPP grants, hired a Technical Consultant to participate in Partnering meetings and review and comment on all project documents. The SVFUDS RAB was jointly chaired by a USACE representative and a community member representative, and met 10 times per year until 2013 when the RAB voted to reduce meetings to 6 times per year. Investigation phases typically involved multiple private property owners: USACE engaged property owner stakeholders early to facilitate property access via a multi-faceted approach including email and phone contact, information briefs, small group, and individual meetings. USACE worked to address and accommodate property owner feedback and concerns, where possible, both prior to and after investigations were completed.

ERT, along with other contractors who performed phases of work to support the SVFUDS RI were required to execute tasks within the framework of extensive agency and community stakeholder collaboration. Contractors participated in Partnering meetings, gave presentations at RAB meetings, met with property owners and, per USACE, worked to efficiently achieve investigation goals while incorporating stakeholder feedback into investigation plans.

1.1 Purpose and Scope

The purpose of this RI is to adequately characterize the nature and extent of any potential Hazardous and Toxic Waste (HTW), MC, and CWM contamination, and/or MEC hazards resulting from the past DoD activities at the SVFUDS.

However, the nature of this RI is notably different from traditional RIs referencing a single set of data quality objectives (DQOs) identified in a single RI work plan. While typical RIs follow a sequence of activities, with steps from Preliminary Assessment to Site Inspection to RI, due to the location of SVFUDS in a suburban community and the nature of the early findings, USACE took a multi-pronged approach to investigate previously identified areas while concurrently analyzing historical records to plan investigations in additional areas. Although each of these concurrent multiple activities, including different types of investigations of different discrete areas, and time-critical and non-time critical removal actions, resulted in completed standalone reports documenting all of the findings, the intention of this RI report is to present the rationale for each key event and summarize their findings to provide a more complete characterization of the SVFUDS. This RI report does not repeat the detail of these individual reports or change any of their conclusions (other than to provide an update or place them into a larger context, where appropriate); however, the primary key reports, as identified in Section 1.6 or Section 7.0, are contained in their entirety on digital versatile discs (DVDs) provided in the appendices.

Generally, the scope of the activities performed for the investigations addressed in this RI included digital geophysical mapping (DGM), intrusive investigations to identify location, density, and types of MEC/Munitions Debris (MD), and environmental sampling to determine the nature and extent of chemicals of potential concern (COPCs) in soil, sediment, surface water, and groundwater.

1.2 Report Organization

The RI documents applicable site information, investigation activities, laboratory analytical data, and an evaluation of the investigation results. Each report section, summarized below, provides information specific to the overall objective of this RI report.

- Section 1.0 Introduction and Background – This section provides an introduction, the purpose and scope, report organization, site description, historical information, site delineation, and summaries of previous site activities.
- Section 2.0 Physical Characteristics of the Study Area – This section details the physical site description.
- Section 3.0 Remedial Investigation Objectives and Conceptual Site Model (CSM) – This section discusses the RI objectives for each investigation activity, provides CSMs and reviews the identified data needs and DQOs.
- Section 4.0 Remedial Investigation Field Activities – This section reviews the procedures developed and used to execute RI field investigations, categorized by the type of activity (i.e., characterization/investigations and removals) and media (i.e., soil and groundwater).
- Section 5.0 Remedial Investigation Results – This section summarizes the results of the initial investigation, follow-on investigations, geophysical investigations, and removal actions; and establishes the nature and extent of contamination.
- Section 6.0 Contaminant Fate and Transport – This section details potential contaminant sources, persistence, and migration, focusing on the primary chemicals found in environmental media at the SVFUDS.
- Section 7.0 Risk Assessment – This section summarizes previously completed Human Health Risk Assessments (HHRA), presents the complete quantitative HHRAs for identified exposure units (EUs), the approach for remaining elevated arsenic in soil, external health studies, the MEC Hazard Assessment (MEC HA), the Munitions Response Site Prioritization Protocol (MRSPP) scoring, the Screening Level Ecological Risk Assessment (SLERA), and uncertainty.
- Section 8.0 Summary and Conclusions – This section summarizes results of the RI, reviews data limitations and provides recommendations for future work and recommended remedial action objectives (RAOs).
- Section 9.0 References – This section contains the references.
- Appendices – Appendices are provided that contain all figures, Technical Memoranda and Signed Documents of Record, key reports of past investigations (in their entirety on DVDs), previous HHRAs and risk screening documents (in their entirety on DVDs), risk tables for the quantitative HHRAs presented in this RI, MEC HA and MRSPP scoresheets, and a Groundwater Summary Report (to be provided later).

Please note that while referenced tables and exhibits are contained in the body of this report, all figures are presented in Appendix A.

1.2.1 Terminology Used in this RI Report

For certain terms used throughout this report, clarification is required either because they can have multiple meanings, or in some cases, while used heavily in the early SVFUDS reports, they have been replaced by newer, more commonly accepted terms. A glossary with formal definitions is provided in the front of this document. However, in the interest of standardization, and to minimize any confusion that could result by applying newer terms when the older ones were used so extensively, or using both older and newer terminology, the key terms below are defined as follows in this RI report:

- Munitions Response Site (MRS) – The Army currently requires MMRP RIs to designate MRSs as the areas of investigation and focus. As the designations of the SVFUDS investigation units predate the MRS terminology, in this document, areas of the SVFUDS are described as points of interest (POIs), areas of interest (AOIs), Operable Units (OUs), or other, with MRS usage limited as described in Section 1.5.6.
- MEC and MD – These terms have various equivalents in older investigations, primarily ordnance and explosives (OE) or OE waste, or OE scrap. While the current terms MEC and MD have narrower, more focused definitions, they are used in this RI report as an umbrella term even though items categorized as OE in earlier efforts may not meet the more rigorous definition of MEC in current usage.
- CWM and Chemical Agent (CA) - CWM are items configured as munitions containing a chemical compound that is intended to incapacitate a person, while CAs are the actual chemical compounds used in CWM. Based on the general use of the term CWM in many SVFUDS documents to mean both the chemicals and the items containing the chemicals, that usage is retained for this RI report.
- HTW and MC – HTW typically indicates specific types of chemical contamination at hazardous waste sites. MC is essentially the MMRP equivalent term, focusing on contamination from material originating from munitions. Because CWM, as described above, is also used to represent chemical contamination, this RI report uses the combined term HTW/MC/CWM to refer to all types of chemical contamination of environmental media.

1.3 Site Description

The SVFUDS comprises 661 acres in the northwest quadrant of Washington, D.C. (Figure 1-1). Although the borders extend beyond the following streets at some points, the SVFUDS is roughly bordered to the west by federal property owned by the Washington Aqueduct (WA) and referred to as the Dalecarlia Woods, to the south by Loughboro Road, to the east by Nebraska Avenue and to the north by Massachusetts Avenue and Van Ness Street. Additional information to describe multiple types of areas delineated within the SVFUDS is included in Section 1.5 and is best explained following a review of past DoD activities within the SVFUDS.

1.4 Historical Information

1.4.1 Civil War

1.4.1.1 Fort Gaines and Battery Vermont

During the Civil War, a series of fortifications were built around the perimeter of Washington D.C. to serve as a last line of defense against the Confederate Army and to protect strategic locations including Chain Bridge and the water supply for the city. Fort Gaines and Battery Vermont were the only major fortifications built within the present boundary of the SVFUDS. Fort Gaines was located near Massachusetts Avenue in Tenleytown, a quarter mile west of present day Nebraska Avenue (Exhibit 1-1). In 1865, the fort was dismantled. Battery Vermont was located near the intersection of present day Little Falls Road and MacArthur Boulevard overlooking the Potomac River (USACE, 1994).

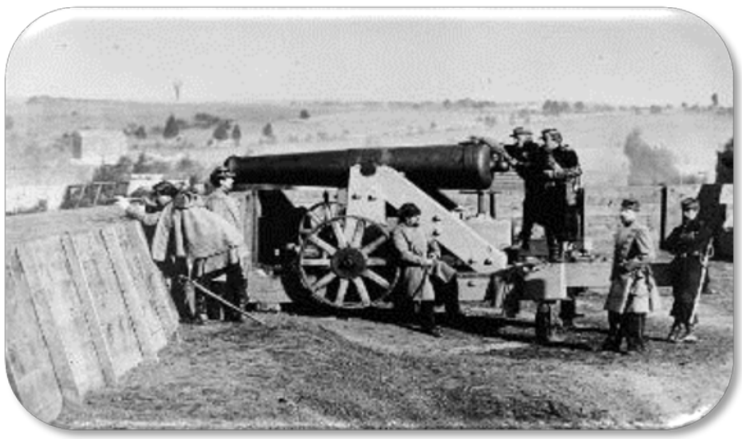

Exhibit 1-1. Fort Gaines, Tenleytown D.C.

(Library of Congress) Detachment of New York Volunteers, 1864

1.4.2 World War I

1.4.2.1 American University Experiment Station

In July 1917, the Bureau of Mines founded the American University Experiment Station (AUES) to do research and perform small-scale testing of chemical warfare items. AUES operations under the Bureau of Mines, and then later under the Chemical Warfare Service (CWS), generally fell into one or more of the following categories: gas mask research, offensive and defensive toxic chemical investigations, medical research, pyrotechnic investigations, and mechanical investigations.

The agreement with AU provided the Bureau of Mines use of the approximately 92 acres of property that was also shared with the Corps of Engineers' Camp American University (later renamed Camp Leach). McKinley Memorial Ohio College of Government (also known as the Ohio Building), one of the two permanent structures on the AU campus, converted its classrooms into laboratories. An additional 124 temporary facilities were constructed in the vicinity of the Ohio Building to accommodate the storage of chemicals, gases, and materials and to conduct field tests to determine the effectiveness of gases, gas masks, and weapons; and housing for the goats, dogs, and other animals used in field tests. To help contain the hazards posed by testing gases, the Bureau of Mines constructed underground concrete bunkers for testing. The bunkers were built both on university grounds and on an adjacent property owned by Charles A. Spaulding. A perimeter fence surrounded the facilities located on the AU campus and the Spaulding property. Additional land for the AUES was used for field testing the chemicals and munitions developed at the research center on AU property. The AUES, including the range and proving ground areas, encompassed about 466 acres (USACE, 2000a) (Figure 1-2). Field testing to determine the effectiveness of toxic chemicals and substances, incendiaries, and smoke mixtures was performed at various sites on the campus and adjoining properties. Sites included the bomb and gun pits, fields and other open areas, and trenches specially constructed for the purpose. Field testing was also conducted at such off-campus locations as the Montgomery County (Maryland) Country Club Test Site (FUDS Number C03MD1027); Fort Foote (FUDS Number C03MD1021), Maryland; Whaley Farm Test Site (FUDS Number C03MD1024), Berlin, Maryland; and Langley Field (active DoD facility), Virginia. It should be noted that the SVFUDS RI does not include investigations at these off-campus locations.

On December 31, 1918, the immediate cessation of operations was ordered for the AUES; however, post-war Congressional actions extended operations at AUES until August 1920, albeit reduced. By June 1919, the number of CWS personnel assigned to AUES was reduced from 1,200 to an average of 18. The bulk of the CWS equipment was transferred to Edgewood Arsenal, Maryland, in November 1919 where the CWS continued to carry out investigations into various aspects of gas warfare for the Navy, the Ordnance Corps, and other War Department agencies. Salvage and restoration work at AUES began in spring 1921: temporary structures not wanted by the university were removed or demolished. Permanent structures-including the shell pits, powder magazines, detonator house, and explosives service building on the Spaulding property were boarded up and enclosed with fences or barbed wire to prevent access (USACE, 1994). A 1937 tour guide for the Washington D.C. area notes the historical context of permanent structures that could still be seen during a visit to the campus:

> …the first building, Hurst Hall, was erected on the campus, and in 1902 a second structure, McKinley Hall, was begun. Both lay vacant until America entered the World War, when the university officials turned over to the Government the disused campus to serve as a training base for the gas and flame division of the Army. It was here that chemists discovered the deadly Lewisite gas. Pits for chemicals and explosives may still be seen on the college grounds (Works Progress Administration, 1937).

Temporary structures identified as too impregnated with chemicals to remove or salvage were burned. A January 1921 article in the *American University Courier* noted that 17 of the temporary structures were burned in January 1921 under the supervision of the D.C. fire department (AU, 1921a).

No official records exist to account for the locations of the final disposition of the chemicals and munitions remaining at AUES, other than anecdotal references made in the AU newspaper. Another article published in the January 1921 issue noted, “the munitions were taken back to the limit of the University acres and there buried in a pit that was digged for them. Would that it were as deep as the cellar of Pluto and Proserpine (AU, 1921b).” A subsequent April 1921 article from the *American University Courier* noted of the chemicals and munitions left on hand:

> There were munitions on hand, including multiplex gas and an invented explosive many times dynamite, valued at $800,000…It was begun by the destruction of munitions… The numerous collections on hand, just ready to go overseas, was valued at nothing now but the expense of putting them away...[P]ermission was given to go far back on the University acres, to dig a pit deeper than the one into which Joseph was cast, bury the munitions there and cover them up to wait until the elements shall melt with fervent heat, when the earth and the works therein shall be burned up (AU, 1921c).

The student newspaper articles provide the clearest written reference to potential burials. Only one known photograph exists, showing disposal of chemicals and munitions at an unidentified location presumably on AUES grounds (Exhibit 1-2). The photo referred to as the SGT Maurer photo was provided to USACE following the initiation of SVFUDS investigations, around 1994. The inscription on the back of the photo states: "The Pit, the most feared and respected place in the ground. The bottles are full of mustard, to be destroyed here in Death Valley. The hole called Hades. You know me? C.W. Maurer at A.U."

Exhibit 1-2. SGT Maurer Photo

(Courtesy of Olsen Family)

1.4.2.2 Camp Leach

Also starting in May 1917, the USACE set up Camp Leach to organize and train the 6th Engineer Regiment. This 195-acre site consisted of the northeast portion of AU and adjacent properties (USACE, 2000a). The camp soon became a training school for engineer officers and AU's College of History Building, the second of the two permanent structures on the AU campus, was converted into a dormitory and offices. From 1917-18, about 100,000 troops trained at Camp Leach, including the 30th Engineer Regiment, which was later to become the 1st Gas and Flame Regiment; the 20th Forestry Regiment; the 40th Camouflage Regiment; the 1st and l0th Training and Replacement Regiments; the 78th and 79th General Construction Regiments; the 97th Supply Regiment; the 98th Roads Regiment; the 477th Depot Regiment; and the 29th, 38th, 76th, and 77th Regiments (Gordon, et al., 1994; USACE, 1994). The camp consisted primarily of tents and barracks, along with staging and training areas for troops (Exhibit 1-3). When space was required for additional drill fields and training trenches, the Construction Division of the Quartermaster Corps leased adjoining properties owned by Mary E. Patton, Charles C. Glover, and other area residents. By the end of the war, Camp Leach contained some 67 structures, including facilities sufficient to quarter, feed, and train 4,400 troops (USACE, 1994).

On December 23, 1918, the immediate cessation of operations was ordered for Camp Leach. Engineer Units were demobilized from the camp, temporary buildings were salvaged, and remaining supplies, transportation, and equipment were disposed of as appropriate for the time. Prior to transfer back to AU and private property owners, the Chief of Engineers ordered training trenches, pits and dugouts be filled in, per agreements regarding the properties (USACE, 1994).

Exhibit 1-3. Trench Training at Camp Leach

1.4.3 <u>World War II</u>

1.4.3.1 Navy Bomb Disposal School

Between July 1942 and October 1945, the Department of the Navy (Navy) used five acres abutting the Music Conservatory and 10 buildings on the AU campus to run the Navy Bomb Disposal School. The school taught handling and disposal of unexploded ordnance. An additional 18 buildings were constructed on the land to support the training activities. The Navy used the property for research and educational purposes.

The school's Research Department, tasked with developing tools and methodologies to extract or otherwise render harmless a wide variety of bomb fuzes and explosive charges, used a variety of chemicals including a urea-formaldehyde resin solution and hydrochloric acid found to be useful in this work. Instructors at the Bomb Disposal School used fulminate of mercury to produce a harmless bang in practical exercises. The stripping of live fuzes and any actual demolitions were conducted at the Navy's Stumpneck Ordnance Investigation Laboratory on the Potomac River at Indian Head, Maryland. There is no evidence indicating that the Navy conducted field testing or disposal of conventional and/or chemical munitions on AU property (USACE, 1994).

1.4.4 Pre-1993 Investigations

1.4.4.1 U.S. Army Toxic and Hazardous Materials Agency (1986)

The U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) conducted an historical records search relating to AUES and Camp Leach activities under the direction of Headquarters, U.S. Army Materiel Command. The records search was conducted in response to a request made by AU. AU researchers had prepared a study which noted that AU was used as a chemical warfare laboratory during World War I (WWI) and that munitions may have been buried in the vicinity of AU. AU specifically requested assistance to try to determine what specific material was buried and the exact location of possible burials.

As a result of USATHAMA's review of AU's study and additional records search, USATHAMA noted two areas where the Army could be of further assistance: search once-classified documents at the U.S. Military History Institute at Carlisle Barracks, Pennsylvania; and contract the support of the USEPA's Environmental Photographic Interpretation Center (EPIC) to conduct photogrammetric analysis of aerial photographs, historical photographs and historical records (U.S. Army Environmental Command [USAEC], 1993).

USATHAMA contracted USEPA EPIC to analyze historical aerial photographs from 1918, 1927, and 1937. The 1918 aerial was a photomosaic provided by AU (Figure 1-3). EPIC identified several significant features including shell pits, trenches, possible test areas, and possible burial sites. The location of those features identified in the analysis related to possible disposal (burial) of munitions and chemical agents were then transferred to a 1982 aerial photograph. EPIC specifically noted that the study did not attempt to determine if the historic features posed any threat to human health or the environment (USEPA, 1986b).

USATHAMA obtained support from the U.S. Army Chemical School at Fort McClellan, Alabama, to have their historian research records at Carlisle Barracks as well as other records, conduct interviews and review documentation provided by AU. The U.S. Army Chemical School historian identified several major issues for USATHAMA to consider. The historian questioned the credibility of the *American University Courier* articles (See Section 1.4.2.1), noting that the stylistic conventions used in the articles suggested references to quantities mainly to emphasize importance, not to describe facts or events accurately. He also reported that there was no official evidence of any burial at AU and noted that official correspondence from the period strongly suggested that all munitions were removed to Edgewood Arsenal. The research could not disprove the burial of some materials on or near AU or that subsurface ordnance could still exist from past military uses of the property. He conjectured that if any materials were buried, they were probably small quantities of laboratory or experimental materials (USAEC, 1993). No additional actions were taken to investigate possible burial locations until 1993 (see Section 1.6.1).

1.5 Site Delineation

Over the course of the many years of investigation of the SVFUDS, it has been delineated in several ways in order to plan focused investigations, incorporate newly identified historical information and analyses, or address updated MMRP requirements. This section provides a background for the overall SVFUDS boundary delineation as well as how investigated areas within or related to the SVFUDS have been defined.

1.5.1 SVFUDS Boundary

As noted in Section 1.3, the SVFUDS comprises approximately 661 acres in the northwest quadrant of Washington, DC. The SVFUDS boundary line was established in January 1993 based on the known AUES and Camp Leach boundaries according to historical records, including real estate documentation, and the spatial orientation of POIs identified from the 1918 aerial photomosaic (Figure 1-3). In 1995, the SVFUDS boundary was increased to approximately 661 acres after an additional 45+ acres were added. The addition was made when an archival search uncovered a letter dated 21 August 1918 from Headquarters, Camp Leach to the Chief of Engineers concerning the proposed development of Camp Leach. The letter listed six specific areas which were leased or used by the Government for Camp Leach and included information on acreage and use of each of the areas (USACE, 1995a).

The northeast and southeast boundary line of the SVFUDS has been subject to several revisions primarily driven by an ongoing effort to use updated technology and analyses to reconcile historic property boundaries with present day property boundaries, as well as a continuous reevaluation of the approach to define the boundary where present day property lines differ from WWI-timeframe property boundaries due to the significant subsequent development of the area (Parsons, 2005 – technical memo included in Appendix B). The result of the boundary revisions was a more clearly defined area of investigation bounded by present day property lines to ensure that any present day property that overlapped the area formerly used by the DoD would be included for planned SVFUDS investigations.

1.5.2 Operable Units

The SVFUDS consists of five OUs (Figure 1-4). USACE began defining general areas of investigation as OUs following the expansion of investigation activities in 1999. OU-1 was defined as the investigation area covered during Operation Safe Removal (OSR). The area investigated as part of the Spaulding and Captain Rankin Area RI became designated as OU-2. Following in sequence, OU-3 consists of 4801 Glenbrook Road, 4825 Glenbrook Road, and 4835 Glenbrook Road, and peripheral parts of AU, that were the first group of properties to undergo expanded investigations after the completion of OSR. Based on findings of the initial OU-3 investigations, an area consisting of approximately 91 acres surrounding OU-3 was designated as OU-4. Through consultation with the USEPA and DDOE, USACE then defined the remaining portions of the SVFUDS outside OU-2, OU-3, and OU-4 as OU-5 to conduct further investigation and characterization of the remainder of the SVFUDS. Section 1.6 provides additional information regarding the nature and progression of investigation activities performed within each of the OUs.

1.5.3 Points of Interest

The SVFUDS includes 54 POIs (Figure 1-5) or areas identified by historical archive screening where DoD activity involving training, testing, research and development may have taken place based on the historical records search conducted by the Army. POIs were established early during OSR and include 53 numbered POIs and one named POI: POI AU. Based upon an initial historical records review, including the 1918 aerial photomosaic, 36 POIs were identified. An additional 18 POIs were identified during an expanded records search during Phase II of OSR for a total of 54 POIs. These POIs were chosen because the historical record indicated AUES testing or research activities occurred in these areas. During the course of RI activities, USACE has developed focused investigations for each of the 54 POIs to further characterize these areas based on the specific activities which may have occurred there. Table 1-1 provides a description of each of the 54 POIs (USACE, 1995a) with updates from their initial 1995 description based on post-OSR remedial investigation results. Exhibits 1-4 and Exhibit 1-5 provide examples of historical photographs depicting activities that took place at some of the POIs.

Table 1-1. Descriptions of Points of Interest (POIs)

POI Number / Title	Description
POI 1 / Circular Trenches	Identified as the Sedgwick Trench. The Army performed extensive field testing of Chemical Warfare Agents (CWA) such as mustard, phosgene, chloropicrin, and cyanogen chloride at this site. The Sedgwick trench comprised circular trenches approximately 200 feet (ft) in diameter. Livens and 75 millimeter (mm) shells with agent were statically fired in the center of the circular trenches.
POI 2 / Possible Pit	Possible location of a pit used for disposal of scrap metal, duds, and other material associated with and adjacent to the Sedgwick Trench. Conclusion was drawn by analogy with the circular trenches (POI 13) and associated known disposal pit (POI 14).
POI 3 / Small Crater Scars	Consists of small crater scars. Located approximately 200 ft north of the center of the circular trenches (POI 1) and on the southern edge of what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 4 / Possible Pit	Possible location of a pit used for disposal of scrap metal, duds, and other material associated with and adjacent to the Sedgwick Trench. Conclusion was drawn by analogy with the circular trenches (POI 13) and associated known disposal pit (POI 14).
POI 5 / Possible Pit	Possible pit located near a possible target or test site (POI 6) and within what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 6 / Possible target or Test Site	Location of a possible target or test site. Located near a tree covered hill within what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 7 / Possible Test Area	Possible test area that was originally fenced. POI 7 encompasses approximately 41,000 sq. ft. A ground scar and small white areas similar to the mustard test fields were visible within the fenced-in area. Reports indicate these areas were as small as 3 ft square and were used to test for agent persistence. Given the proximity of POI 7 to the Sedgwick Trench, it may have also been used as a holding area for animals used in the field tests at AUES.
POI 8 / Possible target or Test Site	Location of a possible target or test site. Located near a tree covered hill within what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 9 / Possible Firing or Observation Stalls	Location of a possible remote firing location or observation stalls. No additional historical information is available for this area
POI 10 / Possible Target or Test Site (Smoke Section Dugout)	Location of a Smoke Section Dugout used for the observation of static testing. Located within a possible static test site and approximately 250 ft west of a possible remote firing line (POI 9).
POI 11 / Scattered Ground Scars	Identified in a 1918 photograph by ground scars visible on the crest and reverse slope to the west of a hill. A possible firing line or observation stalls (POI 9) are located approximately 350 ft east of this area. The scattered ground scars are also located within what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 12 / Possible Graded Area	USEPA EPIC analysis of historical aerial photographs identified this feature as "Possible Graded Area”.

Table 1-1. Descriptions of Points of Interest (POIs)

POI Number / Title	Description
POI 13 / Circular Trenches	Identified as circular trenches that measure approximately 200 ft in diameter. The trenches were used for field testing of CWA, such as mustard, phosgene, chloropicrin, and cyanogen chloride. Initial use of the trenches is believed to have been July-September 1918.
POI 14 / Pit	Located adjacent to POI 13, it is the location of the buried ordnance discovered at 52nd Court during Phase I of OSR. Identified as a disposal pit for scrap metal, duds, live rounds, and lab glassware. The initial use of the pit is believed to have been July-September 1918.
POI 15 / Ground Scar	Identified as a ground scar in a 1918 aerial photomosaic. It is speculated that POI 15 was part of the Chemical Persistency Test Area (POI 16).
POI 16 / Chemical Persistency Test Area	Located on the former Weaver Farm. This large area, approximately 600,000 sq. ft., was cleared of vegetation and sprayed with mustard agent to test for agent persistence.
POI 17 / Possible Pit	Possible pit located near small crater scars (POI 18) and within what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 18 / Small Crater Scars	In a 1918 aerial photomosaic, several small craters that make up POI 18 are visible. The small crater scars are located on the southern edge of what is now known to be a range fan used for ballistic test firing activities at the AUES.
POI 19 / Old Mustard Field	Labeled on a 1918 topographic map as an “old mustard field”. However, no other historical information describing this area is available. If new areas were used for testing (POI 16 for instance), this area could have been abandoned and marked on the topographic map for information purposes.
POI 20 / Ground Scar	Two powder magazines were believed to be located at this site where ground scars were identified in 1918 aerial photomosaic. Extensive disturbance at the same site is visible in a 1927 aerial photograph. These photographs do not clearly show whether the magazines are surface or subsurface features.
POI 21 / Two-chambered shell pit	This concrete walled shell pit consists of an explosive chamber flanked by one observation chamber. The shell pit was used to test the physical properties of explosives, smokes, and CWM. A concrete roof presently covers the shell pit.
POI 22 / Shell pit	Has been incorporated into the foundation of a house.
POI 23 / Three-chambered shell pit	This concrete walled shell pit consists of a central explosive chamber flanked by observation chambers on both sides. The shell pit was used to test the physical properties of explosives and CWM. A concrete roof presently covers the shell pit.
POI 24 / Probable Pit	Probable pit that was initially incorrectly located during the OSR FUDS RI. Now believed to be the pit shown in the SGT Maurer photo (see Exhibit 1-2) and possibly located on 4825 Glenbrook Road.
POI 25 / Possible Trenches	USEPA EPIC analysis of historical aerial photographs identified this feature as "Small Crater Scars". Located on Camp Leach. AUES and Camp Leach were separate entities and were closed on different timelines, Camp Leach prior to AUES; AUES disposals in the trenches are unlikely.
POI 26 / Small Crater Scars	Consists of small crater scars.
POI 27 / Probable Trench or Ditch	Ground scar analyzed by the USEPA EPIC as a probable ditch or trench. Located on Camp Leach. AUES and Camp Leach were separate entities and were closed on different timelines, Camp Leach prior to AUES; AUES disposals in the trenches are unlikely.
POI 28 / Probable Trench or Ditch	Ground scar analyzed by the USEPA EPIC as a probable ditch or trench. Located on Camp Leach. AUES and Camp Leach were separate entities and were closed on different

Table 1-1. Descriptions of Points of Interest (POIs)

POI Number / Title	Description
	timelines, Camp Leach prior to AUES; AUES disposals in the trenches are unlikely.
POI 29 /Ground Scar	USEPA EPIC analysis of historical aerial photographs identified this feature as "Ground Scar".
POI 30 - 36 / Training Trenches	All seven POIs identified as trenches of various kinds. The trenches were used to train troops in trench warfare techniques but were not known to be used for any chemical testing.
POI 37 / Mill Creek	Based upon historical records search, activities related to AUES are unlikely to have been performed at this POI.
POI 38 / Bradley Field/Major Tolman's Field	Test area where shells containing adamsite were fired. Based on a sketch of the test area in an October 1918 AUES test report, the OSR FUDS located the area approximately 400 ft southwest of the Sedgwick Trenches (POI 1). Later analysis of the features on the sketch concluded that the actual location of the test area could not be established.
POI 39 / Static Test Fire Area	Includes POIs 10 and 11 within its boundaries. A triangular shaped area with the base extending approximately 900 ft along the eastern boundary of Dalecarlia Parkway and the apex extending approximately 70 ft to the east. Believed to have been used as a static test fire area for munitions containing chemical agents.
POIs 40-52 were various laboratories and structures located at AUES	
POI 40 / Ohio Hall	No report of present-day AUES-related issues. Currently occupied AU building, McKinley Hall.
POI 41 / History Building	No report of present-day AUES-related issues. Currently occupied AU building, Hurst Hall.
POI 42 / Physiological Laboratory	No report of present-day AUES-related issues. Located on the same footprint as an existing AU building, School of International Service Annex.
POI 43 / Gun Pit	Livens Gun Pit (still present) where Livens rounds were fired from this location. Historic photographs show the gun pit and mortars and the Livens tubes firing smoke rounds. This POI refers to the same Livens Gun Pit included in AOI 4.
POI 44 / Chemical Research Laboratory	No report of AUES-related issues. Currently occupied AU building, Mary Graydon Center.
POI 45 / Explosives Laboratory	No report of AUES-related issues. Located in same footprint as an existing AU building, Media Production Center.
POI 46 / Canister Laboratory	No report of AUES-related issues. Located in same footprint as an existing AU building, Anderson Hall.
POI 47 / Research Laboratory	No report of AUES-related issues. Bacteriological Laboratory located within OU-4 AU Lot 28.
POI 48 / Dispersoid Laboratory	No report of AUES-related issues. Located in same footprint as an existing AU building, Letts Hall.
POI 49 / Pharmacological Laboratory	No report of AUES-related issues. Located in the same footprint as an existing AU building, Anderson Hall.
POI 50 / Gun Pit	No report of AUES related issues. Located in the same footprint as an existing AU building, Media Production Center.
POI 51 / Fire and Flame Laboratory	No report of AUES-related issues. Located within POI 53 on the southern edge of OU-4 AU Lot 1.
POI 52 / Electrolytic Laboratory	No report of AUES-related issues. Located within POI 53 on the southern edge of OU-4 AU Lot 7.
POI 53 /Baker Valley	Suspected to have been located near the western perimeter of the original grounds of AUES based on comments written on the back of 1918-1919 photographs. The photographs of Baker Valley were taken within the fenced area and oriented toward the west. Baker Valley is located on the southern slope of the hill where the shell pits (POI 21/22/23) were built.

Table 1-1. Descriptions of Points of Interest (POIs)

POI Number / Title	Description
POI AU / American University	According to historical photographs of AUES, many small, temporary buildings and several other buildings and features associated with research, development and testing of CWAs were located in the area currently occupied by the AU baseball field. During operations of AUES, several accidents were documented that may have resulted in the release of CWAs.

Source: USACE, 1995b. Remedial Investigation Report for the Operation Safe Removal - Formerly Used Defense Site, Washington, D.C. Prepared by Parsons Engineering Science, Inc. June.

Exhibit 1-4. Bunker with Roof on Rollers

Exhibit 1-5. Shell Containing Chloracetophenone Matrix

1.5.4 Areas of Interest

The SVFUDS has 28 AOIs (Figure 1-6). AOIs were identified by a workgroup of the Partners called the AOI Task Force (AOITF). The AOITF consisted of four members, including one representative from each of the three partnering agencies (USACE, USEPA, and DDOE) and the SVFUDS RAB TAPP consultant. The AOITF was tasked with identifying, evaluating and making recommendations to the Partners regarding AOIs. AOIs were identified and evaluated using all available sources of information, including historical documents and photographs, aerial photographs and photographic analysis, sampling and geophysical data, health-related data, and anecdotal information (Henry & Associates, LLC., 2005). Between 2003 and 2007, the AOITF met and reported on all 28 AOIs for the Partners. Based on the reports developed by the AOITF, including some reports left in draft form, the Partners identified locations within the SVFUDS that required further investigation prior to completion of the RI. The Partners reviewed, discussed, and in some cases revised the AOITF recommendations and formalized the path forward for further investigation in AOI Consensus Memoranda.

Table 1-2 provides a brief description of the AOIs identified by the AOITF (USACE, 2008a). Appendix B contains the AOI Consensus Memoranda in their entirety. Many of the AOIs overlap or encompass one or more POIs, and some are non-contiguous. Figure 1-7 depicts AOIs and POIs as well as the Range Fan described in Section 1.5.5.

Table 1-2. Descriptions of Areas of Interest (AOIs)	
AOI Number / Title	**Description**
AOI 1 / "X" Feature	There is an "X" shaped feature visible on the 1918 aerial photomosaic of the AUES grounds. The origin and function of the feature was initially unknown. It was incorrectly identified as a potential air strip in 1986. It was later thought to represent sets of shallow parallel trenches used for testing. However, when ground scar locations were revised in 2009 using updated GIS software, the "X" Feature was identified as the early beginning of the intersection of 48th Street and Rodman Street.
AOI 2 / Rick Woods Burial Pit	During the 1980s, a Civil War relic hunter entered the WA grounds and encountered a cache of WWI shells, most of which he and a partner removed from the property.
AOI 3 / Gunpowder Magazine Area	Two gunpowder magazines, a detonator storage facility, and an explosive service building were located west of the AUES perimeter fence. Ground scars at these locations were visible into the 1920s.
AOI 4 / Livens Gun Pit	A Livens Gun Pit (still present) and two associated shell storage pits were located on the AUES. Livens rounds and 3" and 4" Stokes mortar rounds were stored and fired from this location. Historic photographs show the gun pit and mortars and the Livens tubes firing smoke rounds. This AOI refers to the same Livens Gun Pit described as POI 43.
AOI 5 / 4825/4835 Glenbrook Road	This current location corresponds to the area described in 1921 where the Army buried munitions. Since 1992 there have been several events where AUES glassware and chemicals have been encountered. In 2001 a munitions disposal pit was discovered at 4825 Glenbrook Road.
AOI 6 / Dalecarlia Impact Area	Downrange terminus for the Range Fan. Previous geophysical surveys in the Dalecarlia Woods have identified numerous anomalies in the woods. Several expended 75mm shells and Livens projectiles were recovered during intrusive investigations in 1994. According to historical documentation, 75mm shells were used for statically fired testing and were therefore likely associated with the nearby POI 39 and POI 13 and not related to the Range Fan ballistically fired testing.
AOI 7 / Rockwood Six Properties	Six properties in what is now the 4600 block of Rockwood Parkway are located in part of the former AUES grounds. These properties are located near the area that was described in 1921 where the Army was given permission to bury munitions. Several of these properties are adjacent to Lot 18 on AU property.
AOI 8 / Possible Graded Area	Location of a ground scar identified as Possible Graded Area in USEPA EPIC report. This AOI was identified as POI 12 during the original 1993 to 1995 OSR investigation. A former resident of a property located on this feature reported health problems to the USEPA after performing yard work one summer.
AOI 9 / Sedgwick Ground Scars	During WWI a double ringed set of test trenches were constructed at what is now the 5000 block of Sedgwick Street. Analysis of the August 1918 aerial photomosaic of the AUES range and reservation showed this trench and also identified several additional ground scars in the vicinity of the test trench. Six of these ground scars were identified as POI's and were investigated.
AOI 10 / Westmoreland Recreation Center	The recreation center is located in Montgomery County, Maryland. While staff at the center asked USEPA if there were any potential hazards related to AUES activities at the park, there is no historical evidence suggesting testing activities at this location.
AOI 11 / 52nd Court Pit and Trenches	This was the site of the original munitions discovery in January of 1993. The munitions and other WWI era materials were removed as part of a Time Critical Removal Action. It was identified as an AOI because there was some concern that the area had not been completely investigated and that chemical contamination or munitions items remain.
AOI 12 / Livens Battery Impact Area	This area was not identified as a POI during the initial OSR FUDS investigation. However, a 1918 topographic map did label a hill top feature as a "TARGET". Review of AUES photographs at Fort Leonard Wood showed a photograph of the Livens battery

Table 1-2. Descriptions of Areas of Interest (AOIs)

AOI Number / Title	Description
	firing several projectiles and their impact down range. This AOI is located in the Livens/Stokes mortar range that was discovered in 2003.
AOI 13 / Quebec/Woodway 13	WWI era maps and aerial photographs suggest much AUES activity took place in this general vicinity. It was close to the fenced perimeter of the AUES and several AUES buildings including a Detonator Shed and a Bomb Filling Shed, and an unidentified building, as well as ground scars including small crater scars (POI 26) were located in this area.
AOI 14 / Sharpe Bunker on Seminary	A former Spring Valley resident recalled a "bunker" type structure present on the Wesley Seminary property in the 1950s. In 2002 the resident and Spring Valley team members conducted a site visit to this location. WWI records do not place any structures at this location and existing Wesley Seminary records showed nothing at this location.
AOI 15 / Dog Wallows	A Spring Valley resident reported a foul smelling odor to DDOE after her dog had rolled in dirt in this area. No historical documentation is related to this area to associate it with past AUES or Camp Leach activities.
AOI 16 / Westmoreland Circle Impact Area	A 1918 test report indicates that 100 chemical shells were ballistically fired from howitzer tubes at the AUES. A 1922 aerial photograph shows several ground scars visible in open fields near the Westmoreland Circle, but AUES and Camp Leach land use records indicate that the Army did not use this parcel of land during WWI.
AOI 17 / $800,000 Burial Site	The original AOI report speculated that this burial site was located on WA property. The subsequent revision moved the location onto the AU campus, but did not identify a specific location. Two AU newsletter articles indicate that munitions were buried in a remote part of the campus prior to 1921. (see Section 1.4.2.1) This burial pit is likely one of the several burial pits identified and removed from 4801 Glenbrook Road and 4825 Glenbrook Road.
AOI 18 / Major Tolman's Field	Major Tolman conducted a number of field tests including test firing of toxic smokes and G-76, diphenylchloroarsine shells. A 1918 field test report at Major Tolman's field contains a sketch map that shows topographic lines, woods, and several other features. In 1993, USACE identified a location that appeared to be the closest fit to match features on the sketch. The DDOE proposed another location for this AOI. Neither of the possible locations were complete matches.
AOI 19 / Tenleytown Station	A search light station was located on Camp Leach grounds near Tenleytown during WWI. The station appears to have remained open after the closure of Camp Leach. The AOI report speculates that chemicals from AUES may have been moved to the Tenleytown facility for storage. There is no historical evidence that this AOI was used for storage or disposal activities.
AOI 20 / Slonecker-Johnson Trenches	The 1922 aerial photograph of the area shows several linear ground scars in a field east of (across Nebraska Avenue) the History Building on the American University campus. The AOI report identifies these features as trenches and speculates they may have been used to dispose of chemicals. The AOI report also cites perchlorate detection in monitoring wells downstream from this location. WWI real estate information indicates this parcel of land was not used by either AUES or Camp Leach.
AOI 21 / Weaver Farm	The Weaver Farm was a focal point of activity in the AUES range and proving ground. The 52^{nd} Court Trench and burial pit were located near the farm complex. Numerous POIs were located in the vicinity of the farm complex as well. The November 1918 AUES land use memo indicates that the Army leased 68.4 acres of land from Mr. Weaver. AUES field test records indicate numerous field tests were conducted on and around the grounds of the Weaver Farm. Overlaps with other AOIs including AOI 8, 9, 11, 12, and 24.

Table 1-2. Descriptions of Areas of Interest (AOIs)

AOI Number / Title	Description
AOI 22 / Mercury Detection Areas	AOI 22 was defined based on previous SVFUDS sampling results indicating detections above background levels of mercury, a component of several explosives used at AUES. There were also several buildings at AUES that were used to store detonators and other explosives.
AOI 23 / Railroad Sidings	Historically a railroad right of way ran through the WA property. A 1940 map of the WA property shows a chemical siding spur adjacent to the rail line. AUES and Camp Leach documents discuss the use of rail lines. "1918 Completion Reports" for AUES and Camp Leach indicate rail lines were not authorized for either facility. Other WWI documents discuss the use of rail lines for shipping supplies in the future tense. WA archives indicated the siding was not present prior to 1920. Construction of this spur is probably tied to the construction of the water treatment building in the 1920s.
AOI 24 / Antimony Detection Areas	Soil sampling during the OSR FUDS Phase 2 detected antimony at several POIs. AOI 24 was defined based on the detections of antimony, a component in detonators and fuzes. The 1995 RI did not recommend remediation at these locations because the antimony levels were below health risk screening levels.
AOI 25 / Camp Leach Trenches	Several sets of training trenches were constructed in the Camp Leach Drill and Trench grounds. These trenches are present on 1918 Camp Leach maps, the 1918 aerial photomosaic, and several other photographs. WWI documents indicate the trenches were filled by December 1918. There were concerns expressed that the trenches may have been used as disposal sites during closure activities. AUES and Camp Leach were separate entities and were closed on different timelines, Camp Leach prior to AUES; AUES disposals in the trenches are unlikely.
AOI 26 / 4801 Glenbrook Road Pit	Portions of what is now 4801 Glenbrook Road were inside the AUES perimeter fence line. Two munitions disposal pits have been found on this property. A third disposal pit straddled the property line of 4801 and 4825 Glenbrook Road.
AOI 27 / Third Circular Trench	The 1918 AUES aerial photograph shows two circular test trenches present in the range and proving ground. The November 1918 AUES ground use memo indicates that 185.65 acres of WA grounds (identified as the Girls Reform School in the memo), were available for use by the AUES. The AOI report speculates that a third circular trench was constructed in a wooded area on the WA grounds to simulate testing in different terrain. The location is in Maryland. No WWI land use documents indicate any AUES use of this area. In 2002, the USEPA prepared a report entitled Aerial Photographic Analysis of Chesapeake and Ohio (C&O) Canal Field Test Site. This report did not identify any possible trenches or any other features at the proposed location of this AOI.
AOI 28 / Hamilton Hall Burial Pit	In 1986, AU expressed concerns about a possible "bomb pit" near Hamilton Hall. It was not clear what, if any, investigations were conducted at this potential feature. The DDOE identified a shallow depression they initially identified as a "probable bomb pit" near the southwest corner of Hamilton Hall.
Source: USACE, 2008a. Spring Valley FUDS Partnership Tier I Memorandum for Record: Completion of Area of Interest Task Force (AOITF) Mission. January.	

1.5.5 <u>Range Fan</u>

The Range Fan is an elongated, cone-shaped area defined by a firing point and potential impact areas down range (Figure 1-8). Historical records for the AUES suggest that Livens projectiles, and 3-inch and 4-inch Stokes mortars may have been fired from the Livens Battery Pit and Stokes Mortar Gun Placement near AU and Woodway Lane and, in turn, may have impacted downrange locations to the northwest towards the Federal property. Historical photographs including Exhibit 1-6 and Exhibit 1-7, established the historical use of a firing range and range targets but could not accurately define the location for use as an evaluation tool to plan investigations. In 2003, the concrete gun pit for the Livens projectors was discovered in OU-2.

Exhibit 1-6. Loading Livens Projector

Exhibit 1-7. Loading Stokes Mortars for Firing
Note: Livens gun pit is located in left background

USACE surveyed the intact concrete gun pit and developed an 'as-built' to assist in developing the projected trajectory for the range. USACE munitions experts developed probable maximum range and trajectories for the types of munitions fired. The Range Fan covers the maximum ranges and buffer zones: the 3-inch and 4-inch Stokes mortar maximum ranges are calculated to be 750 yards and 840 yards, respectively, with a variance of 2.5 degrees transverse from center. The Livens projectile maximum range is calculated to be 1550 yards with a deflection accuracy of 5 percent and a directional accuracy of 7 percent (USACE, 2005c). The POIs and AOIs listed below are possibly associated with the Livens Battery Pit and Stokes Mortar Gun Placement, projected range fans, and the associated impact areas (see Figures 1-5 and 1-6). POI 18, also located within the Range Fan, was initially included in Range Fan investigations. However, it was later determined to be unrelated to the Range Fan.

- POI 3 - Small Crater Scars
- POI 4 - Possible Pit
- POI 5 - Possible Pit
- POI 6 - Possible target or Test Site
- POI 8 - Possible target or Test Site
- POI 10 - Possible Target or Test Site
- POI 11 - Scattered Ground Scars
- POI 17 - Possible Pit
- POI 43 - Gun Pit
- AOI 2 - Rick Woods Burial Pit
- AOI 4 - Livens Gun Pit
- AOI 6 - Dalecarlia Impact Area
- AOI 9 - Sedgwick Ground Scars
- AOI 12 - Livens Battery Impact Area
- AOI 13 – Quebec/Woodway 13 Properties

1.5.6 <u>Munitions Response Sites</u>

The Army currently requires MMRP RIs to designate MRSs as the areas of investigation and focus. A Munitions Response Area (MRA) is any area on a defense site that is known or suspected to contain UXO, DMM, or MC. An MRS is a discrete location within an MRA that is known to require a munitions response. However, the SVFUDS investigation units were designated as POIs, AOIs, OUs, or other, prior to establishment of the MRS terminology, and therefore, MRS usage does not supersede those POI, AOI, or OU designations in this RI report. There are three MRSs located within the SVFUDS, designated as MRS 09 (4825 Glenbrook Road), MRS 08 (Battery Vermont), and MRS 01 (Burial Pits/Field Test Areas).

MRS 09 (4825 Glenbrook Road) is an area located within the fenceline of the AUES. The fenced in area of the AUES was used to develop and investigate toxic gases, toxic and incendiary munitions, defensive and offensive smoke mixtures, antidotes, and protective masks. Operations included the development of CWM, including mustard (H), and Lewisite (L) agents, as well as adamsite, irritants, and smokes. After the war, the AUES was demobilized and CWM and agents were disposed of in on-site pits, within the FUDS boundary. The location of the disposal pit shown in the SGT Maurer photograph is likely located within MRS 09. As shown in Figure 1-9, MRS-09 comprises 4825 Glenbrook Road and includes POI 24 (Probable Pit). MRS 09 underwent a separate RI and the remedial action activities are ongoing at the MRS.

MRS 08 (Battery Vermont) is an area used between 1861 and 1865 as part of the Civil War temporary defenses to protect Washington, DC from Confederate attacks. It was situated to protect the Chain Bridge on the Potomac River and the Dalecarlia Reservoir. Battery Vermont did not engage in any combat and there is no documentation of any firings from the battery and no reports of any munitions found and the presence of residences within the MRS would have limited the use of live fire shots for practice. As shown in Figure 1-9, the site where MRS 08 is located is now the parking lot of the Sibley Memorial Hospital and the Grand Oaks Living Community. No DoD Action Indicated (NDAI) was determined for this MRS.

MRS 01 is 120.1 acres that are a compilation of several test areas and burial pits, and it consists of the areas where field testing to determine the effectiveness of toxic chemicals and substances, incendiaries, and smoke mixtures is thought to have occurred, as well as associated burial pits and disposal areas. The MRS is delineated by the historical documentation that exists, as well as the findings of geophysical and environmental sampling investigations that have occurred. Figure 1-9 provides the detail of the MRS 01 acreage, and shows that the MRS comprises the following areas:

- The Range Fan and its buffer zone, beginning at the POI 43 (Gun Pit) / AOI 4 (Livens Gun Pit) and extending westward into Dalecarlia Woods (encompassing AOI 2, Rick Woods Burial Pit);
- POI 39 (Static Test Fire Area) encompassing POI 10 (Possible Static Test Site), and POI 11 (Ground Scar);
- POI 9 (Possible Firing or Observation Stalls) and its buffer zone;
- AOI 9 Northern Half (Sedgwick Ground Scars) encompassing POI 5 (Possible Pit), POI 6 (Possible Target or Test Site), and POI 8 (Possible Target or Test Site);
- POI 17 (Possible Pit);
- POI 18 (Small Crater Scars);
- POI 25 (Possible Trenches);
- AOI 6 (Dalecarlia Impact Area);

- AOI 9 Southern Half (Sedgwick Ground Scars) encompassing POI 1 (Sedgwick Trench) and its buffer zone, POI 2 (Possible Pit), POI 3 (Small Crater Scars) and POI 4 (Possible Pit);
- AOI 9 Northern Tip (Sedgwick Ground Scars) including POI 7 (Possible Test Area);
- AOI 13 (Quebec/Woodway 13 Properties) including POI 26 (Small Crater Scars);
- AOI 17 ($800,00 Burial Site);
- AOI 22 (Mercury Detection Areas);
- AOI 24 (Antimony Detection Areas);
- AOI 28 (Hamilton Hall Burial Pit);
- 4710 Woodway Lane containing POIs 21, 22, and 23 (Shell Pits) and POI 43/AOI 4;
- POI AU (American University);
- A portion of AOI 21 (Weaver Farm) including that part within the Range Fan;
- A portion of AOI 26 (4801 Glenbrook Road Pit) including only the area within the historical AUES fenceline only;
- A portion of AOI 5 (4825/4835 Glenbrook Road) including only 4835 Glenbrook Road; and,
- A portion of POI 53 (Baker Valley) including only that part between 4710 Woodway Lane and POI AU.

1.6 Previous Site Activities

The SVFUDS is an extremely complex site involving several ongoing and concurrent activities over many years, focusing on different potential hazards and/or different investigation locations. As such, the following discussions describe previous investigations in a narrative format organized primarily by the following key types of activities completed for the SVFUDS: initial investigation/characterization, follow-on investigation/characterization, geophysical investigations, and removal actions. All of the activities conducted at the SVFUDS fall under one (or more) of these activity types.

Following each subsection narrative summary, a table is provided listing the key finalized standalone documents that provide all of the detail associated with the subject activity (Appendix C includes these reports in their entirety). The purpose of this section is to provide a summary level review of previous site activities describing when and why they were performed; it is not intended to discuss how they were conducted, what the findings meant, or repeat the information contained in the standalone reports. Section 4.0 provides a description of how the technical procedures used to perform the RI field activities were conducted. Section 5.0 summarizes the findings and conclusions of each of these reports and places them into the context of the nature and extent of contamination discussions.

1.6.1 <u>Initial Investigation and Characterization</u>

1.6.1.1 OSR FUDS Phase I

On January 5, 1993, a contractor unearthed buried munition items while digging a utility trench on 52nd Court, approximately one-half mile east of the Dalecarlia Reservoir and about one-quarter mile south of the border between the District of Columbia and Maryland. Upon notice of the discovery, the U.S. Army Technical Escort Unit from the Chemical and Biological Defense Agency at Aberdeen Proving Ground, Maryland, initiated an emergency response, known as OSR FUDS Phase I, which was completed on February 2, 1993 (USACE, 1995b).

USACE initiated the preliminary assessment/site inspection (PA/SI) referred to as the Inventory Project Report (INPR) during the OSR Phase I. The INPR officially established the SVFUDS and recommended a Remedial Investigation/Feasibility Study (RI/FS) for the SVFUDS (USACE, 1993b).

1.6.1.2 OSR FUDS Phase II

OSR FUDS Phase II was the start of the RI phase for the SVFUDS. Using historical documentation including reports, maps and photos, USACE focused its investigation on specific areas that were determined to have the greatest potential for contamination. These areas were referred to as POIs (Section 1.5.3). During the two-year investigation that followed, geophysical surveys were done at POIs considered to be potential munitions burial locations. The purpose of the geophysical investigations was to locate any additional possible caches of WWI munitions (USACE, 1995b).

In addition to the geophysical investigations conducted during the OSR FUDS RI to characterize the nature and extent of residual AUES contamination, environmental media samples were collected from 17 POIs. These findings were documented in the 1995 OSR FUDS RI report (USACE, 1995b), which recommended no further action for the SVFUDS with the exception of the Spaulding and Captain Rankin Areas (a single property that contained former shell pits/bunkers associated with AUES activities). The RI report was followed by a No Further Action Record of Decision in June 1995 (USACE, 1995c). In this decision, the Army discussed future actions if additional munitions or contamination related to past DoD activities were to be discovered.

1.6.1.3 Operable Unit 2 Investigations and Removals

The OSR FUDS RI determined that no further action was required for the entire OSR FUDS with the exception of the Spaulding and Captain Rankin Areas (POIs 21, 22, and 23) (see Figure 1-4 and 1-5), designated as OU-2. The Captain Rankin and Spaulding Areas are located on a single property. In June 1994, an Engineering Evaluation/Cost Analysis (EE/CA) was conducted for the Spaulding and Captain Rankin Areas (USACE, 1996) to determine the appropriate action for addressing the soil and material contained within the former shell pits (bunkers) and surrounding areas. The EE/CA identified risk associated with the soil within the bunkers. Based on these findings, a Non-Time-Critical Removal Action (NTCRA) was conducted in this location to remove the soil debris found within the POI structures.

A separate RI for the Spaulding and Captain Rankin Areas, prepared in 1996, addressed exposures to subfloor soils and concrete and pipe drain termini at POIs 21, 22, and 23 for construction workers exposed via incidental ingestion and inhalation. In the June 1996 Spaulding and Captain Rankin RI Report, USACE recommended that no further action be taken at OU-2.

1.6.1.4 USEPA HHRA for the SVFUDS

In 1999, the USEPA prepared an HHRA for the SVFUDS (USEPA, 1999). USEPA conducted an analysis of soil sampling data collected between 1993 and 1995 at 16 locations throughout Spring Valley and AU property (taking splits of the USACE OSR FUDS RI samples). The risk assessment evaluated the toxicity posed by chemical substances in soil and described the exposure routes by which humans may come into contact with these substances.

The USEPA HHRA was intended to evaluate the significance (if any) of residual chemical contamination and to determine the full nature and extent of required follow-on investigations at the SVFUDS. It was intended to be read in conjunction with the final OSR FUDS RI (USACE, 1995b). Based on the splitting of samples with USACE, the POIs assessed included all of those in the USACE OSR FUDS RI with the exception of POI 37 and the LTC Bancroft Area. The USEPA also collected samples from 4825 Glenbrook Road independent of the OSR FUDS RI split sample locations. The LTC Bancroft Area is not a POI; it refers to the location where a partially filled Livens smoke round was recovered during the OSR FUDS anomaly investigation.

Table 1-3 lists some of the key reports for the initial investigation and characterization activities; these are the basis of the nature and extent analysis presented in Section 5.1.

Table 1-3. Initial Investigation and Characterization Key Documents

Date / Title	Description	Section 5.0 Ref.
1995 / Remedial Investigation Report for the Operation Safe Removal - Formerly Used Defense Site	Report of OSR FUDS Phase I and Phase II activities including emergency response actions and remedial investigations.	5.1.1
1994/ Engineering Evaluation/Cost Analysis, Captain Rankin Area Shell Pits, OSR FUDS	OU-2 EE/CA addressing soil and material contained within the former shell pits. Basis for soil removal under NTCRA.	5.1.2
1996 / Remedial Investigation Report for Spaulding and Captain Rankin Areas, OSR FUDS	OU-2 RI addressing exposures to subfloor soils and concrete and pipe drain termini at POIs 21, 22, and 23.	5.1.2
1999/ USEPA Region III Draft Risk Assessment Report, Army Munitions Site, Spring Valley	USEPA's HHRA based primarily on split samples from USACE 1995 OSR FUDS RI.	5.1.3

1.6.2 Follow-on Investigation and Characterization

The D.C. Department of Consumer and Regulatory Affairs (DCRA) prepared a report dated July 1996, that criticized USACE's No Further Action Record of Decision at the SVFUDS and recommended site-wide comprehensive geophysical investigations, soil sampling, and a health study (DCRA, 1996). DCRA provided the report to USEPA (DCRA, 1997a). In November 1997, DCRA transmitted additional comments and concerns regarding the completeness of the OSR FUDS RI and requested a USACE response to the identified concerns (DCRA, 1997b). Aerial and supporting photographs were reviewed by the USACE Topographic Engineering Center (TEC), and it was determined that the location of POI 24 was on the grounds of 4801 Glenbrook Road instead of AU property, incorrectly located by approximately 150 ft. The review also identified POI 24 as a possible mustard agent burial pit (USAESCH, et al., 1998). Additional comments were provided to USACE in March 1998 (DC DOH, 1998).

USACE began meeting with the DDOE and USEPA in 1998 to review these comments and concerns (USACE, 1998a), and completed the Remedial Investigation Evaluation Report (USACE, 1998b) that provided the comprehensive USACE response to the DCRA Report and Letter and evaluated the issues raised in those documents. Given the incorrect location of POI 24, USACE conducted field investigations in the vicinity of the revised POI 24 location, on 4801 Glenbrook Road, where two large burial pits (Pits 1 and 2) were discovered and excavated.

1.6.2.1 Operable Unit 3

To further address DCRA concerns, the USEPA collected surface soil and subsurface soil samples in and around 4801, 4825, and 4835 Glenbrook Road to supplement their HHRA (USEPA, 1999). Based on the interim results from the USEPA sampling, historical information, and the USEPA HHRA, it was determined that the soil of the three properties (4801, 4825, and 4835 Glenbrook Road) may have been impacted by AUES activities in the vicinity of the two burial pits.

USACE completed an EE/CA that recommended that due to elevated arsenic concentrations, the top two feet of soil in the affected areas should be removed and replaced with new soil (USACE, 2000c). The soil removal began in December 2000 and was completed in March 2001 at 4801 Glenbrook Road and 4825 Glenbrook Road (USACE, 2006a; USACE, 2011a).

During approximately the same timeframe, USACE was provided transcripts of interviews conducted with workers involved in the development and construction of the 4825 Glenbrook Road and 4835 Glenbrook Road residential properties. While the transcripts were considered anecdotal information, as they were conducted by an external source and could not be verified by USACE, they helped reinforce the need to complete a thorough investigation of OU-3.

Following the completion of the arsenic contaminated soil removal, USACE excavated test pits (TP) at 4825 Glenbrook Road due to its location adjacent to 4801 Glenbrook Road. Twenty-three TPs and two trenches were investigated in May and June 2001. At TP 23, a third burial pit was located. The investigation was conducted from May 2001 to March 2002, at which time USACE was required to demobilize when the property owner did not renew permission to access the property (USACE, 2011a). The investigation of the third burial pit, referred to as Burial Pit 3, resumed in 2007 in conjunction with plans to excavate additional TPs on the 4825 Glenbrook Road property as well as at 4835 Glenbrook Road (USACE, 2011a; USACE, 2013a).

As a result of Burial Pit 3 and TP investigations conducted at 4825 Glenbrook Road, the decision was made in August 2010, to separate the 4825 Glenbrook Road property from the remainder of the SVFUDS and place it on its own CERCLA process pathway. Accordingly, 4825 Glenbrook Road investigation activities are not incorporated into this RI, and summary information regarding the 4825 Glenbrook Road RI through Remedial Action (RA) efforts is provided for informational purposes only.

<u>1.6.2.1.1 4835 Glenbrook Road</u>

TP investigations were conducted at 4835 Glenbrook Road in conjunction with the resumed effort to investigate Burial Pit 3. The TP investigations were designed to locate potential burial areas on the property. Excavation of arsenic contaminated grids was conducted along with the TP investigations (USACE, 2013a). The TP investigation began in October 2007 and was completed in December 2008. A total of 76 out of 77 TPs planned for the property were completed: one TP was not completed because of the presence of utilities (USACE, 2009a; USACE, 2013a).

1.6.2.2 Operable Unit 4

During the investigations of Pits 1 and 2 on 4801 Glenbrook Road and the removal of arsenic contaminated soil from the area, USACE conducted a review of historical documentation involving several events that may have contributed to elevated arsenic concentrations in soil in the Baker Valley POI (see Figure 1-5). In addition, in 1999, the USEPA conducted multiple sampling events in and around OU-3 and prepared an HHRA for American University (USEPA, 2000b). Based on the results of this sampling and review of historical activities, it was determined in 2000 that the area of investigation should be expanded beyond OU-3. The expanded area of investigation (approximately 91 acres) was designated as OU-4 and it included approximately 80 private residences and significant portions of the AU campus. This investigation was primarily intended to characterize these properties for arsenic in the soil. (USACE, 2000a). However, other investigation and characterization activities, having different objectives, but falling within OU-4, are discussed below.

1.6.2.2.1 USEPA HHRA for American University

In 2000, the USEPA prepared an HHRA specific to the southern portion of the AU campus (USEPA, 2000b). The focus of this HHRA was to evaluate the potential risk to human health from exposures to metals in the soil at AU. The HHRA assessed the following receptors potentially exposed to surface soils: adult trespasser, child trespasser, adult student athlete, and adult maintenance worker.

1.6.2.2.2 AU Child Development Center

As a further result of the expanding sampling efforts, several lots on the AU campus were recommended for more detailed sampling including the AU Child Development Center (CDC) (USACE, 2003a). This sampling, completed in January 2001, identified concentrations of arsenic above USEPA screening levels and natural background levels. As a result of these findings the USACE performed a Time Critical Removal Action (TCRA) for the arsenic contaminated soil (USACE, 2003a).

1.6.2.2.3 AU Small Disposal Area

Another investigation initiated as a result of the USEPA sampling events in 1999 was the identification of the Small Disposal Area (SDA) for investigation (USACE, 2004a). During one of the sampling events, a DDOE representative discovered surface debris, including glass and labware, located on the southwestern edge of AU property behind residential properties on Rockwood Parkway. An intrusive investigation that included debris and soil removal was completed by the end of March 2001 (USACE, 2004a).

1.6.2.2.4 AU Athletic Fields and other Lots

Grid sampling conducted in March 2001 as part of the OU-4 and OU-5 EE/CA identified a number of grids with arsenic contaminated soil on AU campus lots. The arsenic contaminated soil was designated to be removed under a TCRA for lots covering the athletic fields (OU-4 AU Lots 8, 10, 11, 13, 14, and 15); grids in OU-4 AU Lot 12 outside the fencing of the CDC; grids related to soil borings in OU-4 AU Lots 16, 19, and 23; grids located in the vicinity of Watkins Hall; grids in OU-4 AU Lot 18; and grids in the vicinity of Kreeger Hall (USACE, 2010a) (see Section 1.6.4). Geophysical investigations were performed and anomalies were investigated in the lots in conjunction with the TCRA. The anomaly investigations were completed in June 2003 (USACE, 2005e) (see Section 1.6.3).

1.6.2.2.5 AU Lot 18 Disposal Area

Geophysical investigations and TCRA activities began in the area referred to as OU-4 AU Lot 18 in 2002 as an outgrowth of the AU Athletic Fields and Other Lots TCRA and geophysical investigations. During the intrusive investigation of anomalies, a significant amount of debris including domestic trash, AUES-related laboratory glassware and inert munitions debris were recovered. Following discovery of this apparent disposal area by staff from DDOE, the excavation continued to expand in an effort to remove all of the debris associated with the anomalies and continued into mid-2003 as a low probability investigation. The discovery of a bottle containing a small amount of Lewisite solution changed the protocols used to ensure safety during the investigation from low probability to high probability (USACE, 2008b). In 2004 USACE returned to the site to continue the investigation under high probability protocols.

Following the completion of the high probability investigation, additional soil sampling and low probability geophysical anomaly investigations were conducted in 2006 (USACE, 2008b). The debris identified during the 2006 low probability soil removals and investigations extended toward the AU Public Safety Building (PSB). A discrete HHRA was also conducted for this area, as discussed in Section 7.1.1.2.

1.6.2.2.6 AU Public Safety Building

Additional planning was required to continue following the Lot 18 debris to fully investigate and excavate the soil up to the foundation of the PSB, without compromising the structural integrity of the building. In 2006, sampling for the geologic and geotechnical evaluations was completed to assist in planning for the continued investigation. With an approved plan in place, excavations around the PSB were conducted from June 2008 to June 2010 (USACE, 2013b). A discrete HHRA (USACE, 2013c) was also conducted for this area, as discussed in Section 7.1.1.3.

1.6.2.2.7 AU Area Ground Scars Investigations

USACE conducted an evaluation of historical data related to the present day location of the AU soccer fields. Area G was identified as a “Possible Bunker” in the USEPA EPIC report. It was concluded in the December 2009 USACE report that there was no evidence that munitions burials took place within Area G. However, to further assess other similar ground scars that were not recommended for intrusive investigation and to rule out the existence of potential additional disposal pits, USACE investigated the Area G ground scar (USACE, 2012b). In addition to the investigation of the Area G ground scar, the evaluation of historical data identified other areas located on the AU campus to be further evaluated. While not believed to be MEC or CWM related, the features could not be positively identified, and therefore, intrusive trench investigations were recommended to investigate these areas (USACE, 2011b).

1.6.2.2.8 Indoor Air Sampling

An indoor air study was completed at 5065 Sedgwick Street, a residence near the Sedgwick Trenches (POI 1). The initial study in 2001 experienced sampling and analytical difficulties. In 2003, a second study using improved techniques was conducted (USACE, 2004c).

1.6.2.2.9 Sub-Slab Soil Gas Investigations

In 2004, sub-slab soil gas samples were collected from beneath the basement slabs of two Rockwood Parkway properties (4621 and 4625) adjacent to and owned by AU. The objective of this sampling investigation was to determine if past AUES-related activities had impacted indoor air quality at the residences under investigation. These properties are in close proximity to the SDA, OU-4 AU Lot 18 and PSB investigations (USACE, 2006c).

1.6.2.3 Operable Unit 5

In response to significant community concerns regarding possible soil contamination in the greater community, the USACE, in consultation with the USEPA and the DDOE, developed a comprehensive plan to conduct arsenic soil sampling on every property within the SVFUDS and conduct additional geophysical investigations focusing on identifying additional potential pits as well as individual buried munition items. The expanded area of investigation, some 577 acres (the entire SVFUDS minus the OU-2, OU-3, and OU-4 areas), was designated as OU-5.

1.6.2.3.1 OU-4 and OU-5 EE/CA

The soils of both OU-4 and OU-5 were characterized for arsenic under an EE/CA, which addressed the findings of the OU-4 and OU-5 investigations described above. Arsenic was identified as the primary contaminant of concern resulting from past DoD activities (it is a breakdown product of Lewisite and other arsenicals used during the AUES operations). In addition, selected CWM compounds were also sampled based on a property's historical usage and proximity to POIs where CWM testing occurred. Sampling began in 2001 in OU-5. For each residential property or commercial lot, if the initial arsenic screening composite results were above 12.6 milligrams per kilogram (mg/kg), indicating the possible presence of arsenic above the 20 mg/kg arsenic removal goal, additional grid sampling was performed to characterize and delineate the areas of elevated arsenic concentrations (USACE, 2003b). (Section 7.4.1 describes the development of the 20 mg/kg arsenic removal goal.) A total of 151 properties were identified with one or more grids with arsenic concentrations above this goal.

1.6.2.3.2 Evaluation Document Sampling

To develop a strategy to evaluate the need for data gap sampling and to integrate multiple sources of information into a cohesive plan, USACE convened a meeting of key SVFUDS stakeholders on February 4, 2010, and presented a Position Paper that outlined a path forward for resolving these issues. The stakeholders included the Partners, RAB TAPP, and AU. The *Final Evaluation Document* (USACE, 2012c) provided the plan for supplemental sampling to fill identified data gaps and ensure that areas were fully characterized to support conclusions about potential human health risks. The sampling was based on the recommendations in the AOI Memoranda that summarized possible historical AUES impacts not addressed in ongoing investigations, or possible data gaps, and made recommendations regarding whether any additional investigation was necessary. The Evaluation Document sampling was primarily completed in 2012. However, it also includes AOI 8 and AOI 11 sampling, some of which was completed as early as 2009.

Another objective of the Evaluation Document was to ensure that samples from other sampling events would be integrated into a complete SVFUDS picture.

1.6.2.3.3 Groundwater Study

Localized groundwater sampling was conducted as part of the OSR FUDS RI in 1993, but the groundwater data were not suggestive of contamination at that time. USEPA took a groundwater sample from a drain line entering the C&O Canal. This sample contained perchlorate, initiating a Partners' discussion of the need for groundwater sampling. The study of SVFUDS groundwater essentially began with completion of the *Spring Valley FUDS Groundwater Study Work Management Plan* (USACE, 2005f). The installation of five piezometers to measure the water table elevation had been conducted earlier in 2004, but the plan for the comprehensive study of groundwater and the procedures to complete these characterization activities, was provided in that Work Management Plan. Since 2005, over 50 monitoring wells, including three deep bedrock wells, have been sampled at least once as part of the SVFUDS groundwater study.

The groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

Table 1-4 lists some of the key reports for the follow-on investigation and characterization of the SVFUDS; these are the basis of the nature and extent analysis presented in Section 5.2.

Table 1-4. Follow-on Investigation and Characterization Key Documents

Date / Title	Description	Section 5.0 Ref.
2000 / Engineering Evaluation/Cost Analysis - 4801, 4825, and 4835 Glenbrook Road	Report on the results of soil sampling performed at the three subject Glenbrook Road properties.	5.2.1.1
2005 / Site-Specific Anomaly Removal Report 4801 Glenbrook Road	Report on the results of the Pit 1 and 2 investigation at 4801 Glenbrook Road	
2006 / Post Removal Action Report. Non-Time Critical Removal Action for 4801 Glenbrook Road	Report on the NTCRA performed at 4801 Glenbrook Road in 2000-2001	
2011 / Property Closeout Report for 4801 Glenbrook Road	Report on removal conducted in conjunction with adjacent property (4825)	
2013 / Site-Specific Investigation Report – 4835 Glenbrook Road	Report on the TP investigations and soil removal at 4835 Glenbrook Road	5.2.1.2
2000 / USEPA HHRA for AU Property, OU-3	USEPA's HHRA for AU	5.2.2.1
2003 / Post Removal Action Report – Time Critical Removal Action for AU Child Development Center	Report on the completion of the TCRA at the AU CDC	5.2.2.2
2004 / Site Specific Removal Report Small Disposal Area	Report on SDA investigation	5.2.2.3
2005 / Site Specific Anomaly Removal Report AU Lots	Report on the investigation of anomalies at AU Lots	5.2.2.4
2010 / Post Removal Action Report - Time Critical Removal Action (TCRA) for AU Athletic Fields and Other Critical AU Lots	Report on the TCRA performed at AU intramural fields and other lots	
2008 / Parameters Report for Development of the AUES List of Chemicals	Developed the list of analytical parameters to be analyzed	5.2 and 3.3.1.3
2008 / Site Specific Anomaly Investigation Report AU Lot 18	Report of the anomaly investigation performed at AU Lot 18	5.2.2.5
2013 / Site-Specific Investigation Report – AU Public Safety Building (Phase 1 and Phase 2 Investigations)	Report on the AU PSB investigation	5.2.2.6

Table 1-4. Follow-on Investigation and Characterization Key Documents

Date / Title	Description	Section 5.0 Ref.
2012 / Report of Sampling Results, AU Area G Ground Scar	Report on the sampling investigation of AU Ground scar G	5.2.2.7
2011 / Ground Disturbances Site Inspection Report for AU	Report on the anomaly investigations at AU Lots 3 and 11, and parking lot east of Nebraska Avenue	
2004 / Indoor Air Sampling Report for 5065 Sedgwick Street	Report on both phases of indoor air sampling at 5065 Sedgwick Street	5.2.2.8
2006 / Basement Sub-Slab Soil Gas Sampling Report - 4621 and 4625 Rockwood Parkway	Report on the sub-slab soil gas investigation at two properties	5.2.2.9
2003 / Engineering Evaluation / Cost Analysis for Arsenic in Soil	OU-4 and OU-5 EE/CA	5.2.3.1
2012 / Final Evaluation of Remaining Sampling Requirements, Spring Valley FUDS	Evaluation document for data gap sampling	5.2.3.2

1.6.3 Geophysical Investigations

While the focus of these discussions is the geophysical aspect of the investigations performed, many of these individual areas may also have been discussed in the previous section. Since geophysical surveys were often the only investigation performed, a separate discussion is warranted. However, for the larger areas such as AU, where multiple investigation activities were conducted, there is some overlap in these discussions. In addition, for the earlier investigations, such as the OSR FUDS or the OU-3 Glenbrook properties, the geophysical activities were not separated from the investigation and characterization activities; those are addressed in Sections 1.6.1 or 1.6.2.

1.6.3.1 Residential

Geophysical investigations were conducted on 99 residential properties between 1998 and 2011. Properties were prioritized for investigation as a result of an evaluation of all properties within the SVFUDS using the following criteria: USEPA EPIC features, arsenic sampling results, year of the initial EPIC feature identification, cut and fill impacts, and other consideration such as previous geophysical investigation results, POI descriptions, or resident concerns (USACE, 2001). These are explained in detail in Section 4.1.2.4.

The investigations were conducted in two phases: properties were first non-intrusively geophysically surveyed to identify buried metallic anomalies. Following analysis of the geophysical survey results by the Partners' Anomaly Review Board (ARB), intrusive investigations of metallic anomalies with characteristics of possible buried WWI munition items were conducted. Anomaly investigations were completed at all planned residential properties except one, where access was not granted by the home owner (USACE, 2003-2012).

1.6.3.2 American University

Several geophysical investigation efforts have been conducted on approximately 12 acres of the AU campus including areas around the AU intramural athletic fields, Watkins Hall, Kreeger Hall, the Bamboo Area, and the Kreeger Music Roadway. These are discussed in the sections below. For some of the larger efforts, such as OU-4 AU Lot 18, the geophysical investigation activities are included in the Section 1.6.2.2 discussions.

1.6.3.2.1 Athletic Fields

From November 2002 to June 2003, 48 grids with one or more low probability anomalies were investigated in the AU intramural athletic field. In September 2002, while conducting the TCRA investigation at the Athletic Fields, glassware was uncovered during the lateral extension of a grid and the anomaly was investigated under high probability protocols (engineering controls) in December 2002 and January 2003. A geophysical investigation of the adjacent CDC and Watkins Hall area was requested by AU, and seven grids containing anomalies were investigated in June 2003 (USACE, 2005e).

1.6.3.2.2 Bamboo Area

The AU Bamboo Area is located adjacent to the OU-4 AU Lot 18 and the SDA. AUES-related items had been recovered from Lot 18 and laboratory artifacts had been recovered from the SDA. Additionally, analyses of 1918, 1922, 1927, and 1928 historical aerial photographs showed evidence of ground scars stretching across much of this property. Based on these factors, USACE concluded that there was a remote possibility that items associated with the AUES may remain in the vicinity of this area and, consequently, decided to conduct a geophysical investigation of the Bamboo Area (USACE, 2006b).

1.6.3.2.3 Kreeger Hall Area

Ground scarring and disturbed vegetation were also indicated on aerial photographs of the AU Kreeger Hall area. The first of two investigations in the vicinity of Kreeger Hall was performed in 2006 when 2 anomalous areas and 17 single point geophysical anomalies were intrusively investigated. The 2006 investigation was situated along the south side of the Kreeger building near 4801 Glenbrook Road and Lot 18 (USACE, 2007e). In May 2011, a geophysical survey was conducted at the Kreeger Hall area to locate and map anomalies (USACE, 2012d).

1.6.3.3 Dalecarlia Woods

Munitions investigations were also completed on approximately 60 acres of District of Columbia and federal property located in the western edge of the SVFUDS, just east of the Dalecarlia Reservoir, using the same geophysical survey approach employed for the residential investigations. The investigations encompassed two AOIs and the terminus of the AUES firing Range Fan for Livens projectiles (USACE, 2011c, USACE, 2011d, and USACE, 2012a).

Table 1-5 lists some of the key reports for the geophysical investigations; these are the basis of the nature and extent analysis presented in Section 5.3. Note that for the 99 residential properties where these investigations were conducted, only the 24 investigations that resulted in MD being found are included in the table.

Table 1-5. Geophysical Investigations Key Documents

Date / Title	Description	Section 5.0 Ref.
Multiple Residential Property Site Specific Anomaly Investigation Reports:		5.3.1
2006 / Site Specific Anomaly Investigation Report for Anomalies at Nine Properties on Sedgwick Street, Quebec Street, 52nd Street, Fordham Road, 49th Street, and Warren Street	Report on investigations at 9 properties including 4 where MD was recovered	
2005 / Site Specific Anomaly Investigation Report for Anomalies at Seven Properties on Sedgwick Street, Woodway Lane, and 48th Street	Report on investigations at 7 properties including 2 where MD was recovered	
Individual Residential Property Site Specific Anomaly Investigation Reports:		
2011 / 3822 Fordham Road	Report on anomaly investigation	5.3.1
2012 / 3949 52nd Street	Report on anomaly investigation	
2013 / 4835 Glenbrook Road	Included with Table 1-4 discussions	
2011 / 4703 Woodway Lane	Report on anomaly investigation	
2011 / 4710 Woodway Lane	Report on anomaly investigation	
2006 / Property Closeout Report for 4710 Quebec Street	Report on soil removal at 4710 Quebec Street during which MD was recovered	
2010 / 4720 Quebec Street	Report on anomaly investigation	
2011 / 4740 Quebec Street	Report on anomaly investigation	
2012 / 4900 Quebec Street	Report on anomaly investigation	
1998 / Final Remedial Investigation Evaluation Report	Report of 3" Stokes mortar find at 5010 Sedgwick in 1996	
2010 / 5010 Sedgwick Street	Report on anomaly investigation (no MD found, but see above for 1996 find)	
2011 / 5024 Sedgwick Street	Report on anomaly investigation	
2010 / 5027 Sedgwick Street	Report on anomaly investigation	
2011 / 5036 Sedgwick Street	Report on anomaly investigation	
2010 / 5041 Sedgwick Street	Report on anomaly investigation	
2010 / 5047 Sedgwick Street	Report on anomaly investigation	
2010 / 5053 Sedgwick Street	Report on anomaly investigation	
2003 / 5058 Sedgwick Street	Report on anomaly investigation	
2010 / 5100 Tilden Street	Report on anomaly investigation	
AU Site Specific Anomaly Investigation Reports:		5.3.2
2005 / AU Lots	Report on anomaly investigation (also in Table 1-4)	
2006 / AU Bamboo Area	Report on anomaly investigation	
2007 / AU Kreeger Hall Anomalies	Kreeger Hall anomalies, Bamboo Area	
2012 / AU Kreeger Hall	Report of anomaly and trench investigation	
2013 / AU PSB, Phases 1 and 2	PSB included with discussions of activities addressed in Table 1-4 documents	5.2.2.6
Dalecarlia Woods Investigation Reports:		5.3.3
2011 / Geophysical Investigation Report for Grids G4, H4, I4, H5, and I5, and Grids G6, H6, I6, and G7 (separate report)	Report on geophysical investigations in Dalecarlia Woods where MD was found	
2012 / Investigation of Anomalies Report for Dalecarlia Woods Area	Report on anomaly investigation	

1.6.4 Removal Actions

Concurrent with ongoing SVFUDS investigations, for specific areas, it was determined that a removal action was warranted. Removal actions are typically completed as TCRA or NTCRAs.

A TCRA is a response to a release or threat of release that poses such a risk to public health (serious injury or death), or the environment, that clean up or stabilization actions must be initiated within six months. An NTCRA is conducted when a removal action is appropriate and a planning period of at least six months is available before on-site activities must begin. The NCP requires an EE/CA for all NTCRAs.

For the SVFUDS, these were primarily excavations of arsenic contaminated soil. The following discussions describe removal actions conducted within the SVFUDS.

1.6.4.1 TCRA

1.6.4.1.1 AU Child Development Center

As a result of the 1999 sampling efforts previously discussed, nine properties and several lots on the AU campus were recommended for further detailed sampling including the AU CDC. This sampling identified levels of arsenic above USEPA screening levels and natural background levels. AU officials relocated the CDC to another area of the campus and USACE performed a TCRA for the arsenic contaminated soil. The TCRA, which resulted in removal of 1,064 cubic yards of soil from the CDC, was completed in November 2001 (USACE, 2003a).

1.6.4.1.2 AU Athletic Fields and other AU Lots

As a result of the OU-4 and OU-5 EE/CA sampling, a TCRA was performed to address arsenic contaminated soil at the AU athletic fields, and other critical AU Lots within OU-4. The AU Lots TCRA included removal of arsenic contaminated soil from grids located in the athletic fields (OU-4 AU Lots 8, 10, 11, 13, 14, and 15); grids in OU-4 AU Lot 12 outside the fencing of the CDC; grids related to soil borings in OU-4 AU Lots 16, 19, and 23; grids located in the vicinity of Watkins Hall; grids in AU Lot 18; and grids in the vicinity of Kreeger Hall (USACE, 2010a). The TCRA activities took place concurrently with the larger AU Lot 18 investigation (USACE, 2008b) that involved high probability protocols; Lot 18 is addressed separately under investigation/characterization discussions rather than under removal actions.

1.6.4.1.3 Residential

USACE determined that TCRAs to address arsenic contaminated soil would also be performed at several residential properties. The prioritization of these properties was based on the results of the arsenic testing. An Exposure Point Concentration (EPC), derived from the 95 percent Upper Confidence Limit of the grid arsenic data, was used as the primary prioritization strategy. Other factors used to prioritize removals included access agreements and proximity logistics, where otherwise lower priority sites close to high priority sites were also scheduled (USACE, 2003c). Tier I properties had EPCs greater than or equal to 90 mg/kg arsenic. Tier II properties had at least one grid greater than or equal to 150 mg/kg arsenic. This work began in July 2002 (USACE, 2004b). The individual properties are listed in Section 5.4.1.

1.6.4.2 NTCRA

USACE conducted 100 removal actions as NTCRAs to address arsenic contaminated soil (USACE, 2004-2013). An NTCRA is conducted when a removal action is appropriate and a planning period of at least six months is available before on-site activities must begin. The OU-4 and OU-5 EE/CA was the document that recommended the NTCRAs for these properties. The NTCRAs were completed in January 2012, except one property where access was not granted. The individual properties are listed in Section 5.4.2.1.

An NTCRA was also employed to address MEC/CWM recovered from ongoing investigations at the SVFUDS. An EE/CA was developed in 2010 to evaluate alternatives for removal of MEC/CWM from storage at the SVFUDS as well as any MEC/CWM recovered during future SVFUDS activities. The specific items addressed in the EE/CA are listed in Section 5.4.2.2.

1.6.4.3 Phytoremediation

While soil removal was the primary removal action method, for selected properties, USACE also used a non-intrusive remedial alternative using ferns that naturally extract arsenic from soil. This process, known as phytoremediation, was used to fully or partially address approximately 20 properties (USACE, 2007a; 2007b, 2007c, 2008c, 2009b, 2011e). Phytoremediation was completed in September 2008. The individual properties are listed in Section 5.4.3.

1.6.4.4 4825 Glenbrook Road

Following site shut down in 2002 due to property access issues, USACE negotiated access with the new property owner, AU, and began planning to return to the property to continue the investigation. Starting in October 2007, the high probability investigation known as Burial Pit 3 was conducted. In addition to the high probability Burial Pit 3 investigation, test pits were also excavated under low probability protocols and three test pits were excavated under high probability protocols. A total of 22 munition items, 6 CWM items, and 80 MD items were recovered during the Burial Pit 3 investigation. Overall, AUES-related waste, including more than 500 munition items, 400 pounds of laboratory glassware and 100 tons of contaminated soil, have been recovered and safely removed from the property during investigations from 2000-2002 and then again from 2007-2010.

In August 2010, several organizations within the DoD as well as the Partners, made the decision to separate the 4825 Glenbrook Road property from the remainder of the SVFUDS and place it on its own CERCLA process pathway. Accordingly, 4825 Glenbrook Road investigation activities are summarized in this RI to provide context for investigations conducted in the vicinity of 4825 Glenbrook Road.

Table 1-6 lists some of the key reports for the removal actions; these are the basis of the nature and extent analysis presented in Section 5.4.

Table 1-6. Removal Actions Key Documents

Date / Title	Description	Section 5.0 Ref.
1996 / Remedial Investigation Report for Spaulding and Captain Rankin Areas	Report on NTCRA for POIs 21 and 23 (included in Table 1-3 discussions)	5.1.2
2006 / Post Removal Action Report Non-Time Critical Removal Action 4801 Glenbrook Road	Report on NTCRA for 4801 Glenbrook Road (included with discussion of reports in Table 1-4)	5.2.1.1
2011 / Property Closeout Report for 4801 Glenbrook Road	Report on removal conducted in conjunction with adjacent property (included with discussion of reports in Table 1-4)	5.2.1.1
2003 / Post Removal Action Report – Time Critical Removal Action for Child Development Center	Report on the completion of the TCRA at the AU CDC.	5.4.1.1
2010 / Post Removal Action Report: Time Critical Removal Action (TCRA) – AU Athletic Fields and Other Critical AU Lots	Report on TCRA at AU Athletic Fields and other Critical Lots (not including Lot 18 which is covered in Table 1-4)	5.4.1.2
2003 / 2004 -Post Time Critical Removal Action, Arsenic Contaminated Properties (Tier I and II)	Report on completion of TCRA at Residential Properties (2 reports)	5.4.1.3
2004-2013 / Property Closeout Reports for Residential NTCRA Properties and Lots	Reports on residential NTCRA properties and lots (Individual report references included in Section 9)	5.4.2.1
2010 / Munitions Disposal EE/CA	EE/CA for disposal of recovered and potential future recovered munitions	5.4.2.1
2007 / Arsenic Phytoextraction Laboratory Feasibility Study: 2004 Final Report	Report on laboratory feasibility study.	5.4.3
2007 / Arsenic Phyto Study: 2004 Final Report	Report on 3 lots/properties in Phase 1	
2007 / Arsenic Phyto Study: 2005 Final Report	Report on 11 lots/properties in Phase 2	
2008 / Arsenic Phyto Study: 2006 Final Report	Report on 14 lots/properties in Phase 3	
2009 / Arsenic Phyto Study: 2007 Final Report	Report on 6 lots/properties in Phase 4	
2011 / Arsenic Phyto Study: 2008 Final Report	Report on 3 lots/properties in Phase 5	

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2.0 PHYSICAL CHARACTERISTICS OF THE STUDY AREA

2.1 Surface Features

The physical characteristics and surface features of the SVFUDS reflect an important aspect of modernization and development as circa 1918 farm fields and woodlands were transformed into commercial areas and stately private residences. The importance of some of the physical elements of the SVFUDS, and the tools used to support and plan investigation and characterization activities, are discussed below.

2.1.1 Geographic Information System (GIS) Usage

A geographic information system (GIS) is a computer-based system designed to store, manipulate, analyze, and visualize data pertaining to a wide variety of topics. The following discussions describe the general qualities and mechanics of a GIS, how the SVFUDS GIS was built, and how it was used to help characterize the SVFUDS.

A GIS ranges from small-scale, focused on a specific location or narrow topic, to large-scale and collaborative (with access to various datasets created by multiple organizations and agencies). These data are stored spatially (for example, the Washington, DC boundary) and in a tabular format (for example, the population, area, perimeter length, and other attributes associated with the DC boundary). Spatial data can be obtained from existing data sources and/or collected using a global positioning system (GPS) hardware/software and then uploaded into the GIS. Spatial data can also be added manually, by georeferencing aerial photographs or drawings to ensure that their details match known locations as closely as possible, and then digitizing the desired features so they can be visualized and analyzed within the GIS. Tabular data can be entered into the attribute table associated with the spatial features. Accuracy and precision of the GIS data generally depend on the quality of the GPS, if applicable, the quality of the historical sources such as hand-drawn maps that need to be georeferenced, and the skill of the GIS user when importing the new information into the GIS database (Esri, 2011).

The final product of a GIS is a powerful investigative tool that can be interactive, such as choosing the visibility and extent of layers in publically-available transportation and weather mapping services, static, such as published hard-copy maps, or a combination of both. The GIS database can be queried to obtain specific subsets of available information (for example, the number of residential properties that lie completely or partially within a selected POI or AOI). GIS databases are usually maintained and updated with additional information as it becomes available, so that any queries and published products reflect current data.

GIS capabilities have been used on the SVFUDS project as a tool to digitally record and visualize the locations of historical and present-day features, and to assist with site investigations and removal efforts. Key GIS layers containing spatial features and attribute tables include, but are not limited to: the SVFUDS boundary, parcels, buildings, arsenic grids, soil borings, monitoring wells, cut and fill contours, the Range Fan, AOIs, POIs, historical AUES buildings, and historical ground scars. These key features were typically digitized using aerial photography, and hand-drawn maps as necessary, and in some cases they were updated using more accurate field survey data or existing GIS data layers from outside sources when available. For example, current footprints of buildings within the SVFUDS and associated site layout features were digitized from the 2000 Aerial Photo and refined using field survey data. Historical AUES buildings were digitized from the 1918 aerial photomosaic as well as from the

AUES facility plat map prepared in 1918. The GIS was continually updated with field survey data, including horizontal and vertical location coordinates of soil borings and samples, geophysical anomalies, monitoring well locations, etc.

Over time, the role of GIS evolved from basic cartography (mapping) to more advanced spatial analysis to fit the needs of the project. Eventually the geodatabase structure was updated to follow the evolution of GIS technology and spatial data standards, which maximized data storage and accessibility for GIS personnel including those who were unfamiliar with the project. The SVFUDS geodatabase and complementary data sources (such as historic aerial photographs and geophysical mapping images) continue to be maintained during development of this Site-Wide RI and are expected to be updated as necessary throughout the life of the project.

GIS served an important role in the soil sampling process at SVFUDS residential properties. GIS was utilized to generate random sampling points; provide data to, and incorporate data from, the surveyor; prepare sampling work plan maps; prepare field sampling team maps; keep track of each right-of-entry granted by property owners; and keep track of and visually display the status and results of all sampling efforts. During comprehensive soil sampling in OU-5, GIS was used to create a mapping service available on the Spring Valley project website, where residents were able to view information specific to their property and their immediate neighborhood. Additionally, USACE and their contractor, Parsons, were able to internally view the most recent sampling results via the mapping service, prior to validating and making the data accessible to the public.

GIS data were utilized to support more recent soil and groundwater sampling efforts, develop soil cut and fill layers (see Section 2.1.1.3), conduct historical photographic analyses of AUES-related activities, perform footprint analysis to identify areas of likely contamination, and prioritize geophysical investigations to focus on areas most likely to contain AUES-related items (see Section 4.1.2.3). Dynamic GIS mapping during project-related meetings allowed Partnering and RAB participants to view data layers and details pertinent to the meeting presentations, thus enhancing communication between USACE and the public. The GIS software was also used to perform various database management tasks, including standardizing, customizing, and automating, as much as possible, the process of creating and managing data layers and maps.

2.1.2 Ground Scars

Ground scar maps have been developed through the GIS and used on the SVFUDS project as a tool to help identify areas impacted by AUES activities. Ground scars were also used as a tool to determine locations for soil borings and as a tool to prioritize properties for geophysical investigations. Ground scars were a key part of the classification scheme to select geophysical anomalies for further investigation (See Section 4.1.2.3 and Section 4.1.2.4 regarding geophysical prioritization and classification schemes). Section 1.4.4 describes the 1986 USEPA EPIC report (USEPA, 1986b) that provided photogrammetric analysis of SVFUDS ground scars. These ground scars are visible in a series of historic aerial photographs taken over a period of several years from 1918 to 1928. Ground scars are defined as areas of bare soil that may have resulted from human activity, and which could potentially indicate areas of environmental significance such as contaminated soil or burial pits because vegetation often cannot thrive in such areas.

Ground scars may only be present in one aerial photograph, or in several consecutive aerial photographs taken over time, allowing for evaluation of their possible cause through association with the timeframe of known site activities. Some of the prominent ground scars were the primary defining feature basis of an AOI or POI. A large number of POIs were developed based on the USEPA EPIC analysis of ground scars. Proper location of these ground scar locations was important and many efforts were undertaken to maximize their accuracy, as newer computer technology became available.

Ground scar spatial analyses were originally conducted by hand until GIS was introduced as a more efficient method. Initial ground scar analyses were conducted by USEPA using a series of three historic aerial photographs (1918, 1927, and 1937) with results published in the 1986 EPIC report. This was followed by a revised analysis using the original three photographs plus an additional four aerials (1922, 1928, 1936, and 1940) with results published in May 2001 (USACE, 2009c). Ultimately, because the three latest dated aerials contained no more evidence of ground scars, they were not used further, and ground scar analyses were based on interpretation of the four historic aerial photographs from 1918, 1922, 1927, and 1928 (USACE, 2009c). Figure 2-1 presents an example of these four sets of ground scars on a selected portion of the SVFUDS.

During 2000 and 2001, the USEPA EPIC branch conducted an in-depth analysis of these four historic aerial photographs, and they created a total of eight GIS layers (four ground scar layers and four stressed vegetation layers) categorized by the year of the first aerial photograph in which these features are visible. All ground scar data were processed from hard copy to electronic format by US Geological Survey (USGS) in July 2001, and the resulting data (along with the four historic aerial photographs) were incorporated into the SVFUDS GIS database in November 2001. Although the ground scar outlines were georeferenced and fully converted to electronic format, several limitations could not be fully addressed at that time. These limitations included limited software capabilities, relatively poor quality aerial photographs as the source material, relatively limited reference points for ensuring all features lined up correctly, and the separation of each aerial into four sections for the purpose of localizing and limiting any errors (USACE, 2009c).

Revised ground scars were generated by USACE in 2009 to address any inaccuracies that may have been present in the SVFUDS GIS database layers. Adjustments to the ground scars were made to reduce misalignments between the historic aerials, modern aerials, and present-day geographical features such as roads and building footprints. Duplicate ground scars were eliminated to ensure each individual ground scar was represented by only a single feature in the database. Any ground scars that were split along the edges of separate aerial sections were merged or rejoined to maximize accuracy. These revisions were conducted using updated GIS software (ArcGIS 9.2 georeferencing and editor tools). Each historic aerial was re-referenced, using a series of control points to match specific locations on the historic aerial with their corresponding locations on the modern aerial (and current GIS data), with immediate visual feedback allowing the user to verify that the historic and modern sources matched up correctly. These re-referenced historic aerials were then used as the source for realigning each ground scar in the SVFUDS GIS database.

During this ground scar revision process, the historic aerials were not reinterpreted and thus no additional ground scars were identified or added to the SVFUDS GIS database, but some existing ground scar shapes were modified, either shortened or elongated, to better reflect the realigned aerial photographs (USACE, 2009c). Depending on the aerial, ground scar locations shifted in varying degrees from their original positioning. Ground scars in the 1918 aerial shifted an average of 25 feet from the original position. Ground scars in the 1922 aerial shifted an average of 75 feet. Ground scars in the 1927 aerial shifted an average of 18 feet, and ground scars in the 1928 aerial shifted an average of 45 feet from the original position. (USACE, 2009c). Based on GIS software statistical calculations of realignment errors, the 1918, 1927, and 1928 historic aerials are considered to be fairly consistently and more accurately positioned in relation to each other, while the 1922 aerial was more difficult to georeference. According to the 2001 USEPA EPIC report, the 1922 aerial includes imperfections such as seams, created when the 1922 mosaic image was originally compiled from many smaller aerial photographs, cracks caused by physical imperfections in the camera film, and cartographic anomalies, creating some problems with regard to accurate location data. Ground scars in these problem areas were adjusted as necessary to minimize any inaccuracies. Overall, this realignment effort resulted in a more consistent agreement between historic aerials (i.e., a ground scar present in more than one year of aerials, if previously not overlapping with its respective location in other years of aerials, shifted closer to or shifted to overlap with its respective location in other years of aerials), modern aerials, and the GIS data that represent real world features within the SVFUDS (USACE, 2009c).

2.1.3 Cut and Fill

Cut and fill contour maps have been developed and used on the SVFUDS project as a tool to help determine whether topography has changed relative to AUES (circa 1918) conditions. The cut and fill contour map indicates areas of cut (or soil removed relative to what was present in 1918), areas of fill (or soil added relative to what was present in 1918), and level areas (no change relative to the 1918 topography).

USACE used cut and fill maps to determine whether a given area had already had soil removed or added (for whatever reason) and an approximate depth. This was an invaluable tool to help determine for example, whether a burial pit might be located in a certain area. That is, if good cut and fill data showed that the present soil elevation was 12 feet below what it was circa 1918, it was highly unlikely that a burial pit could exist beneath the soil, as 12 feet had already been removed. Conversely, if 12 feet of fill was shown to be present in an area, USACE did not need to apply resources investigating that 12 foot thick layer as it was placed sometime after circa 1918 AUES activities; in such a case USACE acknowledged that a burial pit could still exist there but that it would have to go through 12 feet of fill to find it; this helped determine the proper investigative techniques to use in the situation.

Cut and fill maps were generated by USACE for the 1995 OSR FUDS RI by merging 1917 USGS and 1983 USGS topographic maps. The 1983 topographic map was based on elevation data revised by USGS in 1965. The process involved digitizing the maps and then horizontally aligning them by using features common to both maps (e.g. roads, street intersections, and buildings). The vertical alignment was performed by digitally correcting the scale followed by a comparison of the contour lines. Vertical alignment was also confirmed by identifying two peak elevations with no apparent changes between 1918 and 1991.

In 2000, as additional investigative work was being planned, including site-wide sampling of the SVFUDS, it was necessary to update the cut and fill contours. The cut and fill map was improved considerably by updating the contours and using better computer technology to merge and recalibrate the topographical maps. Specifically, an aerial survey of the entire SVFUDS was conducted in November 2000 to update information provided by USGS in the previous most recent study, their 1983 topographic survey. USACE aerial survey provided updated 2-foot elevation contour intervals. A new cut and fill map was then generated using the same procedures discussed above, but based on the new contour intervals. To complete this map, it was also necessary to make a vertical adjustment based on different datums used at different times. The original 1917 map used the Sandy Point Datum, but in 1929 a general vertical adjustment was made (National Geodetic Vertical Datum NGVD29). In 1988, another vertical adjustment was made (North American Vertical Datum NAVD88). Note that these adjustments were not specific to the SVFUDS, but rather were National Geodetic Survey (NGS) activities that applied to the entire North American continent. The net result was an adjustment of +1.27 feet. That is, 1.27 feet was added to the 1917 contour elevation data to make the 1917 and 2000 map comparisons for the new SVFUDS cut and fill map.

The new version of the cut and fill map was more accurate than the previous version because of the 2-foot elevation contour interval obtained (relative to the 10-foot intervals provided in the 1983 topographical map) and the interpolation program used through GIS (set up on 5 foot by 5 foot grids covering the entire site) to compare the contours from the 1917 map to the new 2000 contours. The GIS set up 5 foot by 5 foot grids across the entire SVFUDS to perform a detailed interpolation of old and new contours to determine cut and fill areas.

Figure 2-2 presents an example of the cut and fill contours placed over a portion of the SVFUDS. The contours are color coded such, relative to circa 1918, blue indicates areas of fill, red indicates areas of cut, and green indicates areas of no change.

With regard to the accuracy and sources for the updated cut and fill map developed, Appendix B provides a September 2005 Technical Memorandum prepared by USACE. It provides detail and figures to support the descriptions in this discussion. As described above, the original map source used as the baseline of topography prior to AUES activities within Spring Valley was the 1917 USGS topographic map. This map was compared to the 2000 contours to determine which areas had been cut, filled, or unchanged since 1918, meaning that the accuracy of the 1917 USGS map is the limiting factor in the overall accuracy of the cut and fill maps produced from it.

National Map Accuracy Standards were formalized in 1941. However, the USGS indicates that the standards used as early as 1912 were essentially the same as those formalized in 1941, and that maps will be more accurate in a well-developed area because there are more points of reference available. For the Washington, DC area, the additional points of reference are National Geodetic Benchmarks. These benchmarks are extremely accurate and are therefore used by USGS as the first point of reference when creating elevation contours. A calculation made by GIS personnel using information derived from the NGS website suggests the horizontal error associated with these benchmarks would be less than 3 feet, and the vertical error would be less than 1-inch. Given the high accuracy of the benchmarks used as the starting points for the 1917 map, its vertical accuracy is likely much better than the +/- 5 feet vertical accuracy default cited for topographical maps.

USACE further checked the accuracy of the cut and fill maps by correlating what has been observed at the site by field personnel with what the cut and fill map predicts in terms of 1918 surface conditions. Subsurface soil borings collected as part of the 2003 OU-4/OU-5 EE/CA sampling effort were taken at the 1918 soil horizon. The cut and fill maps were used to predict the depth to the 1918 soil horizon at the boring location. The field geologist evaluated the lithology of the soil core and assessed fill versus native soil and whether the predicted depth represented the 1918 level. Results for 25 randomly selected borings indicated that, on average, the difference between the predicted and the actual 1918 soil horizon was less than 3 feet.

It is important to note that the cut and fill map was never used as a standalone decision-making tool. Rather, cut and fill data were used to supplement other information such as documented site history, field conditions, and sampling results, prior to making key project decisions.

The above discussions describe the process for identifying whether a specific area had soil removed or added relative to the 1918 timeframe. The important issue of the source of the soil used for fill (i.e., whether AUES-impacted soil could have been removed from one corner of the SVFUDS and used as fill in another), or the final location of soil removed from the SVFUDS (i.e., whether AUES-impacted soil was removed from the SVFUDS and placed in areas outside of the SVFUDS) is discussed in the specific investigations and findings in other sections of this RI, when such information is known. However, it is extremely difficult (certainly prior to initial 1993 investigations) to find useful records of the transport of soil out of the Spring Valley area over the almost 100 years since AUES activities, or specific records of volumes of soil moved from one portion of the neighborhood to help build another portion.

2.2 Environmental Setting

2.2.1 Meteorology

Washington, D.C. is in the humid subtropical climate zone and exhibits four distinct seasons. Its climate is typical of Mid-Atlantic U.S. areas removed from bodies of water. The Washington, D.C. area has an average yearly temperature of 54.5°F. The climate is classified as modified continental. (Weatherwise, 2014).

Spring and fall are warm. Winters are cold but mild with averages in the high 30s °F to low 40s F, with seasonal snowfall averaging just over 17 inches. In the winter, blizzards affect Washington on average once every four to six years. The coldest average daily temperatures are in late January and early February (upper 20s °F). Summers are warm and humid and Washington is popularly known for being one of the hotter cities on the East Coast in summer. The warmest average daily temperatures are in mid-July (upper 80s °F) with an average daily relative humidity around 66%. The combination of heat and humidity in the summer brings very frequent thunderstorms, some of which occasionally produce tornadoes in the area. Remnants of hurricanes periodically track through the area in late summer and early fall, but are often of low intensity partly due to the city's inland location.

Rainfall distribution is nearly uniform throughout the year. The annual precipitation for the area is 39 inches per year. However, flooding of the Potomac River, caused by high tides, storm surge, and or runoff, has caused extensive property damage in low lying parts of the city (Weatherwise, 2014).

2.2.2 Surface Water Hydrology

Located within the Little Falls Watershed, surface water in the vicinity of Spring Valley consists of intermittent streams that flow generally to the west. The District of Columbia’s water supply comes from the Potomac River and is provided by the WA. The intakes for the Potomac River, located at Great Falls and Little Falls, are upstream of the SVFUDS and water is treated either at the McMillan plant or Dalecarlia plant. The Dalecarlia Reservoir, which supplies the Dalecarlia plant, and provides drinking water to more than 600,000 residents, lies just outside the western SVFUDS boundary (Moeller, 2007).

2.2.3 Geology

Four geological formations, three Piedmont and one Coastal Plain, are apparent in the vicinity of the SVFUDS. These formations (from west to east) are the Sykesville Formation, the Dalecarlia Intrusive Suite, the Actinolite Schist, and the Coastal Plain Terrace Formation (USGS, 1994). The Sykesville Formation is a sedimentary melange consisting of fragments of metagraywacke, migmatites, amphibolite, and actinolite schist in a quartzofeldspathic matrix. Weak foliation can be found throughout this formation, with a few areas showing stronger foliation. The Sykesville Formation is thought to be of Cambrian age (Drake, 1985). The Dalecarlia Intrusive Suite consists of massive to well-foliated biotite monzogranite and lesser granodiorites. Local to the SVFUDS, massive to weakly foliated muscovite trondhjemite is present (Fleming et. al., 1994). This intrusive suite is so named due to the outcrops found proximal to the Dalecarlia Reservoir (Fleming, et al, 1994).

The Actinolite Schist unit consists of actinolite schist, actinofels, actinolite-chlorite schist and lesser talc-bearing rocks. Throughout the unit, foliation and strong stretching lineation is present (Fleming et. al., 1994). The Coastal Plain Terrace Gravel consists of highly weathered, crudely bedded gravel, sand, silt, and clay (Fleming, et al, 1994). The Piedmont Formations are igneous or metamorphic in origin, while the Coastal Plain Terrace Formation is fluvial in origin (Fleming, et al, 1994). Schistosity is the major structural feature of the Piedmont rocks and saprolite in the SVFUDS vicinity.

2.2.4 Soils

Four soil associations are present within Spring Valley: the Urban Land-Sassafras Chillum (ULSC), the Urban Land-Manor Glenelg (ULMg), Manor Glenelg (Mg), and Urban Land Brandywine (ULB). The ULMg soil association is a well to moderately well drained soil resulting from the weathering of the basement rocks (schist). The ULSC soil results from the weathering of Coastal deposits. However, typically these soils have been greatly disturbed by construction and landscaping activities. As noted above, the bedrock consists of a variety of metasedimentary rocks of actinolite schist (Smith, 1976).

Most of the soils in the District of Columbia have been affected in one way or another by anthropogenic activities, resulting in the designation of an "Urban Land" soil: in many areas of the District, several feet of miscellaneous artificial fill have been placed over streams, swamps, flood plains and tidal marshes. These areas are now mostly covered with roads, buildings or other structures. Also included are areas where more than 80% of land is covered by impervious surfaces, irrespective of the presence of fill.

2.2.4.1 Saprolite

Saprolite is thoroughly decomposed parent rock formed by in-place chemical weathering. The metasedimentary bedrock weathers to a relatively competent saprolite material that is encountered at depths that range between 3 to 15 feet below ground surface (bgs). This material appears to be the transition between loose soil material and highly competent bedrock. Unaltered saprolite retains characteristics (such as foliation) that were present in the original rock from which it was derived, thus providing a strong indication that man-made activities have not impacted the layer. For this reason saprolite has been used throughout SVFUDS investigations to provide an indication of the limits of past intrusive activities. That is, field geologists can often determine that the saprolite layer in a given area has not been disturbed, and that therefore, it is unlikely that AUES intrusive activities (burial pits, penetrating munitions, etc.) occurred there. Exhibits 2-1 and 2-2 show examples of saprolite at the SVFUDS.

Exhibit 2-8. Competent Saprolite

Exhibit 2-9. USACE Geologist Examining Saprolite

2.2.5 <u>Hydrogeology</u>

The District of Columbia straddles the border of the Northern Atlantic Coastal Plain and the Piedmont aquifer systems. The Coastal Plain is characterized by gently rolling hills and is underlain by a sequence of sand and gravel aquifers with silt and clay confining units throughout. The Piedmont is characterized by more topographic relief than the Coastal Plain region. It is underlain by metamorphic and igneous rock that is overlain by unconsolidated sediments. The aquifer is in the unconsolidated sediments and extends to the bedrock beneath.

In general, the Piedmont-Blue Ridge ground water region consists of a thick mantle of weathering residuum over fractured crystalline and metamorphic rock. Weathered zones in the metamorphic rocks of the Piedmont yield small to moderate amounts of water almost anywhere, with larger-yield wells possible on fracture traces. The regolith, or unconsolidated rock and soil material overlying the bedrock, contains water in pore spaces between rock particles. Because of its larger porosity, the regolith functions as a reservoir that slowly feeds water downward into the fractures of the bedrock. The bedrock contains water in sheet-like openings formed along fractures which serve as an organized intricate network of pipelines that transmit water to springs, streams or wells. Although the hydraulic conductivities are similar to those found in the saprolite, bedrock wells generally have much larger yields because they have much larger available drawdown. The yield of bedrock wells depends on the number and size of penetrated fractures and on the replenishment of the fractures by seepage from the overlying regolith (Schneider et.al., 1993).

The deeply weathered igneous and metamorphic rocks of the Piedmont are covered by the generally unconsolidated sediments of the Coastal Plain. In general, the Coastal Plain ground water region consists of complex sequences of interbedded (alternating and inter-fingering) sand, silt and clay which were deposited in a variety of sedimentary environments that are related to sediment inputs and sea level changes. The overlap of the hard crystalline Piedmont and the softer Coastal Plain sediments define the Fall Line at Great Falls on the Potomac River, approximately 6-8 miles northwest of the SVFUDS. At the Fall Line, the sediments thin out to a few inches, thickening eastward to approximately 800 feet at the southern border of the District. They consist of unconsolidated to consolidated continental and marine sediments. The sorting and grain size of sediments, as well as the thickness and distribution of sand and clay bodies, are determined by the environment of deposition and have a significant influence on aquifer characteristics. Decreasing grain size or degree of sorting results in decreasing hydraulic conductivity values. A thick aquifer with low hydraulic conductivity may have a lower transmissivity than a thin aquifer with high hydraulic conductivity, but wells that yield moderate to large quantities of water can be constructed almost anywhere within the region (Schneider et. al., 1993).

2.2.5.1 Local Groundwater

There are various groundwater aquifer systems within the area. These include terrace gravels and fracture system aquifers associated with the Piedmont formations, saprolite systems, and fill systems. However, because of the impact of urbanization, vegetation and soils in the DC area are often of limited value in providing information on ground water (Schneider et. al., 1993).

Groundwater may be found in any and all of these aquifers, but the majority of the groundwater would be expected to be found in the underlying bedrock that comprises the fracture system aquifer. Additionally, there are a number of major fault and fold systems in the site vicinity. Groundwater has been encountered at depths ranging from approximately 6 feet to more than 50 feet below ground surface, depending on the well location. The groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

2.2.6 <u>Demography and Land Use</u>

The SVFUDS lies wholly with Washington’s Ward 3. This is a largely residential area located in the upper northwest quadrant of the city. Some of these neighborhoods developed out of the Connecticut Avenue streetcar line that connected DC with Chevy Chase in suburban Maryland. Many of the Ward 3 neighborhoods follow a similar pattern of a commercial core with local shops and restaurants, surrounded by a cluster of dense apartment buildings and/or townhouses, and spreading out into single-family homes. Spring Valley, straddling Massachusetts Avenue, follows a similar, though more single-family home-oriented, pattern.

Much of the remainder of the Ward consists of single-family homes set among tall trees and parks. Some are modest in size, while others are veritable mansions, home to some of the wealthiest DC residents and a large number of foreign ambassadorial residences. The character of these areas is more suburban in nature, with a greater concentration of cul-de-sacs than anywhere else in the city.

Land use in and around the SVFUDS is primarily low-density residential (three to four dwellings per acre). Smaller portions are zoned for commercial use. The campus of AU is considered institutional use. Zoning on site is also predominantly for single-family detached housing except on the AU Campus, which is zoned for apartments. The Dalecarlia Woods area on the western edge of the SVFUDS is zoned as Federal or public use. No changes to land use, affecting the discussions in this RI report, are projected (DC Planning, 2013).

2.2.7 Ecology

The ecological conditions at the site include both natural and semi-natural areas where ecological receptors may occur. The low-density housing throughout much of the site, in combination with landscaping that includes native species and trees, provides suitable nesting and foraging habitat for species adapted to urban environments, particularly some birds (i.e., American robins). Throughout the site, there are small woodland streams that are surrounded by native vegetation. There are approximately 5,000 total linear feet of stream in 6 or 7 discrete areas within the SVFUDS boundary. These areas, although small in size, provide habitat for ecological receptors, including birds and some mammals (i.e., raccoons), and amphibians and reptiles. To the west of the site, there is an area included in the SVFUDS boundary that is forested native vegetation. This area provides suitable habitat for a number of species, including birds, mammals (i.e., raccoons and white tailed deer), amphibians, and reptiles.

Vegetation in the area consists of deciduous hardwood forested areas, urban landscaped areas, and small streams and associated deciduous vegetation. Within the SVFUDS, no threatened, endangered, or locally sensitive species are known to occur. The species listed by the United States Fish and Wildlife Service (USFWS) that are known to occur within the area include the Hays Spring Amphipod (*Stygobromus hayi*), and the Bald Eagle (*Haliaeetus leucocephalus*). However, none of these species has been documented within the SVFUDS area.

The Screening Level Ecological Risk Assessment (SLERA), conducted to evaluate the ecological impacts of soil, sediment, surface water, and groundwater contaminants at the SVFUDS, was completed in July 2010 (USACE, 2010b). The SLERA provides significant detail on the ecology of the SVFUDS, including the findings of a biologist's site walk. The SLERA report is summarized in Section 7.8; the entire report is included as Appendix D.

3.0 REMEDIAL INVESTIGATION OBJECTIVES AND CONCEPTUAL SITE MODELS

3.1 RI Objectives

The objective of this RI is to adequately characterize the nature and extent of any potential HTW/MC/CWM contamination or MEC hazards within the SVFUDS resulting from the past DoD activities. To achieve this goal, there must be a thorough understanding of the potential risk posed by a site, a process to determine data needs, and objectives specifying the quality and level of data required to support the decision-making process. These important elements of the RI are discussed below.

3.2 Conceptual Site Models

In order to complete an RI that achieves these objectives, Conceptual Site Models (CSMs) were developed prior to each primary investigative effort. A CSM is used to communicate and describe the current state of knowledge and assumptions about risks at a project site. The CSM presents the exposure pathway analysis by integrating information on the HTW/MC/CWM and MEC source, receptors, and receptor interaction. CSMs assist a project team in designing the required environmental data collection, data interpretation, and response actions, and allow for more efficient use of resources, while ensuring that response actions are protective of human health and the environment.

Many different CSMs were developed over the years, including ones to address specific investigations as well as one, prepared by DDOE for the entire FUDS. They all contain the basic elements of a CSM as described in *USEPA's Guidance for Conducting RI/FS Under CERCLA* (USEPA, 1988): "Information on the waste sources, pathways, and receptors at a site is used to develop a conceptual understanding of the site to evaluate potential risks to human health and the environment. The conceptual site model should include known and suspected sources of contamination, types of contaminants and affected media, known and potential routes of migration, and known or potential human and environmental receptors."

CSMs present the pathway analysis that identifies all complete, potentially complete, or incomplete pathways for both current and reasonably anticipated future land uses for a site. Each pathway must include a source, a receptor, and interaction between them (access and activity). Sources are those areas where HTW/MC/CWM and/or MEC have entered the site. A receptor is an organism (human or ecological) that contacts the source. Interaction describes access and activities that facilitate receptors coming into contact with a source.

While these elements apply to HTW/MC/CWM and MEC, the threats presented by HTW/MC/CWM and MEC are different, and are differentiated by the terms "risk" and "hazard", respectively. As described in the USACE manual (EM 200-1-12), *Environmental Quality, Conceptual Site Models* (USACE, 2012e), HTW/MC/CWM are contaminants which present a risk to human health and the environment through exposures, while MEC presents a hazard of direct physical injury resulting from the blast, heat, fragmentation, or acute chemical effects of a munition or munition component. Therefore, for sites such as the SVFUDS, where both risks and hazards must be considered, CSMs are typically separated into HTW/MC/CWM based or MEC based scenarios, reflecting the key differences between the types of risks or hazards that may be present.

The sections below present site-wide CSMs, for both HTW/MC/CWM and MEC contamination, which combine elements of the many individual CSMs developed over the years. These CSMs show the primary sources, interactions, and receptors within the SVFUDS. The HTW/MC/CWM CSM was prepared in accordance with USEPA guidance, while the MEC based CSM was prepared in accordance with the EM 200-1-12.

3.2.1 HTW/MC/CWM Based CSM

Figure 3-1 presents the site-wide HTW/MC/CWM CSM for the SVFUDS. The following discussion summarizes the elements of this CSM; however, because the ultimate use of the CSM is to establish the pathway analysis that guides the quantitative HHRA, much greater detail on all the elements presented in this figure is contained in the HHRAs presented as Sections 7.2 and 7.3.

This CSM graphically depicts the source area as the SVFUDS community with the source media being the activities of the former AUES. These activities are primarily grouped by open air testing and disposal or burial. Open air testing included both chemical releases through the firing of munitions and through activities such as spraying vegetation for persistency testing of various chemicals. In addition, for some of the laboratory buildings, spills and leakage may also be a release mechanism. These are mechanisms for contaminant releases to the soil.

Two different soil exposure intervals have been evaluated. The current potential receptors were evaluated using an exposure interval of 0 to 2 feet bgs, to represent routine landscaping, gardening, and outdoor play activities. The soil exposure interval for future potential receptors includes mixed soils from 0 to 10 feet bgs, which includes the 0 to 2 foot interval to which current receptors could be exposed. This exposure interval takes into account soil mixing that may occur due to construction. Soil exposure pathways include incidental soil ingestion, dermal contact, inhalation outdoors, inhalation of vapors indoors, and home-grown vegetable ingestion. Current and future receptors include residents, outdoor workers, students (reflecting the student population at AU, and construction workers.

The CSM shows, for example, that a complete pathway exists for a resident to interact through dermal contact with contaminants released by AUES activities to surface soil. This pathway, as well as all the others depicted, was analyzed in the quantitative HHRA to determine whether risk remains on a receptor basis (see discussions in Sections 7.2 and 7.3).

In addition to the quantitative HHRAs presented in this RI, many of the previous HHRAs completed for smaller discrete areas (e.g., OU-4 AU Lot 18 or 4835 Glenbrook Road, summarized in Section 7.1.1), or the SLERA (summarized in Section 7.8), contain CSMs that show the same basic elements but which focus on sources, receptors, and interactions specific to those areas. Appendix D contains the previous HHRAs and the SLERA in their entirety.

3.2.1.1 HTW/MC/CWM CSM Application

The CSM was then compared with known activities at the AUES and Camp Leach to focus HTW/MC/CWM investigations in the SVFUDS. As noted in Section 1.5, the SVFUDS was delineated into OUs, POIs and AOIs that were used to help develop investigation efforts specific to the known previous activities. Figure 1-2 shows the property boundaries of the AUES and Camp Leach as well as the fenced in area on the AU campus. AUES and Camp Leach were used for different purposes as described in Section 1.4 and as summarized below.

Although there were concerns expressed that the Camp Leach trenches may have been used as disposal sites during closure activities, Camp Leach was used for troop training and was not involved in chemical munitions experimentation, neither open air testing nor disposal or burial; therefore minimal HTW/MC/CWM contamination was anticipated in the Camp Leach areas. The AUES was used for testing of chemical warfare materiel and was generally divided into two use areas: the area within the AU and Spaulding property bounded by a perimeter fence served as the research center where chemicals, gases, and munitions were developed and stored; and the area outside the AU and Spaulding property boundaries where chemicals and items developed at the research facilities were field tested.

Based on the past uses of both major areas of the AUES, HTW/MC/CWM contamination was expected; however, higher levels of contamination were expected within the perimeter fence boundaries of the AUES because the activities occurring there (spills, leaks, laboratory mishaps resulting in explosive release of chemicals, and disposal and burial), were more likely to cause contamination than open air testing. This was due to several factors: the high concentration of temporary laboratories (see POIs 42, 44-49, and 51, 52, and AU and Figure 1-5) erected at the AUES to support research operations, historical references to the burning of temporary buildings too impregnated with chemicals to salvage and reuse, the existence of a high concentration of ground scars (including POI 24) analyzed to be a probable pit, and historical documentation indicating the possible disposal of chemicals and munitions within the AU campus boundaries. OU-2, OU-3, and OU-4 were fully or partially located within the fenced-in area of the AUES. Accordingly, the planned investigations within OU-2, OU-3 and OU-4 were based on the concept that HTW/MC/CWM contamination was as a result of these activities.

The field testing area outside the perimeter fence of the AUES was further divided into two major areas in planning the 2003 EE/CA OU-4/OU-5 HTW/MC/CWM investigations. One area, denoted the Central Testing Area (CTA) encompassed POIs where AUES field testing was documented based on ground photographs, testing reports, and other historical documents. The primary activities assumed within the CTA were open air testing. Isolated POIs within the CTA (POIs 2, 4, 5, 14, and 17) were identified as areas where potential disposal or burial took place through the USEPA EPIC analysis. Areas outside the CTA were designated as the Comprehensive Sampling Area (CSA) for the purposes of HTW/MC/CWM characterization activities; these were the remaining areas of the SVFUDS and were not associated with field testing or disposal/burial activities.

3.2.2 MEC Based CSM

Figure 3-2 presents the site-wide MEC CSM for the SVFUDS. The following discussion summarizes the elements of this CSM. However, one of the key uses of the MEC CSM is to establish the pathway analysis that guides the MEC Hazard Assessment (MEC HA) scoring, or the ‘explosive hazard’ component of an HHRA. Therefore, greater detail on the elements presented in this figure is contained in the MEC HA discussion presented as Section 7.6.

The source, interaction, and receptor pathway requirements are basically the same as those described above for HTW/MC/CWM contamination. However, movement of munitions is not usually significant, and interaction will occur only at the source area, limited by the receptor’s access and activity. Natural processes (e.g., erosion, frost heaving, flooding) may cause subsurface munitions to surface, or munitions may get moved as a result of human activity.

However, MEC do not undergo various physical processes, such as volatilization, that can cause media other than the source area to become contaminated.

The primary release mechanisms resulting in the occurrence of MEC are related to the type of military munition activity, or result from the improper functioning of the military munition. For example when a high-explosive military munition is fired it will do one of three things:

1) It will detonate completely (a high order detonation)
2) It will undergo incomplete detonation (a low order detonation)
3) It will fail to function (results in UXO)

Further, military munitions may be lost, abandoned, or buried, resulting in unfired munitions that could be fuzed or unfuzed. There are military munitions that will have a delayed function and may be hidden by design resulting in a deployed, armed, and fuzed munition. In addition, the munitions may possibly be spread beyond the immediate vicinity by the detonation ("kickouts"), or incomplete combustion or low/high order detonation failure can leave uncombusted explosives. In some cases, excess, obsolete, or unserviceable munitions may have been buried near the testing areas.

The MEC CSM for the SVFUDS is based on the historical AUES activities, where munitions were ballistically and statically fired. Section 1.5 describes that the SVFUDS Range Fan was developed based on ballistically fired testing activities of 3-inch and 4-inch Stokes Mortars and Livens projectiles at the AUES. Static firing, the remote firing of fixed or stationary munitions, primarily using 75 mm munitions, was also conducted. For the SVFUDS, the investigations of the sources of munitions were based around the past activities most likely to result in MEC, specifically:

- Ballistically Fired Testing (e.g., Range Fan);
- Statically Fired Testing (e.g., Circular Trenches); and
- Disposal or Burial (e.g., 52nd Court, OU-4 AU Lot 18).

Figure 3-2 graphically depicts the source media being the munitions firing and disposal activities of the former AUES. Ballistic firing can result in MEC in impact areas or buffers around these areas, while static firing often produces kick-out. DMM are often associated with static fire areas where these are buried near the test site. All of these can result in MEC being present in the subsurface. All but burial pits can result in MEC at the surface.

The interaction of receptor and source is a function of whether the source can be accessed and whether an activity is intrusive or non-intrusive. A distinction made for MEC CSMs is that the receptor typically must move toward the munition item, unlike groundwater that can migrate toward the receptor.

The CSM shows, for example, that a complete pathway exists for a resident to encounter MEC in the subsurface through intrusive activity in a MEC impact area, or that the pathway to a burial pit is incomplete for all receptors if there is no intrusive activity taking place. These pathways, as well as the others depicted, were part of the inputs to the MEC HA scoring that helped determine relative explosive hazards remaining for these areas (see Section 7.6).

3.2.2.1 MEC CSM Application

As with the HTW/MC/CWM CSM, the MEC based CSM evaluated known activities at the AUES and Camp Leach to focus MEC investigations in the SVFUDS. POI and AOI information was used to help assess potential previous MEC activities associated with the POI and AOI (whether it be ballistic firing, static firing, or disposal and burial activities). Based on the use of Camp Leach as a troop training facility, minimal MEC release mechanisms were anticipated in any of the AOIs and POIs located within the Camp Leach area of the SVFUDS.

AUES activities both inside the research facility perimeter fence and outside the perimeter fence were expected to potentially result in MEC, although in different ways. The area within the AU and Spaulding property bounded by a perimeter fence served as the research center where chemicals, gases, and munitions were developed and stored. The past activities most likely to result in MEC within the perimeter fence were disposal and burial, rather than ballistically or statically fired testing. This was due to several factors: the presence of POIs analyzed to be possible or probable pits (including POI 24), and historical documentation including aerial photographs, the SGT Maurer photo, and AU newspaper articles indicating the possible disposal of chemicals and munitions within the AU campus boundaries. The firing point for the Range Fan associated with ballistically fired testing was located just within the perimeter fence of the AUES as shown in Exhibit 1-7; however, the Range Fan itself was located in the area outside of the fenced-in AUES.

POIs and AOIs associated with the field testing area were primarily assessed to be impacted by either ballistically fired testing or statically fired testing; in addition, some areas were identified as areas where potential disposal or burial took place (e.g., POI 2, 4, 5, 14, and 17).

3.3 Data Needs and Data Quality Objectives

3.3.1 <u>Data Needs</u>

Many types of data were needed to achieve the goal of assessing the nature and extent of HTW/MC/CWM and MEC contamination caused by the past AUES activities at the SVFUDS, and to determine whether further CERCLA actions were warranted. Over the long course of the various SVFUDS investigations, data obtained included DGM surveys, intrusive anomaly investigations to identify locations and types of MEC, and environmental sampling to determine the distribution and concentrations of HTW/MC/CWM in soil, sediment, surface water, and groundwater. These data were used to quantify risks to human health and the environment and to assess MEC explosive hazards. The general process for collecting these data is described in Section 4.0. The discussions below focus on what the samples were analyzed for and why, and present the background and evolution of the laboratory analytical aspects of chemical characterization of the SVFUDS.

3.3.1.1 Overview of Analytical Requirements

Analytical requirements for all samples collected at the SVFUDS were presented in Work Plans that were reviewed and approved by the stakeholders, as described in Section 3.3.2 below. Laboratories used, whether by USACE or USEPA contractors, were required to have specific certifications and qualifications to perform the analyses; no analytical laboratories without proper certifications and accreditations (i.e., DoD Quality Systems Manual Accreditation, National Environmental Laboratory Accreditation Program, National Institute for Industrial Occupational Safety and Health’s National Voluntary Laboratory Accreditation Program, or the USEPA Contract Laboratory Program, as appropriate at the time of the specific effort) were used for any SVFUDS sampling. The process for determining the chemical constituents for which laboratory analyses will be performed is dependent upon the specific knowledge of past activities and operations that may have impacted the environment and the sampling objectives.

The USEPA has established standard analytical methods for the detection and quantitation of specific target compounds and analytes. Target Compound and Target Analyte Lists (TCL/TALs) provide specific groups of constituents (organic and inorganic compounds) to be analyzed for typical HTW/MC sites. Analysis of samples for these standard suites, TCL volatile organic compounds (VOCs), semi-volatile compounds (SVOCs), and TAL metals, forms the foundation of comprehensive chemical characterization for such sites.

However, as a former experiment station, analytical plans for the SVFUDS required additional parameters, including explosives, CWM and CWM agent breakdown products (ABPs) that would not typically be present on HTW sites. For the SVFUDS, analysis for the non-routine parameters, mustard and its ABPs (dithiane, oxathiane, and thiodiglycol) and Lewisite, required special procedures. For example, subsurface soil samples required headspace testing by the Edgewood Chemical Biological Center (ECBC) air monitoring team to monitor for potential off-gassing CWM contaminants. Following headspace analysis, a separate portion of the sample was then sent to the ECBC facility at the Aberdeen Proving Ground for low level laboratory analysis of mustard and Lewisite. In accordance with USACE CWM safety protocols, no sample could be submitted to any commercial analytical laboratory (i.e., the laboratories performing the standard USEPA suites described above) unless both the headspace testing and the low level analysis indicated no detections of mustard and Lewisite.

3.3.1.2 Early SVFUDS Chemical Analysis

For the early OSR FUDS RI sampling, USACE focused on ordnance and explosives waste and CWM-related contamination that may have occurred as a result of AUES activities. The USEPA concurred with this approach but also considered a wide range of potential contaminants in their split sampling to also identify the presence of any non-DoD-related contamination. Therefore, while USACE's analytical plans focused primarily on explosives, CWM and CWM ABPs, with fewer samples for the full standard suites of chemicals (VOCs, SVOCs, and metals), USEPA tended to include the standard suites for most of their samples. By 2001, long historical lists of chemicals documented to have been used at the AUES were being compiled and USACE expanded their sampling plans to include these non-routine chemicals for which laboratory analysis was possible.

3.3.1.3 Parameters Report

By 2004, USACE's continued evaluation of these multiple lists of chemicals resulted in the formation of the Parameters Work Group, wherein a structured evaluation process was developed to integrate all the chemicals from all the lists into a formal analytical plan for the SVFUDS. The result was the *Parameters Report for the Development of the AUES List of Chemicals*, USACE (USACE, 2008d), which details the process (Appendix C). The objectives of the evaluation process were to:

- Ensure all chemicals previously used at the AUES were considered in the investigations by carefully compiling the various lists identified;
- Provide a structured process using consensus evaluation criteria to include or eliminate specific chemicals from the list; and

- Generate a final table of chemicals to be analyzed in a given medium, e.g., soil or groundwater.

To ensure that the appropriate specialized knowledge was represented and that the process had transparency, the Work Groups comprised members of several entities including the Partners (USACE, USEPA, and DDOE), the RAB consultant, and American University. Other parties were involved at various times in the process, contributing significant input in key areas, including Noblis (CENAB consultant) and the U.S. Army Center for Health Promotion and Preventive Medicine (USACHPPM), now called the US Army Institute of Public Health.

A key element of the process was to evaluate environmental fate and transport properties of these compounds to help consider whether the chemical would conceivably still be present in the soil or water after approximately 85-90 years in the environment. The resulting final tables presented a comprehensive list of chemicals to be analyzed, by media, when site history and sampling objectives called for comprehensive characterization (as opposed to specifically targeting, for example, arsenic for a TCRA or NTCRA action). The earliest use of the comprehensive SVFUDS list of parameters was approximately early 2006. Table 3-1 summarizes the various lists of chemicals used to generate the comprehensive analytical plan.

Table 3-1. Lists of AUES Chemicals

List	Source	Comments
Smart	January 27, 1993 Memo (original source is 1918 Monograph No.16)	Chemicals grouped based on Toxin, Smoke, Incendiary, or Detonator classifications
Baker	September 27, 1993 Memo	Field tested chemicals grouped by location (POI, or "General" locations)
AUES	OU-4 Work Plan Amendment 1 (January 2001)	Smart plus Baker lists combined for this 2001 sampling effort
Bancroft	1919 History of Chem Warfare Service by LTC Bancroft (Added in late 2003)	Directly from the 1919 Bancroft History
Potential Chemicals	January 2004 Parameter Group meeting	Chemicals not on any of the lists but historically analyzed or have potential to be present; added by consensus through the Parameter Group process
Cook	Randy Cook, (USACE Contractor - Researcher) - 1993 Database (Added in 2005)	Part of the original circa 1993 research effort, the list had been misplaced. It added approximately 300 more chemicals associated with the AUES.

Following the Parameters Report establishment of the comprehensive list of chemicals to be analyzed, USACE acknowledged that because of the SVFUDS history as an experiment station, it was possible that a number of 'non-routine' compounds associated with those past activities could be encountered. Therefore, in addition to the standard suites discussed above that addressed the comprehensive list of chemicals, tentatively identified compounds (TICs) were also evaluated. While USEPA provides a standard procedure for TICs, for the SVFUDS, a supplemental evaluation of TICs was developed to provide a more complete picture of analytical sample results.

The Parameters Report organizes the chemicals into those that might only be expected to be detected as a TIC (assuming the chemical is present in the sample). TIC evaluation often results in a number of unknown compounds. To ensure that these unknowns are not SVFUDS comprehensive list chemicals, the supplemental TIC evaluation assesses whether the unknown TIC is likely to be a chemical potentially present at SVFUDS. The supplemental TIC evaluation does not necessarily identify TIC unknowns, but rather eliminates the unknowns as chemicals that are present on the SVFUDS comprehensive list (that is, chemicals documented to have been used at the SVFUDS). The details of this procedure are presented in a Technical Memorandum entitled the *Procedure for Evaluation of Tentatively Identified Compounds in the SVFUDS* (USACE, 2008e), included in Appendix B.

The standard USEPA analytical suites, the SVFUDS comprehensive list of chemicals, and the TIC evaluation procedure form the basis of chemical characterization for all SVFUDS media.

3.3.2 Data Quality Objectives

3.3.2.1 Overview of DQOs

DQOs are qualitative and quantitative statements that specify the quality and level of data required to support the decision-making processes for a project. The *Data Quality Objectives Process for Hazardous Waste Site Investigations (QA/G-4HW)* (USEPA, 2000a) document provides general, non-mandatory guidance on developing DQOs for environmental data collection operations in support of hazardous waste site investigations. In addition, USACE's Technical Project Planning process (USACE, 2012e) closely mirrors USEPA's 7-step DQO process. The 7 steps are described below.

Step 1-The Problem

Step 1 defines the problem that has initiated the study or investigation in an uncomplicated format. This step identifies: the general type of data needed, alternative approaches to investigation and solving the problem, and available resources, constraints, and deadlines associated with planning, data collection, and data assessment.

Step 2-Identify the Decision

Step 2 states how environmental data will be used in meeting objectives and solving the problem, identifies study questions, and defines alternative outcomes. This step organizes multiple decisions into an order of sequence or priority, and multiple estimation problems according to their influence on each other and their contribution to the overall study goals.

Step 3-Identify the Inputs to the Decision

Step 3 identifies the types and potential sources of information needed to resolve the decision statement or produce the desired estimates, whether new data collection is necessary, the information basis for specifying performance or acceptance criteria, and the availability of appropriate sampling and analyses methods.

Step 4-Define the Boundaries of the Study

Step 4 specifies the target population and characteristics of interest, defines spatial and temporal limits, practical constraints, and the scale of inference.

<u>Step 5-Develop Decision Rule</u>

Step 5 defines the parameters of interest and develops an analytic approach that will guide how the study results are analyzed and conclusions drawn from the data. This step constructs an "If...then...else..." decision rule that defines how to choose among alternative actions.

<u>Steps 6-Limits on Decision Error</u>

Step 6 derives the performance or acceptance criteria that the collected data will need to achieve in order to minimize the possibility of making erroneous conclusions or failing to keep uncertainty estimates within acceptable levels.

<u>Step 7-Optimize the Design</u>

Step 7 develops a resource-effective design for collecting and measuring environmental samples, or for generating other types of information needed to address the identified problem.

The DQO process for the SVFUDS has been applied at the individual investigation stage. The 7-steps outlined above were developed specific to those individual investigations. Each of the investigations described in Section 1.6 included a work plan (that included a Quality Assurance Project Plan as part of the document) that was provided to the Partners (or the relevant regulators prior to the formal Partnering process).

These work plans, containing DQOs specific to the individual effort, were usually briefed and discussed at Partnering meetings and then were submitted for review by the Partners. USACE responded to all formal comments provided and then finalized each work plan with the understanding that it represented the consensus path forward with regard to quantity and quality of data required for that particular investigation.

3.3.2.2 Activity-specific DQOs

Section 1.1 discusses how the nature of this RI is notably different from traditional RIs referencing a single set of DQOs identified in a single RI work plan. Therefore, DQOs on an activity-specific (investigation/characterization, geophysical investigation, and removal actions) basis were developed following the steps above; Section 5.6.4 and Table 5-2 present and discuss how these DQOs were met.

3.3.2.3 Site Specific Investigation Objectives

This section reviews the CSM release mechanisms for HTW/MC/CWM and MEC for the sites within the SVFUDS. Table 3-2 combines the preliminary release mechanisms based on the POI/AOI specific background information and the investigation objectives based on that release mechanism, to provide an overall statement of site-specific DQOs. This provides a broad picture of how investigations were planned utilizing CSMs. However, there is necessarily some uncertainty in associating individual sites with specific release mechanisms due to limitations of available background information and/or interpretation of data from multiple sources (e.g., interpretation of groundscars from aerial photos as potential burial pits). In addition, the investigation objectives are grouped for purposes of the table, but there may be some sites that did not receive each type of field investigation shown. The release mechanisms are considered preliminary at the planning stage in that the results of the investigations may suggest changes or revisions to what was initially understood about a specific site. This is discussed in more detail in Section 5.7 (Revised CSMs).

Table 3-2. Site Specific Investigation Objectives
Grouped by Similar Preliminary Release Mechanisms

POIs and/or AOIs	Preliminary Release Mechanisms		Investigation Objectives	Comments
	HTW/MC/CWM	MEC		
AOI 21, AOI 9	Open air testing, Disposal or burial	Ballistically fired testing, Statically fired testing, Disposal or burial	Soil sampling, Geophysical investigations, Groundwater sampling	None.
AOI 11, POI 1, POI 13	Open air testing, Disposal or burial	Statically fired testing, Disposal or burial	Soil sampling, Geophysical investigations, Groundwater sampling	None.
AOI 22	Spills or leaks	None	Soil sampling	AOI 22 focused on HTW only.
AOIs 2-5, AOI 7, AOI 17, AOIs 25-26, AOI 28, POI 2, POIs 4-5, POI 14, POI 17, POI 24, POI 30-36, POI-43	Disposal or burial	Disposal or burial	Soil sampling, Geophysical investigations, Groundwater sampling	None.
AOI 13, POI 26 Range Fan	Disposal or burial	Ballistically fired testing, Disposal or burial	Soil sampling, Geophysical investigations	None.
AOI 24, AOI 8, POI 7, POI 12, POIs 15-16, POI 19	Open air testing	None	Soil sampling	AOI 24 focused on HTW only.
AOI 6, AOI 12, POI 6, POIs 8-9, POI 18	Open air testing	Ballistically fired testing	Soil sampling, Geophysical investigations	None.
AOI 1, AOI 18, POIs 38-39	Open air testing	Statically fired testing	Soil sampling*, Geophysical investigations* *(AOI 1 & POI 39 only)	An accurate location could not be identified for AOI 18/POI 38.
AOI 10, AOIs 14 - 16, AOIs 19-20, AOI 23, AOI 27, POI 37	None	None	Soil sampling*, Surface water sampling* *(POI 37 only)	No evidence of past use that would result in contamination
POI 3, POIs 10-11	Open air testing	Statically fired testing Ballistically fired testing	Soil sampling, Geophysical investigations	None.
POIs 20 - 23	Spills or leaks, Disposal or burial	Statically fired testing, Disposal or burial	Soil sampling, Geophysical investigations* *Excludes POI 22	None.
POI 25, POIs 27-29, POI 50	Disposal or burial	Disposal or burial	Soil sampling, Geophysical investigations (excluding POI 50)	None.
POIs 40-42, POIs 44-49, POIs 51-52	Spills or leaks, Disposal or burial	None	Soil sampling, Groundwater sampling	None.
POI AU, POI 53	Spills or leaks, Disposal or burial	Disposal or burial	Soil sampling, Geophysical investigations, Groundwater sampling	None.

Note: See Figure 1-7 for the locations of AOIs, POIs and the Range Fan.-

3.3.3 <u>Data Validation</u>

The quality of the data is formally assessed through the data validation process, where data are reviewed for usability. Data validation is an analyte and sample specific process used to determine the analytical quality of a specific data set, involving quality control deviations, inspection of data handling conformances, and assignment of qualification codes, intended to provide legally defensible usable data. This process is conducted on the laboratory data deliverable provided by the analytical laboratory; it is not done by the laboratory.

The data validation process is conducted in accordance with the *Laboratory Data Validation National Functional Guidelines for Evaluating Inorganic and Organic Analyses* (USEPA, 1994, as updated June 2008 and January 2010), and all appropriate updates to this guidance document. Specific procedures for validating the data, including any site-specific deviations for the guidance, are captured in the work plans and reviewed and approved prior to any sample analysis being completed. The completed data validation report is included as part of the larger report deliverable for that particular investigation.

All data from all investigations were validated in accordance with these USEPA procedures. Only accepted validated data were used in making project decisions (no rejected results were used).

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4.0 REMEDIAL INVESTIGATION FIELD ACTIVITIES

Section 4.0 describes how the field activities for the SVFUDS investigations were conducted. Similar to Section 1.6, these discussions are organized by specific type of activities conducted to complete the investigation/characterization and removal activities, rather than by the individual resulting reports of the key SVFUDS investigations or removals discussed in Section 1.6. A broad timeline of SVFUDS activities is presented in Figure 4-1, indicating approximate time periods for the types of activities described below.

The investigation and characterization activities typically involved soil sampling, geophysical surveying, and in some cases, groundwater well installation and sampling. The removal activities involved excavation of soil, followed by backfill with clean soil. While these activities generally employed the same basic procedures at each different location, there were situations where the technical approach was refined to reflect updated technology, or where the objective was different. Therefore, the discussions below describe the basic field activities, as well as how and why they may have deviated from previous practice, rather than focusing on each individual investigation or removal where the same geophysical or excavation techniques were employed.

4.1 Investigation/Characterization

4.1.1 Soil Sampling

4.1.1.1 Overview of Soil Sampling Procedures

Soil sampling has been completed multiple times during various investigative efforts, using standard USEPA procedures as documented in individual work plans. Many elements of the sampling process are common to all efforts, whether conducted in 1993 or 2012.

Soil samples are collected either from the surface (0-6 inches bgs) or the subsurface (greater than 6 inches bgs), depending on the sampling objectives. Surface soil sampling involves samplers using stainless steel trowels or equivalent implements to fill laboratory provided containers specific for the analytical needs of the sample. Subsurface sampling at the SVFUDS also involves anomaly avoidance so that intrusive sampling implements do not contact potential munitions items (UXO technicians use metal detectors to identify metallic objects in advance of the borehole so they can be avoided, and an alternate nearby location is selected). Subsurface soil samples can be obtained using a hand auger (if not too deep) or powered equipment such as a direct push rig, or even a drilling rig. The vast majority of subsurface samples at the SVFUDS were collected using a hand auger.

Surface sampling is conducted to characterize soils to which current receptors (e.g., residents, students) may be exposed, even though that soil may no longer represent past contamination. That is, as discussed in Section 2.1.1.3, the soil that may possibly have been impacted during AUES operations, may long since have been removed as a result of landscaping or building activities. However, it is still necessary to characterize surface conditions. Subsurface soil sampling is conducted to evaluate whether past activities such as a burial or disposal of wastes may have directly impacted deeper soil, or indirectly through leaching of contaminants spilled or applied at the surface. Contamination from subsurface soils may result in direct exposure to workers (and potentially other future receptors) should the soils be disturbed. Contaminants in subsurface soils may also eventually reach groundwater and migrate to other areas. These CSM pathways were discussed in Section 3.2.

Some of the specific sampling approaches used at the SVFUDS, representing different techniques and/or different objectives and analytical needs, are described below.

4.1.1.2 OSR FUDS Soil Sampling

Soil sampling conducted for the earliest SVFUDS investigations, the OSR FUDS RI, was designed to determine whether the soils within the project area were contaminated with CWM and/or their ABPs, and explosives. To ensure that potential residual soil contamination was detected, the following primary types of soil sampling activities were performed for the OSR FUDS:

- Soil sampling of specific POIs at the 1918 ground surface; and
- Soil sampling (subsurface) from sidescan boreholes installed as part of the intrusive investigation of geophysical anomalies (a downhole magnetometer was placed in the borehole to perform a sidescan and determine anomaly depth).

The main focus of the soil sampling program was the statistically-based sampling of POIs identified as having the greatest potential for residual environmental contamination. The samples targeted the 1918 soil horizon, the presumed location of greatest residual contamination based on the historical past practices. A sufficient number of samples was collected to statistically determine if the average concentration of a chemical detected in a POI was significantly different than the average concentration of that chemical in the background samples. These samples were randomly located within the suspected areas of potential contamination in the POIs.

For the OSR FUDS sampling, USACE used the interval of 0 to 1.5 feet bgs to represent composite exposure to surface soil (maximum gardening depths), while samples greater than 1.5 feet bgs were considered indicative of subsurface conditions. Subsurface soil samples were collected using a hand auger, or powered equipment depending on depth.

4.1.1.3 OU-3 Soil Sampling

Soil sampling activities under the EE/CA developed for 4801, 4825, and 4835 Glenbrook Road were focused on investigating possible arsenic contamination in surface and subsurface soils. While the EE/CA was for 4801, 4825 and 4835 Glenbrook Road, soil sample results evaluated in the EE/CA for 4825 Glenbrook Road and 4835 Glenbrook Road were from USEPA split samples collected in 1999 following OSR FUDS RI sampling procedures described above. Samples collected at 4801 Glenbrook Road were collected in two phases following separate sampling procedures.

The first phase of sampling was performed in a grid system consisting of 10 foot by 10 foot grid squares. One discrete surface sample was taken from each grid to characterize the grid for arsenic. The grid system was located between the former location of circa 1918 buildings associated with the AUES and Pits 1 and 2 as well as locations where previous USEPA sample results showed elevated levels of arsenic in the soil.

The second phase of sampling at 4801 Glenbrook Road associated with the OU-3 EE/CA was performed to define the nature and extent of arsenic contamination found during the first phase of sampling performed in November 1999. Surface soil samples were collected following a grid system consisting of 20 foot by 20 foot grid squares. In addition to arsenic characterization, samples were collected for trivalent and hexavalent chromium. A sample was collected every twenty feet at the intersection of the grid lines. Except for sampling those locations for Cr^{+6} where arsenic concentrations were previously found to be the highest, samples were not collected from the original grids. Samples were not collected where cultural features and/or current site features prevented access to the surface soils (i.e. equipment sheds, patios, and gravel roads etc.). Samples were collected from the first 6 inches of surface soil.

4.1.1.4 OU-4 and OU-5 Arsenic Screening Soil Sampling

The soil sampling activities for OU-4 and OU-5 conducted under the Arsenic in Soil EE/CA (USACE, 2003b) focused on residential and commercial property lots within the SVFUDS for investigation of possible arsenic contamination in surface and subsurface soils. OU-4 was organized into residential properties and AU half-acre (approximate) lots, while OU-5 was organized into two areas; the CTA (the area that had been determined most likely to contain arsenic or other CWM-related chemicals in soil based on historical information) and the CSA (the remaining portion of the SVFUDS). To determine if there was any potential arsenic contamination on a given property, initial soil screening sampling was conducted. For arsenic screening purposes, each OU-4 property/lot and each OU-5 CTA property was divided into quadrants, and each OU-5 CSA property was divided into halves.

The initial surface samples for the sampling in the OU-4 and OU-5 CTA properties consisted of six random soil samples taken from each quadrant for each property. These random soil samples were composited to make up one arsenic sample for each quadrant. Where any sampled property had at least one composited quadrant result greater than the established background-based screening level of 12.6 mg/kg, more extensive sampling, commonly referred to as grid sampling (explained below), was conducted. While primarily sampled for arsenic, quadrant surface samples at the OU-4 AU Lots were also analyzed for mustard ABPs because the OU-4 AU Lots are the general location of the former AUES laboratories, where several documented accidents occurred that could have resulted in the release of CWM. The initial surface samples for the sampling in the OU-5 CSA properties consisted of eight random soil samples from each property half. These eight random soil samples were composited to make up one sample for each property half. Where any sampled property had at least one half-lot result above the established screening level of 12.6 mg/kg, grid sampling was conducted.

Subsurface samples were collected from all OU-4 properties/lots, all CTA properties, and from approximately 15% of the CSA properties. The selected CSA properties contained physical characteristics such as proximity to previous ground scars and stressed vegetation, or because of a composite arsenic screening level greater than 43 mg/kg. All subsurface borings were analyzed for arsenic. Additionally, specific borings were selected to be analyzed for one or more of the following parameters: cyanide, mustard, mustard ABPs, Lewisite breakdown products, and the following explosives: tetryl, trinitrotoluene (TNT), nitroglycerin, 2,4-dinitrotoluene (2,4-DNT), 2,6-dinitrotoluene (2,6-DNT) and nitrobenzene. Selection for this expanded analytical plan was based on the properties' historical usage and proximity to identified POIs where CWM testing occurred. All of the borings taken at the selected CSA properties were analyzed for arsenic, mustard, mustard ABPs, Lewisite, and cyanide. Arsenic samples were taken using a direct-push sampling device at one-foot intervals ranging from 6 to 10 feet bgs. The samples where parameters other than arsenic were collected were taken at the 1918 soil horizon (determined based on soil cut-and-fill data and field observations).

4.1.1.5 OU-4 and OU-5 Arsenic Grid Soil Sampling

The arsenic soil screening resulted in the need for additional sampling when arsenic concentrations greater than 12.6 mg/kg were detected on a property or lot. This more extensive grid sampling was intended to more accurately define the extent of arsenic contamination. The grid system consisted of 20-foot by 20-foot squares (grids) oriented across the entire site, with a single discrete arsenic sample collected at the grid center. On a case-by-case basis, some properties (for example, some residences near the former Sedgwick Trench area) where historical records indicated extensive AUES activities, were identified for a tighter grid layout (10-feet by 10-feet). Some properties with arsenic screening results less than the 12.6 mg/kg level, were also grid sampled because they were in close proximity to other sites that contained screening level exceedances. This sampling formed the basis for the TCRA and NTCRA arsenic removals discussed in Section 4.2.

4.1.2 <u>Geophysical Surveys</u>

For the SVFUDS, geophysical surveys have been the primary initial tool used to investigate the presence of MEC or MD, as well as buried pits and trenches. However, much more than soil sampling, well installation, or soil excavation, geophysical techniques have evolved and have been refined over the many years of SVFUDS work. Consequently, a variety of geophysical instruments and procedures for interpreting the data have been used to obtain the best possible picture of site conditions at the time. More recently, the term Digital Geophysical Mapping (DGM), has been used to describe geophysical surveying. The term DGM is used for more recent geophysical investigations in this RI report.

The discussions below provide an overview of geophysical field procedures, an indication of what types of instruments were used, what they were intended to find, how analysis and interpretation of the data was formalized through the ARB process, and finally, how the geophysically identified anomalies were intrusively investigated.

4.1.2.1 General Geophysical Survey Procedures

In general, geophysical surveys are carried out with an electronic detector that records its measurements digitally. The detector is pushed, pulled, or carried by an operator in a systematic way over the area of investigation, usually in uniformly-spaced parallel transects. Digital instruments record their measurements in data files and the data must be referenced to specific points on the ground; the process of capturing the location of a data point is called navigation. Navigation may be accomplished by integrating the detector with ultrasonic systems, GPS, Robotic Total Station (RTS), or by entering reference marks with known coordinates (fiducials) into the data file as the data are collected.

Geophysical instrument technology largely falls into two categories, electromagnetic and magnetic instruments. Electromagnetic instruments such as the EM31, EM61, GEM-2, or any ground penetrating radar (GPR) unit, are active detectors that produce a signal that interacts with the environment and the response to the signal is recorded. Magnetic instruments such as the G-858, G-856, or Schonstedt GA-52-Cx, are passive instruments because they measure a potential field that is always present.

The basic field procedures for many of the geophysical survey investigations employed the same work elements regardless of what instrument was used or when the work was conducted. Initially, a geophysical prove out (GPO) is completed to test the instrument’s performance in an area of the site that reflects soil conditions of the test areas, establishing the best performing instrument and the transect spacing to meet the investigation objectives.

At the area of investigation, the geophysical survey team would establish a survey grid and conduct static quality control tests on the instruments. The survey would then commence by moving the instrument along parallel transects over the gridded area. At the SVFUDS, since many of the investigation areas were residential properties, the transect spacing was designed to effect 100% coverage. However, this goal was often limited by existing cultural features and the inability to cut decorative shrubbery or otherwise impact landscaped areas.

The collected data are then processed and contoured by an experienced geophysicist, producing maps of anomalies. Other advanced processing methods allow estimations of mass or depth of objects causing anomalies, or they filter out site noise or anomalies unlikely to represent targets of interest. Ultimately a "dig sheet" of anomalies representing probable targets of interest, including location, intensity, and estimated depth, is generated.

4.1.2.2 Geophysical Instrumentation Used at the SVFUDS

Following the discovery of buried munitions at the 52nd Court area, the first geophysical instruments to be used at the SVFUDS were the Geonics EM31 and the Schonstedt hand-held metal detector during the OSR FUDS RI investigations in 1993-1994. The EM31 is a frequency-domain instrument that measures the ground conductivity and the presence of metals to a depth of approximately 20 feet. The EM31 was used during the OSR FUDS investigation to survey some 492 properties at specific POIs. However, it has a large geophysical "footprint" that is not conducive to detecting small individual items, and therefore, the goal of the survey was to identify or confirm burial pits and trenches "indicative of UXO." The device was integrated with the Data Acquisition and Navigation System to record position data. The Schonstedt hand-held metal detector is an analog magnetic gradiometer capable of detecting ferrous metals. These were used as a secondary instrument to investigate anomalies identified by the EM31, or to investigate areas where the EM31 could not be used. In the wooded Zone 9 designated area, a survey using only a magnetometer was completed to identify some 370 anomalies.

A suite of other devices was first used at the 4801 Glenbrook Road property in 1998 and 1999. These included the Geonics EM61 time-domain electromagnetic metal locator (which is designed to have a better response to metallic objects than for conductive earth and are better suited for locating small metallic objects than the EM-31 technology), the Geometrics G-858 Cesium Vapor Magnetometer, the Geophex GEM-2 and GEM-3 frequency-domain electromagnetic sensors, and the Geophysical Survey Systems SIR System-2 Ground Penetrating Radar (GPR). The navigation system for all the instruments was the line & fiducial method, the primary instrument navigation approach used throughout the SVFUDS investigations.

These earlier geophysical surveys were performed using what had been considered standard state of the art survey equipment. However, as newer geophysical technologies became available, USACE completed a GPO for the SVFUDS at the Federal property near Sibley Hospital in April 2000, to determine which instruments were best suited for locating the kinds of munitions suspected to be present. Instruments tested included the standard equipment types employed throughout the 1980s and 1990s to find buried metallic and non-metallic objects and newer instruments designed specifically to find small metallic objects. As technologies evolved, the GPO was revised or expanded, as needed, to evaluate these instruments for site-specific use.

The GPO evaluates the impact of site-specific factors that can affect an instrument's ability to detect a potential target. These include the size, depth and composition of the target, cultural features, and the underlying site geology. Cultural features such as metal fences, reinforcing steel in sidewalks, electric power lines, and underground utility pipes, can produce electromagnetic noise that interferes with the operation of geophysical equipment. Geologic conditions on some sites can also make it difficult to detect potential targets because types of soil and rock have different conductivity properties. Geologic materials that are conductive are harder to "see through," making it difficult to detect small metallic objects. Other factors that affect the performance of geophysical surveys include site development features, the type and extent of vegetation, and site topography. These factors can affect the area that can be surveyed, the ease of data collection, and whether the site can be geophysically surveyed at all.

The first step in performing the GPO for the SVFUDS was to locate an area free of background magnetic or electromagnetic noise. Each instrument included in the GPO was then deployed to collect data over the grid, and the data were then contoured to develop a picture of the background conditions for each instrument. Once the background surveys were completed, items were planted to simulate buried munitions. The seeded items were planted in shallow trenches or pits within each grid, in various groupings and orientations, and at various depths, with locations recorded. Each geophysical instrument included in the GPO effort was then re-deployed over the grids. The data were contoured, and the ability of each instrument to detect the seeded items was evaluated. Since that time, all contractors performing geophysical surveying at the SVFUDS must prove their capabilities at the GPO grids. This process ensures that each contractor can achieve the objectives outlined for the original GPO survey and demonstrate performance within the stated contract specifications for target detection and navigational accuracy.

The instruments investigated during the initial GPO included the Geonics EM-31; a Geonics EM-61 and a Geonics EM-61HH; and a Geometrics G-858G Cesium Vapor Magnetometer. Other instruments tested in later GPO efforts included GPR and a Man Portable Electromagnetic Multi-system Towed Array Detection System or EM MTADS. The GPR systems generally performed poorly and their use was not further recommended. While the MTADS performed as well as the EM-61 system, the MTADS was difficult to maneuver over hilly terrain and dense vegetation and it was not used for any actual geophysical surveys in the SVFUDS.

The conclusions of the GPO were as follows:

- The EM-61 was able to detect all of the metallic seeded items and was well suited for detecting geophysical targets of the type and size anticipated for the SVFUDS. This instrument was retained for use on future geophysical investigations.
- The EM-61HH was also effective in locating the seeded items, but showed depth limitations of approximately 2 feet. This instrument was recommended for use in target reacquisition.
- The G-858 Magnetometer, while not as robust as the EM-61 units in detecting the seeded items, when used in combination with the EM-61, it provides the ability to distinguish between metallic and ferrous items. This instrument was recommended to be used in combination with the EM-61.

- The EM-31 performed poorly. Though used in the early SVFUDS geophysical investigations, the EM-31 is not well suited for detecting small metallic items. This instrument was not retained for use on future geophysical investigations.
- The primary instruments to be used to conduct geophysical surveys at the SVFUDS were both the EM-61 and G-858.

Exhibits 4-1 and 4-2 show the EM61 and the G-858, respectively, being used at the GPO.

Exhibit 4-10. EM61 used at GPO

Exhibit 4-2. G-858 used at GPO

USACE further evaluated the potential ability for GPR in 2005 to identify non-metallic AUES related items. A geophysical feasibility investigation was performed by the USGS for USACE using the GPO established at the Federal property near Sibley Hospital. The study also included acquiring several profiles of GPR data from a portion of OU-4 AU Lot 18 to identify any special needs or limitations that activities at Lot 18 would potentially impose. G-858 and EM38 instruments were used concurrently with the GPR to survey the same areas to assist in understanding the GPR data. GPR was determined to not be particularly useful in discriminating between isolated buried GPO targets and rocks, debris, and small dry or wet zones. Coupled with its limited depth of penetration at the site to less than 5 feet bgs, the GPR was not recommended to be a cost effective tool to locate targets of interest at the SVFUDS due to its inability to discriminate between GPO targets and unrelated items (USACE-USGS, 2005a).

The many geophysical surveys conducted at the SVFUDS over the years are summarized in Table 4-1. This table provides a timeline of geophysical activities, showing the different instrumentation used to achieve the objectives listed. The EM31 was initially used in an effort to detect burial pits and trenches, but it was not always successful and was not used much for later efforts. Similarly, as noted above, the GPR was only used at a few sites for the early investigations, but the results were not conclusive when searching for pits and trenches, although GPR was used near AU's Kreeger Hall in 2011 to identify utilities during that investigation. The table indicates that following the 2000 GPO, based on performance, the EM61-MK2 (a smaller and more sophisticated version of the EM61) and the G-858 instruments were the primary tools used for geophysical investigation of the SVFUDS.

Table 4-1. Geophysical Survey Timeline

Year	Geophysical Investigation	Geophysical Instrument	Objective	Comments
1993-94	OSR FUDS Phase 2	EM31, Schonstedt	Pits and trenches	
1998-99	4801and 4825 Glenbrook Rd	EM61, G-858, GEM-2, GEM-3, GPR	Pits and trenches, individual items	GEM-2 and GEM-3 similar to EM31
2000	GPO (Parsons)	EM61, EM61HH, EM31, G-858	Instrument tests under controlled conditions	EM61 selected, also stated that EM31 not useful for individual items
2000	Sedgwick Trench properties	EM61, EM61HH, EM31, G-858	Pits and trenches, individual items	
2002	GPO (Weston)	EM61-MK2, G-858	Instrument tests under controlled conditions	Expanded the GPO
2002	AU lots	EM61-MK2, G-858	Pits and trenches	
2002	4710 Woodway Lane	EM61-MK2, G-858	Pits and trenches, individual items	Discovery of Range Fan
2003-07	Residential Properties	EM61-MK2, G-858	Pits and trenches, individual items	55 properties
2005	OU-4 AU Lot 18	GPR	Tested GPR usefulness at Lot 18	GPR not recommended to be cost effective for this use
2007	Anomaly Selection Process Improvement Study	EM61-MK2, EM63, and G-858	Tested EM63, RTS navigation, tighter line-spacing, and UX-Analyze software	EM63 not recommended, tighter line spacing and RTS recommended but not done due to cost
2007	Dalecarlia Woods grids	EM61-MK2, G-858	Test of methods in Dalecarlia Woods	Anomaly density and difficulties of forest environment established
2008	Anomaly Classification Memorandum	EM61-MK2, G-858	Improvement in anomaly classification based on both instruments	Designed to reduce number of digs
2008	GPO (ERT)	EM61-MK2, G-858	Instrument tests under controlled conditions	Expanded the GPO
2009-10	Residential Properties	EM61-MK2, G-858	Pits and trenches, individual items	38 properties
2010-11	Dalecarlia Woods	EM61-MK2, G-858	Pits and trenches, individual items	
2011	Kreeger Hall at AU	EM61-MK2, G-858, EM31, GPR	Pits and trenches, individual items, utilities	EM31 and GPR also used in search for utilities and pits and trenches

4.1.2.3 Geophysical Data Interpretation

A crucial part of the evolution of the use of geophysics to characterize the SVFUDS is the interpretation of the collected geophysical data. At the SVFUDS, there have been several classification schemes to assess the nature of the anomalies. These interpretation systems are then used by the ARB to recommend which anomalies are investigated further (i.e., excavated), and which are likely to represent non-munitions related metal.

The ARB was formed during the OSR FUDS in 1993 and rechartered in 2003 under *Engineer Pamphlet 1110-1-18* (USACE, 2000b) guidance which recommends ARBs be formed to support munitions investigations being conducted under exceptional circumstances, such as performing investigations in a heavily urbanized area or conducting removals at highly contaminated sites. The ARB's purpose was to review information related to geophysical anomalies to determine whether further intrusive investigation was warranted (USACE, 1993a, USACE, 2005b). Additionally the ARB was also tasked with determining when anomalies did not require investigation or could be considered resolved based on the information provided for review.

The ARB members included Army experts in MEC/CWM, geophysical detection methods, and associated health and safety issues. In addition, regulatory agency representatives from the Partners were ARB members. Numerous technical staff from multiple organizations participated in ARB meetings and discussions; however, only four member organizations had voting authority and designated one voting member from each organization: CENAB, USAESCH, USEPA Region 3, and DDOE. ARB decisions were documented in ARB memos which are included as Appendix B.

The ARB established general criteria for evaluating anomalies for investigation, which were also supported by the anomaly classification scheme discussed below. The general factors considered included: the anomaly's location with respect to historical information; the anomaly's position with respect to 1918 ground elevations; the size of the detected anomaly; the electronic signature of the anomaly; the presence of nearby cultural features or interference which affect the sensitivity/reliability of the geophysical instruments; results of chemical testing in nearby soils; previous finds and results at other nearby anomalies; and other factors, such as anecdotal information, health issues, RAB input, etc. The ARB's anomaly evaluation methodology also considered different scenarios that could be present at the SVFUDS. These included single items in suspect impact areas from statically or ballistically fired testing, and pits and trenches that could represent burials of munitions items or other AUES related debris.

In the earlier geophysical investigations, the evaluation of anomalies based on the above-described factors relied on experience and professional judgment. However, the analyses often resulted in excavation of anomalies that were not related to munitions, wasting time and resources. In 2008, a more formalized scheme for anomaly classification and evaluation was developed by USACE. In a USACE Technical Memo, contained in Appendix B, (*Proposed analyses and classification scheme for anomaly selection within the Spring Valley FUDS*, Weston Solutions) (USACE, 2008f), the Spring Valley Geophysical Team developed an analytical process for evaluating and classifying geophysical anomalies acquired within the boundaries of the SVFUDS.

This analytical classification scheme incorporated a detailed process designed to establish a logical basis for selection and prioritization of anomalies based on the attributes of the geophysical signature and correlation to other SVFUDS features, such as identified POIs or ground scars. The intent of developing this scheme was to exclude from future dig lists those anomalies (i.e., smaller scrap items) currently being encountered in the excavation efforts that do not fit a prescribed geophysical profile of MEC, and to provide to the ARB a summary of the anomalies that should be given priority for further investigation.

The primary method of this prioritization used geophysical factors such as anomaly size and coincident signatures between instrument types (EM61 and G-858) to initially score each anomaly. Based on this scoring, an anomaly was placed into one of four categories:

- Category A - Possible MEC item shallow, (equivalent to shallow items from the surface to 22 inches deep). Category A is an anomaly that exhibits with high certainty all of the characteristics of an object 75mm or greater in diameter.
- Category B - Possible MEC item deep, (equivalent to deeper items, at greater depth than 22 inches). Category B is an anomaly that exhibits some of the characteristics of an object 75mm in diameter or greater, with low to moderate certainty.
- Category C – Possible MEC item deep. Category C anomalies exhibits few characteristics of an object 75mm or greater in diameter, but cannot be ruled out as being a possible munitions-related item.
- Category D - Not indicative of MEC. Category D anomalies exhibit with high certainty none of the characteristics of an object 75mm or greater in diameter.

The process was tested using GPO and production survey data (for 75mm and similar items) to develop a baseline to "prove-out" or validate specific routines and criteria that are most applicable. In order to test and help establish the necessary criteria, independent baseline analyses were performed by USACE and WESTON geophysical personnel on multiple GPO databases (Spring Valley, Seneca Army Depot, and Tobyhanna Artillery Range) containing 75mm and similar sized MEC items. For each condition, a series of tests was used to place the anomaly in one of the four categories.

The secondary method of prioritization, compared the location coordinates of EM61 and G-858 anomalies in Categories A, B and C to other SVFUDS features such as POI/AOI boundaries, Range Fan locations, and ground scars. The correlation between the two was used to segregate anomalies in Categories A, B, and C into higher and lower priority levels, such that Category A1 is a higher priority than A2, Category B1 is a higher priority than B2, and Category C1 is a higher priority than C2. An anomaly in Category A, B or C coincident with one of the SVFUDS features would automatically be sorted into A1, B1 or C1 levels, respectively. If there is no correlation, the anomaly would be sorted to lower priority levels, A2, B2, or C2, respectively.

Using this approach, the Geophysical Team was able to better prioritize anomalies encountered within the SVFUDS, providing a classification scheme that presented a more reliable dig sheet of anomalies for the ARB to review and determine either further intrusive investigation or no further action.

4.1.2.4 Categorizing Properties for Geophysical Survey

In 2001, USACE proposed the use of a classification scheme to prioritize each residential property and half-acre non-residential lot for subsequent geophysical investigations. The scheme utilized the 1986 USEPA EPIC report, the GIS database, and an automated sorting algorithm to accurately prioritize the properties.

For each property, a four digit classification code was developed. Each step in the sorting process considered a key factor in determining the potential of an uninvestigated burial pit or trench remaining on the site.

The four key factors (in order of importance) were:

- EPIC Feature Type and Overlaps;
- Arsenic Sampling Results;
- Year of the Initial EPIC Ground Scar Feature; and
- Cut and Fill Impacts.

This provided a baseline prioritization that could be subsequently modified by other considerations such as POI location and historical use, previous geophysical results and dig finds, impact of cultural features, sampling data, or resident concerns.

For the EPIC feature factor, a code ranging from 1 to 4 or No Further Action (NFA) was assigned to each property. The report listed the possible presence of ground scars from historical aerial photographs with pits or trenches (Code of 1), overlapping ground scars (2), ground scars with overlapping stressed vegetation (3), single ground scars (4), or no ground scars (NFA).

For the arsenic sampling results factor, a code ranging from 1 to 4 was assigned based on the maximum concentration of arsenic found in soil samples at the property. A code of 1 was assigned for greater than 43 mg/kg, a code of 2 for concentrations between 20 and 43 mg/kg, a code of 3 for 12.6 to 20 mg/kg (or no arsenic data), and a code of 4 was assigned for less than 12.6 mg/kg.

For the initial EPIC ground scar year feature factor, a code ranging from 1 to 4 was assigned based on the year of the aerial photo on which a ground scar first appeared. Codes for 1 through 4 were assigned for the aerial photo years 1918, 1922, 1927, and 1928, respectively.

For the cut and fill impact factor, a code of 1, 2, or NFA, was assigned based on the thickness of fill placed on the property or the depth soil removed. A code 1 was assigned for undisturbed ground, or ground with cut/fill less than 4 feet. A code 2 was assigned for disturbed ground, or ground with cut between 4 and 10 feet or fill between 4 and 12 feet. NFA was assigned for a cut interval greater than 10 feet or fill greater than 12 feet.

Using this scheme, which provided classification codes ranging from 1111 (highest priority), to 4442 (lowest priority), a methodical prioritization of all properties and lots within the SVFUDS was completed. Some properties were determined not to require any further consideration and were assigned an NFA designation.

Table 4-2 provides the results of the classification scheme for the first 50 properties, prioritized for geophysical investigation based on their classification. As shown on the table, in some situations, logistical considerations such as properties with similar but not identical codes being adjacent to one another, resulted in re-ordering the priority of the property without relying only on the classification code.

Table 4-2. Property Categorization for Geophysical Survey

No.	Classification Code	Location	No.	Classification Code	Location
1	1111	4710 Woodway Lane	**26**	1411	OU5-CSA-9-L42 Lot
2	1111	4825 Glenbrook Road	**27**	2111	4801 Glenbrook Road
3	1111	4835 Glenbrook Road	**28**	2111	OU4-AU12 Lot
4	1111	OU4-AU10 Lot	**29**	2111	OU4-WATKINS Lot
5	1111	OU4-AU11 Lot	**30**	2111	3717 Fordham Road
6	1111	OU4-AU16 Lot	**31**	2111	4922 Quebec Street
7	1111	OU4-KREEGER Lot	**32**	2111	3812 48th Street
8	1111	5011 Sedgwick Street	**33**	2111	4810 Sedgwick Street
9	1111	5046 Sedgwick Street	**34**	2111	4115 45th Street
10	1111	5054 Sedgwick Street	**35**	2121	4230 Fordham Road
11	1121	4621 Rockwood Parkway	**36**	2121	5035 Rockwood Parkway
12	1211	OU4-AU13 Lot	**37**	2121	4256 Warren Street
13	1211	OU4-AU14 Lot	**38**	2121	4333 Van Ness Street
14	1211	5040 Sedgwick Street	**39**	2211	OU4-AU19 Lot
15	1211	4920 Rodman Street	**40**	2211	4900 Quebec Street
16	1411	4800 Woodway Lane	**41**	2111	4119 45th Street *
17	1311	4814 Woodway Lane	**42**	1411	4921 Quebec Street
18	1411	4822 Woodway Lane	**43**	1411	4936 Rodman Street
19	1211	OU4-AU08 Lot	**44**	1411	5111 52nd Court
20	1111	3720 Fordham Road	**45**	1411	4050 52nd Street
21	1311	3822 Fordham Road	**46**	1411	4720 Woodway Lane
22	1411	5036 Sedgwick Street	**47**	1411	4818 Woodway Lane
23	1411	5059 Sedgwick Street	**48**	1421	3244 Nebraska Avenue
24	1411	5065 Sedgwick Street	**49**	2411	3819 48th Street
25	1211	4349 Verplanck Place	**50**	2421	3803 52nd Street

* No further action determination (no geophysics) for this property based on no MEC/MD finds at the adjacent property of 4115 45th where an anomaly investigation was conducted during a TCRA. In addition, significant soil removal was conducted under a TCRA at 4119 45th, and no MEC/MD related items were encountered.

4.1.2.5 Low Probability Intrusive Investigation of Anomalies

After the ARB had established the list of anomalies to be further investigated, they were excavated by a dig team of UXO Technicians. However, prior to conducting the intrusive investigations, USACE was required to prepare a probability assessment to determine the probability of encountering chemical warfare materiel (which for the purposes of this report per Section 1.2.1 will be referred to as MEC/CWM) during intrusive activities as required by the *Interim Guidance for Chemical Warfare Materiel Responses* (DA, Department of the Army, 2009). The probability of encountering MEC/CWM is ranked in accordance with DA PAM 385-30, Mishap Risk Management (DA, 2010).

The *Site-Wide Work Plan for the SVFUDS* (USACE, 2007d) includes procedures and methods for conducting investigations at both suspected "MEC/CWM sites" and "non-MEC/CWM sites" at the SVFUDS. A site may be determined to be "non-MEC/CWM" if the site-specific USACE probability assessment determines that the probability of encountering MEC/CWM is "seldom" or "remotely possible" (defined as the likelihood that the occurrence of a mishap was "Unlikely but possible to occur"). For the purposes of investigations at the SVFUDS, non-MEC/CWM sites are referred to as "low probability" sites, while suspect CWM sites are referred to as "high probability" sites. For non-MEC/CWM sites, the anomaly investigation could proceed under low probability protocols. In these situations the anomalies could be excavated in open air without evacuations of people in the vicinity of the dig.

Sites that are determined to be "non-MEC/CWM" in this manner may still have chemical agent present and a contingency plan is still implemented to protect workers and the public. If evidence of potential MEC/CWM was encountered during the investigation of a non-MEC/CWM site, the probability assessment was revisited by USACE to determine whether the previous findings should be revised.

Most of the intrusive anomaly investigations were conducted under low probability protocols, with the general process being largely the same for each area of investigation. Logistics of the intrusive anomaly investigations depended on the location of the anomalies. Since many of the areas of investigation were private residential properties, significant coordination with the residents was often required. Pre-excavation landscape evaluations were typically conducted, with plants, shrubs, and other hardscape features near the area of excavation identified and their values assessed.

The anomaly dig sheet was provided for a particular grid or area of investigation along with information regarding the relative location of the anomalies to be excavated. The field geophysicist then had to reacquire the anomaly and mark it with a flag for the dig team. The objectives of anomaly reacquisition were to refine and mark the location of the anomaly peaks and measure the peak and background response values in accordance with work plan criteria.

All intrusive excavations were performed by hand digging by UXO Technicians. Following excavation, the hole was re-checked with the appropriate geophysical instrument to ensure the anomaly had been resolved. Typically, if the geophysical signal following anomaly removal was reduced by 90 percent or more compared to the reacquisition reading or the source of the anomaly signal was positively identified, the anomaly was considered to be resolved.

After the intrusive investigation was completed, all debris was cleaned up and the site was restored to original conditions. Excavated anomalies were then processed and segregated based on categorization as MEC or MD or non-munitions related scrap, and were properly disposed as discussed in Section 5.3.4.

4.1.2.6 High Probability Intrusive Investigation of Anomalies

If the site-specific USACE probability assessment determined that the probability of encountering MEC/CWM during the investigation was "frequent", "likely", or "occasional", then the site was considered a MEC/CWM site and the high probability protocols applied. In this case, safety measures such as agent air monitoring and on-site medical support was required.

High probability investigations were conducted several times at the SVFUDS, for example, the OU-4 AU Lot 18 and 4825 Glenbrook Road efforts discussed previously in Section 1.6. Relative to low probability investigations, high probability sites required significantly more planning, resources, and equipment to ensure safety of workers and the community because of the possibility of encountering MEC/CWM during the investigations.

For these sites, the anomaly excavation team performed the initial intrusive investigation either using engineering controls or under evacuation. Often a complete Engineering Control Structure (ECS), such as an elaborate tent, was used to effect negative pressure for vapor containment, and excavation would proceed inside the ECS. Each time an ECS was used during intrusive investigations, it was designed, reviewed, and approved to meet specific objectives such as vapor or blast containment in the event of an incident occurring while excavating.

Development of the specific engineering controls for each high probability site was based on a review of many factors such as the site history and previous investigation findings (if available). The types of MEC or CWM expected to be encountered during the investigation would be evaluated to develop the munition with the greatest fragmentation distance and the maximum credible event (the maximum release of a chemical agent that could occur as a result of an unintended, unplanned, or accidental incident) which would drive specific ECS design requirements.

Many different organizations are required for high probability investigations, including the USAESCH as the implementing agency for MEC/CWM activities, the U.S. Army 22nd Chemical Battalion's Technical Escort to provide capability for responding to, neutralizing, and interim holding of chemical agents, and munitions, ECBC's air monitoring team, explosive ordnance detail teams, and medical support teams.

The Site-Wide Work Plan (USACE, 2007d) is the current SVFUDS document intended to be all-inclusive and tailored to address all foreseeable potential investigation actions at various sites throughout the SVFUDS. However, since that work plan could not realistically address all site-specific contingencies, Site-Specific Work Plans were prepared for each individual site to be investigated at the SVFUDS, whether under low or high probability protocols.

Exhibit 4-3. High Probability Work Inside an ECS

4.1.3 Groundwater Investigations

Localized groundwater sampling was conducted as part of the OSR FUDS RI in 1993, but the groundwater data were not suggestive of contamination at that time. The study of SVFUDS groundwater essentially began with completion of the *Spring Valley FUDS Groundwater Study Work Management Plan* (USACE, 2005f). The installation of five piezometers to measure the water table elevation had been conducted earlier in 2004, but the plan for the comprehensive study of groundwater and the procedures to complete these characterization activities, was provided in that Work Management Plan.

Field procedures included the installation of groundwater monitoring wells and piezometers, and the sampling of the wells. Monitoring wells were generally installed using anomaly avoidance protocols, where geophysical instruments were used to clear the hole before the drill rig could advance deeper. Depending on the well-specific location and the objectives, the wells were sometimes simple shallow overburden wells, or more complex multi-port wells monitoring different hydrogeologic zones in the deep bedrock.

Multiple rounds of groundwater sampling of the finished wells were conducted at various times of the year, to evaluate seasonal effects and to provide sufficient data to make comparisons to baseline conditions. A Groundwater RI report, containing a groundwater focused HHRA, will be presented as a separate stand-alone document.

4.2 Removals

Removal responses are common at sites when the contamination poses an immediate threat to human health and the environment. Removals are classified as either time-critical or non-time-critical depending on the extent and type of contamination.

A TCRA is a response to a release or threat of release that poses such a risk to public health (serious injury or death), or the environment, that clean up or stabilization actions must be initiated within six months.

NTCRAs are conducted when a removal action is appropriate and a planning period of at least six months is available before on-site activities must begin. The NCP requires an EE/CA for all NTCRAs. It is intended to: satisfy environmental review requirements for removal actions; satisfy administrative record requirements for documentation of removal action selection; and provide a framework for evaluating and selecting alternative technologies. The EE/CA identifies the objectives of the removal action and analyzes the effectiveness, implementability, and cost of various alternatives that may satisfy these objectives.

Section 1.6.4 described some of the SVFUDS removals completed as TCRAs/NTCRAs, including the AU CDC, AU Athletic Fields, and individual properties.

4.2.1 Soil Removal

4.2.1.1 Removals Based on Arsenic

Removal actions necessitated by elevated arsenic concentrations in the soil were conducted primarily by excavation, whether under time critical or non-time critical actions. As outlined in the arsenic EE/CA (USACE, 2003b), excavation and off-site disposal of arsenic-contaminated soil at residential and non-residential properties was the recommended alternative for addressing properties or lots with at least one grid sample result showing an arsenic concentration higher than the removal goal of 20 mg/kg (see Section 7.4.1 for more detail on derivation of this goal). While the majority of these removals were completed under low probability protocols, in some cases depending on the history of past AUES operations in that area, or items uncovered during the removal, the high probability protocols described in 4.1.2.6 were required.

The procedures for completing these excavations were essentially the same for each property, with minor logistical adjustments based on property-specific conditions. Generally, soil within each 20-by-20-foot grid having an arsenic concentration greater than 20 mg/kg, was removed to a minimum depth of two feet bgs, a depth determined to be protective of gardening and landscaping activities. To ensure sufficient removal of arsenic-contaminated soil, confirmation soil samples were collected at the bottom center of each grid square after the minimum depth of soil has been removed, and compared to the removal goal. If a confirmation sample exceeded the goal, an additional one to two feet of soil was removed and then that grid bottom was sampled; this process was repeated until a grid confirmation sample result of less than or equal to the removal goal was obtained. The method of soil excavation to remove arsenic contamination, and use of confirmation sampling to ensure full delineation of each grid to below 20 mg/kg, also removed other constituents that may have been present.

Soil samples were also collected from each grid sidewall that bordered a grid with an arsenic result less than or equal to 20 mg/kg. These confirmation samples were collected from the horizontal midpoint of the sidewall at a depth of six inches bgs. When a sidewall sample exceeded the removal goal, the sidewall excavation was extended five feet laterally. Additional confirmatory samples were then collected from the base of the extended excavation and from each sidewall that bordered a grid with an arsenic result less than or equal to 20 mg/kg.

In some cases, soil containing up to 43 mg/kg arsenic was left in the root zones of specimen trees or plants, or where access or other construction limitations made soil removal difficult or unsafe. See Section 7.4.2 for a more detailed discussion of this situation.

The procedure was to remove soils from grids in two foot lifts. Excavation utilized standard construction equipment such as excavators, loaders and backhoes to remove contaminated soil and place it into shipping containers. For removals on private residential properties, the smallest, most efficient construction equipment was used, when possible, to minimize noise and to reduce homeowner concerns regarding property damage risks. Care was taken to minimize the impact of construction traffic in the work area and to keep open access to homes. During excavation activities, dust abatement and control procedures were employed to minimize the transport and inhalation of fugitive dust by site workers and nearby personnel. These procedures included the monitoring and cleaning of visible surface soil on roads, dust suppression with water, and air monitoring for dust downwind of excavation operations.

Clean fill and topsoil was used to fill the excavation. Clean backfill was obtained through soil brokers to find supplies near the SVFUDS; it was always sampled and approved by USEPA and DDOE before it could be used. Once approved, backfill was often stockpiled at the Federal property for later use, or if possible, was delivered directly to the specific removal location to avoid double handling. Geotechnical testing, including standard and modified Proctor testing was performed to meet compaction requirements. Upon completion of the excavation to original grade, sod was placed upon the re-graded surface to establish grass. Exhibits 4-4 and 4-5 show during and after excavation pictures at a typical residential property.

Exhibit 4-4. During Grid Excavation

Exhibit 4-5. After Excavation

4.2.2 Phytoremediation

Removal actions necessitated by elevated arsenic concentrations in the soil were conducted primarily by excavation, whether under time critical or non-time critical actions. However, for selected TCRA and NTCRA properties, phytoremediation technology was also used at the SVFUDS as an alternative approach for reducing arsenic soil levels at some of the properties designated for removal actions for arsenic-contaminated soils. Phytoremediation is a technology based on the ability of plants (primarily different varieties of ferns) to accumulate heavy metals such as arsenic in unusually high concentrations in their stems and leaves. Although phytoremediation was not recommended as a primary approach over the excavation and backfill method, phytoremediation was successful in reducing arsenic concentrations to below the removal goal of 20 mg/kg (or 43 mg/kg) at several properties. A more detailed discussion of the results of phytoremediation is presented in Section 5.0.

In 2003, a laboratory feasibility study was conducted at the USACE Engineering Research and Design Center (ERDC) in Vicksburg, MS, to evaluate the potential effectiveness of phytoremediation for remediating arsenic from the site soils from SVFUDS properties. Encouraging results from this lab study lead to the use of phytoremediation on selected properties throughout the SVFUDS.

Field procedures for this alternative removal approach are described in detail in *Arsenic Phytoextraction Field Verification Study Spring Valley FUDS, Operable Units 4 and 5* (USACE, 2007a). Operations typically consisted of site mobilization, plot layout and construction, and soil sampling combined with other agricultural practices designed specifically for phytoremediation. Site mobilization activities consisted of an initial site visit to prospective plot locations to determine the requirements for soil preparation, fencing, irrigation, and planting of the ferns.

Throughout the study, a grid system was used and pre-planting soil arsenic concentrations were determined for each of the grids. The study grids were divided into four equal quadrants with a maximum of 400 square feet per sampling grid. For Phase 1 and Phase 2 of the field verification study, discrete core samples to a depth of six inches bgs were collected in the center of each quadrant and from the center intersection of the sampling grid and composited to create a five point composite from each study grid. For Phase 3 through Phase 5 of the field verification study, soils in the study grids were sampled so that thirty discrete cores were collected and composited from each grid. Discrete core sample locations were laid out in a symmetrical pattern for even coverage throughout each grid. The soil cores were collected using a one-inch stainless steel hand-held auger.

Each plot area was fertilized prior to transplanting. Fern plants were then established in the test plots through transplanting of four-inch high live plants. Where existing turf grass or sod was present, the soil was rototilled to a maximum depth of four inches or turned over by hand using a shovel in preparation for planting. Where existing vegetation or other landscape features prevented rototilling, the ferns were transplanted directly into the soil to avoid disruption of existing vegetation. The selected Edenfern species (*Victory*, *Moonlight*, *P. cretica nervosa*, *Pteris vittata, P. cretica parkerii, or Arctic*) were transplanted into the soil using a 12-inch plant spacing. The fern species were selected based on site specific conditions favoring growth of a specific variety with a goal of maintaining uniformity and consistency in experimental design.

At each residence, a surface irrigation system was designed and installed to accommodate the moisture requirements of the ferns at each plot. Plant growth and development was monitored by USACE. During the growing season, diagnostic leaf and frond samples were obtained on an as needed basis, depending on weather conditions and the physiological condition of the plants to monitor the progress and status of the plants for removing arsenic. Samples of the biomass were collected for laboratory analysis; all remaining biomass was properly disposed. Post-harvest soil samples were collected after the collection of the plant samples in the same manner as in the pre-planting soil sampling. At the conclusion of site activities, the plots were restored and former grass areas were resodded. Bare soil areas were mulched to prevent erosion. Exhibits 4-6 and 4-7 depict different varieties of ferns planted at two of the selected SVFUDS properties.

Exhibit 4-6. *Pteris vittata* Ferns

Exhibit 4-7. *Victory* Ferns along Fenceline

5.0 REMEDIAL INVESTIGATION RESULTS

The primary objective of an RI is to characterize the nature and extent of HTW/MC/CWM risk and MEC hazards such that informed decisions can be made as to the level of risk or hazard presented by the site and the appropriate remedial response to mitigate them. Section 5.0 summarizes the results of the investigation and characterization activities and the removal actions conducted since the inception of the SVFUDS.

Each of these concurrent multiple activities, including different types of investigations of different discrete areas, geophysical investigations, and time-critical and non-time critical removal actions, resulted in completed standalone reports documenting the findings and presenting conclusions of each effort. Therefore, the intention of the nature and extent discussions in this RI report is to present the rationale for each key event and summarize their findings to provide a more complete characterization of the SVFUDS. This RI report does not repeat the detail of these individual reports or change any of their conclusions (other than to provide an update or place them into a larger context, where appropriate).

Sections 5.1 through 5.4 discuss the findings of the individual key reports that are organized by type of investigation or removal, as presented in the Section 1.0. That is, Sections 5.1 through 5.4 continue the description of activities introduced in Sections 1.6.1 through 1.6.4, respectively. Tables 1-3 through 1-6 from the Section 1.0 discussions list the key reports that are contained in their entirety, in Appendix C.

Section 5.5 summarizes disposition of all waste materials generated throughout the investigations and removals, and Section 5.6 presents an overall summary of the nature and extent of contamination for the SVFUDS based on the findings of these reports.

While these Section 5.0 discussions focus on sampling results and munitions findings, it is important to understand how the data represented in these many reports were integrated into a cohesive evaluation of risk. Section 7.1.2 describes how risk screening was completed in stages to review all of the previously completed HHRAs and incorporate all of the samples not addressed in a previous HHRA, and Sections 7.2 and 7.3 present the new quantitative HHRAs completed as part of this RI report to assess risk remaining within the SVFUDS.

5.1 Initial Investigation and Characterization Results

This discussion provides a summary of the findings of the key initial investigation and characterization reports introduced in Section 1.6.1 and shown in Table 1-3.

5.1.1 <u>OSR FUDS Phases I and II</u>

On January 5, 1993, a buried munition disposal pit was discovered on 52nd Court, approximately one-half mile east of the Dalecarlia Reservoir and about one-quarter mile south of the border between the District of Columbia and Maryland. Upon notice of the discovery, the U.S. Army Technical Escort Unit from the Chemical and Biological Defense Agency at Aberdeen Proving Ground, Maryland, initiated an emergency response, designated OSR FUDS Phase I, which was completed on February 2, 1993.

Items recovered from the disposal pit during the emergency response included 141 intact munitions, assorted munitions-related debris, and laboratory materials. Forty-three of the intact munitions recovered were deemed suspect chemical munitions. Thirty-four of these were sent to Pine Bluff Arsenal, Arkansas, for destruction, and nine of the suspect chemical munitions items were subjected to additional analysis by the Army's Edgewood Research, Development, and

Engineering Center (ERDEC) at Edgewood Arsenal, Maryland (USACE, 1995b). All items were safely removed from the SVFUDS and the pit was backfilled.

USACE initiated the INPR during the OSR Phase I to officially establish the SVFUDS and proceed with an RI/FS. OSR FUDS Phase II was the start of the RI phase for the SVFUDS (USACE, 1993b).

During Phase II, using historical documentation including reports, maps and photos, USACE developed and focused its investigation on the POIs (Section 1.5.3), specific areas that were determined to have the greatest potential for contamination. During the two-year investigation that followed, geophysical surveys were conducted at POIs considered to be potential munitions burial locations. The purpose of the geophysical investigations was to locate any additional possible caches of WWI munitions. An additional 10% of properties outside of the POIs were also investigated to serve as a measure to verify the quality and completeness of the historical information that had been gathered.

Surveys were performed on a total of 492 properties and lots, and 840 geophysical anomalies were intrusively investigated. The majority of the anomalies were identified as construction debris from property development. A total of three intact munition items were recovered during OSR FUDS Phase II:

- one spent Livens smoke round,
- one unfired 75 mm munition recovered from the ground surface, and
- one unfuzed 3-inch Stokes Mortar round.

The 3-inch Stokes Mortar round was presumably an amnesty round (items found and kept by residents which were ultimately provided to USACE for documentation and disposal purposes) as it was left outside the Spring Valley Resident Office (USACE headquarters for the OSR FUDS operations). All items were safely removed from the SVFUDS. No additional burial pits were identified and no additional CWM was recovered (USACE, 1995b).

In addition to the geophysical investigations conducted to characterize the nature and extent of residual AUES contamination, a total of 260 soil samples were collected at 14 areas that included 17 POIs. Samples were taken from randomly selected locations within each POI, as close as possible to the 1918 ground surface level. The samples were analyzed for CWM and CWM ABPs, metals and explosives by USACE; the USEPA collected split samples and conducted their own analyses (Section 5.1.3).

No chemical agents, ABPs, or explosives were found in any of the samples taken. However, several metals were identified that exceeded the USEPA's risk based screening criteria. These metals were included in a quantitative baseline HHRA that found no elevated health risk requiring remedial action. At that time, arsenic was not identified as a chemical of potential concern in the HHRA since the sampling results were not significantly different from the background concentrations (USACE, 1995b).

These findings were documented in the March 1995 OSR FUDS RI report (USACE, 1995b). The report recommended no further action for the FUDS with the exception of the Spaulding and Captain Rankin Area (a single property, discussed below). The RI report was followed by a No Further Action Record of Decision in June 1995 (USACE, 1995c). In this decision, the Army took responsibility for any future actions required if additional munitions or contamination related to past DoD activities were discovered.

The HHRA that was part of the OSR FUDS RI was one of those pre-2005 HHRAs that were reviewed against updated USEPA standards and more recent SVFUDS background data to determine whether its conclusions would still be protective today. As discussed in Section 7.1.2.1, its findings and conclusions were updated and integrated into the overall statement of remaining risk for the SVFUDS.

5.1.2 OU-2 Spaulding and Captain Rankin Investigations

The OSR FUDS RI determined that no further action was required for the entire OSR FUDS with the exception of the Captain Rankin Area (POIs 21, 22, and 23), designated as OU-2. The June 1994 EE/CA for the Spaulding and Captain Rankin Areas (USACE, 1996) determined the appropriate action for addressing the soil and material contained within the former shell pits (bunkers) and surrounding areas. A Streamlined Risk Evaluation in the EE/CA identified risk from lead and arsenic in the soil within the bunkers. Based on these findings, an NTCRA was conducted in this location to remove the soil debris found within the POI structures. Figure 5-1 presents the OU-2 property location.

A separate OU-2 RI for the Spaulding and Captain Rankin Area was prepared in 1996. It consisted of two parts: the NTCRA and the Captain Rankin Area POI 23 pipe drain terminus remedial investigation sampling. The NTCRA included the removal of the debris from the Captain Rankin Area structures and sampling in and around the Spaulding and Captain Rankin Area structures to confirm that potential contamination was removed.

The OU-2 RI addressed exposures to subfloor soils and concrete and pipe drain termini at POIs 21, 22, and 23 for construction workers exposed via incidental ingestion and inhalation. None of the subfloor soil samples collected from POI 22 contained detectable concentrations of CWAs, agent breakdown products (ABPs) (chemicals whose only source could be chemical agent), explosives, or explosives breakdown products. Soil debris characterization, concrete, subfloor soil, and pipe drain terminus soil samples were collected from POI 21. None of the concrete, subfloor soil samples or pipe drain terminus soil samples contained detectable concentrations of CWM, ABPs, or explosives.

Soil debris characterization, concrete, pipe drain debris, subfloor soil, and pipe drain terminus soil samples were collected from POI 23. None of the concrete, pipe drain debris, subfloor soil, and pipe drain terminus soil samples contained detectable concentrations of explosives. During the NTCRA confirmation sampling, mustard agent was detected in all the pipe drain terminus soil samples at low concentrations; however, duplicate analyses of these samples did not detect mustard agent. Due to this inconsistency, additional pipe terminus soil samples were collected and analyzed by two other qualified laboratories as part of the subsequent RI and no mustard or mustard ABPs were detected. Therefore, the mustard detections were considered to be analytical errors.

The HHRA portion of the OU-2 RI report determined that while arsenic was a COPC for all three POIs, it did not pose any unacceptable risks. In the June 1996 Spaulding and Captain Rankin RI Report, USACE recommended that no further action be taken at OU-2.

The HHRA for OU-2 was also one of those pre-2005 HHRAs that were reviewed against updated USEPA standards and more recent SVFUDS background data to determine whether its conclusions would still be protective today. As discussed in Section 7.1.2.1, its findings and conclusions were updated and integrated into the overall statement of remaining risk for the SVFUDS.

5.1.3 USEPA Human Health Risk Assessment for SVFUDS

In 1999, the USEPA prepared an HHRA for the SVFUDS (USEPA, 1999). USEPA conducted an analysis of soil sampling data collected between 1993 and 1995 at 16 locations throughout Spring Valley and AU property (taking splits of the USACE OSR FUDS RI samples). The risk assessment evaluated the toxicity posed by chemical substances in soil and described the exposure routes by which humans may come into contact with these substances.

The USEPA HHRA was intended to evaluate the significance (if any) of residual chemical contamination and to determine the full nature and extent of required follow-on investigations at the SVFUDS. The HHRA was intended to be read in conjunction with the OSR FUDS RI. The exposure scenarios evaluated included residents, groundskeeper/lawn maintenance workers, and recreational users (representing lounging activities associated with a 4-year college student) exposed to surface soil and construction workers exposed to subsurface soil. Based on the splitting of samples with USACE, the POIs assessed included all of those in the USACE OSR FUDS RI with the exception of POI 37 and the LTC Bancroft Area. The USEPA also collected samples from 4825 Glenbrook Road independent of the OSR FUDS RI split sample locations.

The HHRA concluded that the non-cancer hazard index (HI) for all receptors were, in most instances, below USEPA's acceptable threshold HI value of 1.0 (adverse health effects are not anticipated). There were only a few POIs where concentrations of COPCs (primarily antimony and thallium) resulted in exceedances of the threshold HI value of 1.0. However, the HHRA only considered the conservative reasonable maximum exposure (RME) exposure scenarios which evaluate the upper percentile exposure scenarios. The HHRA concludes that assessment of a Central Tendency (CT) exposure scenario would be expected to reduce HI values by more than one order of magnitude, thereby eliminating all instances where HI values exceeded 1.0. Further, based on a review of available metals data and comparison between USEPA and USACE soil sampling data, there was an indication that inter-laboratory bias was at least partially responsible for elevated levels of antimony and thallium.

The HHRA showed that excess lifetime cancer risks for adult/child residents and construction workers were within USEPA's acceptable risk range. While an exceedance of the acceptable cancer risk was observed for arsenic at POI 24 for the adult resident and child resident, a CT exposure scenario was expected to reduce this estimated cancer risk to within the acceptable risk range. The HHRA further concluded that residential land use was not a realistic exposure scenario at this POI, and thus, that the HHRA results were unnecessarily conservative.

As presented in Section 7.1.2, this HHRA was reviewed, and its findings and conclusions were updated and integrated into the overall statement of remaining risk for the SVFUDS.

5.2 Follow-on Investigation and Characterization Results

This discussion provides a summary of the findings of the key follow-on investigation and characterization reports introduced in Section 1.6.2 and shown in Table 1-4.

5.2.1 Operable Unit 3

5.2.1.1 4801 and 4825 Glenbrook Road

While these OU-3 investigations included geophysical and removal activities, this discussion is self-contained and those activities are not separately discussed in Sections 5.3 and 5.4. Figure 5-1 presents the location of the OU-3 properties.

Based on concerns of the DCRA in 1997, USACE reviewed aerial and supporting photographs and determined POI 24 to be on the grounds of 4801 Glenbrook Road instead of AU property, incorrectly located by approximately 150 ft. Given the incorrect location of POI 24, USACE conducted field investigations in the vicinity of the revised POI 24 location, on 4801 Glenbrook Road. In 1998, a geophysical survey of the area identified two high probability anomalies (large metallic areas indicative of possible burial pits below the ground surface). Nine low probability anomalies were also identified. Three of these anomalies were investigated in open air without evacuation and were resolved. The remaining six anomalies were investigated in open air with evacuation and were resolved. The two anomalous areas were investigated under engineering controls. Another seven low probability anomalies were identified in a 2002 geophysical survey after access was gained to the specific area. These seven anomalies were investigated in open air without evacuation and were resolved.

In March 1999, the intrusive investigation of the two large burial pits, referred to as Pits 1 and 2, began on 4801 Glenbrook Road. This work was completed as a high probability investigation with both pits excavated within an ECS. Approximately one year later (March 2000), the investigation was completed. A total of more than 600 items were recovered; these included 368 MEC and munitions debris items. Nineteen of the items were determined to contain CWM, predominantly mustard agent (USACE, 2005d).

To further address DCRA concerns, the USEPA collected surface soil and subsurface soil samples in and around 4801, 4825, and 4835 Glenbrook Road to supplement their HHRA (USEPA, 1999), which recommended additional sampling around 4801 Glenbrook Road. Based on the interim results from the USEPA sampling, historical information, and the USEPA HHRA, it was determined that the soil of these three properties may have been impacted by AUES activities in the vicinity of the two burial pits on 4801 Glenbrook Road.

USACE completed an EE/CA to address potential metals contamination on these three properties that included an HHRA and recommended a preferred alternative to address the metals contamination in soil. The EE/CA determined that the top 2 feet of soil in the affected areas should be removed and replaced with new soil (USACE, 2000c). The soil removal began in December 2000, and was completed in March 2001 at 4801 Glenbrook Road and 4825 Glenbrook Road (USACE, 2006a; USACE, 2011a).

The 4801 Glenbrook Road NTCRA was performed to remove the soils from selected 20 by 20 foot grids to a minimum depth of 2 feet in areas defined in the EE/CA as requiring removal. The EE/CA also recommended the removal of sediment from the stream that runs through the property, parallel to Rockwood Parkway, from the source of the stream to where it exits 4801 Glenbrook Road in the southwest corner of the property.

Grid confirmation soil samples were collected at the bottom of each 20 by 20 foot excavated grid square. When a grid confirmation sample exceeded the arsenic removal goals (prior to establishment of the 20 mg/kg goal, the property-specific goals of 17 mg/kg arsenic for the North Area and 25 mg/kg arsenic for the South Area were derived in the HHRA component of the EE/CA), additional soil was removed from the grid and a subsequent grid confirmation sample was collected. This process continued until there were no more exceedances. Once the excavation operation in an area was completed, each area was backfilled with clean backfill soil and topsoil, compacted, and then seeded. After completing the excavation of the 4801 Glenbrook grids, the stream was excavated. Once the stream removal goals were met, the streambed was backfilled with clay material. A total of approximately 3,200 cubic yards or

4,750 tons of soil was excavated from 65 grids and from the stream running through the 4801 Glenbrook Road property. All materials excavated were disposed as non-hazardous solids at a permitted Resource Conservation and Recovery Act (RCRA) Subtitle D land disposal facility.

Additional minor soil removal actions took place from November 2008 through January 2009 to remove three grids in an area impacted by site logistics of the neighboring 4641 Rockwood Parkway property (USACE, 2011f).

Following the completion of the arsenic contaminated soil removal, USACE developed a plan to excavate TPs at 4825 Glenbrook Road due to its location adjacent to 4801 Glenbrook Road, and the existence of possible disturbed areas identified in the USEPA EPIC aerial photograph review. The TPs were located in the eastern portion of the property and the driveway based on high arsenic soil sampling results. Twenty-three TPs and two trenches were investigated in May and June 2001, and no significant items were recovered during the investigation of these TPs and trenches, except at TP 23 where a third burial pit (Burial Pit 3), was located.

The investigation was conducted from May 2001 to March 2002, at which time USACE was required to demobilize when the property owner did not renew permission to access the property. Eighteen CWM items and 406 munitions-related items were recovered during the initial investigation. Glassware items were found to contain mustard and Lewisite breakdown products. One 75mm projectile was found to contain arsine and two other items had potentially similar fill (USACE, 2011a). The investigation of Burial Pit 3 resumed in 2007 in conjunction with plans to excavate additional TPs on the 4825 Glenbrook Road property as well as at 4835 Glenbrook Road (USACE, 2011a; USACE, 2013a). As a result of Burial Pit 3 and TP investigations conducted at 4825 Glenbrook Road, the decision was made in August 2010, to separate the 4825 Glenbrook Road property from the remainder of the SVFUDS and place it on its own CERCLA process pathway. Section 5.4.4 provides additional detail on the 4825 Glenbrook Road investigation activities, but they are not incorporated into this RI report, and summary information regarding the 4825 Glenbrook Road site RI through RA efforts is provided for informational purposes only.

5.2.1.2 4835 Glenbrook Road

Note that while this investigation included geophysical and removal activities, this discussion is self-contained and those activities are not separately discussed in Sections 5.3 and 5.4.

TP investigations were conducted at 4835 Glenbrook Road in conjunction with the resumed effort to investigate Burial Pit 3 identified during the excavation of TP 23 at 4825 Glenbrook Road. The purpose of the TP investigations was to locate potential burial areas and the investigation was designed to achieve a 95% confidence in determining the location of potential burial pits or trenches with dimensions of not less than 10 ft by 20 ft on the property. Excavation of arsenic contaminated grids was conducted along with the TP investigations (USACE, 2013a).

The TP investigation began in October 2007 and was completed in December 2008. A total of 76 out of 77 TPs planned for the property were completed: one TP was not completed because of the presence of utilities. In 14 TP excavations and the area north of TP 17, suspect AUES-related items were recovered. Of these 14 TPs, 13 TPs included suspect AUES-related labware fragments (glass tubing, stoppers, glass fragments), and one TP included a Livens projectile. Approximately 539 cubic yards of arsenic impacted soil at concentrations exceeding the 20 mg/kg removal goal were also removed from the property during the investigation effort

(USACE, 2009a; USACE, 2013a). All soil excavated was disposed as non-hazardous solids at a permitted RCRA Subtitle D land disposal facility.

Soil samples collected during these activities, as well as other data collected from the previous investigations (1992, 1996, 1999, and 2000), were evaluated in an updated HHRA for the property. The HHRA concluded that unacceptable cancer risks and non-carcinogenic health effects to the human receptors were not expected from assumed exposures to COPCs in soil at this property. Based on results and conclusions of these investigations and the HHRA, no further investigations at this property were recommended. As one of the more recent, discrete SVFUDS HHRAs, it is further summarized in Section 7.1.1.1.

5.2.2 Operable Unit 4

During the investigations of OU-3 Pits 1 and 2 and the removal of arsenic contaminated soil from the area, USACE conducted a review of historical documentation involving several events which may have contributed to elevated arsenic concentrations in soil in the Baker Valley POI. In addition, in 1999, the USEPA conducted multiple sampling events in and around OU-3. Based on the results of this sampling and review of historical activities, the area of investigation was expanded to include approximately 91 additional acres. This was designated as OU-4 and it included approximately 80 private residences and significant portions of the AU campus (USACE, 2000a). The findings of the investigation and characterization activities for areas that fell within OU-4 are discussed in this section.

5.2.2.1 USEPA HHRA for American University

In 2000, the USEPA prepared an HHRA specific to the southern portion of the AU campus (USEPA, 2000b). The area addressed in the HHRA included areas south and west of Watkins Hall, areas surrounding Kreeger Hall, and the area stretching from east of Kreeger Hall to south of Hamilton Hall. Samples used in the HHRA were collected in April and December 1999 and included both surface and subsurface samples. The general area addressed by the HHRA is shown in Figure 5-2. The focus of this HHRA was to evaluate the potential risk to human health from exposures to metals in the soil at AU. The HHRA assessed the following receptors potentially exposed to surface soils: adult trespasser, child trespasser, adult student athlete, and adult maintenance worker.

The child trespasser and maintenance worker non-cancer risks were greater than the target HI of 1.0, primarily due to chromium. However, these non-cancer risks were determined using the toxicity values for hexavalent chromium. The USEPA HHRA concluded that the non-cancer risks determined using the toxicity values for trivalent chromium, which were within or below USEPA's acceptable risk range, were more appropriate, and that using hexavalent toxicity values most likely overestimated non-cancer risks due to chromium concentrations on the site.

The HHRA concluded that the excess lifetime cancer risk to the receptors was within USEPA's acceptable risk range. In all cases, the primary cancer risk was from exposure to arsenic. However, the concentrations of arsenic found on the AU property were not found to be significantly different than the concentrations found in the background samples.

As presented in Section 7.1.2, this HHRA was reviewed, and its findings and conclusions were updated and integrated into the overall statement of remaining risk for the SVFUDS.

5.2.2.2 AU Child Development Center

As a further result of the expanding sampling efforts, several lots on the AU campus were recommended for more detailed sampling including the AU CDC (USACE, 2003a) (see Figure 5-2). In November 2000, arsenic was detected in the CDC at a concentration of 31.30 mg/kg exceeding the background arsenic concentration of 12.6 mg/kg, and therefore grid sampling to define the extent of arsenic contamination was performed. In January 2001, grid sampling of OU-4 AU Lot 12 and the CDC was completed. Arsenic concentrations ranged from 3.43 mg/kg to 498 mg/kg, and a TCRA (USACE, 2003a) was conducted (see Section 5.4.1.1).

Prior to completion of the TCRA, in February 2001, additional soil samples were collected from various locations at the CDC and OU-4 AU Lot 12 with the objective of determining whether compounds documented as having been used during AUES activities were present in the soil. Some of these samples were analyzed for the AUES List chemicals (prior to establishment of the SVFUDS Comprehensive list as discussed in Section 3.3.1.3). Although the findings of those samples are discussed in the context of the risk screening conducted in the Pre-2005 HHRA Review report (USACE, 2013e), given the thoroughness of the CDC TCRA, the soil from which those samples were collected was excavated and properly disposed, and they were ultimately screened out via the risk screening process (i.e., the soil is no longer present). Section 7.1.2.2 describes the overall screening of risk for the SVFUDS. The screening reports are contained in their entirety in Appendix D.

5.2.2.3 AU Small Disposal Area

Another investigation initiated as a result of USEPA sampling events in 1999 was the SDA (USACE, 2004a). During one of the sampling events, a DDOE representative discovered surface debris located on the southwestern edge of AU property behind residential properties on Rockwood Parkway. The surface debris, which covered an area of approximately 12 ft by 23 ft, included used oil filters, glass and labware, and other miscellaneous debris dating from the late 1800s to 1940. Figure 5-3 presents the location of the SDA and other AU areas of investigation.

The intrusive investigation of the SDA was performed in several phases, with initial intrusive investigation conducted from January through March 2000. On May 1, 2000, a geophysical survey was conducted at the SDA to locate subsurface anomalies associated with labware and other debris. In January 2001, the investigation of the SDA site began under evacuation protocols in accordance with an addendum to the Site Safety Submission.

All soil removed from the SDA excavation was determined to be clear of CWM. Forty five archaeological artifacts were recovered. A total of 130 drums and approximately 47 tons of bulk material were generated during the intrusive investigation. Fifty-seven drums of excavated RCRA hazardous soil, glassware (empty and broken bottles and labware, as well as one open unbroken container with groundwater/seepage inside), and metal (non-munitions scrap) debris from the 2000 phase of the investigation were disposed. From the January 2001 phase of the investigation, 73 drums of excavated RCRA hazardous soil, broken glassware, and non-munitions scrap were disposed.

In March 2001, a total of approximately 19 tons of over-excavated RCRA hazardous soil, broken glassware, and non-munitions scrap were also disposed. In addition, about 47 tons of RCRA nonhazardous soil, broken glassware, and non-munitions scrap from the over-excavation were disposed at a permitted RCRA Subtitle D land disposal facility.

All intrusive work was completed by the end of March 2001. Complete site restoration was part of the larger OU-4 AU Lot 18 activities (USACE, 2004a).

5.2.2.4 AU Athletic Fields and Other Lots

Grid sampling conducted in March 2001 as part of the OU-4 and OU-5 EE/CA identified a number of grids with arsenic contaminated soil on AU campus lots (see Figure 5-2). The arsenic contaminated soil was removed under a TCRA (USACE, 2010a). The TCRA is discussed in more detail in Section 5.4.1.2. Geophysical investigations were also performed and anomalies were investigated in the lots in conjunction with the TCRA (see Section 5.3.2.1) (USACE, 2005c).

With regard to some of the non-arsenic sampling results, in response to DDOE concerns, further evaluation of thallium concentrations in two locations identified during the OSR FUDS RI (one located in OU-4 AU Lot 10 and one located to the south of Hamilton Hall) was conducted. These two locations had thallium concentrations greater than the USEPA standard for residential soil. Samples were collected at varying depths at these two locations and at several points around these two locations and the results were below the standard.

Nine samples collected from five soil borings on the south and west sides of Watkins Hall in 2001 were analyzed for VOCs, SVOCs, and TAL metals. Three metals were detected at concentrations above the applicable standards, and these data underwent the comprehensive risk screening conducted in the Addendum to the Pre-2005 HHRA Review report. Section 7.1.2.2 describes how data points similar to these throughout the SVFUDS were integrated into the overall evaluation of risk for the SVFUDS. The data tables presenting the individual sample results are contained in the Site-Wide HHRA Work Plan for the new quantitative HHRAs completed as described in Sections 7.2 and 7.3. Those reports are contained in their entirety in Appendix D.

5.2.2.5 OU-4 AU Lot 18 Disposal Area

Geophysical investigations and TCRA activities began in the area referred to as AU Lot 18 (see Figure 5-3) in 2002 as part of the AU Athletic Fields and other Lots TCRA and geophysical investigations. During the intrusive investigation of anomalies, a significant amount of debris was encountered. Recovered items included laboratory wares and MD (including 75mm scrap, 4.7-inch scrap, 3-inch Stokes mortar scrap, and 8-inch Livens smoke scrap). Following discovery of this apparent disposal area, the excavation continued to expand in an effort to remove all of the debris associated with the anomalies and continued into mid-2003 as a low probability investigation.

In April 2003 a bottle that had been recovered from Lot 18 was identified as containing a small amount of Lewisite (0.3%). The discovery of the container with the Lewisite solution changed the protocols used to ensure safety during the investigation from low probability to high probability (USACE, 2008b).

In 2004 USACE completed revisions to its site safety and work plans and returned to the site to continue the investigation under high probability protocols. All intrusive operations were conducted inside a negative pressure ECS. Intrusive operations were conducted between 24 June 2004 and 21 January 2005. Following additional revisions to safety and work plans to improve efficiency of operations including a larger negative pressure ECS, high probability investigations continued from 20 June 2005 through 26 January 2006. At the completion of the high probability investigation in January 2006, a total of 73 MD items, 6 intact munitions-related items, and 31 intact containers had been removed. One intact munitions-related item was assessed as a 75 mm round containing white phosphorous. No munitions related items were determined to be explosively or chemically configured. One intact container was determined to contain a 0.28 parts-per-million (ppm) concentration of mustard agent, and three containers contained mustard ABPs.

Following the completion of the high probability investigation, additional soil sampling and low probability geophysical anomaly investigations were conducted in 2006. During the anomaly investigations, a total of eight MD items and two intact glassware containers were recovered, in addition to a large amount of debris and broken glassware. No CWM or ABPs were detected in the debris and containers (USACE, 2008b). The debris identified during the 2006 low probability soil removals and investigations extended toward the AU PSB.

This investigation also included a soil over-excavation effort, performed as an interim measure to excavate soil containing compounds that could pose a risk to human health. Approximately 27 pounds of glassware and one MD item were found, and approximately 870 cubic yards (1,479.6 tons) of non-hazardous soil was excavated during the over-excavation effort and disposed offsite at a permitted Subtitle D Landfill.

A discrete HHRA (USACE, 2008g) was also conducted for this area, as discussed in Section 7.1.1.2.

5.2.2.6 AU Public Safety Building

Additional planning was required to continue following the Lot 18 debris to fully investigate and excavate the soil up to the foundation of the AU PSB, without compromising the structural integrity of the building (see Figure 5-3).

Under Phase 1 investigations (August 21 through September 12, 2006), a geotechnical investigation was followed by advancement of boreholes and investigation of three test pits. Sampling for geologic and geotechnical evaluations was completed in support of this phase. During installation of Sump 3, one MD item, some glassware, and suspect AUES-related ceramic crockery were recovered; no CWM was found by ECBC headspace analysis.

Intrusive operations were conducted under the PSB Phase 2 investigations between 3 June 2008 and 3 June 2010. Phase 2 activities included investigations of single item anomalies, anomalous areas, and the debris area located on the south side of the PSB identified during the Lot 18 investigation. All intrusive operations were conducted under the low probability operations.

Twelve single-item anomalies were investigated in June 2008. No MEC, CWM, or AUES-related items were encountered; they mostly consisted of items such as nails, wire, scrap metal, metal strapping, and magnetic rocks. The two anomalous areas were investigated by excavating three trenches. No CWM, or AUES-related items were encountered; the items were mostly nails, metal cables, cast iron pipe, and similar cultural debris.

The debris area investigation resulted in the recovery of thirteen closed cavity items assessed as closed cavity rounds and intact containers that did not contain CWM or ABPs. These items include three closed cavity 75 mm projectiles, one burster tube for a 75 mm projectile (later classified as MEC due to the presence of residual energetics), one pressurized gas cylinder, two metal pipes with end caps, and six intact containers. Fifty six MD items recovered included multiple types of open cavity items. These open and closed cavity munitions-related items were demilitarized using a controlled detonation chamber (Section 5.5.3) and disposed. All intact containers were cleared for the headspace analysis and low level agent analysis by ECBC and properly disposed.

Elemental mercury was encountered during the Phase 2 debris area investigation; it was excavated and 84 drums were disposed offsite at a mercury retort facility or to a hazardous waste stabilization facility. Additional areas of suspected AUES-related debris were encountered in four areas while installing a headwall in the vicinity, but all items were cleared for headspace analysis by ECBC. Arsenic impacted soil in the utility area was excavated and disposed offsite. Finally, horizontal drilling beneath the PSB was conducted to obtain soil samples. No CWM, MEC, MD, or suspected AUES-related debris were encountered beneath the building.

The results of the Phase 1 and 2 investigations confirm the presence of AUES-related material at the locations investigated at PSB. The investigations removed impacted soil and recovered and safely disposed of 1 MEC item, 62 MD items, 6 intact containers, and approximately 400 pounds of AUES-related intact and broken lab glassware debris. A discrete HHRA (USACE, 2013c) was also conducted for this area, as discussed in Section 7.1.1.3.

5.2.2.7 AU Area Ground Scars Investigations

USACE conducted an evaluation of historical data related to the present day location of the AU soccer fields (see Figure 5-2). Area G was identified as a “Possible Bunker” in the USEPA EPIC report. Geophysical investigations performed in 1993 in the vicinity did not identify any MEC/CWM items, but in July 1994, an MD item, an empty bomb nose cone, was discovered by an AU contractor while replacing sod on the nearby AU soccer field. However, it was concluded in the December 2009 USACE report that there was no evidence that munitions burials took place within Area G. To further assess other similar ground scars that were not recommended for intrusive investigation and to rule out the existence of potential additional disposal pits and potential associated soil contamination, USACE investigated the Area G ground scar. A single soil boring was collected at 3 feet bgs, below the fill associated with the soccer field construction. It was analyzed for the SVFUDS Comprehensive list parameters and no explosives, CWM, or CWM ABPs, were detected. Several metals and phenol were detected, but not at levels exceeding the SVFUDS comparison values. It was concluded that there is no evidence of potential munitions burial pits associated with the Area G ground scar (USACE, 2012b).

In addition to the Area G ground scar, the evaluation of historical data identified other areas located on the AU campus to be further evaluated. While not believed to be MEC or CWM related, the features could not be positively identified in the evaluation, and therefore, intrusive trench investigations were completed to investigate them. In September 2009, seven trenches from three areas were intrusively investigated (AOI 20, OU4-AU11, and OU5-AU3). In March 2010 seven more trenches from six other areas were intrusively investigated (OU4-AU3, OU4-AU11, OU4-AU1, OU4-AU40, OU4-AU18, and OU4-AU27A). These were low probability open air investigations and no MEC, MD, or CWM items were encountered in any of the 14 trenches (USACE, 2011b).

5.2.2.8 Indoor Air Sampling

An indoor air study was completed at 5065 Sedgwick Street, a residence near the Sedgwick Trenches (POI 1). The initial study in 2001 experienced sampling and analytical difficulties. Samples were analyzed for mustard, Lewisite, arsine, particulate arsenic, and arsenic trioxide. None of these were detected with the exception of arsenic. However, it was determined that the method used did not quantify respirable levels of arsenic. Therefore, in 2003, a second study using improved techniques was conducted (USACE, 2004c). Wipe and bulk arsenic samples were also collected to identify potential airborne sources of particulate arsenic inside the residence. The study concluded that the average indoor air arsenic results were not significantly higher than the USEPA standard and that they were within the ambient outdoor air concentration reported for two sources outside of the SVFUDS (McMillan Reservoir and Haines Point stations). No further sampling for arsenic was recommended for the residence.

The results were further evaluated by the Agency for Toxic Substance and Disease Registry (ATSDR) in a January 2004 letter (ATSDR, 2004) that concluded that the airborne arsenic levels (of respirable particles less than 10 microns in diameter) were low and would not be harmful to the residents, and that realistic exposure scenarios did not indicate that exposures to this level would lead to adverse health effects.

5.2.2.9 Sub-slab Soil Gas Investigations

In 2004, sub-slab soil gas samples were collected from beneath the basement slabs of 4621 and 4625 Rockwood Parkway, two properties adjacent to and owned by AU (see Figure 5-3). These properties were in close proximity to the SDA, OU-4 AU Lot 18 and PSB investigations, and as described in Sections 1.6.2.2.3 and 1.6.2.2.5, based on some of those findings, this investigation was conducted to determine if past AUES-related activities had impacted indoor air quality at the residences under investigation.

Both properties had arsenic screening soil sampling performed and based on the results, follow-on grid sampling for arsenic was conducted. The grid sampling results for both properties indicated exceedances of the arsenic removal goal and those grids were removed.

The tenant of 4625 Rockwood contracted with a private consultant to perform an investigation of the soil and indoor air of the property and residence. The results were evaluated by the ATSDR, which concluded that the detected concentrations appeared to be too low to create a health hazard to adult or child occupants (ATSDR, 2003b). There was no indication that the chemicals found were associated with AUES. Further, ATSDR concluded that the concentrations found were typical of many indoor air samples taken in urban dwellings and are considered to be in the range of background.

The results of the USACE investigation indicated that common VOCs were detected at very low levels. Based on the findings, it was concluded that:

- SVFUDS or AUES-related activities have not impacted the indoor air quality of 4621 and 4625 Rockwood Parkway;
- Phosgene was found in the site samples, but also in the laboratory blank sample, suggesting that this represented laboratory contamination.
- There was no evidence to indicate that previously detected compounds from other investigations were the result of AUES-impacted subsurface soil; and
- It was concluded that compounds found in the sub-slab soil gas were not present at concentrations that warrant additional investigation. Therefore, no further action is recommended for sub-slab soil gas or indoor air evaluation for these residences (USACE, 2006c).

5.2.3 Operable Unit 5

5.2.3.1 OU-4 and OU-5 EE/CA

Based on the findings of the OU-3 investigations, the soils of both OU-4 and OU-5 were characterized for arsenic and selected CWM compounds associated with AUES activities under an EE/CA, which presented the findings of the OU-4 and OU-5 investigations (USACE, 2003b).

Within OU-4 and OU-5, all acreage, residential and non-residential, was divided into one-half acre (approximate) exposure areas, or sites, for sampling purposes. Sampling began in 2001 in OU-5. Figure 5-4 presents the sampling overview map of the SVFUDS. This figure shows that more than 99% of all properties (residential properties and commercial lots) within the SVFUDS have received some level of soil sampling, much of it is screening-level sampling conducted under the EE/CA. The green and tan shading indicates areas that received some type of soil sampling under the EE/CA. The majority of these samples have been for arsenic analysis only (in addition to the surface soil samples, 538 subsurface soil borings were collected for arsenic analysis). However, more than 500 samples (including 409 subsurface soil borings) were analyzed for a wide variety of parameters, including the CWM ABPs (Figure 7-11 includes the boring locations). The parameters analyzed for many of these samples were based on the historical understanding of the AUES activities performed in that area.

To date, 1,632 sites have been investigated and the soil characterized for arsenic contamination. Of these, 287 sites also had the soil characterized for selected CWM constituents representative of past practices at that specific site. Although a small number of samples had detections for possible CWM degradation products, none of the sites contained any CWM or CWM ABPS at levels above their respective screening criteria

For each residential property or commercial lot, if the initial screening indicated elevated levels of arsenic in the soil, additional grid sampling was performed to characterize and delineate the areas of elevated arsenic (USACE, 2003b). A total of 183 properties were identified with one or more grids with arsenic concentrations above the 20 mg/kg removal goal. Of the 1,644 lots in the study area, all but 12 properties have undergone arsenic screening to date. The remaining properties have refused access even though USACE was screening to assess potential dangers to human health at these properties. Those properties refusing USACE access include 10 residential properties, one commercial property, and one federal property (National Park Service). The commercial property was an electrical substation, and while the owners were willing to grant access, the significant safety protocols required to sample it could not be negotiated and it was decided that the highly secured and restricted nature of the property sufficiently limited or reduced any potential exposures to the soil.

The remaining properties are:

- 4306 50th Street
- 4208 49th Street
- 4906 Tilden Street
- 5113 Yuma Place
- 4420 50th Street
- 4203 48th Place
- 4844 Van Ness Street
- 4436 Windom Place
- 4311 44th Street
- 4235 Alton Place
- 4000 Van Ness Str (commercial property)
- Glover Archbold Park (federal property)

The EE/CA recommended excavation of soil as the preferred alternative to address arsenic contaminated soil; this document was the basis of the TCRA and NTCRA removals discussed in Section 5.4.

5.2.3.2 Evaluation Document Sampling

The *Final Evaluation Document* (USACE, 2012c) provided the plan for supplemental sampling to fill identified data gaps and ensure that areas were fully characterized to support conclusions about potential human health risks. The sampling was based on the recommendations in the AOI Memoranda that summarized possible historical AUES impacts not addressed in ongoing investigations, or possible data gaps, and made recommendations regarding whether any additional investigation was necessary. Based on these memoranda, the following supplemental soil sampling was completed for these AOIs:

- AOI 8 (POI 12) and AOI 11 (POIs 13/14) sampling for SVFUDS Comprehensive List.
- AOI 9 sampling for antimony at the POI 7/7R location.
- AOI 13 sampling for the SVFUDS Comprehensive List.
- AOI 22 and 24, which are non-contiguous areas, were sampled on the 4710 Woodway Lane property for nickel and thallium at POIs 21, 22, and 23 in the backyard, and for the SVFUDS List metals near the OSR FUDS RI sidescan boring locations in the front yard.
- AOI 22 and 24 (POIs AU, 24, and 53) sampling for antimony.

The Evaluation Document sampling was primarily completed in 2012. However, it also includes AOI 8 and AOI 11 sampling, some of which was completed as early as 2009. Figure 5-5 shows the locations of the supplemental sampling conducted under the Evaluation Document.

The findings are discussed in the context of the risk screening conducted in the Addendum to the Pre-2005 HHRA Review report. Section 7.1.2.2 describes how these data points were integrated into the overall evaluation of risk for the SVFUDS. The data tables presenting the individual sample results are contained in the Site-Wide HHRA Work Plan for the new quantitative HHRAs completed as described in Sections 7.2 and 7.3. Those reports are contained in their entirety in Appendix D.

Another objective of the Evaluation Document was to ensure that samples from other miscellaneous sampling events, sometimes a single sample collected based on anomaly removals, or for other reasons, would be integrated into a complete SVFUDS picture. Section 7.1.2 describes how this was accomplished through the risk screening activities completed to assess risk for the entire SVFUDS.

5.2.3.3 Groundwater Study

Localized groundwater sampling was conducted as part of the OSR FUDS RI in 1993, but the groundwater data were not suggestive of contamination at that time. The study of SVFUDS groundwater essentially began with completion of the *Spring Valley FUDS Groundwater Study Work Management Plan* (USACE, 2005f). The installation of five piezometers to measure the water table elevation had been conducted earlier in 2004, but the plan for the comprehensive study of groundwater and the procedures to complete these characterization activities, was provided in that Work Management Plan.

The first monitoring wells were installed and sampled in 2005. Two chemicals were identified with sample concentrations above their respective comparison values. Groundwater in Spring Valley is not used as a drinking water source, but for comparison purposes, groundwater contaminant concentrations are compared to drinking water standards and advisory levels established by the USEPA. Arsenic was identified above USEPA's maximum contaminant level (MCL) of 10 parts per billion (ppb). Perchlorate was identified above the USEPA's Interim Drinking Water Health Advisory Level of 15 ppb.

Since 2005, over 50 monitoring wells, including seven deep bedrock wells, have been sampled at least once as part of the SVFUDS groundwater study. The highest perchlorate concentration, 146 ppb, was identified in 2007 in a piezometer located near Kreeger Hall on the AU campus. Another area of elevated perchlorate was identified in the vicinity of Sibley Hospital. Subsequent groundwater study efforts have focused on isolating the source of the elevated perchlorate, particularly in the vicinity of the piezometer on the AU campus and assessing down gradient groundwater flow patterns.

The groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

5.3 Geophysical Investigation Results

This discussion provides a summary of the findings of the key geophysical investigation reports introduced in Section 1.6.3 and shown in Table 1-5. However, for the earlier investigations, such as the OSR FUDS or the OU-3 Glenbrook properties, or for some of the larger more complex areas such as OU-4 AU Lot 18, the geophysical activities were not separated from the investigation and characterization activities; those are addressed in Sections 5.1 or 5.2.

5.3.1 Residential Geophysical Investigations

Geophysical investigations were conducted on 99 residential properties between 1998 and 2011. Properties were prioritized for investigation using the criteria described in Section 4.1.2.4. Anomaly investigations were completed at all planned residential properties except one, where access was not granted by the home owner (USACE, 2003-2012). Figure 5-6 shows geophysical survey extent and munitions-related finds for the SVFUDS.

Following the basic procedures presented in Section 4.1.2, the investigations were conducted in two phases: properties were first non-intrusively geophysically surveyed to identify buried metallic anomalies. Then, after analysis of the geophysical survey results by the ARB, intrusive investigations (excavations) of metallic anomalies with characteristics of possible buried WWI munition items were conducted.

Thousands of metallic anomalies were investigated with a large percentage of them determined to be harmless metallic cultural or construction debris such as old horse and mule shoes, rebar, wire, and screws. Although many metallic anomalies were not related to AUES, the investigations may have nonetheless resulted in further characterizing AUES-related areas such as ground scar locations.

There were 24 residential properties where one or more MD items were recovered (4835 Glenbrook Road is discussed in more detail in Section 5.2.1.2). Of these, items formally classified as MEC were found at only three properties. These include:

- 5027 Sedgwick Street, 3-inch Stokes mortar
- 4740 Quebec Street, pipe with explosives
- 4900 Quebec Street, thermite grenade and 60 flash tubes

The remaining properties containing miscellaneous MD included:

- 5011 Sedgwick Street
- 4005 52nd Street
- 4015 52nd Street
- 3706 Fordham Road
- 5040 Sedgwick Street
- 5065 Sedgwick Street
- 3822 Fordham Road
- 3949 52^{nd} Street
- 4703 Woodway Lane
- 4710 Woodway Lane
- 5010 Sedgwick Street
- 4710 Quebec Street
- 4720 Quebec Street
- 5100 Tilden Street
- 5024 Sedgwick Street
- 5036 Sedgwick Street
- 5041 Sedgwick Street
- 5047 Sedgwick Street
- 5053 Sedgwick Street
- 5058 Sedgwick Street
- 4835 Glenbrook Road

For the 5010 Sedgwick Street property, the Stokes mortar MD was found during construction of an addition to the house in 1996, not during the 2010 geophysical investigation.

For the 4710 Quebec Street property, the MD item was found during soil removal, not during the 2006 geophysical investigation. Also, one of the MD items found at 4005 52^{nd} Street was also found during soil removal activities, not during the geophysical investigation at the property.

Although not included in the removal action discussions, based on the results of soil samples associated with the MEC finds, the 4740 Quebec Street and 4900 Quebec Street properties included spot removal of soil based on TNT and mercury contamination, respectively.

All MEC and MD items were safely recovered and disposed offsite during these residential intrusive activities.

5.3.2 AU Geophysical Investigations

Several geophysical investigation efforts have been conducted on approximately 12 acres of the AU campus including areas around the AU intramural athletic fields, Watkins Hall, Kreeger Hall, the Bamboo Area, and the Kreeger Music Roadway. The geophysical investigation activities for some of the larger AU areas, such as Lot 18 and the PSB, were discussed in Section 5.2.2 and are not repeated here.

5.3.2.1 Athletic Fields

From November 2002 to June 2003, 48 grids with one or more low probability anomalies were investigated in the AU intramural athletic fields (Figure 5-2). The low probability anomaly locations were mechanically excavated in open air using a mini-excavator. Two unfused, unfired 75 mm rounds were recovered and designated as MD. In September 2002, while conducting the TCRA investigation at the Athletic Fields, glassware was uncovered during the lateral extension of the grid. The anomaly located in this vicinity was investigated under high probability protocols (engineering controls) and cleared in December 2002 and January 2003. No AUES-related materials were found during the investigation. A geophysical investigation of the CDC and Watkins Hall area was requested by AU; seven grids containing anomalies were investigated in June 2003, but no MEC, MD, CWM, or AUES-related items were uncovered during the anomaly investigation (USACE, 2005e).

5.3.2.2 Bamboo Area

The AU Bamboo Area is located adjacent to Lot 18 and the SDA (see Figure 5-3). AUES-related items had been recovered from Lot 18 and laboratory artifacts had been recovered from the SDA. Additionally, analyses of 1918, 1922, 1927, and 1928 historical aerial photographs showed evidence of ground scars stretching across much of this property. USACE concluded that there was a remote possibility that items associated with AUES may remain in the vicinity of this area and decided to conduct a geophysical investigation of the Bamboo Area.

A total of eight munitions debris and two intact containers were recovered during the AU Bamboo Area investigation. All of these items were headspaced for off-gassing and cleared for CWM by ECBC. A large amount of debris contained broken glassware that appeared to be AUES-related. The glass fragments were also headspaced. The remaining items recovered were identified as cultural debris (USACE, 2006b).

Excavation of glass and debris in anomalous area BA-P6, located west/northwest of the AU PSB, extended under the concrete patio located at the rear (western side) of the building. The area under the patio was partially excavated for glass and debris. The two intact containers and six of the munitions debris items were found under the patio. On April 26, 2006 the Partners agreed to suspend excavation operations at the patio area due to the proximity to the building and were completed with the PSB investigation (USACE, 2013b). The PSB investigations were addressed in Section 5.2.2.6.

5.3.2.3 Kreeger Hall Area

Ground scarring and disturbed vegetation were also indicated on aerial photographs of the AU Kreeger Hall area (see Figure 5-3). The first of two investigations in the vicinity of Kreeger Hall was performed in 2006 when two anomalous areas and 17 single point geophysical anomalies were intrusively investigated. The anomalous areas were investigated with three trenches. The 2006 investigation was situated along the south side of the Kreeger building near 4801 Glenbrook Road and Lot 18. No MEC or MD items or AUES-related items were encountered during the intrusive investigation of the anomalies in the Kreeger Hall Area (USACE, 2007e).

The additional characterization in 2011-2012 focused on the north side of Kreeger Hall in the nearby parking lot. The investigation used electromagnetic, magnetic, and GPR surveying methods to collect geophysical data needed to characterize the subsurface conditions due to the extensive utilities present in the investigation area. Based on the geophysical survey results, 18 single-item anomalies and four anomalous areas were selected for intrusive investigation; these were subsequently investigated in 2012, completing five trench excavations for the four anomalous areas, and no MEC or MD or other AUES-related items were encountered (USACE, 2012a). No contaminated soil was encountered in this investigation.

5.3.3 <u>Dalecarlia Woods Geophysical Investigations</u>

Munitions investigations were also completed on approximately 60 acres of District of Columbia and federal property located in the western edge of the SVFUDS, just east of the Dalecarlia Reservoir (see Figure 5-6), using the same geophysical survey approach employed for the residential investigations. The investigations encompassed more than 90 grids (200 ft by 200 ft), two AOIs (AOI 2 – Rick Woods Burial Pit and AOI 6 – Dalecarlia Impact Area), and the western terminus of the Range Fan (USACE, 2011c; USACE, 2011d).

USACE conducted both EM61-MK2 and G-858 geophysical surveys to locate and characterize anomalies that may have represented potential individual MEC items, burial pits or trenches. Geophysical surveys were conducted in stages, by various contractors, from September 2007 to December 2010 to locate and map electromagnetic and magnetic anomalies.

A total of 3,101 single-item anomalies and 32 trenches were recommended by the ARB to be intrusively excavated over the entire Dalecarlia Woods area. As a result of field decisions based on MEC discovery and/or site conditions in individual lots, a total of 3,178 single-item anomalies and 29 trenches were actually investigated. These intrusive anomaly investigations were conducted under low probability protocols over a 19-month time period. The findings, all of which were safely removed from the SVFUDS, included:

- Two AUES-related MEC items (two 75 mm projectiles);
- 38 AUES-related MD items;
- 27 non-AUES related MD (cannonball fragments); and
- No CWM related items

Thirteen soil samples were also collected based on the presence of MEC or MD throughout the entire investigation. The findings are discussed in the context of the risk screening conducted in the Addendum to the Pre-2005 HHRA Review report. The data tables presenting the individual sample results for this area (and all areas evaluated in the Addendum to the Pre-2005 HHRA Review report) are contained in Appendix D.

5.4 Removal Action Results

Removal actions necessitated by elevated arsenic concentrations in the soil were conducted primarily by excavation, whether under time critical (TCRA) or non-time critical (NTCRA) actions. The OU-4 and OU-5 EE/CA (USACE, 2003b) identified excavation and offsite disposal of arsenic-contaminated soil as the recommended alternative for properties with at least one sample result showing an arsenic concentration higher than the removal goal of 20 mg/kg. In some situations, USACE also used phytoremediation to address arsenic-contaminated soils.

This discussion provides a summary of the findings of the key removal action reports introduced in Section 1.6.4 and shown in Table 1-6. Note that two of the earlier removal efforts, the NTCRAs for OU-3 and 4801 Glenbrook Road, were included in Sections 5.1.2 and 5.2.1, respectively, and the OU-4 AU Lot 18 findings are included in Section 5.2.2.5.

5.4.1 <u>Time-Critical Removal Actions</u>

Several TCRAs have been undertaken in the SVFUDS, including discrete areas of AU and multiple residential properties.

5.4.1.1 AU Child Development Center

A TCRA was undertaken at the AU CDC (Figure 5-2) from July 2001 to November 2001 in order to remove arsenic-contaminated soils from within the playground area at this facility, as authorized by the Action Memorandum dated July 16, 2001. AU officials relocated the CDC to another area of the campus and USACE performed the TCRA for the arsenic contaminated soil.

The TCRA included removal of all soils from 20 by 20 foot square grid sections to a minimum depth of two feet within the fenced area around the CDC and an additional two-foot wide buffer outside the entire fence line of the CDC. Two feet was the depth for removal to minimize the risk to the children, CDC workers and facility maintenance personnel.

Confirmation soil samples were collected at the bottom of each 20 ft by 20 ft grid square. The confirmation sample results were compared to the removal goal of 26 mg/kg arsenic (prior to the establishment of the 20 mg/kg removal goal, twice the background concentration was used). If a confirmation sample exceeded 26 mg/kg arsenic, additional soil was removed. This process was repeated until the confirmation sample result did not exceed the removal goal for arsenic. Eight grids required excavation beyond the initial depth of two feet based on arsenic exceedances in the grid confirmation samples, with the deepest reaching 11 feet.

Notable findings included an intact glass bottle. Headspace analysis performed by ECBC did not indicate CWM. An archeological evaluation determined that the mark on the bottle indicated usage between circa 1929 and 1942, and it was assumed that this bottle was deposited after AUES operations ceased. Also, during backfill operations, an item believed to be a test tube containing black granules was discovered in a grid. Headspace analysis performed by ECBC did not indicate CWM. An archaeological evaluation determined that the item did not have any diagnostic features that are necessary in order to make a determination regarding the age or date of production of the item.

Once the excavation operation in an area was completed, the area was backfilled to its original grade with approved clean backfill soil and topsoil, compacted, then seeded. The fence around the playground area and the sidewalk was replaced. All contaminated soil was transported to an approved landfill for disposal. The TCRA resulted in removal of 1,064 cubic yards of soil (a total of 1,958 tons of material) from the CDC (USACE, 2003a).

5.4.1.2 AU Athletic Fields and Other AU Lots

A TCRA was conducted at AU for the excavation and offsite disposal of arsenic-contaminated soil above 20 mg/kg from the athletic fields, other AU lots located in OU-4, and the grounds in the vicinity of Kreeger Hall and Watkins Hall as authorized by the Action Memorandum dated May 31, 2002. The AU Lots TCRA included removal of arsenic contaminated soil from grids located in the athletic fields (AU Lots 8, 10, 11, 13, 14, and 15); grids in AU Lot 12 outside the fencing of the Child Development Center (CDC); grids related to soil borings in AU Lots 16, 19, and 23; grids located in the vicinity of Watkins Hall; grids in AU Lot 18; and grids in the vicinity of Kreeger Hall. (USACE, 2010a).

Contaminated soil was removed during the TCRA in 20 by 20 foot grid square sections to the specified depth (minimum two feet). Grid confirmation soil samples were collected at the bottom and sidewalls of each 20 by 20 foot grid square and compared to the arsenic removal goal of 20 mg/kg. If a grid confirmation sample exceeded 20 mg/kg, additional soil was removed. Confirmatory sampling was repeated for the extended excavation area until the results were acceptable. As agreed by AU and USACE, the alternative goal of 43 mg/kg (see Section 7.4.2) was applied in six grids containing large trees.

A total of 216 whole or partial grids were excavated, comprising an area of approximately 71,231 square feet. Once the excavation operation in an area was completed, each area was backfilled to its original grade with clean backfill soil and topsoil, compacted, and then seeded. The backfill and topsoil material were approved for restoration. All excavated soil was transported to an approved landfill for disposal. At the completion of the AU Lots TCRA activities, a total of approximately 5,705 cubic yards of soil were excavated. An additional 477 tons of material was disposed from the removal of the access road to the south and west of Kreeger Hall.

These amounts do not include soil from grids that were excavated in conjunction with the Lot 18 anomaly investigation. These TCRA activities took place concurrently with the larger Lot 18 investigation (USACE, 2008b), but the Lot 18 effort ultimately became a separate operation involving high probability protocols; the Lot 18 activities were separately discussed in Section 5.2.2.5.

5.4.1.3 Residential

USACE determined that TCRAs would also be performed at several residential properties as authorized by several different Action Memoranda from approximately 2002 to 2003. The prioritization of these properties was based on the results of the arsenic testing. An EPC, derived from the 95% Upper Confidence Limit (UCL) of the grid arsenic data, was used as the primary prioritization strategy. Other factors used to prioritize removals included access agreements and proximity logistics, where otherwise lower priority sites close to high priority sites were also scheduled (USACE, 2003c). Tier I properties had EPCs greater than or equal to 90 mg/kg arsenic. Tier II properties had at least one grid greater than or equal to 150 mg/kg arsenic. This work began in July 2002 (USACE, 2004b). Figure 5-7 shows all TCRA and NTCRA residential properties.

The properties with removal actions conducted as TCRAs include:

- 3709 Corey Place
- 3800 52nd Street
- 4007 49th Street
- 4115 45th Street
- 4119 45th Street
- 4219 50th Street
- 4230 Fordham Road
- 4434 Tindall Street
- 4438 Tindall Street
- 4442 Tindall Street
- 4446 Tindall Street
- 4456 Springdale Street
- 4460 Springdale Street
- 4624 Van Ness Street
- 4633 Rockwood Parkway
- 4637 Rockwood Parkway
- 4641 Rockwood Parkway
- 4647 Massachusetts Avenue
- 4651 Massachusetts Avenue
- 4655 Massachusetts Avenue
- 4710 Woodway Lane
- 4850 Rockwood Parkway
- 5001 Rockwood Parkway
- OU5-CSA-5-L15 (Lot 15)

During the TCRA at 4115 45th Street, sidewall samples along the property line indicated elevated arsenic concentrations extending onto a small portion of a neighboring property, 4425 Upton Street; therefore, additional excavation of one partial grid was required. Excavations were performed in two foot increments from the planned grid onto the neighboring property until sidewall samples were 20 mg/kg or lower.

Nine properties included in the TCRA were completed through excavation and regulator approval for grids with less than 43 mg/kg located in the vicinity of sensitive hardscape or landscape features. The properties are as follows:

- 4007 49th Street
- 4119 45th Street
- 4442 Tindall Street
- 4456 Springdale Street
- 4651 Massachusetts Avenue
- 4710 Woodway Lane
- 4850 Rockwood Parkway
- 5001 Rockwood Parkway

- 4460 Springdale Street

One TCRA property was completed using excavation, phytoremediation and regulatory approval for grids with less than 43 mg/kg located in the vicinity of sensitive hardscape or landscape features: Lot 15. Grids located outside the drip line of trees were excavated and phytoremediation was used in grids located within the drip line of valued trees. Following the completion of the phytoremediation study, arsenic concentrations were reduced to below 43 mg/kg but above 20 mg/kg: regulator approval was obtained to leave the soil in place.

Another TCRA property was closed out through a combination of TCRA, regulatory approval for grids with less than 43 mg/kg located in the vicinity of sensitive hardscape or landscape features, and NTCRA: 4641 Rockwood Parkway. Prior to completing clean up through NTCRA, phytoremediation was unsuccessfully employed to non-intrusively reduce soil arsenic to below 43 mg/kg in the drip line of a tree. Therefore the grids not addressed during the TCRA or through regulator approval were excavated during the NTCRA.

5.4.2 Non-Time Critical Removal Actions

5.4.2.1 Arsenic Contaminated Soil NTCRA

USACE conducted removal actions at 100 properties and 9 lots as NTCRAs (USACE, 2004-2013). An NTCRA is conducted when a removal action is appropriate and a planning period of at least six months is available before on-site activities must begin. The OU-4 and OU-5 EE/CA was the document that recommended the NTCRAs for these properties and lots. The NTCRAs were conducted under the March 2004 Action Memorandum. The lots included in the NTCRA are as follows (note that the date of the individual Property Closeout Report is provided in parentheses):

- OU5-CSA-2-L8 (2012)
- OU5-CTA-1B-L10 (2011)
- OU5-CSA-2-L11 (2012)
- OU5-CTA-1B-L11 (2011)
- OU5-CSA-13-L15 (WA) (2011)
- OU5-CSA-13-L80NW (2011)
- OU5-CSA-13-L81 (2011)
- 4400 Massachusetts Avenue, OU-5 AU Lots 33 and 34 (2011)

One lot, OU5-CTA-1B-L10, located along Dalecarlia Parkway, was included in the 2006 Phase 3 field study for phytoremediation; however, it was used as a sample control lot only and was closed out through excavation during the NTCRA. Lot OU5-CSA-5-L15 (Lot 15), located along Van Ness Street, while part of the TCRA, was used during the 2004 laboratory feasibility study and all years of the field study. Additional information regarding this lot is provided in Section 5.4.3.

The residential properties included in the NTCRA, shown on Figure 5-7, are as follows (note that the date of the individual Property Closeout Report is provided in parentheses):

- 3641 49th Street (2006)
- 3650 Fordham Road (2008)
- 3706 Fordham Road (2007)
- 3717 Fordham Road (2009)
- 3806 49th Street (2010)
- 3812 48th Street (2005)
- 3816 48th Street (2005)
- 3816 49th Street (2009)
- 4328 Windom Place (2009)
- 4329 Verplanck Place (2010)
- 4329 Warren Street (2011)
- 4330 42nd Street (2005)
- 4333 Van Ness Street (2011)
- 4337 Verplanck Place (2007)
- 4347 Warren Street (2008)
- 4349 Verplanck Place (2011)
- 4900 Quebec Street (2012)
- 4901 Rodman Street (2009)
- 4907 Indian Lane (2009)
- 4911 Van Ness Street (2011)
- 4918 Hillbrook Lane (2008)
- 4920 Rodman Street (2010)
- 4922 Quebec Street (2007)
- 4925 Loughboro Road (2010)

- 3933 Fordham Road (2010)
- 3945 52nd Street (2012)
- 4000-04 47th Street (2007)
- 4001 47th Street (2007)
- 4005 47th Street (2007)
- 4005 52nd Street (2006)
- 4008 47th Street (2007)
- 4009-13 47th Street (2007)
- 4012 47th Street (2007)
- 4015 52nd Street (2006)
- 4016 47th Street (2004)
- 4070 52nd Street (2010)
- 4201 Fordham Road (2010)
- 4211 Alton Place (2009)
- 4215 Yuma Street (2008)
- 4221 43rd Street (2008)
- 4226 50th Street (2010)
- 4227 Fordham Road (2010)
- 4248 50th Street (2010)
- 4256 Warren Street (2006)
- 4301 Warren Street (2006)
- 4316 Yuma Street (2007)
- 4317 Warren Street (2005)
- 4318 Warren Street (2011)
- 4323 Warren Street (2010)
- 4354 Warren Street (2006)
- 4427 Springdale Street (2004)
- 4428 Sedgwick Street (2007)
- 4437 Warren Street (2011)
- 4457 Sedgwick Street (2008)
- 4462 Tindall Street (2006)
- 4615 Rodman Street (2004)
- 4621 Rockwood Parkway (2008)*
- 4625 Rockwood Parkway (2007)
- 4625 Sedgwick Street (2011)
- 4641 Rockwood Parkway (2009)
- 4710 Quebec Street (2006)
- 4715 Sedgwick Street (2010)
- 4730 Massachusetts Avenue (2011)
- 4801 Glenbrook Road (2006, 2011)
- 4801 Quebec Street (2007)
- 4810 Glenbrook Road (2010)
- 4813 Quebec Street (2009)
- 4828 Rodman Street (2010)
- 4834 Quebec Street (2010)
- 4835 Glenbrook Road (2013)*
- 4847 Sedgwick Street (2011)
- 4849 Rodman Street (2007)
- 4851-53 Sedgwick Street (2009)
- 4861 Indian Lane (2011)
- 4938 Quebec Street (2010)
- 4940 Indian Lane (2010)
- 4944 Quebec Street (2008)
- 4955 Glenbrook Road (2008)
- 4962 Quebec Street (2007)
- 5001 Van Ness Street (2007)
- 5004 Loughboro Road (2011)
- 5006 Massachusetts Avenue (2006)
- 5011 Sedgwick Street (2006)
- 5017 Loughboro Road (2011)
- 5026 Tilden Street (2010)
- 5032 Tilden Street (2010)
- 5035 Rockwood Parkway (2006)
- 5040 Sedgwick Street (2004)
- 5046 Sedgwick Street (2006)
- 5054 Sedgwick Street (2003)*
- 5058 Sedgwick Street (2003)*
- 5060 Overlook Road (2010)
- 5069 Overlook Road (2010)
- 5100 Upton Street (2008)
- 5120 Rockwood Parkway (2009)
- 5125 Upton Street (2007)
- 5131 Yuma Street (2010)
- 5141 Yuma Street (2007)
- 5145 Yuma Street (2010)
- 5169 Tilden Street (2012)

*Note: A Property Closeout Report was not prepared for these properties as soil removal was conducted in conjunction with anomaly investigations and was therefore documented in the investigation report.

While 4641 Rockwood Parkway was partially remediated under a TCRA, remediation was completed during the NTCRA (See Section 5.4.1.3). The 3650 Fordham Road and 4938 Quebec Street first participated in the phytoremediation study to reduce levels of arsenic in soil to below the 20 mg/kg cleanup goal. Both properties were partially remediated through phytoremediation. Excavation during the NTCRA was used to complete remediation at the properties.

Four of these 100 residential properties where elevated levels of arsenic in soil were removed via excavation were remediated concurrently with intrusive anomaly investigations (USACE, 2013a; 2003-2013; 2008b), and the NTCRA removal results were included in the intrusive anomaly investigation reports. Elevated grids located on the 4621 Rockwood Parkway property, owned by AU, were removed during the adjacent OU-4 AU Lot 18 investigation. They are listed as follows:

- 4621 Rockwood Parkway (2008)
- 4835 Glenbrook Road (2013)
- 5054 Sedgwick Street (2003)
- 5058 Sedgwick Street (2003)

There were instances during the NTCRA where sidewall samples along property lines indicated elevated arsenic concentrations extending onto a small portion of a neighboring property; therefore, additional excavation onto the neighboring property was required. One of the properties, 3712 Fordham Road obtained regulator approval for grids less than 43 mg/kg located in the vicinity of sensitive landscaping and no excavation onto this property was performed.

Excavations were performed in two foot increments from the planned grid onto the neighboring property until sidewall samples were 20 mg/kg or lower. These properties include:

- 3645 49th Street
- 3712 Fordham Road
- 3730 Fordham Road
- 3809 47th Street
- 4225 43rd Street
- 4311 Warren Street
- 4329 Van Ness Street
- 4335 Van Ness Street
- 4348 Warren Street
- 4423 Springdale Street
- 4466 Tindall Street
- 4801 Rodman Street
- 4819 Quebec Street
- 4840 Quebec Street
- 5116 Rockwood Parkway

Eighteen properties included in the NTCRA were completed through excavation and regulator approval for grids with less than 43 mg/kg located in the vicinity of sensitive hardscape or landscape features. The properties are as follows:

- 3706 Fordham Road
- 3717 Fordham Road
- 3933 Fordham Road
- 4316 Yuma Street
- 4318 Warren Street
- 4323 Warren Street
- 4329 Verplanck Place
- 4330 42nd Street
- 4347 Warren Street
- 4354 Warren Street
- 4462 Tindall Street
- 4641 Rockwood Parkway
- 4810 Glenbrook Road
- 4813 Quebec Street
- 4907 Indian Lane
- 4918 Hillbrook Lane
- 4925 Loughboro Road
- 4955 Glenbrook Road

Five properties with grids above 20 mg/kg were closed out with regulator approval as an alternative to NTCRA as a result of grids located in the vicinity of sensitive hardscape or landscape features. The concentrations of arsenic were below 43 mg/kg and property owners opted to accept the 43 mg/kg cleanup goal to preserve hardscape and landscape features. These include:

- 4004 49th Street
- 4212 Yuma Street
- 4216 Van Ness Street
- 4950 Quebec Street
- 5147 Yuma Street

There were also properties outside the SVFUDS boundary that received arsenic soil screening either at the request of the USEPA and DDOE, or because they were adjacent to properties located within the SVFUDS that contained arsenic-contaminated soil. These were sampled and analyzed for arsenic. There are:

- 4137 Yuma Street
- 4201 47th Street
- 4631 Van Ness Street
- 5004 Loughboro Street
- 5016 Loughboro Street
- 5018 Loughboro Street
- AU Tenley Area

The 5004 Loughboro Road property was sampled at the request of the USEPA and DDOE. It was the only property outside the SVFUDS with arsenic screening results above 12.6 mg/kg arsenic. Subsequent grid sampling resulted in two grids above 20 mg/kg arsenic. These grids were excavated under the NTCRA. Some portions of 4430 Newark Street that received arsenic screening extend beyond the SVFUDS boundary in the southeast portion of the SVFUDS.

5.4.2.2 Munitions NTCRA

USACE prepared an EE/CA for the disposal of MEC, MD, and MEC items containing CWM (USACE, 2010c). This included DMM, including both conventional and chemical munitions, and material documented as an explosive hazard (MDEH) (i.e., material potentially presenting an explosive hazard that cannot be documented as safe, that has been assessed and documented as to the maximum explosive hazards the material is known or suspected to present, and for which the chain of custody has been established and maintained) recovered during investigations at the SVFUDS.

Based on the site-specific conditions at the SVFUDS, the recommended removal action alternative for DMM/MDEH was on-site demilitarization using contained destruction technologies. Conventional DMM/MDEH was destroyed on-site using approved controlled detonation chambers following approval by the DoD Explosive Safety Board (DDESB).

A controlled detonation chamber was used at the SVFUDS:

- To destroy 73 conventional munitions (March 2003)
- To destroy 113 conventional munitions (January 2011)
- To destroy 2 conventional munitions (February 2012)

Once rendered safe and certified as material documented as safe (MDAS), these items were either sent to an incinerator, or a smelter facility.

Based on the evaluation of the individual alternatives in the EE/CA, the recommended removal action alternative for CWM munitions items was onsite demilitarization using the Explosive Destruction System (EDS). This involved destroying the CWM on-site using the mobile, contained treatment system that was designed to destroy CWM. The EDS uses explosive cutting charges to open the munitions, followed by addition of neutralizing agents which react with the chemical agent. The explosive detonation and chemical neutralization process is conducted within a stainless steel containment vessel which contains the blast, vapors and fragments.

The EDS was used at the SVFUDS:

- To destroy 15 chemical munitions (June 2003), and
- To destroy 5 chemical munitions and 19 conventional munitions (May 2010).

5.4.3 <u>Phytoremediation</u>

While soil removal was the primary removal action method for arsenic in soil, USACE also used phytoremediation to achieve arsenic removal goals at selected TCRA and NCRA properties. Phytoremediation is a non-intrusive removal alternative using ferns that naturally extract arsenic from soil. Phytoremediation technology is based on the discovery of plants that were observed to naturally hyperaccumulate heavy metals or other soil contaminants. At the SVFUDS, phytoremediation was used to fully or partially achieve arsenic removal goals at approximately 20 properties (USACE, 2007a; 2007b, 2007c, 2008c; 2009b; 2011e).

In late 2003 a laboratory feasibility study was conducted by the USACE ERDC to evaluate the potential effectiveness of phytoremediation for remediating arsenic from SVFUDS soils.

Encouraging results from this laboratory study lead to further field testing in 2004. Results from the 2004 field testing indicated a general trend toward reduction of arsenic levels in the plots tested in the range of 10 mg/kg on average and achieved the treatment of one property plot to below 20 mg/kg.

Similar results were gathered in 2005, although in both years some plots inexplicably showed trends toward increases in arsenic levels. Further testing activities in 2006 and 2007 incorporated sampling improvement techniques to reduce sampling error. Sampling improvement techniques consisted of increasing the composite sampling, increasing the mass of soil sampled, reducing particle size by expanded grinding and sieving of the soils, and also increasing the mass of digested soil for analysis at the laboratory.

While this method significantly reduced sampling uncertainty and increased precision of the results, a small percentage of plots still indicated an increase in arsenic levels after phytoremediation treatment. Therefore, due to this limitation, phytoremediation was not recommended as a preferred remediation alternative for reducing arsenic soil levels on all SVFUDS properties. In certain situations, such as when a property owner refused to allow excavation on the property or preferred this alternative to preserve mature trees or other sensitive landscape items, phytoremediation was used.

Throughout the course of phytoremediation testing, most of these properties yielded post season sampling results below the cleanup goal of either 20 mg/kg or the alternate cleanup goal of 43 mg/kg. The Partners consider these properties fully remediated with no further action required.

Figure 5-8 shows the properties where phytoremediation was used in the SVFUDS. These include:

- OU5-CSA-5-L15 (Lot 15)
- 3318 45th Street
- 3514 Overlook Lane
- 3650 Fordham Road
- 4316 Windom Place
- 4335 Warren Street
- 4341 Warren Street
- 4445 Sedgwick Street
- 4449 Sedgwick Street
- 4641 Rockwood Parkway
- 4708 Sedgwick Street
- 4871 Glenbrook Road
- 4938 Quebec Street
- 4959 Hillbrook Lane
- 5001 Loughboro Road
- 5030 Van Ness Street
- 5040 Upton Street
- 5041 Upton Street
- 5044 Van Ness Street
- 5063 Loughboro Road
- 5148 Tilden Street
- 5149 Yuma Street

Two properties, 4335 Warren Street and 4449 Sedgwick Street, which participated in the phytoremediation study, were neighboring properties to NTCRA properties where sidewall samples along property lines indicated elevated arsenic concentrations extending onto a small portion of a neighboring property. As an alternative to excavation, phytoremediation was used to reduce arsenic in soil to below the cleanup goal of 20 mg/kg.

At Lot 15 and 4641 Rockwood Parkway, excavation was conducted during the TCRA prior to participation in the phytoremediation study in areas not in the vicinity of landscape or hardscape features (See Section 5.4.1.3).

In some cases, excavation of arsenic contaminated soils was required following phytoremediation efforts to address all areas of arsenic contamination. This was required at three properties: 4641 Rockwood Parkway, 3650 Fordham Road, and 4938 Quebec Street.

Five properties included in the phytoremediation study were closed out with regulator approval as an alternative to TCRA/NTCRA as a result of grids located in the vicinity of sensitive hardscape or landscape features. The concentrations of arsenic were below 43 mg/kg and property owners opted to accept the 43 kg/kg cleanup goal to preserve hardscape and landscape features.

- OU5-CSA-5-L15 (Lot 15)
- 3514 Overlook Lane
- 4641 Rockwood Parkway
- 5001 Loughboro Road
- 5041 Upton Street

5.4.4 4825 Glenbrook Road

Sections 1.6.2.1 and 1.6.4.4 provide some of the background of the many investigations of the 4825 Glenbrook Road property. In 2002, right of entry and property access issues caused a shutdown of site activities. In 2006, following negotiations with the new property owner, AU, USACE began planning to return to the property to continue the investigation. Starting in October 2007, the high probability investigation known as Burial Pit 3 was conducted.

During the Burial Pit 3 investigation a total of 22 munition items, 6 CWM items, and 80 MD items were recovered. Elevated levels of several metals including aluminum, arsenic, cobalt, iron, magnesium, mercury, and vanadium, were identified in the soil and removed during the investigation. In addition to the high probability Burial Pit 3 investigation, test pits were also excavated under low probability protocols and three test pits were excavated under high probability protocols. AUES-related waste, including more than 500 munition items, 400 pounds of laboratory glassware and 100 tons of chemical agent contaminated soil, have been recovered and safely removed from the property during investigations from 2000-2002 and then again from 2007-2010.

In August 2010, several agencies within the DoD as well as the Partners, made the decision to separate the 4825 Glenbrook Road property from the remainder of the SVFUDS and place it on its own CERCLA process pathway. This was done by performing a 4825 Glenbrook Road site-specific RI/FS, Proposed Plan, and Decision Document to focus and expedite the decision on a remedial action. After thorough reviews and a public comment period, USACE, with concurrence from the Partners and AU, selected the alternative to remove the house, and cleanup and restore the property to residential standards, providing for unrestricted future use of the property. That remedial action is ongoing at this time.

Accordingly, 4825 Glenbrook Road investigation activities are not incorporated into this RI and summary information regarding these efforts from RI through RA stages is provided for informational purposes only.

5.5 Disposition of Investigation Derived Waste

5.5.1 General Procedures

Detailed procedures addressing the proper disposal of all investigation derived waste (IDW) are contained in the *Site-Wide Work Plan for the SVFUDS* (USACE, 2007d). General procedures that applied to all IDW are discussed below.

All disposal documentation was in full compliance with applicable rules and regulations, including DA 385-61 for "3X" scrap, USEPA requirements, and Department of Transportation (DOT) Hazardous Material Regulations (49 CFR 100-199). USACE (CENAB) was listed as the generator of all waste streams and provided a person responsible for signing all required paperwork. The site manager maintained copies of all disposal documentation paperwork.

Upon receipt of the waste approval codes, the disposal subcontractor manifested the waste in compliance with all existing rules and regulations. A Notification of Waste Shipped form, identifying treatment standards required in 40 CFR 268, was completed by the disposal subcontractor; it was prepared as an addendum to the manifest.

A receiving manifest indicating acceptance of all materials by the disposal facility was signed by the disposal facility representative and furnished to USACE. A signed weight slip was furnished to USACE indicating the actual weight of the waste shipped to the approved disposal facility, and a Certificate of Disposal/Destruction was also furnished once the disposal action has been completed.

Documentation of the disposal, including volume, tonnage, was provided in the individual reports associated with the particular removal.

5.5.2 IDW Categories

Many different types of IDW were generated during the SVFUDS activities. The broad categories for disposition purposes included:

- Non-munitions related AUES items (e.g., glassware) containing CWM,
- Non-munitions related AUES items,
- Excavated soil, and
- Excavation pit water

5.5.3 Non-munitions related AUES items containing CWM

Non-munitions items such as glassware required headspace testing by ECBC's air monitoring team to monitor for potential off-gassing CWM contaminants. Used personal protection equipment (PPE) was considered to be CWM-contaminated, based on its association with contaminated soil encountered the same day the PPE was worn. These items, and decontamination water, if determined to be CWM-contaminated, were incinerated at a RCRA-permitted facility.

5.5.4 Non-munitions related AUES items

The non-munitions related AUES items that were not determined to be CWM-contaminated, were disposed in a non-hazardous waste Subtitle D landfill.

5.5.5 Disposal of Excavated Soil

Soil excavated during removal actions was always sampled for disposal characterization to determine whether it was hazardous or non-hazardous waste so that it could be disposed of in an appropriate manner. Excavated soil was cleared of any non-soil debris that could have been related to AUES activities.

Toxicity Characteristic Leaching Procedure (TCLP) and RCRA Characteristics (corrosivity, ignitability, and reactivity) sampling is the standard methodology to determine whether soils are hazardous or non-hazardous. Full TCLP parameters, including VOCs, SVOCs, pesticides, herbicides and metals) were analyzed for the SVFUDS soil to be disposed. Disposal facilities require these analyses prior to making a decision whether to accept the material. However, based on the SVFUDS history as an experiment station, additional sampling information including SVFUDS comprehensive list characterization data, was also provided to the disposal facility. This was considered 'generator knowledge' and it helped the facility determine whether the material was acceptable for their facility.

Soil determined by the sampling to be RCRA non-hazardous waste was transported to a sanitary landfill (Subtitle D) properly licensed to receive it, where it was disposed of directly, without pretreatment. Soil determined to be RCRA hazardous was disposed of at a RCRA-permitted Subtitle C landfill or a RCRA-permitted incinerator, depending upon the nature and quantity of the material. Note that soil with CWM or CWM ABP detections was considered hazardous waste but was not landfilled; this soil was sent to incinerator facilities.

The majority of all soil excavated during all SVFUDS removals was determined to be non-hazardous, and was disposed in Subtitle D landfills.

5.5.6 Disposal of Excavation Pit Water

During operations such as OU-4 AU Lot 18, where large excavations generated pit water, the water was collected in tanks and sampled prior to disposal. In some cases, it was discharged to the sanitary sewer in accordance with temporary discharge permits from the District of Columbia Water and Sewer Authority (DCWASA). In other situations, it was transported to disposal facilities based on whether sample results determined it was hazardous or non-hazardous.

5.6 Nature and Extent of Contamination

The determination of the nature and extent of HTW/MC/CWM and MEC contamination for the SVFUDS is based on the findings summarized in Sections 5.1 through 5.4. The findings of each of the three primary types of activities conducted at the SVFUDS (investigation/characterization, geophysical surveys, and removals) define the nature and extent, as discussed below.

5.6.1 Investigation and Characterization

The investigation and characterization activities described in Sections 5.1 and 5.2 were completed as standalone reports performed at discrete areas of the SVFUDS. The findings of each of those reports have been previously reviewed by stakeholders. Recommendations leading to additional soil sampling were made at the time those reports were reviewed, and any additional samples required to further define nature and extent of HTW/MC/CWM contamination were collected at that time. Several discrete areas of the SVFUDS have proceeded through quantitative HHRAs, including those discussed in Section 7.1.1, and any conclusions indicating remaining risk have been addressed in follow-on investigation or removal actions such that characterization of those discrete areas was considered to be complete.

However, where there was more recent supplemental sampling, as described in the Evaluation document (USACE, 2012c), these results were assessed in the Addendum to the Pre-2005 HHRA Review document (see Section 7.1.2.2) and they have been incorporated into the quantitative HHRA included in this RI report (Sections 7.2 and 7.3). Figure 7-2 presents the areas with remaining COPCs and Figure 7-3 shows, based on risk screening, those areas where the additional risk assessment was required.

While the findings of the Section 7.2 and 7.3 quantitative HHRAs could result in the need for additional sampling in the future (through the Feasibility Study process) to determine extent of contamination in smaller focused areas of the exposure units designated in Figure 7-3, no additional sampling is currently required for further nature and extent characterization of the SVFUDS.

The groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

5.6.2 Geophysical Investigations

For the OSR FUDS investigation, some 492 properties within the 661 acres of the SVFUDS, with focus on the identified POIs, were geophysically surveyed with an objective to locate burial pits and trenches. However, it is not practical to geophysically survey 100% of a site the size of the SVFUDS, and therefore, sound rationale for the selection of properties is crucial to determining the nature and extent of MEC contamination. Since 2001, a structured classification scheme to prioritize each residential property and non-residential lot for geophysical investigations has been followed. The scheme utilized ground scar data, soil sampling results, cut and fill considerations, and other factors to prioritize the properties. While this process has provided high quality geophysical data of all key areas based on historical review of past practices and likelihood of MEC or MD being present, the presence of single items representing individual munitions-related items will remain a possibility. One property remains to be intrusively investigated for potential MEC or MD in the 3700 block of Fordham Road. Geophysical surveys were conducted that identified one potential burial pit or trench and 27 single item anomalies. However, access to perform the intrusive investigation of the anomalies has not been granted by the property owner. There are additional scenarios where supplemental geophysical data may be useful. Section 5.3.1 notes properties where MEC or MD were found through geophysical investigation. However, for some of these, the adjacent properties received no geophysical survey. Also, as discussed in more detail in 7.6.3.2, static testing areas may suggest the presence of munitions burial pits near the testing locations (analogous to the findings at the initial 52nd Court trenches), identifying areas for possible further geophysical investigation; for these static testing areas, geophysical surveys for the properties within the assumed buffer zone may provide useful information. The properties within the buffer zone that were not geophysically investigated are shown in Figure 7-7.

5.6.3 Removal Actions

Removal actions at the SVFUDS have been concurrent with other investigations, being expedited through the TCRA and NTCRA process. The nature and extent of contamination in the areas of removals has been bounded through the removal actions, with soil excavations continuing until clean confirmation samples are obtained.

Excluding the ongoing RA at 4825 Glenbrook Road, one property in the 3700 block of Fordham Road, identified for arsenic contaminated soil removal through an NTCRA, remains to be completed. However, access has not been granted by the property owner to perform the removal action.

5.6.4 Nature and Extent Summary

A significant amount of data was gathered over the course of the RI. The key activity types of investigation and characterization, geophysical investigations, and removals, all contributed to achieving the DQOs for the SVFUDS sites.

Table 5-1 provides a summary of completed investigations at delineated areas. The table is organized by listing all POIs and AOIs sequentially, then the Range Fan. The 'Related Areas' column indicates where these delineated areas overlap (e.g., where a POI may be wholly or partially within an AOI). The intention of the table is to review the investigation objectives identified in Table 3-2, summarize the completed activities (previously described in Section 5.1 through 5.4 on an individual property and lot basis) in relation to the area-specific investigation objectives, and determine whether the investigation objectives were achieved to define the nature and extent of contamination for each area.

Table 5-2 presents the SVFUDS-specific DQOs, organized by activity type, and how they were achieved. These are general, to some extent, in terms of addressing the key activity types conducted over many years of work. While there may have been discrete site-specific DQOs for an investigation conducted many years ago that are not captured in this table, those previous investigations always proceeded in accordance with work plans approved by the SVFUDS Partners, and the associated reports were finalized through the Partner review process.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 1 / Circular Trenches	AOI 9, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Soil sampling for full AUES list parameters also conducted as part of the 2003 EE/CA with NTCRAs completed on 3 of the 5 properties based on arsenic contamination. Geophysical investigations found and removed MD items on 2 properties; no MEC/MD found on the other 3 properties. Miscellaneous soil samples were collected during geophysical investigations. All soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 2 / Possible Pit	AOI 9, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA with NTCRA required based on arsenic contamination. Geophysically surveyed; a possible pit anomaly was identified. Site access has not been granted for intrusive follow-on actions.	Investigation objectives achieved. Nature and extent of contamination to be defined.
POI 3 / Small Crater Scars	AOI 9, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigations found and removed MD items on all 3 properties. Miscellaneous soil samples were collected during geophysical investigations. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 4 / Possible Pit	AOI 9, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed MD items. Miscellaneous soil sample collected during geophysical investigation. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 5 / Possible Pit	AOIs 9, 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed MD items. Miscellaneous soil samples collected during geophysical investigation. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 6 / Possible Target or Test Site	AOIs 9, 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed a Stokes Mortar MEC item and MD items. Miscellaneous soil samples collected during geophysical investigation. Soil sample results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 7 / Possible Test Area	AOIs 9, 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. POI specific sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA with arsenic based NTCRAs completed on 2 of the 8 properties. Geophysical investigations found and removed MD items on 2 of 3 properties investigated. Supplemental soil samples collected to address AOITF recommendations with results carried to HHRA for AOI 9 (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 8 / Possible Target or Test Site	AOIs 9, 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA with NTCRA completed based on arsenic contamination. Partial (part of POI under street) geophysical investigation completed with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 9 / Possible Firing or Observation Stalls	AOI 21; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA with NTCRAs completed on the 2 properties based on arsenic contamination. Geophysical investigations found and removed MD items on both properties. Miscellaneous soil samples collected during geophysical investigations. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 10 / Possible Target or Test Site	POIs 11, 39; AOIs 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	POI specific soil sampling (surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Geophysical investigation completed with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 11 / Scattered Ground Scars	POIs 10, 39; AOIs 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Geophysical investigation completed with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 12 / Possible Graded Area	AOIs 8, 21	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria on the 4 properties. Geophysical investigations were conducted on 3 properties under the OSR FUDS; no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 13 / Circular Trenches	POI 14; AOIs 11, 21	Soil sampling, Geophysical investigations, Groundwater sampling	POI specific soil sampling (surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria on the 10 properties. Geophysical investigation completed on 3 properties with no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified. Multiple groundwater sampling events conducted at nearby MW-23 indicate no results exceeded comparison criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 14 / Pit	POI 13, AOIs 11, 21	Soil sampling, Geophysical investigations, Groundwater sampling	1993 excavation and remediation of munitions burial pit under the OSR FUDS. MEC/MD and CWM found and removed. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Subsequent geophysical investigation completed with no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified. Multiple groundwater sampling events conducted at nearby MW-23 indicate no results exceeded comparison criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 15 / Ground Scar	AOI 21	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS with no MEC/MD found. POI specific sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, and cyanide) conducted as part of the 2003 EE/CA on the 5 properties. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 16 / Chemical Persistency Test Area	AOI 21	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS with no MEC/MD found. Soil sampling conducted under the OSR FUDS. POI specific sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA with TCRAs and NTCRAs completed on 8 of the 63 properties based on arsenic contamination. Subsequent geophysical investigation of one property with no MEC/MD found. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 17 / Possible Pit	Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation conducted with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 18 / Small Crater Scars	Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. NTCRAs completed on 2 of the 3 properties based on arsenic contamination. Geophysical investigations found and removed a Thermite Grenade MEC item and MD items on one of 3 properties investigated. Soil sample collected during geophysical investigation identified mercury contamination on one property. Contaminated soil removed as part of the NTCRA. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 19 / Old Mustard Field	None	Soil sampling	Geophysical investigations conducted under the OSR FUDS with no MEC/MD found. Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, and cyanide) also conducted as part of the 2003 EE/CA with NTCRAs completed on 5 of 23 properties based on arsenic contamination. Remaining soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 20 / Ground Scar	AOIs 3, 24	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation conducted with no MEC/MD finds. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 21 / Two-chambered Shell Pit	POIs 22, 23; AOIs 22, 24; MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. NTCRA conducted to remove contaminated soil and debris from the shell pit. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted on the property containing POIs 21, 22, and 23 with MD items found and removed. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 22 / Shell Pit	POIs 21, 23; AOIs 22, 24; MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted on the property containing POIs 21, 22, and 23 with MD items found and removed. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 23 / Three-chambered Shell Pit	POIs 21, 22; AOIs 22, 24; MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. NTCRA conducted to remove contaminated soil and debris from the shell pit. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted on the property containing POIs 21, 22, and 23 with MD items found and removed. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results carried to HHRA for Spaulding - Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 24 / Probable Pit	POI 53, AOIs 5, 17; MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Current information locates this POI at 4825 Glenbrook where a separate remedial action is being conducted. Numerous MEC/ MD and CWM items have been found and removed from this property.	Work at 4825 Glenbrook Road is addressed in a separate RI/FS/RA.
POI 25 / Possible Trenches	AOI 3, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic conducted on the 4 properties as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigations conducted on all 4 properties with no MEC/MD items found. OSR FUDS RI mistakenly attributes Spaulding-Rankin Area samples to POI 25.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 26 / Small Crater Scars	POI 53, AOI 13, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation found and removed MD items. Miscellaneous soil samples collected during geophysical investigation. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 27 / Probable Ditch or Trench	None	Soil sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. This ground scar was investigated under the AU ground disturbance study; no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 28 / Probable Ditch or Trench	None	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS; no MEC/MD found. Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. One subsurface sample result exceeded screening criteria for arsenic, but left in place at request of property owner.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan				
AOI or POI Number	**Related Areas**	**Investigation Objectives**	**Investigation Summary**	**Nature and Extent Determination**
POI 29 / Ground Scar	AOI 14	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS; no MEC/MD found. Soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 30 - 36 / Training Trenches	AOI 25	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. NTCRAs completed on 17 of the 32 properties where arsenic contamination exceeded the screening criteria. Geophysical investigations conducted on 2 properties with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 37 / Mill Creek	None	Soil and Surface Water sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS with no MEC/MD found. Soil/surface water sampling also conducted under OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. NTCRAs completed on 6 of the 15 properties where arsenic contamination exceeded the screening criteria. Geophysical investigation conducted on one property; no MEC/MD found. Miscellaneous soil samples collected during geophysical investigations. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Surface water sample results did not indicate risk from arsenic, chemical agents/ABPs or explosives.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 38 / Bradley Field/Major Tolman's Field	AOI 18	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA with NTCRAs completed on 2 of the 7 properties based on arsenic contamination. Geophysical investigation conducted on one property; no MEC/MD found. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Subsequent evaluation by the AOITF determined that an accurate location of POI 38 (AOI 18) could not be identified.	Investigation objectives were not achieved for this POI. POI was not located.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 39 / Static Test Fire Area	POIs 10, 11; AOIs 21, 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) conducted as part of the 2003 EE/CA. NTCRA completed on one property where arsenic contamination exceeded the screening criteria. Geophysical investigations performed on three of the 5 residential and all four DC right-of-way properties located within this POI. One 75 mm projectile MEC item and several MD items were recovered from the DC right-of-way portion of the POI. Miscellaneous soil sample collected during geophysical investigations. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 40 / Ohio Hall	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 41 / History Building	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. One subsurface sample result exceeded screening criteria for arsenic, but left in place at request of property owner.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 42 / Physio-logical Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 43 / Gun Pit	POIs 21, 22, 23, 53; AOI 4, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted with MD items found and removed. Supplemental soil samples collected to address AOITF recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 44 / Chemical Research Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
POI 45 / Explosives Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 46 / Canister Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 47 / Bacterio-logical Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 48 / Dispersoid Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 49 / Pharmaco-logical Laboratory	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 50 / Concrete Gun Pit	None	Soil sampling	Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria.	Investigation objectives achieved. Nature and extent of contamination defined.
POI 51 / Fire and Flame Laboratory	POI 53	Soil sampling, Geophysical investigations	Geophysical investigations conducted under the OSR FUDS; no MEC/MD. Soil sampling conducted under the OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. A ground scar was investigated adjacent to POI 51 under the AU ground scar disturbance study with no MEC/MD found. All soil sample results carried to HHRA for Southern AU (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan				
AOI or POI Number	**Related Areas**	**Investigation Objectives**	**Investigation Summary**	**Nature and Extent Determination**
POI 52 / Electrolytic Laboratory	POI 53	Soil sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS; no MEC/MD found. Soil sampling conducted under OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. All soil sample results carried to HHRA for Southern AU (see Section7).	Investigation objectives achieved. Nature and extent of contamination defined.
POI 53 / Baker Valley	POIs 24, 26, 43, 51, 52, AU; AOIs 4, 5, 13, 17, 22, 24, 26; Range Fan, Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that contains many AOIs and POIs. Soil sampling conducted under the OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. TCRAs and NTCRAs completed based on arsenic contamination. Geophysical investigations conducted on properties within POI 53 with MEC, MD, and CWM items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results from the AU campus portion of POI 53 were carried to HHRA for Southern AU. Soil sample results from Spaulding-Rankin Area portion of POI 53 were carried to HHRA for Spaulding- Rankin Area (see Section 7). The remaining sample results within POI 53 were evaluated during the HHRA screening process; no risks identified. Multiple groundwater sampling events conducted within POI 53 have detected results exceeding comparison criteria (see Appendix G).	Characterization of nature and extent of groundwater contamination ongoing. Excluding the separate POI 24 RA, investigation objectives have been achieved, and nature and extent of contamination have been defined.
POI AU	POI 53; AOIs 17, 22, 24, 28; MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that contains many AOIs and POIs. Soil sampling conducted under the OSR FUDS. Surface soil screening for arsenic and subsurface screening for arsenic, mustard ABPs, and cyanide conducted as part of the 2003 EE/CA. TCRAs completed based on arsenic contamination. Geophysical investigations conducted on areas within POI AU with MEC, MD, and CWM items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. Soil sample results were carried to HHRA for Southern AU (see Section 7). Multiple groundwater sampling events conducted within POI AU have detected results exceeding comparison criteria (see Appendix G).	Characterization of nature and extent of groundwater contamination is ongoing. Soil sampling and geophysical investigations are completed to define the nature and extent of contamination at this POI.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 1 / "X" Feature	None	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide conducted as part of the 2003 EE/CA with NTCRAs completed on 3 of the 17 properties based on arsenic contamination. Soil sampling for full AUES list parameters also conducted as part of the 2003 EE/CA on one property. Geophysical investigation on 6 properties with no MEC/MD found. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 2 /Rick Woods Burial Pit	Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and soil boring for arsenic, agent/ABPs, explosives, and cyanide conducted as part of the 2003 EE/CA. Sample results did not exceed screening criteria. Geophysical investigations found and removed MD items.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 3 / Gunpowder Magazine Area	POI 20	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. Geophysical investigation conducted with no MEC/MD found. All soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 4 / Livens Gun Pit	POIs 43, 53; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA completed based on arsenic contamination. Geophysical investigations conducted with MD items found and removed. Supplemental soil samples collected to address AOITF recommendations. Soil sample results carried to HHRA for Spaulding- Rankin Area (see Section 7).	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 5 / 4825/4835 Glenbrook Road	POIs 24, 53, AU; AOI 17; Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	4835 Glenbrook Road has undergone significant soil removal through the NTCRA process and considerable geophysical anomaly intrusive investigation via test pitting. One Livens projectile classified as MD and AUES-related laboratory glassware were identified during investigations. No MEC or CWM was identified. An HHRA concluded that unacceptable cancer risks and non-carcinogenic health effects were not expected. 75 MEC items, 24 CWM items, and 413 MD items along with numerous AUES – related laboratory glassware items were recovered during investigations at 4825 Glenbrook Road. Multiple groundwater sampling events conducted down gradient of AOI 5 have detected results exceeding comparison criteria (see Appendix G).	Investigation objectives have been achieved to define the nature and extent of contamination 4835 Glenbrook Road. Work at 4825 Glenbrook Road is addressed in a separate RA.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 6 / Dalecarlia Impact Area	Range Fan, Partially within MRS 01	Geophysical investigations	Geophysical investigations conducted under the OSR FUDS. One MEC item, a partially filled Livens smoke round, and numerous MD items found. Soil sample associated with the MEC item conducted under OSR FUDS. Surface soil screening for arsenic conducted as part of the 2003 EE/CA with NTCRA completed on one lot based on arsenic contamination. Subsequent geophysical investigations found and removed additional MD items. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 7 / Rockwood Six	AOI 17	Soil sampling, Geophysical investigations, Groundwater investigations	Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with TCRA or NTCRA completed on 5 of the 6 properties based on arsenic contamination. Soil sampling for full AUES list parameters also conducted for 2003 EE/CA on two properties. Geophysical investigation on all 6 properties with no MEC/MD or CWM found except for that relating to the adjacent POI AU (AU Lot 18). Soil sample results evaluated during HHRA screening process; no risks identified. Multiple groundwater sampling events conducted at PZ-3 within AOI 7 indicate no unacceptable results.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 8 / Possible Graded Area	POI 12, AOI 21	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria on the 5 properties. Geophysical investigations were conducted on 3 properties under the OSR FUDS; no MEC/MD found. Supplemental soil samples collected to address AOITF recommendations with results evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 9 / Sedgwick Ground Scars	POIs 1-8; AOI 24; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Large area that includes many POIs, one AOI, and the Range Fan. Significant soil sampling conducted under OSR FUDS and the 2003 EE/CA. NTCRAs completed on 11 of the 52 properties based on arsenic contamination. Geophysical investigations were conducted on 29 properties within AOI 9; MEC/MD items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. All soil sample results were carried to HHRA for AOI 9 (see Section 7). See Related Areas for additional information.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 10 / Westmore-land Recreation Center	None	None	The AOITF found no documents, maps, sampling results, geophysics, or anecdotal evidence of any AUES contamination or activity at this AOI. Further, the area is greater than 2000 feet from the SVFUDS boundary, and additional investigations were determined not to be required for this AOI.	Investigation objectives were not developed for this AOI.
AOI 11 / 52nd Court Pit and Trenches	POIs 13, 14; AOI 21	Soil sampling, Geophysical investigations, Groundwater sampling	See POIs 13 and 14	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 12 / Livens Battery Impact Area	AOI 21, Range Fan, MRS 01	Soil sampling, Geophysical investigations	Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with arsenic based NTCRA completed on 1 of 2 properties. Geophysical investigations conducted on both properties with MD items found and removed on one property.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 13 / Quebec / Woodway 13 Properties	POIs 26, 53; Range Fan, MRS 01	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. Surface and subsurface soil screening for arsenic conducted as part of the 2003 EE/CA with NTCRA completed on one property based on arsenic contamination. Soil sampling for full AUES list parameters also conducted as part of the 2003 EE/CA on one property. Geophysical investigation on 11 of 13 properties with MEC/MD found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF report recommendations. All soil sample results were evaluated during HHRA screening process; no unacceptable risks identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 14 / Sharpe Bunker on Seminary	POI 29	Soil sampling, Geophysical investigations	Geophysical investigations conducted under OSR FUDS with no MEC/MD found. Surface soil screening for arsenic conducted as part of the 2003 EE/CA; results did not exceed screening criteria. Further investigations were determined not to be required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 15 / Dog Wallows	None	Soil sampling, Geophysical investigations	Surface soil screening for arsenic conducted as part of the 2003 EE/CA. Arsenic results did not exceed screening criteria. A ground scar was investigated within AOI 15 under the AU ground scar disturbance study with no MEC/MD found. Further investigations were determined not to be required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 16 / Westmore-land Circle Impact Area	None	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide for 2003 EE/CA with NTCRA completed on 6 of the 77 properties based on arsenic contamination. Geophysical investigations conducted on 2 properties; no MEC/MD items found. Further investigations were determined not to be required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 17 / $800,000 Burial Site	POIs 24, 53, AU; AOIs 5, 26	Soil sampling, Geophysical investigations, Groundwater sampling	The AOITF did not identify a specific location for this AOI. The burial pit is likely one of the several burial pits identified and removed from 4801 and 4825 Glenbrook Road. The Partners concurred that no further actions are required for this AOI.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 18 / Major Tolman's Field	POI 38	Soil sampling, Geophysical investigations	Soil sampling conducted under the OSR FUDS. POI specific soil sampling (surface soil screening for arsenic and soil borings for arsenic, agent/ABPs, explosives, and cyanide) also conducted as part of the 2003 EE/CA with NTCRAs completed on 2 of the 7 properties based on arsenic contamination. Geophysical investigation conducted on one property; no MEC/MD found. Soil sample results evaluated during HHRA screening process; no unacceptable risks identified. Subsequent evaluation by the AOITF determined that an accurate location of POI 38 (AOI 18) could not be identified. Subsequent evaluation by the AOITF determined that an accurate location of POI 38 (AOI 18) could not be identified.	Investigation objectives were not achieved for this AOI. AOI was not located.
AOI 19 / Tenleytown Station	None	Soil sampling	All 8 properties had previously been sampled for arsenic as part of the 2003 EE/CA and all sampling results were less than screening levels. No geophysical surveys were conducted. There is no historical evidence that AOI 19 was ever used by AUES or Camp Leach for disposal or storage activities and the Partners concluded that there is insufficient evidence to warrant further investigation.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 20 / Slonecker-Johnson Groundscars	None	Test trenching	An intrusive investigation of the linear ground scars was completed via trenching. No AUES-related material was found, no soil staining was observed, and there was no evidence to indicate this AOI was a burial area.	Investigation objectives achieved. Nature and extent of contamination defined.

Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 21 / Weaver Farm	POIs 5-16, 39; AOIs 8, 9,11,12, 24; Range Fan, Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that includes many POIs, AOIs, and the Range Fan. Much soil sampling conducted under OSR FUDS and 2003 EE/CA. TCRA and NTCRA removals completed based on arsenic contamination. Geophysical investigations conducted; MEC, MD, and CWM items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF recommendations. All soil sample results were evaluated during the HHRA screening process; no unacceptable risks identified. Multiple groundwater sampling events at MW-23 and down-gradient wells. See Related Areas for additional information.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 22 / Mercury Detection Areas	POIs 21- 23, 24, 53, AU; Partially within MRS 01	Soil sampling	Inappropriate mercury analytical method used in the OSR FUDS RI was further investigated with more recent sampling and updated methodology for this RI. All mercury sample results were evaluated during the HHRA screening process. A small area of POI AU contains mercury above acceptable risk levels (see HHRA Section 7.3).	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 23 / Railroad Sidings	None	None	Research was conducted to determine when the railroad siding was constructed. While research was unable to identify a construction date, an analysis of records at the WA archives indicated that a railroad siding was not present at the WA prior to 1920 and therefore could not have been used as a distribution point for shipping supplies to the AUES and Camp Leach. Further investigations were determined not to be required.	Investigation objectives were not developed for this AOI.
AOI 24 / Antimony Detection Areas	POI 7, 10, 11, 20-23, 25, 39, 53, AU; AOI 3, 9, 21; Partially within MRS 01	Soil sampling	Antimony detections from the OSR FUDS RI were further investigated in accordance with the AOITF recommendations. Supplemental sampling for antimony in soils was completed as part of this RI. All antimony sample results were evaluated during the HHRA screening process; no unacceptable risks were identified.	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 25 / Camp Leach Trenches	POIs 30-36	Soil sampling, Geophysical investigations	Surface soil screening for arsenic and subsurface screening for arsenic, agent/ABPs, and cyanide conducted as part of the 2003 EE/CA. NTCRAs completed on 17 of the 32 properties where arsenic contamination exceeded the screening criteria. Geophysical investigations conducted on 2 properties with no MEC/MD found.	Investigation objectives achieved. Nature and extent of contamination defined.

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Table 5-1. Completed Investigation Summary for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Investigation Objectives	Investigation Summary	Nature and Extent Determination
AOI 26 / 4801 Glenbrook Road	POI 53, AOI 17, Partially within MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Significant soil sampling and geophysical investigations conducted at this property. NTCRA activities removed arsenic contaminated soil. Intrusive investigations excavated and removed two large burial pits and a third burial pit on the property line shared with 4825 Glenbrook Road. Multiple groundwater sampling events conducted down gradient of AOI 26 have detected results exceeding comparison criteria (see Appendix G).	Investigation objectives achieved. Nature and extent of contamination defined.
AOI 27 / Third Circular Trench	None	None	Research was conducted to determine whether documentation supported that a third circular trench was constructed off the grounds that were leased or used by the AUES. AOITF determined there was no evidence to support a third circular trench.	Investigation objectives were not developed for this AOI.
AOI 28 / Hamilton Hall Burial Pit	POI AU, Partially within MRS 01	Soil sampling, Geophysical investigations	Geophysical investigations associated with this AOI were conducted to address the AOITF recommendations. No MEC/MD or CWM items found. However, a soil sample associated with AUES-related debris was found to contain elevated arsenic. The arsenic contamination was removed under the AU TCRA. The Partners reviewed the findings from the intrusive activities in the vicinity of Hamilton Hall and concluded that no additional investigation of this AOI is necessary.	Investigation objectives achieved. Nature and extent of contamination defined.
Range Fan	POIs 3-11, 17, 18, 25, 39, 43, 53; AOIs 2, 4, 6, 9, 12, 13, 21, 22, 24; MRS 01	Soil sampling, Geophysical investigations, Groundwater sampling	Large area that includes many POIs and AOIs. Significant soil sampling conducted under OSR FUDS and the 2003 EE/CA. TCRAs and NTCRAs completed based on arsenic contamination. Geophysical investigations conducted; MEC/MD items found and removed. Miscellaneous soil samples collected during geophysical investigations. Supplemental soil samples collected to address AOITF recommendations. All soil sample results were evaluated during the HHRA screening process; no risks were identified. Multiple groundwater sampling events conducted at down-gradient monitoring wells. See Related Areas for additional information.	Investigation objectives achieved. Nature and extent of contamination defined.

See Tables 1-1 and 1-2 for descriptions of POIs and AOIs.

Table 5-2. Activity-Specific DQOs

Activity Type	Step 1: State the Problem	Step 2: Identify the Decision	Step 3: Identify Inputs to the Decision	Step 4: Define the Study Boundaries	Step 5: Develop a Decision Rule	Step 6: Specify the Limits on Decision Errors	Step 7: Optimize the Design	Conclusion
Investigation and Characterization	HTW/MC/CWM (typically arsenic-contaminated soil) had been released into the environment as a result of historical AUES activities that could pose a potential risk to human or ecological receptors having the potential to come into contact with the soil. The RI objective is to determine the level of risk or hazard presented by past DoD use of the property.	Is there HTW/MC/CWM related contamination in the SVFUDS soil that could pose a risk to current or future site users? In particular, does soil with arsenic greater than 20 mg/kg exist on the property? Are there areas of cultural importance such that arsenic up to 43 mg/kg can be left in place to avoid impacting them?	Photogrammetry of historical aerial photographs, document research, and anecdotal information from residents, relating to past AUES activities and potential HTW/MC/CWM releases to these areas. The CSM identified release mechanisms of the AUES testing.	Discrete areas within defined POIs or AOIs. The FUDS boundary as determined by historical site usage. Operable units identified for different areas of the SVFUDS. Laterally, the discrete areas were often individual properties; vertically, the depth of investigation was a function of potential burial depths relative to the 1918 horizon (using cut and fill contours).	For arsenic screening purposes, sample surface soil on a quadrant basis using composite sampling methods. If > 12.6 mg/kg arsenic, grid sample along 20 ft x 20 ft grids. In selected areas based on ground scars or other historical evidence, sample surface and subsurface soil for SVFUDS comprehensive analytical list	Analytical methods were selected based on levels of detection being at or below delineation criteria provided in the respective QAPP. Quality Control samples were collected in addition to the site samples in numbers and types in accordance with the most current DoD Quality Systems Manual. Measurement performance criteria for the QC samples were provided in the respective QAPP.	The sampling design was optimized, and adjusted in certain situations, based on SVFUDS Partner review of the respective work plans, including home owner input, or based on specific field conditions encountered such as stained soils; sample plans were flexible enough to accommodate such site conditions where additional samples may have been warranted.	The DQOs for the investigations were met in that the nature and extent of contamination was properly characterized and areas requiring additional work were identified following the investigation criteria established for that area. Reports of these activities were finalized based on SV Partner consensus.

Table 5-2. Activity-Specific DQOs

Activity Type	Step 1: State the Problem	Step 2: Identify the Decision	Step 3: Identify Inputs to the Decision	Step 4: Define the Study Boundaries	Step 5: Develop a Decision Rule	Step 6: Specify the Limits on Decision Errors	Step 7: Optimize the Design	Conclusion
Geophysical Investigations	MEC and/or MD, or CWM, had been released into the environment as a result of historical activities that could pose a potential explosive hazard to human receptors having the potential to come into contact with it. Single items as well as potential burial pits and trenches may have resulted from past DoD use of the site.	Are there MEC/MD or cWM items on or in the soils of the SVFUDS that could pose an explosive hazard to current or future site users? Are there potential burial pits that may contain MEC/MD or AUES related laboratory glassware?	Photogrammetry of historical aerial photographs, document research, and anecdotal information from residents, relating to past AUES activities and potential MEC/MD or CWM releases to these areas. The CSM identified release mechanisms of the ballistic and static testing or documented disposals.	Discrete areas within defined POIs or AOIs. Laterally, the discrete areas were often individual properties; vertically, the depth of investigation was a function of geophysical intrumentation, with both single items and potential burial pits as targets.	Categorize anomalies in accordance with the criteria defined in the technical memos. Recommend anomaly excavations to ARB based on categorization. Excavate anomalies as recommended by ARB.	Geophysical intrumentation selection and performance criteria based on single items and potential burial pit targets (see Section 4.1.2.2). QC and measurement performance criteria in accordance with the respective work plan QAPP for the specific investigation.	The survey design was optimized, and adjusted in certain situations, based on ARB and SVFUDS Partner review of the respective work plans or initial data return, or based on specific field conditions encountered such as cultural interferences or access issues.	The DQOs for the investigations were met in that the coverage goals were met (with only minor exceptions based on cultural features present), the anomalies were individually categorized, and those identified by the ARB for investigation were excavated and characterized following the criteria established in the technical memos developed for SVFUDS geophysics. Reports of these activities were finalized based on SV Partner consensus.

Table 5-2. Activity-Specific DQOs

Activity Type	Step 1: State the Problem	Step 2: Identify the Decision	Step 3: Identify Inputs to the Decision	Step 4: Define the Study Boundaries	Step 5: Develop a Decision Rule	Step 6: Specify the Limits on Decision Errors	Step 7: Optimize the Design	Conclusion
Removal Actions	HTW/MC/CWM (typically arsenic-contaminated soil) had been released into the environment as a result of historical AUES activities that could pose a potential risk to human or ecological receptors having the potential to come into contact with the soil. The removal action objective is to remove the risk or hazard presented by past DoD use of the property.	Does soil with arsenic greater than 20 mg/kg exist on the property? Are there areas of cultural importance such that arsenic up to 43 mg/kg can be left in place to avoid impacting them?	The locations and concentrations of HTW/MC contamination (typically > 20 mg/kg arsenic in soil) that have been found previously at the site, based on grid sampling. The current and projected future land uses for that site, including home owner input on the desire not to impact certain cultural features (such as large, old trees, that would be impacted by excavation).	Laterally, the overall site boundary was typically an individual residential property with excavation delineated along 20 ft x 20 ft grids.Vertically, the study boundaries were typically the depth of soil containing arsenic greater than 20 mg/kg.	If analysis of the soil indicates arsenic concentrations greater than 20 mg/kg (or 43 mg/kg on a site-specific basis), excavate and backfill with clean soil. Conduct confirmation sampling to determine lateral and vertical limit of excavation.	Analytical methods were selected based on levels of detection being at or below delineation criteria provided in the respective QAPP. Quality Control samples were collected in addition to the site samples in numbers and types in accordance with the most current DoD Quality Systems Manual. Measurement performance criteria for the QC samples were provided in the respective QAPP.	The sampling design was optimized, and adjusted in certain situations, based on SVFUDS Partner review of the respective work plans, including home owner input. Sample plan was flexible to accommodate unanticipated site conditions where additional samples may have been warranted.	The DQOs for the removal actions were met in that soil characterized as contaminated was successfully removed following the criteria established for that area. Reports of these activities were finalized based on SV Partner consensus.

5.7 Revised CSMs

Generally the CSMs established for the SVFUDS as described in Section 3.2.1 and 3.2.2 were validated through the RI process. However, RI findings resulted in some revisions to the assumed release mechanisms associated with the past MEC-related activities at the AUES, as well as the assumptions made in relation to HTW/MC/CWM characterization.

5.7.1 HTW/MC/CWM-Based CSM

The primary rationale for the HTW/MC/CWM CSM application was that areas that fell within OU-2, OU-3 and OU-4 were likely to contain higher levels of contamination, namely arsenic, as a result of the concentrated activities using organoarsenicals for research and the likely disposal or burial of chemicals within the AUES perimeter fenceline. This was validated through the investigation and characterization and removal activities associated with OU-2 (Section 5.1.2), OU-3 (Section 5.2.1) and OU-4 (Section 5.2.2) where significant contamination was identified at 4801 Glenbrook Road, 4825 Glenbrook Road, the AU CDC, SDA, Lot 18, and the PSB. This was also true in some cases for other metals at the SVFUDS. Mercury, for example, when found above its comparison standards, was determined to be associated with AUES disposal areas including Lot 18 and 4900 Quebec Street.

The CSM projected that HTW/MC/CWM contamination would also potentially be concentrated within the CTA as it covered the major field testing areas identified as POIs (Section 4.1.1.4 provides the details of the approach used for investigating the CTA). However, the site-wide sampling associated with the OU-4 and OU-5 EE/CA (USACE, 2003b) found no spatial distribution correlation between arsenic contamination and AOI/POI locations. The highest levels of arsenic contamination centered around OU-2, OU-3 and the AU portion of OU-4 as expected from the CSM. Figure 5-7 shows this as a function of TCRA and NTCRAs required based on arsenic, where the highest density of arsenic-based removal actions were located. Outside of this area, the figure also indicates a fairly random spread of properties requiring arsenic based removal actions. This likely reflects the many non-AUES sources of arsenic. As described in Section 6.4.1, arsenic is a naturally occurring element abundant in the earth’s crust. Arsenic levels may have been increased by human activities other than those associated with the AUES, including fertilizer, pesticide and herbicide usage, and coal burning. In addition another major source of arsenic was the use of pressure treated wood used for decks, playgrounds and fencing that contained chromated copper arsenate prior the voluntary discontinuation of its use for residential purposes in 2003. While the specific anthropogenic source of the arsenic (AUES or other sources) could not be definitively determined, it is reasonable to conclude that in some cases, elevated arsenic concentrations were more likely associated with pesticides, fertilizer, and herbicides use than AUES activities.

With regard to constituents other than arsenic, even in the CTA areas of field testing of chemicals, there were no significant findings of CWM or CWM ABPS, or other organic chemicals. The highest concentrations on chemicals other than arsenic tended to be associated with disposal or burial areas.

5.7.2 MEC-Based CSM

The source activities included in the MEC based CSM were validated through RI field activities. MEC and MD finds strongly correlated with the previous uses of areas throughout the SVFUDS (outside the AUES perimeter fence, AOIs, POIs, and the Range Fan). As Figure 5-6 shows, MEC and MD was identified either within AOIs, POIs, or the Range Fan, with the vast majority of MEC finds associated with disposal or burial areas. Overall, the previous activities presumed to have occurred within AOIs and POIs matched the investigation findings, with a few exceptions.

The following discussions describe specific instances where the investigation results led to a revised application of the CSM for a given AOI or POI.

- AOI 1 – initially thought to represent sets of shallow parallel trenches used for testing (open air and statically fired testing release mechanisms). However, when ground scar locations were revised in 2009 using updated GIS software, the "X" Feature was identified as the early beginning of the intersection of 48th Street and Rodman Street and AOI 1 is not considered to be associated with HTW/MC/CWM or MEC release mechanisms.
- AOI 6 – Dalecarlia Impact Area. It is the downrange terminus for the Range Fan where Livens projectiles and 75mm shells were recovered. According to historical documentation, 75mm shells were used for statically fired testing and were therefore likely associated with the nearby POI 39 and POI 13 and not related to the Range Fan ballistically fired testing. Therefore statically fired testing for MEC was added as a release mechanism for this AOI to account for 75mm shells which were statically fired in the Range Fan.
- AOI 25 – a series of trenches associated with Camp Leach activities and related to POIs 30-36. However, AUES and Camp Leach were separate entities and were closed on different timelines. Camp Leach was closed prior to AUES and therefore AUES disposals in those trenches are unlikely. The disposal or burial release mechanism was revised to indicate no release mechanism for this AOI.
- Range Fan - the elongated cone-shaped area defined by a firing point and potential impact areas. While the release mechanisms for the Range Fan were not revised as a result of field investigations, findings indicated a revision to the POIs associated with the Range Fan; geophysical investigations associated with POI 18 resulted in the recovery of a storage box which contained MEC items (a thermite grenade and 60 flash tubes) not associated with ballistically fired testing of the Range Fan.
- POI 27 and 28 - ground scars analyzed by the USEPA EPIC as a probable ditch or trench. Located on Camp Leach. However, AUES and Camp Leach were separate entities and were closed on different timelines. Camp Leach was closed prior to AUES and therefore AUES disposals in those trenches are unlikely. The disposal or burial release mechanism was revised to indicate no release mechanism for these POIs.

6.0 CONTAMINANT FATE AND TRANSPORT

This chapter discusses the fate and transport mechanisms potentially affecting releases and distribution of constituents and examines how these mechanisms affect migration of the constituents. Specifically, the subsections below detail the potential contaminant sources, routes of migration, contaminant properties, and migration and persistence.

6.1 Potential Contaminant Sources and Release Mechanisms

As discussed in Section 3.2.1, the potential contaminant sources are the activities of the former AUES. These primary activities expected to contribute contaminants included the laboratory operations (spills, leaks, laboratory mishaps resulting in explosive release of chemicals), open air testing, disposal or burial, or the munitions themselves. Open air testing included chemical releases through both the firing of munitions and land application activities such as spraying vegetation for persistency testing of various chemicals. The Figure 3-1 CSM graphically depicts the source area as the SVFUDS community with the source media being the activities of the former AUES (primarily open air testing and disposal or burial). These are mechanisms for contaminant releases to the soil. The AUES was generally divided into two use areas: the area within the AU and Spaulding property bounded by a perimeter fence served as the research center where chemicals, gases, and munitions were developed and stored; and the area outside the AU and Spaulding property boundaries where chemicals and items developed at the research facilities were field tested. The investigation results described in Section 5 indicate that higher levels of contaminant release within the perimeter fence boundaries of the AUES because the activities occurring there (spills, leaks, laboratory mishaps resulting in explosive release of chemicals, and disposal and burial) were more likely to cause contamination than open air testing.

While these were the primary sources, as described in more detail in Section 1.4.2.1, as a large military operation, there were potentially many other activities that were sources of possible contaminants, including housing of troops and workers, vehicle operation and maintenance, and care and feeding of livestock.

6.2 Potential Contaminant Migration Pathways

The past activities resulted in migration of contaminants through possible downward infiltration/percolation of rainfall into the surface soils or contaminated fugitive dust. Contaminant infiltration to the subsurface environment can result in groundwater and subsurface soil becoming secondary sources of contamination. Soil in the vadose (unsaturated) and saturated zones can be contaminated by the vertical and horizontal migration of contaminants from surface spills, land application (spraying) of chemicals, or burial of wastes. After migrating through the vadose zone, contaminants can then enter the groundwater where they may undergo hydrolysis, oxidation, reduction, or other processes resulting in the chemical transformation of a contaminant.

The contaminants are also attenuated mechanically as they migrate through the subsurface by processes such as dilution, dispersion, diffusion, and absorption. Potential secondary release mechanisms include infiltration and/or percolation of water through contaminated subsurface soil and the discharge of contaminated groundwater to the surface in the form of leachate/seeps. Potential contaminated media can include surficial soil, groundwater, surface water, or sediment.

In general, contaminants released to surface water can be transported downstream dissolved in water or on suspended sediment, or can be transported to the atmosphere. At the SVFUDS, infiltration of precipitation is high and surface runoff is minimal except for the paved areas. Movement of surface soil particulates from contaminated soils via atmospheric wind or fugitive dust generation is considered a potential transport mechanism. Such particulate transport is generally limited to particle size, wind speeds and other site-specific conditions. The surficial soils at the SVFUDS are typically grassy landscaped lawns, with significant vegetation to retard the airborne transport.

Contaminated soil can be tracked from one location to another; plant life may absorb soil contaminants; and, wildlife may ingest plants that have assimilated contaminants in leaf and stem tissue. In addition, contaminants can be conveyed by surface water and/or sediments to aquatic life that may be ingested by wildlife.

The transport pathways in groundwater include advection, hydrodynamic dispersion, diffusion, and sorption. The SVFUDS groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

Contaminants can be physically transformed through volatilization or biodegradation or can accumulate in a specific medium. The potential for specific contaminants to migrate from one medium to another or to be transformed is dependent on the physical and chemical properties of each contaminant.

In general, with regard to future migration pathways in the SVFUDS, significant volumes of contaminated soil have been removed through NTCRAs and TCRAs, as described in detail in Section 5, and therefore, migration of contaminants to groundwater is not a continuing concern. As described below, only arsenic and perchlorate have been found in the groundwater at levels of concern. Finally, as the SVFUDS neighborhood is fully developed, land use is not expected to change and new or different migration pathways are not expected in the future.

6.3 Contaminant Properties

The environmental fate and transport of chemicals are dependent upon the physical and chemical properties of the compounds, the environmental transformation processes affecting them, and the media through which they migrate. In this section, these chemical and physical properties are broadly described, while the next discussion addresses contaminant specific properties of some of the primary contaminants encountered during the many investigations at the SVFUDS.

In the *Parameters Report for the Development of the AUES List of Chemicals* (USACE, 2008d), long historical lists of chemicals documented to have been used at the AUES were evaluated to determine whether sampling was appropriate. As an experiment station, many of the chemicals used at the AUES were non-routine. The Parameters report details the procedures to use environmental fate and transport properties of these compounds to help consider whether the chemical would conceivably still be present in the soil after approximately 85-90 years in the environment. To evaluate that question, basic chemical and physical properties of the individual chemicals were reviewed. Volatility was assessed by using Henry's Law constant and Molecular Weight. The octanol-water partition coefficient (Kow) was used to assess whether the chemical would more likely be found in soil or water. The USEPA presents general guidance on using these properties for determining the likelihood of the chemical still being present.

The water solubility of a substance is a critical property affecting environmental fate. Highly soluble chemicals can be leached rapidly from soils and are generally mobile in groundwater. The solubility of chemicals that are not readily soluble in water may be enhanced by the presence of organic solvents, which are more soluble in water.

Volatilization of a compound depends on its vapor pressure and water solubility. Vapor pressure is a relative measure of the volatility of chemicals in their pure state. The higher the vapor pressure the greater the volatility. Henry's Law is used to estimate equilibrium vapor pressures of dilute contaminants in water and how readily they will volatilize.

Kow provides a measure of the extent of chemical partitioning between water and octanol at equilibrium. The greater the Kow, the more likely a chemical is to partition to octanol than to remain in water. Octanol is used as a surrogate for lipids (fat); therefore, Kow is used to predict bioconcentration in aquatic organisms.

The bioconcentration factor (BCF) measures the extent of chemical partitioning at equilibrium between biological media (e.g., fish or plant tissue) and external environmental media (e.g., water). The higher the BCF, the greater the accumulation in living tissue is likely to be. The organic carbon partition coefficient (Koc) reflects the propensity of a compound to sorb to organic matter found in soil. Higher Koc values indicate greater sorption potential. Chemicals that have a strong tendency to sorb to organic matter will move more slowly between environmental compartments than chemicals with a low Koc.

The molecular weight of a chemical is the sum of the atomic weights of its constituent elements. This property helps determine dermal exposure routes. The media-specific half-lives provide a relative measure of chemical persistence in a given medium, although actual values can vary greatly depending on site-specific conditions. The greater the half-life, the more persistent the chemical. Half-life properties can be valuable in examining the long-term risks from chemicals at a site and developing remediation alternatives (RAIS/ORNL, 2014).

These chemical and physical properties are key to evaluating the fate and transport of some of the primary contaminants found over the years of investigation at the SVFUDS. The persistence of some of these contaminants is discussed in the next section.

6.4 Contaminant Persistence

The following environmental fate and transport discussions focus on the chemical and physical characteristics of chemicals potentially present at the SVFUDS.

6.4.1 <u>Arsenic</u>

Arsenic is a naturally occurring element widely distributed in the earth's crust. It occurs in soil and minerals and it may enter air, water and land through wind-blown dust and water run-off. Arsenic in the atmosphere comes from various sources, including volcanoes and microorganisms, but human activity (e.g., heating coal) is responsible for release through the burning of fossil fuels. In industry, arsenic is a byproduct of the smelting process (separation of metal from rock) for many metal ores. Due to human activities, mainly through mining, naturally immobile arsenics have also mobilized and can now be found in many more places than where they existed naturally (RAIS, 2014).

In the past, the United States primarily used arsenic in insecticides such as ant killers and animal dips. However, regulatory restrictions for arsenic, especially for home products, have reduced its use and the exposure to it. In the 19th Century, arsenic was used in paints and dyes for clothes, paper, and wallpaper. Arsenic compounds are used in making special types of glass, as a wood preservative and, more recently, in semiconductors. During the 18th, 19th, and 20th centuries, a number of arsenic compounds have been used as medicine.

Production of wood preservatives, primarily copper chromated arsenate (CCA), accounted for more than 90% of domestic consumption of arsenic trioxide in 2003. Wood treated with CCA is known as "pressure treated wood". In 2002, the USEPA reached an agreement with the manufacturers of wood preservative products containing CCA to cancel the registration of CCA for use in virtually all residential applications. However, wood treated prior to this date can still be used, and CCA-treated wood products continue to be used in industrial applications.

Organoarsenic compounds have been used as chemical weapons, especially during World War I. Lewisite (Section 6.4.5) is a primary example. It is a compound from the chemical family of arsines that has different health effects than arsenic compounds. Arsenic at the SVFUDS may have resulted from the use of Lewisite and other arsenicals used during the AUES operations.

Arsenic appears in three allotropic forms: yellow, black and grey; the stable form is a silver-gray, brittle crystalline solid. It tarnishes rapidly in air, and at high temperatures burns forming a white cloud of arsenic trioxide. Arsenic combines readily with many elements. In the environment, arsenic combines with oxygen, chlorine, and sulfur to form inorganic arsenic compounds. Arsenic in animals and plants combines with carbon and hydrogen to form organic arsenic compounds. Inorganic arsenic compounds are mainly used to preserve wood, while some organic arsenic compounds have been used as pesticides.

The most common forms of arsenic in groundwater are their oxy-anions, arsenite (As+3) and arsenate (As+5). Under moderately reducing conditions, arsenite is the predominant species. In oxygenated water, arsenate is the predominant species. Both anions are capable of adsorbing to various subsurface materials, such as ferric oxides and clay particles. Ferric oxides are particularly important to arsenate fate and transport as ferric oxides are abundant in the subsurface and arsenate strongly adsorbs to these surfaces in acidic to neutral waters. An increase in the pH to an alkaline condition will cause both arsenite and arsenate to desorb, and they can be expected to be very mobile in an alkaline environment. The arsenic oxy-anions are also sensitive to redox conditions, and the speciation differential between them will change with changing redox.

Elemental arsenic is extremely persistent in both water and soil. Environmental fate processes may transform one arsenic compound to another; however, arsenic itself is not degraded. Soluble forms of arsenic tend to be quite mobile in water, while less soluble species adsorb to clay or soil particles. Microorganisms in soils, sediments, and water can reduce and methylate arsenic to yield methyl arsines, which volatilize and enter the atmosphere. These forms then undergo oxidation to become methyl arsonic acids and are ultimately transformed back to inorganic arsenic. Fish and shellfish can accumulate arsenic, but the arsenic in fish is mostly in a form that is not harmful. Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and lower invertebrates. Biomagnification in aquatic food chains does not appear to be significant, although some fish and invertebrates contain high levels of arsenic compounds which are relatively inert toxicologically. Plants may accumulate arsenic, subject to various factors including soil arsenic concentration, plant type, and soil characteristics (ATSDR, 1991).

The toxicity of inorganic arsenic depends on its valence state and also on the physical and chemical properties of the compound in which it occurs. Water soluble inorganic arsenic compounds are absorbed through the gastrointestinal tract and lungs; distributed primarily to the liver, kidney, lung, spleen, aorta, and skin; and excreted mainly in the urine. Symptoms of acute inorganic arsenic poisoning in humans are nausea, anorexia, vomiting, epigastric and abdominal pain, and diarrhea.

While persistent in the soil, the pathway exists for future migration of arsenic from subsurface soil to the groundwater. The mobility of arsenic is limited because it strongly sorbs to soil particles and does not readily enter the groundwater. Within the SVFUDS, arsenic has been found in the groundwater at levels of concern at various times in different locations, including in wells located in close proximity and downgradient to 4801 Glenbrook Road and 4825 Glenbrook Road. However, the arsenic contaminated soil at 4801 Glenbrook Road has been removed, and is in the process of being removed at 4825 Glenbrook Road. In addition, significant volumes of soil containing elevated arsenic have been removed through NTCRAs and TCRAs throughout the SVFUDS, as described in detail in Section 5. For these reasons, arsenic migration to groundwater is not considered to be a continuing concern.

6.4.2 <u>Mustard</u>

The term "mustard" refers to several manufactured chemical agents, including sulfur mustard. They are not naturally occurring in the environment. Mustard agents are vesicants (blister agents) used in warfare to produce casualties, degrade fighting efficiency, and force opposing troops to wear full protective equipment. Sulfur mustard (bis(2-chloroethyl)sulfide) was the only blister agent in major use in WWI; it was the primary form used at the SVFUDS and the term mustard, as used in this RI, is intended to indicate sulfur mustard (USACE, 2013d).

Mustard is suitable for use in land mines, spray tanks, bombs, artillery shells, mortar shells, and rockets. Although often referred to as mustard “gas,” unless weaponized, it is actually an oily liquid. Mustard agents range from colorless (in pure state) to pale yellow to dark brown, depending on the type and purity. They have a faint odor of mustard, onion, garlic, or horseradish. The name was given to mustard agent as a result of an earlier production method which yielded an impure mustard-smelling product.

Mustard persists 1 to 2 days in average weather conditions and may persist up to a week or more in very cold conditions. If released to air, its vapor pressure indicates it will exist solely as a vapor in the atmosphere. Vapor-phase mustard will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be about 2 days. Direct photolysis, while possible, is not expected to be an important fate process (OPCW, 2014).

If released to soil, mustard is expected to have moderate mobility based upon its estimated Koc. It has been observed to bind through a reversible interaction with dry soil. It can be highly persistent under conditions of low temperature and moisture. It is expected to volatilize from moist soil surfaces but not from dry surfaces. Volatilization from moist soil surfaces is expected to be an important fate process based upon its Henry's Law constant.

If released into water, mustard is not expected to adsorb to suspended solids and sediment; rather, it is expected to volatilize from water surfaces. Because it has limited solubility in water, hydrolysis is limited by its slow rate of solution. During the dissolution process, the outer surfaces of mustard droplets form a stable polymerized hydrolysis product. Without agitation, this polymerized hydrolysis product creates a boundary layer that interferes with the dissolution of mustard in water. Polymerized mustard presents as a tar-like product that can be toxic as a dermal hazard, requiring skin contact. This can occur where the mustard was in a glass or metal container and buried in the soil. Without agitation, bulk mustard may persist in water for several years. Mustard's estimated BCF suggests the potential for bioconcentration in aquatic organisms is low. (Toxnet, 2014).

Mustard agent can easily be dissolved in most organic solvents but has poor solubility in water. In aqueous solutions, mustard agent decomposes into non-poisonous products by means of hydrolysis. This reaction is catalyzed by alkali. However, only dissolved mustard agent reacts, which means that the decomposition proceeds very slowly. Based on instability and volatility, as validated with modeling, blister agents are not anticipated to contaminate groundwater (USACHPPM, 1999). Therefore, groundwater sampling is not recommended for blister agents.

Mustard agent's ABPs are dithiane, oxithiane, and thiodiglycol, discussed below (Sections 6.4.3 and 6.4.4).

6.4.3 1,4-Dithiane and 1,4-Oxathiane

These two compounds are breakdown products (ABPs) of mustard. 1,4-dithiane is a thermal degradation product of mustard formed by dechlorination, and 1,4-oxathiane is formed by dehydrohalogenation of partially hydrolyzed mustard. Based on similar chemical structure, the behavior of these two compounds is expected to be similar to one another. Incomplete hydrolysis yields products of varying, but lower toxicity than the parent (mustard); both are considered to have low toxicity and are practically non-toxic to vegetation and aquatic organisms.

1,4-dithiane is an impurity and thermal decomposition product of mustard, but its production and use as an organic synthesis reagent may result in its release to the environment through various waste streams. If released to air, its vapor pressure indicates 1,4-dithiane will exist solely as a vapor in the ambient atmosphere. Vapor-phase 1,4-dithiane will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals; the half-life for this reaction in air is estimated to be 10 hours.

If released to soil, 1,4-dithiane is expected to have high mobility based upon its Koc value, and volatilization from moist soil surfaces is expected to be an important fate process based upon its estimated Henry's Law constant. 1,4-oxathiane is somewhat more volatile and more water soluble than 1,4-dithiane. The detection of these compounds in environmental samples long after the release of mustard agent (as documented in other sites) suggests it may persist in the environment.

Hydrolysis is not expected to be an important environmental fate process since this compound lacks functional groups that hydrolyze under environmental conditions. Occupational exposure to these compounds may occur through inhalation and dermal contact at workplaces where they were used.

6.4.4 Thiodiglycol

Thiodiglycol is a hydrolysis product of sulfur mustard and is considered a mustard ABP. However, thiodiglycol's production and use as an intermediate for elastomers and antioxidants, in the manufacture of ball-point pen ink and its use as a solvent for dyes in textile printing may also be a factor in its release to the environment through various waste streams.

If released to air, thiodiglycol will exist solely as a vapor in the atmosphere. Thiodiglycol is not susceptible to direct photolysis by sunlight, and if released to soil, is expected to have very high mobility. Volatilization from moist soil surfaces is not expected to be an important fate process based upon its Henry's Law constant, and it is not expected to volatilize from dry soil surfaces based upon its vapor pressure. Thiodiglycol would be expected to biodegrade slowly in the environment under aerobic and anaerobic conditions. If released into water, thiodiglycol is not expected to adsorb to suspended solids and sediment based upon the estimated Koc.

The potential for bioconcentration in aquatic organisms is low. Occupational exposure to thiodiglycol may occur through inhalation and dermal contact with this compound at workplaces where thiodiglycol is produced or used, or at sites where chemical weapons were used.

6.4.5 Lewisite

Lewisite (dichloro(2-chlorovinyl)arsine) is an organic arsenical compound. It is a vesicant (blister agent) developed, but never deployed, for use in warfare to produce casualties, degrade fighting efficiency, and force opposing troops to wear full protective equipment. Lewisite is suitable for use in land mines, spray tanks, bombs, artillery shells, mortar shells, and rockets. Lewisite's former use as a chemical agent can result in its direct release to the environment. It does not exist naturally in the environment.

It is slightly less persistent than mustard and does not persist under humid conditions due to its rapid rate of hydrolysis, which results in the formation of 2-Chlorovinyl arsenous acid (CVAA) and 2-Chlorovinyl arsenous oxide (CVAO). Lewisite, CVAA, and CVAO are all derivatized in the same reaction as part of the analytical procedure and, thus, the three compounds are reported together as Lewisite. CVAA is toxic but not mobile in the environment.

Lewisite also has a relatively low vapor pressure, and consequently, it will not migrate in the ambient air via volatilization. Because Lewisite is not readily volatile, has a relatively high Koc, and an extremely short half-life, the fate of the chemical is controlled by the transport of particulates and the presence of water in the atmosphere.

If released to air, Lewisite's vapor pressure indicates it will exist solely as a vapor in the atmosphere. Vapor-phase Lewisite will be degraded in the atmosphere by reaction with photochemically-produced hydroxyl radicals.

If released to soil, Lewisite is expected to have high mobility based upon its estimated Koc. Volatilization from moist soil surfaces is expected to be an important fate process based upon its estimated Henry's Law constant. While the Henry's Law constant for Lewisite indicates volatilization from moist soil surfaces, the rapid rate of hydrolysis may reduce the significance of this fate pathway. Lewisite is rapidly hydrolyzed by soil moisture, and minerals present in the soil would speed the process. Alkaline soils would neutralize Lewisite. No direct information has been found regarding Lewisite biodegradation in soil, however, suggested pathways of microbial degradation in soil include reductive dehalogenation and dehydrodehalogenation.

If released into water, Lewisite is not expected to adsorb to suspended solids and sediment based upon the estimated Koc. Its estimated BCF suggests the potential for bioconcentration in aquatic organisms is low. Based on instability and volatility, Lewisite is not anticipated to contaminate groundwater (USACHPPM, 1999), and therefore, groundwater sampling is not typically conducted for blister agents.

6.4.6 Perchlorate

Perchlorates are colorless salts that have no odor. There are five perchlorate salts that are manufactured in large amounts: magnesium perchlorate, potassium perchlorate, ammonium perchlorate, sodium perchlorate, and lithium perchlorate. Perchlorate salts are solids that dissolve easily in water (USEPA, 2014).

Perchlorate is both a naturally occurring and man-made chemical that is used mainly in explosives, fireworks, and rocket motors. Perchlorates are also used for making other chemicals. In the past, perchlorate was used as a medication to treat an over-reactive thyroid gland. Perchlorate occurs naturally in saltpeter deposits in Chile, where the saltpeter is used to make fertilizer. In the past, use of this fertilizer on tobacco plants in the United States occurred, but information regarding frequency of usage or quantities used is not readily available. However, very little of it is used now. The potential for groundwater contamination via agricultural runoff is an obvious concern, and USEPA and other agencies have been analyzing fertilizers to quantitatively determine perchlorate content. Perchlorate can also be present in bleach.

The health effects of perchlorate salts are due to the perchlorate itself and not to the other component (i.e., magnesium, ammonium, potassium, etc.). Perchlorate may have adverse health effects because scientific research indicates that this contaminant can disrupt the thyroid's ability to produce hormones needed for normal growth and development. The USEPA is continuing to evaluate the available science on perchlorate health effects and exposure, and is also evaluating laboratory methods for measuring and treatment technologies for removing perchlorate in drinking water (ATSDR, 2014).

In the literature, key aspects of perchlorate's environmental fate have been assessed based on the analysis of physical and chemical properties, available monitoring data, and known sources of release. In water, perchlorates are expected to readily dissolve and dissociate into their component ions. Given that perchlorates completely dissociate at environmentally significant concentrations, their cations are spectators in the environmental fate of perchlorates dissolved in water. Therefore, when in water, the cations do not substantially influence the fate of the perchlorate anion in the environment.

Since the perchlorate ion is only weakly adsorbed to mineral surfaces in solutions of moderate ionic strength, its movement through soil is not retarded. This indicates that perchlorate will travel rapidly over soil with surface water runoff or be transported through soil with infiltration. Therefore, if released to soil, perchlorates are expected to be highly mobile and travel to groundwater and surface water receptors. This is consistent with surface water and groundwater monitoring data that indicate that perchlorates can be found far from known sites of their release to soil. Within the SVFUDS, perchlorate has been found in the groundwater at levels of concern at various times in different locations, including the Sibley hospital area and at AU. However, there are no sources of perchlorate in the soil near or downgradient of the monitoring wells with elevated perchlorate concentrations, and therefore, perchlorate migration to groundwater is not considered to be a continuing concern. The stable isotope analysis of perchlorate at the SVFUDS suggests that there are significant differences in the isotopic signature of perchlorate found at Sibley compared to that found at AU.

Perchlorates are not expected to volatilize from soil to the atmosphere given their very low vapor pressure. Moreover, dissociated inorganic ions do not undergo volatilization. Perchlorates may be transported from soil to the atmosphere by wind-borne erosion. This convective process may release either aerosols or particulate matter to which dry perchlorate salts are adsorbed.

The water solubility of perchlorates indicates that they will not be removed from the water column by physical processes and become adsorbed to sediment and suspended organic matter. Since the perchlorate ion is only weakly adsorbed to mineral surfaces in solutions of moderate ionic strength, perchlorate is not expected to adsorb to sediment and organic matter. Since perchlorate does not serve as a ligand in aqueous solutions, it is not expected to undergo removal from water through the formation of insoluble metal complexes. In cases where high concentration perchlorate brines enter the subsurface, the movement of perchlorate is expected to be controlled by gravity and the topography of confining layers.

Limited data indicate that perchlorate may accumulate in living organisms, as it has been detected in vegetation, fish, amphibian, insect, and rodent samples collected near a site of known contamination. Bioconcentration of perchlorates in aquatic organisms is expected to be low. The FDA samples 500 foods annually for perchlorate. Published FDA of some 500 foods analyzed for perchlorate indicates that shrimp, milk and many salad greens can contain perchlorate, suggesting that bioaccumulation can occur. Perchlorate tends to move more rapidly in groundwater relative to some other contaminants and also downward through the soil column, reducing the potential for exposure, even through vegetable gardens.

6.4.7 Metals

A few metals (cobalt, mercury, and vanadium) were shown through the HHRA process (Sections 7.2 and 7.3) to be COCs in specific areas of the SVFUDS. The discussion below addresses basic fate and transport of metals as a group. Note that arsenic is also a metal, but is discussed separately in Section 6.4.1 above.

The fate and transport of metals is highly complex and is governed by several major reaction types, including dissolution-precipitation as a function of pH and redox environment and sorption-desorption reactions as a function of soil composition, extent of soil saturation, and soil organic content. Metals, in general, are immobile under the subsurface conditions at the SVFUDS. Approximately 90 percent of the SVFUDS is underlain by saprolitic (clay-rich) micaceous soils derived from underlying crystalline rocks, and slightly acidic to neutral soil pH and oxidizing conditions are expected for soils throughout the area. Movement of metals through soils is dependent on the chemical properties controlling speciation, the presence of ligands that control complexation of metals within pore water (and groundwater) and adsorption onto mineral surfaces, and the rate of water flux through the soil.

The potential for future migration of metals from subsurface soil to groundwater exists at the SVFUDS. While the removal of significant volumes of contaminated soil through NTCRAs and TCRAs, as described in detail in Section 5, minimizes the potential future migration of metals of concern to groundwater, the groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

Metals are lost from the soil by leaching into ground water. The potential for transport of metals in the subsurface is based upon the specific metal's affinity to soil and groundwater. Soil factors affecting transport dynamics include soil-water chemistry and charge deficiency on adsorbent surfaces, such as soil and sediment. Factors including geology, soil chemistry, pH, redox potential, ionic strength, dominant cations and ligands also enhance or diminish the mobility of a particular metal analyte. Generally, the solubility of metals tends to increase proportionate to increased acidity, and decrease under alkaline conditions. Metal sorption is affected primarily by physical and geochemical processes (i.e., oxidation, adsorption, precipitation and complexation). Generally, the sorption coefficient for a metal is indicative of the relative affinity of a metal to soil, and ultimately the mobility of the metal. Physical adsorption is due to surface charges which attract ionic species of the opposite charge. Chemical processes for adsorption include ion exchanges, precipitation, solid-state diffusion, and isomorphic substitution. Organic matter may also result in metals sorbing to soil and sediment making them insoluble in groundwater.

6.4.8 Polycyclic Aromatic Hydrocarbons

Polycyclic aromatic hydrocarbons (PAHs) are a group of chemicals that are formed during the incomplete burning of coal, oil, gas, wood, garbage, or other organic substances, such as tobacco and charbroiled meat. PAHs are found naturally in the environment but they can also be man-made. PAHs generally occur as complex mixtures (for example, as part of combustion products such as soot and car exhaust), not as single compounds. As pure chemicals, PAHs generally exist as colorless, white, or pale yellow-green solids. They can have a faint, pleasant odor. A few PAHs are used in medicines and to make dyes, plastics, and pesticides. Others are contained in asphalt used in road construction. They can also be found in substances such as crude oil, coal, coal tar pitch, creosote, and roofing tar. They are found throughout the environment in the air, water, and soil. They can occur in the air, either attached to dust particles or as solids in soil or sediment.

PAHs are a concern because they are persistent. Because they do not burn very easily, they can stay in the environment for long periods of time. PAHs enter the environment mostly as releases to air from volcanoes, forest fires, residential wood burning, and exhaust from automobiles and trucks. They can also enter surface water through discharges from industrial plants and waste water treatment plants, and they can be released to soils at hazardous waste sites if they escape from storage containers (ATSDR, 2014.)

Carcinogenic PAHs were shown through the HHRA process (Sections 7.3) to be a COC in specific areas of the SVFUDS.

The movement of PAHs in the environment depends on properties such as how easily they dissolve in water, and how easily they evaporate into the air. PAHs in general do not easily dissolve in water. They are present in air as vapors or stuck to the surfaces of small solid particles. They can travel long distances before they return to earth in rainfall or particle settling. Some PAHs evaporate into the atmosphere from surface waters, but most stick to solid particles and settle to the bottoms of rivers or lakes.

In soils, PAHs are most likely to stick tightly to particles. Some PAHs evaporate from surface soils to air. Certain PAHs in soils also contaminate underground water. The PAH content of plants and animals living on the land or in water can be many times higher than the content of PAHs in soil or water. PAHs can break down to longer-lasting products by reacting with sunlight and other chemicals in the air, generally over a period of days to weeks. Breakdown in soil and water generally takes weeks to months and is caused primarily by the actions of microorganisms.

PAHs have a high affinity for organic matter and low water solubility. Water solubility tends to decrease, and affinity for organic material tends to increase with increasing molecular weight. When present in soil or sediments, PAHs tend to remain bound to the soil particles and dissolve only slowly into groundwater or the overlying water column. Because of the high affinity for organic matter, the physical fate of these chemicals is usually controlled by the transport of particulates. Thus, soil, sediment, and suspended particulate matter (in air) represent important media for chemical transport. Furthermore, because of their high affinity for organic matter, PAHs are readily bioaccumulated by living organisms. There is a slight potential for future migration of PAHs from subsurface soil to groundwater, but PAHs at levels of concern have not been found in the groundwater. In addition, significant volumes of contaminated soil have been removed through NTCRAs and TCRAs throughout the SVFUDS, as described in detail in Section 5, and therefore, future migration of PAHs to groundwater is unlikely to be a continuing concern.

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7.0 RISK ASSESSMENT

7.1 Risk Assessment Overview

The objective of Section 7.0 is to integrate multiple risk-related issues on a site-wide basis as a critical step to a comprehensive understanding of risk remaining within the SVFUDS. A key part of this understanding is the completion of quantitative Human Health Risk Assessments (HHRAs) conducted on the residential and AU EUs, as described in the *SVFUDS Site-Wide Human Health Risk Assessment Work Plan* (USACE, 2014). These are presented as Sections 7.2 and 7.3, respectively.

However, in addition to these quantitative HHRAs, this section addresses other risk-related elements that contribute to understanding risk within the SVFUDS, including:

- Previously completed HHRAs;
- Arsenic within the SVFUDS: derivation and protectiveness of 20 mg/kg arsenic as the soil cleanup goal, and arsenic potentially remaining in soil beneath city streets;
- External health-related studies (prepared by others including Johns-Hopkins and the ATSDR);
- MEC Hazard Assessment (MEC HA);
- Groundwater Data;
- Screening Level Ecological Risk Assessment; and
- Uncertainty discussions focusing on the sufficiency of the existing sampling to characterize risk within the SVFUDS, DGM, and the potential for remaining disposal areas or burial pits.

Many of these efforts were completed as separate studies or investigations; they are discussed in the sections below.

7.1.1 <u>Summary of Completed HHRAs</u>

In addition to the HHRAs completed as part of the early site-wide investigation activities (as described in Section 1.6), several HHRAs have been completed on smaller, discrete areas as standalone documents. These are summarized below. Each of the reports summarized in Section 7.1.1 is presented in its entirety in Appendix D. The locations of the areas covered by the HHRAs are shown in Figure 7-1.

7.1.1.1 4835 Glenbrook Road

An HHRA for 4835 Glenbrook Road was conducted in 2002 to evaluate the risk associated with exposure to arsenic-contaminated soil at this property and completed in April 2002 (USACE, 2002). The HHRA concluded that the risk estimates did not exceed USEPA's target risk range and that no adverse health effects were expected for human receptors at the 4835 Glenbrook Road property. However, in the *Human Health Risk Assessment, 4835 Glenbrook Road, Revised Final*, (USACE, 2009d), those findings were re-evaluated using additional data that had been collected since the previous HHRA.

Test pit investigations and arsenic removal was performed subsequent to the 2002 HHRA. Suspected AUES-related labware components (i.e., glass tubing, stoppers, glass fragments, etc.) and a Livens projectile were encountered. Multiple arsenic contaminated soil grids were excavated. A total of 185 soil samples, representative of soil still in place at the site, were evaluated in this HHRA.

The 2009 HHRA was performed to estimate the potential risks/hazards to current and future receptors from site-related contamination in the soil. The type and magnitude of exposures to COPCs at the site were estimated, potential exposure pathways, receptors, and exposure scenarios were identified, and exposure was quantified. The HHRA concluded that cancer risks were in the acceptable range and non-carcinogenic health effects to the receptors were not expected from assumed exposures to COPCs in soils at the site. Overall, this indicated that the risks and hazards from assumed exposures to soils at 4835 Glenbrook Road were acceptable and that further action was not warranted.

7.1.1.2 American University Lot 18

The *Human Health Risk Assessment, American University Lot 18, Final*, (USACE, October, 2008g) documents the HHRA performed to estimate the potential risks to current and future receptors from site-related contamination in the soil at OU-4 AU Lot 18 within the SVFUDS. The type and magnitude of exposures to COPCs at the site were estimated, potential exposure pathways, receptors and exposure scenarios were identified, and exposure was quantified.

During intrusive investigations conducted by USACE, MD, AUES-related glassware including intact containers, and a disposal area were uncovered. One intact container held a 0.3% Lewisite solution. MD items were recovered including items related to Livens projectiles, 4.7-inch rounds, 75mm projectiles, 3-inch Stokes mortars, and bomb fragments. Approximately 4,018 tons of non-hazardous soil and 507 tons of hazardous soil were excavated during the AU Lot 18 operations. Pit characterization soil samples were collected (126) and evaluated in this HHRA.

The HHRA concluded that for all receptors, the carcinogenic risk was in USEPA's acceptable risk range, and non-carcinogenic health effects to the receptors were not expected.

7.1.1.3 American University Public Safety Building

The *Human Health Risk Assessment, American University Public Safety Building, Final*, (USACE, 2013c) documents the HHRA performed to estimate the potential risks/hazards to current and future receptors from site-related contamination at the AU Public Safety Building within the SVFUDS. The type and magnitude of exposures to COPCs at the site were estimated, potential exposure pathways, receptors, and exposure scenarios were identified, and potential exposure was quantified. The PSB is an occupied building used for administration functions on the AU campus. It is adjacent to the intrusive operations conducted by USACE at the OU-4 AU Lot 18 disposal area, described in Section 7.1.1.2.

Sixty-six samples of currently in-place soil were used to perform the quantitative HHRA; no data from soils that have been excavated (i.e., removed from the site) were used. The PSB site was divided into two exposure units, the PSB area, and a small area known as the Silver Substance area. Soil excavations have occurred in both exposure units, and the excavation areas have been backfilled with clean soil.

The HHRA concluded that the estimated current and future risks associated with soil exposures at the PSB and Silver Substance areas were below levels of concern, and that no further action was recommended for these areas.

7.1.1.4 4825 Glenbrook Road

The *Human Health Risk Assessment, 4825 Glenbrook Road, Final*, (USACE, July, 2011g), documents the HHRA performed to estimate the potential risks/hazards to current and future receptors from site-related contamination in the soil at the 4825 Glenbrook Road property, within the SVFUDS. The type and magnitude of exposures to COPCs at the site were estimated, potential exposure pathways, receptors, and exposure scenarios were identified, and potential exposure was quantified.

During intrusive investigations conducted by USACE, 25 full or partial soil grids contaminated with arsenic were excavated at 4825 Glenbrook Road. A total of 115 soil samples, representative of soil still in place at the site, were evaluated in this HHRA.

The HHRA concluded that the cumulative cancer risk estimates for adult and child residents, child recreational green space users, and outdoor workers exposed to surface soil (i.e., 0-0.5 ft or 0-2 ft bgs), and for outdoor workers exposed to mixed soil (0-12 ft bgs) were within the USEPA acceptable risk range. Thus, unacceptable cancer risks to the receptors at the site were not expected from assumed exposures to COPCs in soils. However, the cumulative cancer risk estimate for residents exposed to arsenic in mixed soil, as both a child and an adult, (i.e., 30 years) exceeded the USEPA acceptable level.

The HHRA concluded that the hazard indices (HI) estimated for adult and child residents, and child recreational green space users, exposed to surface soil, and for outdoor workers exposed to both surface soil (0-2 ft bgs) or mixed soil (0-12 ft bgs) were below the benchmark of 1 under both the reasonable maximum exposure (RME) and central tendency (CT) exposure scenarios. Thus, unacceptable hazards to these receptors at the site were not expected from assumed exposures to COPCs in soils. However, the HI for residents exposed to mixed soil (0-12 ft) at the site exceeded the benchmark of 1 under the RME exposure scenario due to assumed exposures to arsenic.

The only chemical of concern (COC) identified was arsenic based on samples from soil remaining at the site. With regard to arsenic, the HHRA concluded that the exposure point concentration for arsenic in soil would be less than the SVFUDS site-specific arsenic background level of 12.6 mg/kg by removing the three highest elevated arsenic concentrations (this removal has since been completed).

7.1.2 <u>Risk Screening Documents</u>

This section discusses the analysis that resulted in the decision to conduct quantitative HHRAs for specific areas of the SVFUDS. The quantitative HHRAs that were conducted based on the risk screening documents are presented as Sections 7.2 and 7.3 of this RI.

As previously described, significant investigation, sampling, and remediation has been performed at the SVFUDS over the course of many years of ongoing project activity. The discrete HHRAs of individual areas (described in Section 7.1.1) and a Site-Wide SLERA, prepared by multiple contractors over a range of time periods, have been completed. In addition, a Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

However, there was still a need to develop a strategy to organize and assess this existing information, to evaluate the need for additional data, and to integrate this information into a cohesive plan. Therefore, USACE convened a meeting of key SVFUDS stakeholders in 2010 and presented a Position Paper that outlined a path forward for resolving these issues. The stakeholders included personnel from the USEPA, the DDOE, the RAB consultant, and AU. The overall goal was to integrate the previous and ongoing risk assessment studies and findings into a comprehensive site-wide risk assessment that would address all elements of human health and ecological risk, and which would be presented as part of this Site-Wide RI report.

The participants determined that the primary actions required included review of the previous (pre-2005) HHRAs to assess whether they remain protective, and additional soil sampling to address data gaps. To achieve the overall goal, three separate efforts were conducted, each one building off the findings of the previous one. These efforts focused on identifying specific areas where further risk assessment was warranted, concluding with the identification of the EUs requiring full quantitative HHRAs.

The first effort was the completion of the *Final Evaluation Document for the Spring Valley FUDS Integrated Site-Wide Remedial Investigation/Feasibility Study, Washington, DC* (USACE, 2012c). This was essentially a work plan presenting the methodology to review pre-2005 HHRAs to determine whether the COPCs identified, the exposure pathways considered, and the toxicity evaluations, would still be appropriate when considering updated USEPA guidance and site-specific background concentrations, and to identify remaining areas that require additional risk screening and risk assessment.

7.1.2.1 Pre-2005 HHRA Review

The second effort was the completion of the *Final Pre-2005 Human Health Risk Assessment (HHRA) Review* (USACE, 2013e). It provided the results of the review of five pre-2005 HHRAs where re-screening of all soil data from SVFUDS was done using updated risk-based screening levels and background data, to ensure that any potential risks associated with soils still in place were evaluated. The review was based on the historical information, analytical data, and conclusions presented in five pre-2005 discrete HHRAs. These included:

1. *Remedial Investigation Report for the Operation Safe Removal - Formerly Used Defense Site, Washington, D.C.* (USACE, 1995b)
2. *Final Remedial Investigation Report for Spaulding and Captain Rankin Areas, Volumes I and II.* Parsons (USACE, 1996)
3. *USEPA Region III Draft Risk Assessment Report, Army Munitions Site, Spring Valley. October, 1999* (USEPA, 1999)
4. *USEPA Region III American University Property, Spring Valley Operable Unit (OU) 3 HHRA. August 2000* (USEPA, 2000b)
5. *Revised Final Engineering Evaluation/Cost Analysis (EE/CA) - 4801, 4825, and 4835 Glenbrook Road, Spring Valley OU 3, Washington, DC* (USACE, 2000c)

The review showed that for some of the five previously conducted HHRAs, COPCs still remained in various POIs or areas of investigation through the initial and additional screening steps performed for the review. Recommendations to address the remaining COPCs focused on identifying larger EUs, integrating the pre-2005 HHRA sample data with more recent samples collected (i.e., pooling all data), and then conducting risk evaluations on a single data set for each larger EU. The POIs or areas of investigation with remaining COPCs were developed into five larger EUs based on similar past practices, similar receptor populations and exposure pathways, and geography, so that an area could be assessed based on all data available, without regard as to when the data were collected. Figure 7-2 shows the five EUs still containing COPCs, for which further risk assessment was recommended in the document.

7.1.2.2 Addendum to the Pre-2005 HHRA Review

The third effort was the completion of *Addendum 1 to the Final Pre-2005 Human Health Risk Assessment Review* (USACE, December 2013f). This document presents the results of the completion of the recommended activities identified in the Pre-2005 HHRA Review report. Starting with the five EUs and COPCs identified in the Pre-2005 HHRA Review document, and using the screening procedure developed for that review, Addendum 1 presented a follow-on screening effort of the larger EUs that incorporated additional, more recent sampling. That is, while the Pre-2005 HHRA Review only used the older data associated with those HHRAs, Addendum 1 integrated all sampling completed after the data sets used in the older HHRAs. The objective was to integrate all remaining sampling results in the SVFUDS and identify specific remaining areas that require additional human health risk assessment.

The follow-on screen determined that for three of the five larger EUs, COPCs remained that may present a risk. Based on the COPCs identified and the risks calculated, that is, hazard quotients that exceeded one, and, for some chemicals, estimated incremental cancer risks greater than the USEPA acceptable range, quantitative HHRAs were recommended for:

- The AOI 9 EU;
- The Spaulding-Rankin EU; and
- The Southern AU EU.

These EUs are shown in Figure 7-3. For all other EUs, no quantitative HHRAs were recommended. The HHRAs completed for these three EUs are presented in Sections 7.2 and 7.3 below.

Each of the three reports summarized in Section 7.1.2, including the details of the individual steps conducted to complete the analyses, is presented in its entirety in Appendix D.

7.2 Quantitative HHRA – Residential Exposure Units

7.2.1 Overview

This section presents the quantitative HHRA for the residential EUs, AOI 9 and Spaulding-Rankin, as defined in the previous sections.

7.2.1.1 Objectives and Scope

The objectives of the HHRA for the two residential EUs are to ensure that all potential human health risks that may remain at these locations are evaluated by conducting a site-specific quantitative risk assessment. For the receptors present at the residential EUs, the HHRA estimates the magnitude of exposure to COPCs, identifies potential exposure pathways, and quantifies exposures. This information, in conjunction with toxicity information for the COPCs, is used to quantitatively estimate the risks posed to human receptors associated with exposure to the COPCs in soil at each residential site. This HHRA was conducted in accordance with the Final SVFUDS Site-Wide Human Health Risk Assessment Work Plan (USACE, 2014). This

HHRA does not address explosive hazards that may exist due to the presence of munitions; those hazards are addressed separately in the MEC Hazard Assessment (Section 7.6). USEPA Risk Assessment Guidance for Superfund (RAGS) Part D (USEPA, 2001) table formats were used in the HHRA text and appendices when applicable.

7.2.1.2 Summary of Data Used in the Risk Assessment

As described in more detail in *Addendum 1 to the Final Pre-2005 Human Health Risk Assessment Review* (USACE, 2013f), three sets of sample data were used in the follow-on screen. The first data set comprised all of the samples used in the pre-2005 risk assessments, i.e., all the data points used in the Pre-2005 HHRA Review document. The second data set comprised samples from miscellaneous sampling efforts conducted during anomaly investigations, or other samples collected for various reasons, which were not captured in any prior risk assessments. These included samples with collection dates from as early as 2001 to as late as 2011. The third data set comprised samples resulting from the Evaluation Document (USACE, 2012c) recommendations. The sampling was based on possible historical AUES impacts not addressed in ongoing investigations, or possible data gaps. This relatively recent sampling was primarily completed in 2012. Data from soil that has been removed were not used in the risk assessment.

As described in the Work Plan, the analytical data were evaluated based on USEPA protocols to determine an appropriate set of data for use in performing a quantitative HHRA. These data were generated during various investigation activities as previously described and additional details concerning data quality can be found in reports specific to those investigations.

Occurrence and distribution of COPCs tables for each EU are included in Appendix E-1.

7.2.1.3 COPC Selection Process

Section 7.1.2 describes the COPC screen that was also used for this HHRA. To summarize: the initial screen of all detected chemicals in soil was conducted using current criteria, comparing the maximum detected value of each constituent against current risk-based screening levels and current background concentrations. Analytes were eliminated as COPCs if the maximum detected concentration was less than the greater of the background value or the risk-based screening level (RSL). The two steps used to select COPCs were:

- The maximum detected concentration of a chemical in soil was compared to the USEPA residential soil RSL that is protective to a risk level of 1 in 1,000,000, or 1 x 10^{-6} (for carcinogens) or a hazard quotient (HQ) level of 0.1 (to account for cumulative effects for non-carcinogens). The generic residential soil RSLs are based on potential exposures via the dermal, ingestion, and inhalation routes, and reflect current toxicity values from sources used in the USEPA's toxicity hierarchy.
- Additionally, the maximum detected concentration was compared to the current 2008 SVFUDS soil background data (USACE, 2008h). In general, COPCs may be eliminated from quantitative evaluation in the HHRA if the maximum detected concentration is less than the background concentration. Comparison to background to determine which COPCs are elevated over background is consistent with USEPA (1989, 1992, 2002a) guidance.

The COPCs are typically derived during the actual HHRA. However, because all EU data have already been screened in the Addendum 1 document (USACE, 2013f), the previously selected

COPCs are included as COPCs for these EUs. Appendix E-2 presents tables that show a screen of all available data for each EU, screened to the provisional COPC stage (as defined in the Addendum 1 document). That is, all provisional COPCs derived in Addendum 1 for the residential EUs are COPCs for this quantitative HHRA. These COPCs are also shown in Table 7-1.

7.2.1.4 Additional Screen for Outlier Locations

As part of the additional screen in Addendum 1 (USACE, 2013f), detected concentrations using the combined data sets were reviewed to ensure that the identified EUs were not so large that they diluted higher concentrations of a chemical over the larger area. This screening process evaluated whether maximum concentrations of each chemical were more than 10 times higher than the average of the remaining concentrations of that chemical (i.e., identified whether the maximum was an outlier). Where an outlier was determined, that sample location was removed from the data set and the EU was separately evaluated in this HHRA using the remaining samples.

There were no outliers at the AOI 9 residential EU.

For the Spaulding-Rankin EU, as an individual residential property, it had not originally undergone the outlier analysis process in the Addendum 1 document. However, subsequent discussions with the USEPA resulted in USACE applying the process to the Spaulding-Rankin EU. Using the ’10 times’ screening process, seven metals from five locations were identified as potential outliers (see Appendix E Table E-7.2O), and one metal, cobalt underwent more formal outlier testing using USEPA’s ProUCL software (version 5.0.00, USEPA, 2013b, c) (see Appendix E-3).

These eight metals in the Spaulding-Rankin EU that could qualify as potential outliers were evaluated separately in the HHRA, using the maximum detected concentrations, that is, from the individual sample containing the maximum concentration (see Section 7.2.4 and Appendix E tables E-7.2H through N).

Referenced tables are presented at the end of Section 7.2.

7.2.2 <u>Exposure Assessment</u>

The objectives of the exposure assessment are to characterize the exposure setting, identify potentially exposed populations and potential exposure pathways, and quantify the exposures to potential human receptors at the site. The potentially exposed populations, exposure media, and exposure pathways are presented in the CSM.

7.2.2.1 Conceptual Site Model

A CSM for the EUs illustrating the potential human receptors and the associated pathways of exposure to the affected media, both current and future, was developed following USEPA (1989, 1996a) guidance, and is shown in the bottom half of Figure 7-4. The CSM provides an overall assessment of the primary and secondary sources of contamination at a site and the corresponding release mechanisms and impacted media. The CSM present assumptions regarding:

- Suspected sources and types of contaminants present,
- Contaminant release and transport mechanisms,
- Affected media,
- Potential receptors that could contact site-related contaminants in affected media under current or future land use scenarios, and
- Potential routes of exposure.

An exposure pathway is not considered to be complete unless all five of the elements listed above are present.

The AOI 9 EU comprises neighborhood residential properties. The Spaulding-Rankin area EU is a large single residential property.

7.2.2.1.1 Suspected Sources and Types of Contaminants

Based on the historical use of the site, buried wastes and testing associated with the AUES research and development of CWM are potential sources of contamination. Historical sampling of the SVFUDS has included analyses for many analytical parameters including metals, organics, CWM, and CWM breakdown products. Section 1.6 contains more detailed summaries of the past activities that could contribute to contamination in the SVFUDS.

7.2.2.1.2 Contaminant Release and Transport Mechanisms

Release of contaminants from past practices would be directly to surface or subsurface soil. Excavation activities (e.g., tree planting or construction) could transport contaminants to the surface through mixing of the soil column associated with digging. Leaching of soil contaminants to groundwater is also a potential transport mechanism. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

7.2.2.1.3 Affected Media

Previous investigations at the SVFUDs have shown that past activities have impacted surface and subsurface soil. There are no surface water and sediment locations at the EUs.

7.2.2.2 Potential Receptors

Potential human receptors are defined as individuals who may be exposed to site-related contaminants in environmental media. Consistent with USEPA (1989) guidance, current and reasonably anticipated future land uses were considered in the receptor selection process.

7.2.2.2.1 Residential EUs

The AOI 9 EU comprises multiple residential properties and defines an area with common receptors and exposure pathways. The EU contains POI 1, the circular trenches where static testing of CWM munitions was conducted, and POI 7, where agent persistency testing was reportedly conducted. There are a number of ground scars in the vicinity of POI 1 that became POIs 2, 3, 4, 5, 6, and 8. Portions of AOI 9 fall within the downrange impact areas of the Range Fan.

The Spaulding-Rankin EU is defined by previous areas of investigation (as described in more detail in the Addendum 1 report). It is limited to a single residential property previously known as the Spaulding-Rankin area, where the Range Fan firing point and concrete shell pits were located. The EU includes POIs 21, 22, 23, and 25 (POI 25 location as identified and as sampled for the 1995 RI). This property was maintained as a discrete EU based on the differences in past activities that occurred within this EU versus the other nearby residential properties.

The future use of these two residential EUs is not expected to change.

Current potential exposures to surface soil were evaluated for:

- Outdoor workers (i.e., landscapers); and
- Adult and child residents.

Future exposures to mixed surface/subsurface soil were evaluated for:

- Outdoor workers (i.e., landscapers);
- Construction workers; and
- Adult and child residents.

7.2.2.3 Potential Exposure Pathways

USEPA (1989) defines an exposure pathway as: "The course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point, and an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of inter-media transfer) is also included." The CSM links the sources, locations, and types of environmental releases with receptor locations and activity patterns to determine exposure pathways of potential concern.

Two different soil exposure intervals are evaluated. The current potential residential receptors were evaluated using an exposure interval of 0 to 2 feet bgs, to represent routine landscaping, gardening, and outdoor play activities. The soil exposure interval for future potential receptors includes mixed soils from 0 to 10 feet bgs, which includes the 0 to 2 foot interval to which current receptors could be exposed. This exposure interval takes into account soil mixing that may occur due to construction.

For these EUs, the potential soil exposure pathways, both currently to surface soil and in the future to mixed surface/subsurface soil, include the exposure pathways of incidental soil ingestion, dermal contact, and inhalation outdoors for all receptors, with the addition of inhalation of vapors indoors if the criteria for volatility are met, and home-produced vegetable ingestion for residents.

For both current and future scenarios, the inhalation of dust indoors is discussed qualitatively, based on published studies of transfer factors for outdoor-to-indoor transfer of dust.

7.2.2.4 Exposure Assumptions

USEPA (1992, 1995) typically requires two types of exposure evaluations: a Reasonable Maximum Exposure (RME) and an average, or Central Tendency Evaluation (CTE). The RME scenario is defined as the maximum exposure that is reasonably expected to occur (USEPA, 1989). The RME is an "upper bound" estimate of risk, which, for most of the potentially exposed populations at a site, overestimates exposures and risks. For the RME exposure scenario, exposure parameters are chosen so that the combination of variables for a given pathway would result in an estimate of the RME for that pathway (USEPA 1992, 1995). Under this approach, some variables may not be at their individual maximum values, but when combined with other variables, they will result in estimates of the RME. The CTE scenario is defined as the average exposure that could occur for receptors at a site. CTE risk estimates are calculated using central tendency, or average, estimates for each of the exposure parameters (USEPA, 1992, 1995).

Default and site-specific exposure assumptions are both used, as appropriate, in the HHRA, and are presented in this section in order to quantify exposures. The CTE and RME exposure parameters for each potentially exposed population and exposure pathway are outlined in Tables 7-2 through 7-5, and are presented in the following subsections.

7.2.2.4.1 Parameters Applicable to All Exposure Pathways

Exposure Frequency

Exposure frequency is based on expected activities for each of the receptors at the site. USEPA standard default values based on national data on the distribution of exposure frequencies is used.

For the outdoor worker, a high-end exposure frequency of 225 days/year is used for the RME scenario, representing a worker that is present on site almost every working day during the year (USEPA, 2014). The estimated CTE outdoor worker exposure frequency is one-half a year, or 125 days/year, in order to account for time likely spent landscaping at other locations, and to account for lower work levels in the winter months.

For the construction worker, exposure frequencies of 225 days/year for the RME and 125 days/year for the CTE scenarios are also used.

The standard high-end default residential exposure frequency of 350 days/year recommended by USEPA (1991a, 2011) is used for residents and students for the RME scenario. This value is based on the assumption that residents and students might be exposed to contaminants on a daily basis, except during a two-week period when they are away from the home or school (e.g., on vacation). For the CTE scenario, an exposure frequency of 160 days/year is assumed, based on eight months per year (March through October) for 5 days/week.

Exposure Duration

For workers, the outdoor worker exposure durations are 25 years for the RME scenario (USEPA, 2014) and 8 years for the CTE scenario (median value presented in USEPA, 2011). For the future construction worker, an exposure duration of 1 year is assumed to be the time period of construction for the RME scenario and one-half year is assumed for the CTE scenario.

National statistics are available for residential occupancy periods based on U.S. Bureau of Census data, as summarized by USEPA (2011). The USEPA-recommended residential exposure durations of 20 years for RME (USEPA, 2014) and 12 years for CTE is used (USEPA, 2011). Although there are no statistical data available on childhood residential occupancy periods, it is assumed that a child (0-6 years old) would reside for six years at a single residence.

Averaging Time

The averaging time selected depends on the type of toxic effect being assessed (USEPA, 1989). For non-carcinogens, exposure is averaged over the period of exposure (i.e., the exposure duration). For carcinogens, exposure is averaged over an individual’s lifetime; although current data suggest that 75 years would be an appropriate value to reflect the average life expectancy of the general population, an averaging time of 70 years is used to be consistent with the use of 70 years in the derivation of USEPA cancer slope factors and unit risks.

Body Weight
The USEPA (2011) reports an average body weight for all adults (males and females between the ages of 18 and 75 years) of 80 kilograms (kg) (USEPA, 2014). This body weight is used for all adult exposure scenarios.

An average body weight of 15 kg is used for children. The average body weight for children ages 1 year to 6 years (USEPA, 2008a) is 14.6 kg, which is rounded to 15 kg.

7.2.2.4.2 Dermal Exposure Pathway

Skin Surface Area
The surface area (SA) parameter describes the amount of skin exposed to the contaminated media. The amount of skin exposed depends upon the exposure scenario. Clothing is expected to limit the extent of the exposed SA in cases of soil contact. Body-part-specific SAs are those listed by USEPA (2014) for adults and children (Tables 7-2 through 7-5).

Soil Adherence Factors
The soil adherence factors are the recommended soil adherence factors for given receptors and activities (USEPA, 2014) (Tables 7-2 through 7-5).

Dermal Absorption Factors
USEPA RAGs Part E (USEPA, 2004) recommends limited dermal absorption factors (in their Exhibit 3-4), based on a literature review and states that chemicals for which data on dermal absorption are limited or do not exist should be qualitatively evaluated. According to USEPA, 2004, although it is known that inorganics have relatively low dermal absorption, there are limited data for the dermal absorption of inorganic compounds from soil. Therefore, hazard indices and cancer risks via the dermal exposure pathway are not calculated for some of the selected inorganic COPCs. Of the selected COPCs, dermal absorption factors are available for arsenic (0.03), cadmium (0.001), and PAHs (0.13).

7.2.2.4.3 Incidental Soil Ingestion Pathway

Incidental Soil Ingestion Rate
Incidental soil ingestion rates are receptor-specific. The recommended incidental soil ingestion rates from the USEPA’s Exposure Factors Handbook (USEPA, 2011) are a CTE of 50 milligrams per day (mg/day) for an adult, while the recommended adult soil ingestion RME value is 100 mg/day (USEPA, 2014). The recommended soil ingestion rates (which are combined soil + dust) for children are 100 mg/day for CTE and 200 mg/day for RME (USEPA, 2011).

For the outdoor worker, the recommended resident adult RME incidental soil ingestion rate of 100 mg/day for RME (USEPA, 2014) is used, and for CTE, one-half of that value, 50 mg/day, is assumed. For the construction worker, the recommended RME incidental soil ingestion rate of 330 mg/day (USEPA, 2002a) is used for the RME and 50 mg/day (assumed to be the same as outdoor workers) for CTE is used.

Fraction of Soil Ingested from Site

The fraction of soil incidentally ingested from the site is dependent on the medium and exposure pathway being evaluated. A value of 1 (100%) for the fraction ingested from the site is used for the RME outdoor worker and construction worker scenarios, while a CTE value of 20% is used for these two scenarios. For residential receptors and students, a value of 1 (100%) for the fraction ingested from the site is used for both RME and CTE scenarios. This approach conservatively assumes that 100% of a receptor's daily exposure to the specified medium via a particular exposure pathway (e.g., soil ingestion) occurs on the site.

7.2.2.4.4 Home-Produced Vegetable Ingestion Pathway

Plant Uptake Factors

The estimation of concentrations of COPCs in plants in this HHRA is based on the application of uptake equations or plant uptake values (USEPA, 2005a) to chemical concentrations in the soil. For COPCs not listed in USEPA 2005a, plant uptake values from RAIS/ORNL (2014), based on Baes et al. (1984), are used. This approach does not take into account that different soil types, plant species, and plant parts (e.g., roots, leaves, fruits) modify the uptake of chemicals from soil to plants, as discussed further in the uncertainty section.

The plant uptake equations for each COPC are listed in Table 7-6.

Oral Absorption Factors

Oral absorption factors are applied to the vegetable ingestion pathway, and are taken from the USEPA RSL table (USEPA, 2013a) (Table 7-6).

Home-Produced Vegetable Ingestion Rates

The vegetable ingestion rate for resident adults is based on USEPA (2011) recommendations for total vegetable intake of home-produced vegetables for the gardening population. The values provided by USEPA in their Table 13-70 (2011) are adjusted for cooking loss, therefore a cooking loss factor is not needed in the vegetable intake equation.

For adults, for the CTE scenario, the intake of home-produced vegetables is assumed to be the average of the 50^{th} percentile values for the appropriate population age groups (ages 6 to 70 years) provided by USEPA (2011). This CTE value is 0.0006 kg of vegetable intake/kg body weight/day (kg/kg-day). For the RME scenario, the home-produced vegetable ingestion rate is assumed to be the average of the 95^{th} percentile values for age groups from 6 to 70 years. This RME value is 0.0032 kg/kg-day. For resident children the USEPA recommendations for the appropriate population age groups (from ages 1 to 6) are averaged, resulting in a CTE home-grown vegetable ingestion rate of 0.0011 kg/kg-day and an RME rate of 0.0065 kg/kg-day. This HHRA assumes for both the RME and the CTE scenarios a fraction ingested of 25% for home-grown vegetable consumption.

Based on USEPA's analysis of the 1987-1988 US Department of Agriculture (USDA) Nationwide Food Consumption Survey, only 11.86% of the population in the northeast U.S. consume home-produced vegetables. Therefore, the approach used in the HHRA is conservative, in that any risks that are estimated for this pathway apply only to a limited number of receptors.

Dry Weight and Cooking Loss Corrections

Since vegetable intake rates are provided by USEPA in terms of wet weight, the intake rates must be converted to dry weight, as the soil and vegetable EPCs are in terms of dry weight. This is accomplished by multiplying the vegetable ingestion rate by the average dry weight percentage of vegetables (15.57%, as derived in Appendix E of the 4825 HHRA from the average moisture content of vegetables listed in USEPA 1997).

7.2.2.4.5 Inhalation Pathway

Inhalation Rates
The inhalation chronic toxicity factors derived by USEPA are inhalation unit risks (IURs), which are expressed as air concentrations, in order to be comparable to inhalation reference concentrations (RfCs). USEPA (1996a) recommends direct comparison of measured or modeled air concentrations to inhalation toxicity factors rather than using daily inhalation rates to convert to internal doses (i.e., mg/kg-day). Given that USEPA uses dosimetric adjustments (e.g., ventilation rate) based on adult ventilatory parameters in the derivation of select RfCs, a degree of uncertainty is introduced when applying these values to child receptors. However, as stated by USEPA (2009), "An inhalation reference concentration (RfC) is defined as an estimate (with uncertainty spanning perhaps an order of magnitude) of a continuous inhalation exposure to the human population (including sensitive subgroups) that is likely to be without appreciable risk of deleterious non-cancer health effects during a lifetime." Therefore, direct comparison of measured or modeled air concentrations to inhalation toxicity factors, without converting to internal doses, is appropriate.

Time Spent Outdoors for Inhalation Pathway
Chronic inhalation toxicity factors developed by USEPA assume continuous (i.e., daily, 24-hour exposure) long-term exposure. Therefore, it is necessary to adjust for the fraction of time breathing contaminated air for daily exposures less than 24 hours. It is assumed that 8 hours per day are spent outdoors.

7.2.2.5 Estimation of Intake

Human intakes over a long-term period of exposure, called chronic daily intakes (CDIs), are calculated for each COPC identified. Intake is defined as "a measure of exposure expressed as the mass of a substance in contact with the exchange boundary per unit body weight per unit time (e.g., mg chemical/kg body weight-day)" (USEPA, 1991a). Calculation of the CDI also takes into account exposure variables (assumptions about patterns of exposure to contaminated media), and whether the chemical is a carcinogen or a non-carcinogen. The total exposure is divided by the time period of interest to obtain an average exposure over time. The averaging time is a function of the toxic endpoint: for carcinogenic effects it is the lifetime of an individual; for non-carcinogenic effects is the exposure duration.

7.2.2.5.1 Exposure Point Concentrations

EPCs are the concentrations of constituents in a given medium to which human receptors are exposed at the point of contact (e.g., exposure to soil during gardening). EPCs are used to calculate the constituent intakes for human receptors based on methodology provided in RAGS (USEPA, 1989).

The 95% UCL of the mean (95% UCL) of each COPC can be used to estimate the concentration of a contaminant that a receptor would be exposed to over a length of time. For selected COPCs, the 95% UCL concentration is calculated using the latest version of USEPA's ProUCL software (version 5.0.00, USEPA, 2013b, c), and using the method recommended by the software. For the

CTE scenario, the mean from the method used to calculate the recommended UCL is used as the EPC. For data sets with non-detects, ProUCL uses the Kaplan-Meier method to account for non-detects in the calculation of UCLs (USEPA 2013b; 2013c).

For sample sets with few detects (either <4-6 detected samples, or <4%-5% detects) or a small sample size (<5 samples), the maximum detected concentration is used as the EPC for the RME scenario and the mean of the detected concentrations (using ½ the detection limit for non-detects) is used as the EPC for the CTE scenario.

The EPCs for RME and CTE scenarios calculated using ProUCL are shown in the risk tables in Appendix E-7 and in the ProUCL output contained in Appendix E-3.

Outdoor Air Exposure Concentrations - Particulates from Soil

USEPA (1996a and 2002a) guidance does not recommend estimating intakes (i.e., mg/kg-day) for the air inhalation pathway. Rather, risks and hazards are determined by comparing estimated particulate air concentrations, adjusted for exposure frequencies/durations/time, with inhalation toxicity values. This subsection describes methods to be used for estimating concentrations of COPCs entrained in airborne dusts.

Per USEPA (1996a and 2002), EPCs for COPCs in airborne fugitive dust are based on soil EPCs and are estimated using the following equation:

$$C_{air} = \frac{C_{soil}}{PEF}$$

Where:
C_{air} = COPC concentration in air at the exposure point (mg/m^3)
C_{soil} = COPC exposure-point concentration soil (mg/kg)
PEF = Particulate emission factor (m^3/kg)

The particulate emission factor (PEF) is a factor that relates the concentration of the COPC in surface soil to the concentration of dust particles in air (USEPA, 1996a). Per USEPA (1996a), the PEF represents an annual emission rate based on wind erosion and should be used only for estimating chronic exposures. This calculation addresses dust generated from open sources, which is termed “fugitive” because it is not discharged into the atmosphere in a confined flow. PEF calculations include a Q/C specific to the site’s size and meteorological conditions. The PEF calculation is based on default values from USEPA 1996a and 2002a, as shown below:

$$PEF = (Q/C)\left(\frac{3600 s/h}{(0.36)(1-V)\left(\frac{U_m}{U_t}\right)^3 (F(x))}\right)$$

Where:
PEF = particulate emission factor (m^3/kg)
Q/C = 87.37 g/m^2-s per kg/m^3, based on 0.5 acre source for Zone VIII Philadelphia (PA), from Table 3 of USEPA, 1996a
s/h = seconds per hour

V = 0.5, fraction of vegetative cover (USEPA, 1996a and 2002b)
U_m = 4.29 meter per second (m/s), mean annual wind speed in Philadelphia (PA) (USEPA, 1996a)
U_t = 11.32 m/s, equivalent threshold value of wind speed at 7 m (USEPA, 1996a)
F(x) = 0.0993, wind speed distribution function for Philadelphia (PA) (USEPA, 1996a)

Indoor Air Exposure Concentrations – Vapor Intrusion of Volatile Compounds

Infiltration of volatile compounds from soil can occur due to vapor intrusion through basements. The potential for vapor intrusion into current or future buildings is evaluated, first, by determining if any of the selected COPCs in soil are considered "volatile" by USEPA (USEPA, 2002b, defines volatiles as chemicals with a Henry's Law constant greater than 10^{-5} atm m^3 mol^{-1} at room temperature). USEPA's draft vapor intrusion guidance (2002b) (USEPA is currently preparing its final guidance for the vapor intrusion pathway, which is scheduled to be finalized in 2014) lists some of the more common chemicals of sufficient volatility and toxicity. In addition, USEPA provides a Vapor Intrusion Screening Levels spreadsheet calculator that lists chemicals considered to be volatile and sufficiently toxic through the inhalation pathway. Table 7-6 lists those COPCs that are considered volatile. These COPCs are evaluated using the Johnson-Ettinger vapor intrusion model (USEPA spreadsheet tool available on-line).

The potential for soil COPCs to migrate to indoor air is evaluated based on their volatility, as defined by USEPA's draft vapor intrusion guidance (USEPA, 2002b) as chemicals with sufficient volatility (i.e., chemicals with a Henry's Law constant greater than 10^{-5} atm m^3 mol^{-1} at room temperature) and toxicity. Indoor air is a potential exposure route based on the volatility of several COPCs, thus the Johnson-Ettinger vapor intrusion model (USEPA on-line tool) is used to estimate indoor air concentrations, in order to evaluate the exposure pathway of inhalation of indoor air. The details of the vapor intrusion model and its assumptions are provided in Appendix E-5.

7.2.2.5.2 Incidental Ingestion

To estimate an oral CDI for the incidental ingestion of COPCs in soil, the following equation (USEPA, 1989) is used:

$$CDI = \frac{EC \ x \ IR \ x \ FI \ x \ EF \ x \ ED \ x \ CF}{BW \ x \ AT}$$

Where:

CDI = Chronic daily intake (mg/kg-d)
EC = Exposure concentration in soil (mg/kg)
IR = Soil ingestion rate (mg/day)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
CF = Conversion factor, 1E-06 (kg/mg)
BW = Body weight (kg)
AT = Averaging time (days)

7.2.2.5.3 Dermal Contact

Dermal exposure to contaminants in soil is estimated using the methodology and algorithms described in RAGS, Part E (USEPA, 2004), as follows:

$$CDI = \frac{DA_{event} \text{ x } EV \text{ x } EF \text{ x } ED \text{ x } SA}{BW \text{ x } AT}$$

Where:

CDI	=	Chronic daily intake (absorbed dose) (mg/kg d)
DAevent	=	Absorbed dose per event (mg/cm^2 - event)
SA	=	Skin surface area available for contact (cm^2)
EF	=	Exposure frequency (days/year)
ED	=	Exposure duration (years)
EV	=	Event frequency (events/day)
BW	=	Body weight (kg)
AT	=	Averaging time (days)

DAevent (mg/cm^2-event) for contaminants in soil is calculated using the following equation (USEPA, 2004):

$$DA_{event} = (C_{soil})(AF)(DAF)(CF)$$

Where:

DAevent	=	Absorbed dose per event (mg/cm^2 - event)
Csoil	=	Contaminant concentration in soil (mg/kg)
AF	=	Soil-to-skin adherence factor (mg/cm^2-day)
DAF	=	Dermal absorption fraction (unitless)
CF	=	Conversion factor (1E-06 kg/mg)

7.2.2.5.4 Ingestion of Home-Grown Vegetables

USEPA guidance (USEPA, 2011) presents per capita (average over the whole population) and consumer-only ingestion rates for all fruits and vegetables, combining both homegrown and commercially purchased. Average daily vegetable ingestion rates were developed by USEPA (2011) using reported body weights to generate intake rates in units of grams of vegetables ingested per kilogram of body weight per day (g/kg-day), thus there is no body weight needed in the equation below.

$$CDI = \frac{EC \text{ x } IR_{veg} \text{ x } FI \text{ x } EF \text{ x } ED}{AT}$$

Where:

CDI = Chronic Daily Intake from Ingestion of Home-Grown Vegetables (mg/kg-day)
EC = Concentration of EPC in Vegetables (mg/kg) = Soil concentration x Soil-to-Dry Plant Uptake Factor (RAIS/ORNL, 2014)
IR_{veg} = Ingestion Rate of Vegetables (kg/kg body weight/day)
FI_{veg} = Fraction of Home-Produced Vegetables Consumed (unitless)

EF = Exposure Frequency (days/year)
ED = Exposure Duration (years)
AT = Averaging time (days)

7.2.2.5.5 Inhalation

As described in Section 7.2.2.4.5, for the inhalation pathway, inhalation risks are estimated based on a direct comparison of measured or modeled air concentrations to inhalation unit risks (i.e., inhalation chronic toxicity factors) rather than using daily inhalation rates to convert to internal doses (i.e., mg/kg-day). This is a direct comparison of measured or modeled air concentrations to inhalation toxicity factors, as described in Section 7.2.4.1.

7.2.2.6 Age-Adjusted Residential Exposure

This HHRA initially presents the carcinogenic risks to potential adult and child receptors separately. However, to better protect human health, exposure to carcinogenic compounds is often assumed to occur during the first 30 years of life. Thus, exposure is assumed to occur during childhood when the intake is greater and the child is more susceptible to the effects of carcinogenic compounds. These 30 years may be divided into 6 years of child exposure and 24 years of adult exposure. The risk associated with each of these exposures is combined to obtain an age-adjusted carcinogenic risk estimate that is often more conservative than an evaluation of either the child or adult alone. For residential receptors, the estimated carcinogenic risks to an integrated child/adult residential receptor are calculated separately in Appendix E-4.

Age-adjusted factors are not necessary for exposure to non-carcinogens. The equation for residential non-carcinogen exposure can be applied to either children or adults using age-appropriate exposure factors. Typically, it is more important to evaluate non-carcinogenic exposure to children given their larger exposure rates (such as incidental soil ingestion) and lower body weight. However, for residential receptors, this risk assessment presents non-carcinogenic hazards for a both adult and child residents.

7.2.2.7 Estimating Impacts of Exposure to Lead in Soil

For assessing the potential risks of lead exposures, the USEPA has developed the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK model) which predicts geometric mean blood lead (PbB) concentrations for a hypothetical child or population of children (birth to 84 months of age) resulting from exposure to environmental sources of lead, including soil, dust, air, drinking water, and diet (USEPA, 1994b; White et al., 1998). An assumption in the model is that the absolute bioavailability of lead in soil and dust for children, at low intake rates, is 0.3 (30%) and the absolute bioavailability of soluble lead in water and food for children is 0.5 (50%). The USEPA has also developed the Adult Lead Model (ALM) for assessing lead risks in adult populations (USEPA, 1996b, updated 2009). An assumption in the ALM is that the absolute bioavailability of lead in soil for adults is 0.12 (12%). The USEPA Lead Model is described further in Appendix E-6. It should be noted that lead was only selected as a COPC in the Spaulding-Rankin EU, and thus, the lead model is only applied to this residential EU.

7.2.3 Toxicity Assessment

The purpose of the toxicity assessment is to weigh available evidence regarding the potential for COPCs to cause adverse effects in exposed individuals and to provide, where possible, an estimate of the relationship between the extent of exposure to a contaminant and the increased likelihood and/or severity of adverse effects. The steps to be performed in the toxicity assessment include:

- Gathering toxicity information for the COPCs being evaluated;
- Identifying exposure periods for which toxicity values are necessary (e.g., chronic or sub-chronic); and
- Compiling toxicity values for carcinogenic and non-carcinogenic effects (i.e., carcinogenic slope factors and IURs for carcinogens, and reference dose (RfDs) and RfCs for non-carcinogens).

Following USEPA (2003a, 2013d) guidance, as well as the hierarchy provided for the source of toxicity values in the USEPA's RSL table (USEPA, 2013d), toxicity information is obtained from the following USEPA sources:

- USEPA's Integrated Risk Information System (IRIS) (2013d)
- USEPA's Provisional Peer Reviewed Toxicity Values (PPRTVs)

The toxicity values are listed in Tables 7-7 and 7-8. Some COPCs (e.g., aluminum, cobalt, iron, thallium, and vanadium) are PPRTVs, that is, provisional values are not published on USEPA's IRIS database.[1] PPRTVs may be published as regular or "screening" PPRTVs - PPRTVs that are classified as "screening" are considered less well-supported and are approved for use only in a screening assessment (USEPA, 2013a). PPRTVs are used in these HHRAs, with the exception of thallium, for which only a screening PPRTV is available. The PPRTV document for thallium (USEPA, 2012a) states the following:

"For the reasons noted in the main document, it is inappropriate to derive a subchronic or chronic p-RfD for thallium. However, information is available which, although insufficient to support derivation of a provisional toxicity value, under current guidelines, may be of limited use to risk assessors. In such cases, the Superfund Health Risk Technical Support Center summarizes available information in an appendix and develops a screening value. Users of screening toxicity values in an appendix to a PPRTV assessment should understand that there is considerably more uncertainty associated with the derivation of a supplemental screening toxicity value than for a value presented in the body of the assessment."

The uncertainty section addresses the uncertainties associated with the use of these PPRTVs to evaluate the human health toxicity of COPCs, and the limitations on their use for site decision-making.

Tables 7-7 and 7-8 list both chromium VI and chromium III for completeness, but for the HHRA, both for the screening of COPCs and for the risk calculations, it is assumed that

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[1] A Provisional Peer-Reviewed Toxicity Value (PPRTV) is defined as a toxicity value derived for use in the Superfund Program. PPRTVs are derived after a review of the relevant scientific literature using established Agency guidance on human health toxicity value derivations. All PPRTV assessments receive internal review by a standing panel of National Center for Environment Assessment (NCEA) scientists and an independent external peer review by three scientific experts. The PPRTV review process provides needed toxicity values in a quick turnaround timeframe while maintaining scientific quality. When a final Integrated Risk Information System (IRIS) assessment is made publicly available on the Internet (www.epa.gov/iris), the respective PPRTVs are removed from the database.

chromium in soil is chromium III. For various previous investigations, chromium VI has been analyzed but has not often been detected. It is a reasonable assumption that chromium is chromium III; there are no known sources of chromium VI based on AUES activities. Further, Kimbrough et al., 1999, concluded that most naturally occurring chromium is trivalent. Therefore, it is concluded that trivalent chromium is likely the predominant species at the site.

For the evaluation of carcinogenic PAHs, toxicity equivalency factors based on the toxicity of benzo(a)pyrene are used (USEPA, 1993).

7.2.4 Risk Characterization

Following USEPA (1995) guidance, the risk characterization step integrates the toxicity and exposure assessment outputs into quantitative expressions of risk. Detailed risk calculation tables are shown in Appendix E-7.

7.2.4.1 Non-Cancer Hazard Assessment

Noncancer hazards are calculated by comparing the estimated CDI with the published reference dose based on non-cancer toxic effects. The non-carcinogenic hazard posed by a given chemical to a given receptor in a given exposure pathway is calculated as follows:

$$\text{Hazard Quotient}_{\text{oral/dermal}} = \frac{\text{Chronic Daily Intake (mg/kg - day)}}{\text{Reference Dose (RfD) (mg/kg - day)}}$$

$$\text{Hazard Quotient}_{\text{inhalation}} = \frac{\text{Air Concentration (mg/m3)}}{\text{Inhalation Reference Concentration (RfC) (mg/m3)}}$$

The total potential non-carcinogenic hazard, that is, the hazard associated with exposure to all COPCs by all exposure routes, is determined by summing the HQs for all non-carcinogenic COPCs to derive a total HI for each receptor. If a receptor-specific HI is greater than one, target organs are identified based on the critical toxicity study that was used to develop the non-cancer reference dose for each COPC. Those COPCs affecting the same target organ are summed and a separate HI is calculated for each target organ.

An HI of 1 is used when evaluating total non-carcinogenic hazards and/or total target organ hazards for each receptor.

Table 7-9 lists all of the non-cancer hazard results by exposure pathway and potentially exposed population.

The detailed risk assessment tables for AOI 9 (Tables E-7.1A through E-7.1G) and Spaulding-Rankin EUs (Tables E-7.2A though E-7.2G) are presented in Appendix E-7. The risk assessment tables for the Spaulding-Rankin outliers are shown in Appendix Tables E-7.2H through E-7.2N.

Each individual COPC-specific HI is shown in Appendix E-8. The risk summary listed below describes the results of the COPC-specific HIs from Appendix E-8 only where they are greater than one. In addition, the target organ assessments for each receptor are shown in Appendix E-8.

AOI 9 EU Non-Cancer Hazard

Target organ analysis for the COPCs in this EU indicates that the majority of non-cancer COPCs have different target organs, except for aluminum and manganese, for which the RfDs are both based on nervous system effects. If the target organ-specific HI for aluminum plus manganese is less than or equal to one, there are unlikely to be nervous system effects.

For the AOI 9 EU, the estimated soil non-cancer hazards for current receptors are listed below:

- Current outdoor worker:
  - CTE HI=0.01; RME HI=0.2.
- Current adult resident:
  - CTE HI=0.1; RME HI=0.6.
- Current child resident:
  - CTE HI=0.6; RME HI=4.0, based primarily on an RME incidental soil ingestion pathway HI=3.5. However, all individual COPC-specific total HIs for this exposure pathway are ≤ 1.
  - The total RME HI for nervous system effects (aluminum plus manganese) is 0.5.

The non-cancer hazard results for potential future receptors are as follows:

- Future outdoor worker:
  - CTE HI=0.01; RME HI=0.2.
- Future adult resident:
  - CTE HI=0.1; RME HI=0.6.
- Future child resident:
  - CTE HI=0.6; RME HI=3.3, based primarily on an RME incidental soil ingestion HI=2.9. Except for cobalt, all individual COPC-specific total HIs across all exposure pathways for this receptor are ≤ 1.
  - Cobalt has a COPC-specific RME total HI=1.6 (Appendix Table E-8.1F) based primarily on the incidental soil ingestion pathway. The COPC-specific CTE HI for this receptor, using more realistic exposure assumptions, is 0.3. Based on a statistical comparison to background (USACE, 2013f), cobalt at AOI 9 is greater than background. However, as described in more detail in Section 7.3.5, cobalt is an essential element, and the toxicity value for cobalt is a provisional value, and is associated with considerable uncertainty.
  - The total HI for nervous system effects (aluminum plus manganese) is 0.6.
- Future construction worker:
  - CTE HI=0.009; RME HI=0.6.

Spaulding-Rankin EU Non-Cancer Hazard

Target organ analysis for the COPCs in this EU indicates that there are three target organs with more than one corresponding COPC:

- The nervous system is the target organ for aluminum, lead, and manganese. Lead is evaluated separately using the IEUBK model. Thus, if the target organ-specific HI for aluminum plus manganese is less than or equal to one, there are unlikely to be nervous system effects.
- Hematological effects is the target organ for antimony and zinc. If the target organ-specific HI for antimony plus zinc is less than or equal to one, there are unlikely to be hematological effects.

- The kidney is the target organ for cadmium and vanadium. If the target organ-specific HI for cadmium plus vanadium is less than or equal to one, there are unlikely to be kidney effects.

For the Spaulding-Rankin EU, the estimated soil non-cancer hazards for current receptors are listed below:

- Current outdoor worker:
  - CTE HI=0.02; RME HI=0.5.
- Current adult resident:
  - CTE HI=0.3; RME HI=2.1, although all individual COPC-specific total HIs across all exposure pathways for this receptor are <1.
- Current child resident:
  - CTE HI=1; RME HI=10, based primarily on an RME incidental soil ingestion HI=7.9. Except for cobalt, all individual COPC-specific HIs across all exposure pathways for this receptor are ≤1. Cobalt has a COPC-specific RME total HI=5.5 for the current child resident receptor (Appendix Table E-8.2E) based primarily on the incidental soil ingestion pathway. The CTE total HI for cobalt for this receptor, using more realistic exposure assumptions, is 0.7. Based on a statistical comparison to background (USACE, 2013f), cobalt in soil at Spaulding-Rankin is greater than background.
  - The total HIs for each of the three organ effects (i.e., nervous system effects (aluminum and manganese), hematological effects (antimony and zinc), and kidney effects (cadmium and vanadium)) are all ≤1.

The non-cancer hazard results for potential future receptors at the Spaulding-Rankin EU are as follows:

- Future outdoor worker:
  - CTE HI=0.01; RME HI=0.5.
- Future adult resident:
  - CTE HI=0.3; RME HI=2.1, although all individual COPC-specific total HIs across all exposure pathways for this receptor are < 1.
- Future child resident:
  - Total CTE HI=1; total RME HI=10, based primarily on an RME incidental soil ingestion HI=7.5. Except for cobalt, all individual COPC-specific total HIs across all exposure pathways for this receptor are ≤1. Cobalt has a COPC-specific RME total HI=5.2 for this receptor (Appendix Table E-8.2F) based primarily on the incidental soil ingestion pathway. The CTE total HI for cobalt for this receptor, using more realistic exposure assumptions, is 0.7. Based on a statistical comparison to background (USACE, 2013f), cobalt in soil at Spaulding-Rankin is greater than background.
  - The total HIs for each of the three target organ effects (i.e., nervous system effects (aluminum and manganese), hematological effects (antimony and zinc), and kidney effects (cadmium and vanadium)) are all ≤1.
- Future construction worker:
  - CTE HI=0.02; RME HI=0.5.

Spaulding-Rankin EU Outliers (Maximum Concentrations) Non-Cancer Hazard
For the maximum detected concentrations of the eight metals at the Spaulding-Rankin EU that were determined to be outliers, HIs greater than one were determined for these maximum concentrations: arsenic (131 mg/kg), cobalt (427 mg/kg), cadmium (110 mg/kg), and mercury (2.5 mg/kg). The HIs are:

- Current Adult Resident: COPC-specific RME total HI=2.6 for arsenic; HI=1.8 for cobalt (Appendix Table E-8.2J)
- Future Adult Resident: COPC-specific RME total HI=2.6 for arsenic; HI=2.7 for cobalt (Appendix Table E-8.2K)
- Current Child Resident: COPC-specific RME total HI=10 for arsenic; HI=13 for cobalt; HI=1.9 for mercury (Appendix Table E-8.2L)
- Future Child Resident: COPC-specific RME total HI=10 for arsenic; HI=1.6 for cadmium; HI=20 for cobalt; HI=1.9 for mercury (Appendix Table E-8.2M)
- Future Construction Worker: COPC-specific RME total HI=3.6 for cobalt (Appendix Table E-8.2N)

When current and future HIs are the same, the maximum detected concentration was the same for 0-2 foot and 0-10 foot depth.

For the current and future outdoor worker, no HIs were greater than one for the Spaulding-Rankin outlier locations.

7.2.4.2 Carcinogenic Risk Characterization

The carcinogenic risk posed by a given chemical to a given receptor in a given exposure pathway is calculated as estimated as follows:

$$Risk_{oral/dermal} = \text{Chronic Daily Intake (mg/kg-day)} * \text{Cancer Slope Factor (mg/kg-day)}^{-1}$$

$$Risk_{inhalation} = \text{Inhalation Unit Risk Factor (mg/m}^3)^{-1} * \text{Air Concentration (mg/m}^3)$$

The total carcinogenic risk for a receptor, that is, the risk associated with exposure to all COPCs for all exposure pathways, is derived by adding all the pathway-specific carcinogenic risks.

The USEPA-promulgated acceptable incremental risk range of $1x10^{-6}$ to $1x10^{-4}$ is used to evaluate total cancer risks.

Table 7-9 lists the estimated carcinogenic risk results by exposure pathway and potentially exposed population. COPC-specific cancer risks are shown in Appendix E-8.

AOI 9 EU Cancer Risks
Cancer risks for the AOI 9 EU are based only on the inhalation pathway and on the cobalt inhalation unit risk, because all other selected COPCs either are not associated with cancer risks or do not have published cancer slope factors. All estimated inhalation carcinogenic risks in the AOI 9 EU are considered acceptable and are below USEPA's acceptable incremental cancer risk range.

Spaulding-Rankin EU Cancer Risks

The estimated cancer risks for the Spaulding-Rankin EU are all within or below USEPA's acceptable incremental cancer risk range

Spaulding-Rankin EU Outliers (Maximum Concentrations) Cancer Risks

For the maximum detected concentrations of the eight metals at the Spaulding-Rankin EU that were determined to be outliers, estimated cancer risks that exceeded acceptable levels were as follows:

- Current and Future Adult Resident: 3.3×10^{-4} and 3.4×10^{-4}, respectively, using the maximum detected arsenic concentration (131 mg/kg), and based primarily on the vegetable ingestion pathway
- Current and Future Child Resident: 3.9×10^{-4}, using the maximum detected arsenic concentration (131 mg/kg), and based primarily on the soil ingestion and vegetable ingestion pathways

Arsenic is the only COPC in the Spaulding-Rankin EU with a published oral cancer slope factor. However, based on a statistical comparison to background (USACE, 2013f), concentrations of arsenic in soil at Spaulding-Rankin are less than or equal to background. Note that the cancer risk described above is based on a single pipe drain debris soil sample collected beneath the concrete floor of the POI 23 bunker; there are no current completed pathways and the risk scenario would require demolition and removal of the bunker.

Combined Adult/Child Carcinogenic Risks

Combined adult/child carcinogenic risks for the residential EUs are presented in Appendix E-4. These combined cancer risk results are of the same order of magnitude as the separately calculated child and adult estimated cancer risks.

COPCs Without Toxicity Values

There are no toxicity values published for thallium, lead, and magnesium. The primary targets of thallium toxicity are the nervous, integumentary, and reproductive systems. Human and animal chronic exposures result in alterations of the brain, spinal cord, and peripheral nerves. In both humans and animals, alopecia is the most common indicator of long-term thallium poisoning (RAIS/ORNL, 2014). Lead is evaluated in Appendix E-6, to determine whether lead in soil at the Spaulding-Rankin EU is of concern for potentially exposed children. Magnesium is a low toxicity element.

7.2.4.3 Results of the Vapor Intrusion Model

Although the mercury HIs for the Spaulding-Rankin EU (mercury is not a COPC at AOI 9) are less than one, mercury is the only COPC with sufficient volatility to consider with respect to vapor intrusion (as described in Appendix E-5). The results of the Johnson-Ettinger model indicate that the CTE mercury concentrations found at the Spaulding-Rankin EU result in an HQ less than one while the RME mercury concentration results in an HQ slightly greater than one (1.5). Non-cancer vapor intrusion risks based on mercury in soil, however, are not considered likely, primarily because of the many default conservative inputs to the Johnson-Ettinger model and the use of the single RME concentration in the model (noting that mercury is distributed across the site in a range of concentrations, most of which would be below the 95% UCL of the mean).

7.2.4.4 Results of the Lead Model

Lead was selected as a COPC in the Spaulding-Rankin EU only. The USEPA's IEUBK model (USEPA, 2010) was used to determine if the soil lead concentrations at Spaulding-Rankin EU would be of concern for children who live currently at the site or who may live at this site in the future. Both current (0-2 ft bgs) soil concentrations and future potential (0-10 ft bgs) soil and vegetable concentrations were run in the model, as well as CTE and RME concentrations. The results of the model, as described in Appendix E-6, indicate that the range of predicted blood lead levels using Spaulding-Rankin EU lead in soil concentrations are below a level of concern (corresponding to 5 micrograms lead per deciliter of blood).

However, because lead was determined to be an outlier in the Spaulding-Rankin EU, the IEUBK model was run for the maximum detected concentration of lead (868 mg/kg), and an unacceptable risk was calculated, as described in Appendix E-6.

7.2.4.5 Qualitative Assessment of Indoor Dust Inhalation

The USEPA IEUBK lead model guidance uses, as a default, 30% of the outdoor air Pb concentration to calculate indoor air Pb concentrations. Based on the relatively low risk results for outdoor dust inhalation, it is not likely that dust infiltration to indoor air will result in risks of concern.

7.2.5 Uncertainty Discussion

The uncertainty discussion presented in Section 7.3.5 applies to both the residential EUs and the Southern AU EU.

7.2.6 Conclusions and Recommendations

AOI 9 EU

Based on the results of the HHRA for the AOI 9 EU, the COPC-specific RME non-cancer HI was >1 (HI=1.6) for cobalt for a future child resident, based primarily on incidental ingestion of soil. A statistical comparison to background shows that cobalt at AOI 9 is greater than background. However, cobalt is an essential element in the diet, and because it is a natural element found throughout the environment, the general population may be exposed to cobalt in the air, drinking water, and food. In addition, there is considerable uncertainty associated with the provisional toxicity value used to estimate the cobalt non-cancer hazards, as detailed in Section 7.3.5, and the RME scenario uses very conservative assumptions, resulting in an estimate of exposure for the 95th percentile of the potentially exposed population; note that the CTE HI (using average exposure assumptions) for cobalt at AOI 9 was $\leq$1.

For these reasons, USACE proposes a cobalt HI of $\leq$2 as an appropriate remedial action objective (RAO). Non-cancer reference doses (RfDs) are, in general, overly protective by up to an order of magnitude. For the derivation of the cobalt RfD, a very large uncertainty factor of 3000 was applied to the oral RfD, reflecting toxicity data limitations and to ensure protectiveness. USEPA's confidence in the principal study behind the RfD is low to medium, and the practical implication is that the RfD is set at such a low value that true risk tends to be exaggerated. When this extra low RfD value is combined with the RME scenario (which uses very conservative assumptions resulting in an estimate of exposure at the high end for exposed receptors), the resulting risk estimates may be artificially high. The COPC-specific RME estimated non-cancer HI was <2 (1.6) for cobalt in soil for the future resident child scenario at the AOI 9 EU, and accordingly, using this proposed RAO, no further action based on cobalt is recommended.

With regard to cancer risks, all estimated incremental cancer risks are below the level of concern.

<u>Based on these results, for the AOI 9 EU, no COCs have been identified and no further action is required.</u>

Spaulding-Rankin EU

Based on the results of the HHRA for the Spaulding-Rankin EU, the COPC-specific RME estimated non-cancer HI was >1 for cobalt in soil for both the current and future resident child scenarios (HI=5.5 for the current and 5.2 for the future resident child scenarios). A statistical comparison to background shows that cobalt in soil at Spaulding-Rankin is greater than background. Further, outlier testing using ProUCL indicated that the five highest cobalt results were sufficiently elevated to be considered outliers. Consequently, further action at the Spaulding-Rankin EU based on cobalt is warranted.

However, cobalt is an essential element in the diet and is a natural element found throughout the environment. There is also considerable uncertainty associated with the provisional toxicity value used to estimate the cobalt non-cancer hazards, as described in more detail in Section 7.3.5, and the RME scenario uses very conservative assumptions, resulting in an estimate of exposure for the 95th percentile of the potentially exposed population; note that the CTE HI (using average exposure assumptions) for cobalt for both current and future resident child scenarios at Spaulding-Rankin was $\leq$1.

For these reasons, while further action based on cobalt is warranted, USACE proposes a cobalt HI of $\leq$2 as an appropriate RAO. For the derivation of the cobalt RfD, a very large uncertainty factor of 3000 was applied to the oral RfD, reflecting toxicity data limitations and to ensure protectiveness. USEPA's confidence in the principal study behind the RfD is low to medium, and the practical implication is that the RfD is set at such a low value that true risk tends to be exaggerated. When this extra low RfD value is combined with the RME scenario (which uses very conservative assumptions resulting in an estimate of exposure at the high end for exposed receptors), the resulting risk estimates may be artificially high. However, the COPC-specific RME estimated non-cancer HI was >2 for cobalt in soil for both the current and future resident child scenarios, and accordingly, using this proposed RAO, further action based on cobalt is recommended.

With regard to cancer risks, the estimated cancer risks at the Spaulding-Rankin EU were within or below USEPA's acceptable incremental cancer risk range.

Spaulding-Rankin EU Outliers (Maximum Concentrations)

The maximum detected concentration of arsenic was determined to be an outlier, and this location resulted in an estimated non-cancer HI of 10 for the current and future child resident scenarios and an HI of 2.6 for the current and future adult resident scenarios. However, this maximum concentration is from a pipe drain debris sample collected from beneath the concrete floor of the POI 23 bunker, there are no completed pathways, a statistical comparison to background (USACE, 2013f) across the EU indicates arsenic is less than background, and the risk scenario would involve demolition and removal of the bunker. Therefore, no further action based on arsenic is recommended.

The maximum detected concentration of lead was determined to be an outlier, and this location also resulted in an unacceptable risk for the current and future child resident scenarios. However, this maximum concentration is from a sample collected from beneath the concrete floor of the POI 22 bunker, there are no completed pathways, lead across the EU is less than background, and the future risk scenario would involve demolition and removal of the residence. Therefore, no further action based on lead is recommended.

The maximum detected concentration of mercury was determined to be an outlier, and this location resulted in an estimated non-cancer HI of 1.9 for the future child resident scenario. However, this maximum concentration is from a sample collected from beneath the concrete floor of the POI 22 bunker (the same location as the maximum lead sample discussed above), there are no completed pathways, and the future risk scenario would involve demolition and removal of the residence. Therefore, no further action based on mercury is recommended.

The maximum detected concentration of cadmium (110 mg/kg) was determined to be an outlier, and this location resulted in an estimated non-cancer HI of 1.6 for the future child resident scenario, just slightly above the acceptable level of 1. However, this maximum concentration is from a 1993 OSR FUDS sample collected at a depth of 7-9 feet, in the front yard of this residential property. This same location and depth was sampled during the more recent Evaluation Document data gap sampling in 2012 (the intent of the Evaluation Document sampling was to mirror those 1993 locations). The result was 0.75 mg/kg. It is unlikely that there exists a significant area of cadmium contaminated soil at depth. Therefore, no further action based on cadmium is recommended.

The five highest cobalt results were identified as outliers at the Spaulding-Rankin EU, resulting in HIs greater than one for all potential receptors. As described above, further action at the Spaulding-Rankin EU based on cobalt is recommended.

With regard to cancer risks, the estimated cancer risks at the Spaulding-Rankin EU outliers for the current and future adult and child resident RME scenarios exceed USEPA's acceptable incremental cancer risk range, based on the sample with the maximum arsenic concentration discussed above. This maximum concentration is from a pipe drain debris sample collected from beneath the concrete floor of the POI 23 bunker, there are no completed pathways, a statistical comparison to background (USACE, 2013f) across the EU indicates arsenic is less than background, and the future risk scenario would involve demolition and removal of the bunker. Therefore, no further action based on arsenic is recommended.

<u>Based on these results, for the Spaulding-Rankin EU, cobalt is a COC that poses unacceptable risks, and follow-on actions are required to address it.</u>

Table 7-1. Chemicals of Potential Concern in Residential EUs

COPC	AOI 9 EU	Spaulding-Rankin EU
Aluminum	YES	YES
Antimony	YES	YES
Arsenic		YES
Cadmium		YES
Chromium		YES
Cobalt	YES	YES
Copper		YES
Iron	YES	YES
Lead		YES
Magnesium	YES	YES
Manganese	YES	YES
Mercury		YES
Nickel		YES
Selenium		YES
Thallium		YES
Vanadium	YES	YES
Zinc		YES

Notes:
COPCs were determined in the initial screen in Addendum 1 to the Pre-2005 HHRA Review report.
YES means this chemical is a COPC for this EU.

Table 7-2. Exposure Factors for the Outdoor Worker Exposure Scenario

Exposure Variable	Scenario [a/]	Rationale	Reference
BW = Body Weight 80 kg [b/]	RME and CTE	Standard reference weight for adult males.	USEPA, 2014
EF = Exposure Frequency 225 days/yr [c/] 125 days/yr	RME CTE	Assumes year-round weekday exposure. Assumed.	RME, USEPA, 2014 CTE, Assumed
ED = Exposure Duration 25 years 8 years	RME CTE	Assumed upper bound time at one place of employment. Median time at one place of employment.	RME, USEPA, 2014 CTE, USEPA, 2011
SA = Surface Area 3,470 cm^2 3,470 cm^2 [d/]	RME CTE	95% percentile and mean adult skin surface area for head, arms, hands.	USEPA, 2014
AT = Averaging Time 25,550 days (carcinogens) ED x 365 days/year (non-carcinogens)	RME CTE	Conventional human lifespan. Intakes for carcinogens are averaged over the duration of exposure. Equal to the exposure duration (in days).	USEPA, 1989 USEPA, 1989
FI = Fraction Ingested (unitless) 1.0 0.20	RME CTE	RME conservatively assumes 100 percent of daily soil incidental ingestion occurs on-site. CTE assumes 1/5 of time spent at this site.	Professional judgment
DAF = Dermal Absorption Fraction Chemical-specific	RME and CTE	Chemical-specific.	USEPA, 2004
IR = Incidental Soil Ingestion Rate 100 mg/day [e/] 50 mg/day	RME CTE	Standard default soil incidental ingestion rate for workers. Assumed.	USEPA, 2002a
AF = Soil-to-Skin Adherence Factor 0.12 mg/cm^2 [f/] 0.12 mg/cm^2	RME CTE	Activity and body part-specific weighted based on exposed body parts. Activity and body part-specific weighted based on exposed body parts.	USEPA, 2014 USEPA, 2014
ET = Exposure Time 8 hours/day	RME and CTE	Based on 100 percent of working day spent.	Professional Judgment
PEF = Particulate emission factor 3.23E+09 (m^3/kg) [g/]	RME and CTE	Calculated using site-specific Q/C term and default parameters listed in USEPA 1996a and 2002.	USEPA, 1996a, Equation 10, and 2002

Table 7-2. Exposure Factors for the Outdoor Worker Exposure Scenario

Exposure Variable	Scenario [a/]	Rationale	Reference
Q/C = Inverse of mean concentration at center of source 87.37 g/m^2-s per kg/m^3 [h/]	RME and CTE	Q/C value of 0.5 acre source area of Zone VIII, Philadelphia. Philadelphia is the nearest eastern seaboard city to Washington, D.C. for which a Q/C is derived.	USEPA, 1996a Table 3.

Legend:
a/ RME = Reasonable Maximum Exposure; CTE = Central Tendency Exposure
b/ kg = kilogram
c/ days/yr = days per year
d/ cm^2 = square centimeters..
e/ mg/day = milligrams per day
f/ mg/cm^2 = milligrams per square centimeter
g/ m^3/kg = cubic meters per kilogram
h/ g/m^2-s per kg/m^2 = grams per square meters – second per kilograms per cubic meters

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Table 7-3. Exposure Factors for the Adult Resident Exposure Scenario

Exposure Variable	Scenario [a]	Rationale	Reference
BW = Body Weight 80 kg [b]	RME and CTE	Standard reference weight for adult males.	USEPA, 2014
EF = Exposure Frequency 350 days/yr [c]	RME	Assumes year-round exposure with one 2-week vacation.	USEPA, 1991
160 days/yr	CTE	Mean exposure to soil by residents.	Assumed based on 8 months March-October, 5 days/week.
ED = Exposure Duration 20 years 12 years	RME CTE	Upper bound time at one residence. Average time at one residence.	USEPA, 2014 USEPA, 2011
SA = Surface Area 6,032 cm^2 6,032 cm^2 [d]	RME CTE	Skin surface area for head, arms, hands, legs, and feet.	USEPA, 2014
AT = Averaging Time 25,550 days (carcinogens) ED x 365 days/year (non-carcinogens)	RME CTE	Conventional human lifespan. Intakes for carcinogens are averaged over the duration of exposure. Equal to the exposure duration (in days).	USPEA, 1989 USEPA, 1989
FI = Fraction Ingested 1.0 (unitless)	RME and CTE	Conservatively assume 100 percent of daily soil incidental ingestion occurs on-site.	Professional Judgment
DAF = Dermal Absorption Fraction Chemical-specific	RME and CTE	Chemical-specific.	USEPA, 2004
IR = Incidental Soil Ingestion Rate 100 mg/day [e] 50 mg/day	RME CTE	Assumed adult residential incidental soil ingestion rate. Central tendency adult residential incidental soil ingestion rate.	USEPA, 2014 USEPA, 2011
AF = Soil-to-Skin Adherence Factor 0.07 mg/cm^2 [f]	RME and CTE	Mean adherence factor for face, arms, hands, legs, and feet for gardening activities.	USEPA, 2014
ET = Exposure Time 8 hours/day	RME and CTE	Assumed 8 hours/day outdoors.	Assumed
PEF = Particulate emission factor 3.23E+09 (m^3/kg) [g]	RME and CTE	Calculated using Equation 10 and site-specific Q/C term and default parameters listed in USEPA 1996a and 2002.	USEPA, 1996a, Equation 10, and 2002
Q/C = Inverse of mean concentration at center of source 87.37 g/m^2-s per kg/m^3 [h]	RME and CTE	Q/C value of 0.5 acre source area of Zone VIII, Philadelphia. Philadelphia is the nearest eastern seaboard city to Washington, D.C. for which a Q/C is derived.	USEPA, 1996a, Table 3
IRveg = Ingestion Rate for Home-Produced	RME and CTE	RME=0.0032	USEPA, 2011

Table 7-3. Exposure Factors for the Adult Resident Exposure Scenario

Exposure Variable	Scenario [a/]	Rationale	Reference
Vegetables (kg/kg-day)		CTE=0.0006	
FIveg = Fraction of Home-Produced Vegetables from site	FIveg	RME=25% CTE=25%	Assumed

Legend:
a/ RME = Reasonable Maximum Exposure; CTE = Central Tendency Exposure
b/ kg = kilogram
c/ days/yr = days per year
d/ cm^2 = square centimeters
e/ mg/day = milligrams per day
f/ mg/cm^2 = milligrams per square centimeter
g/ m^3/kg = cubic meters per kilogram
h/ g/m^2-s per kg/m^2 = grams per square meters – second per kilograms per cubic meters

Table 7-4. Exposure Factors for the Child Resident Exposure Scenario

Exposure Variable	Scenario a/	Rationale	Reference
BW = Body Weight 15 kg b/	RME and CTE	Average body weight for children (1 to 6 years).	USEPA, 2008a
EF = Exposure Frequency 350 days/yr c/ 160 days/yr	RME CTE	Assumes year-round exposure with one 2-week vacation. Assumed	USEPA, 1991a, Section 2.1. Assumed
ED = Exposure Duration 6 years	RME and CTE	Time for ages 0 to 6 at one residence.	USEPA, 1997
SA = Surface Area 2,690 cm^2 2,690 cm^2 d/	RME CTE	Assumed contact with head, arms, hands, legs, and feet.	USEPA, 2014
AT = Averaging Time 25,550 days (carcinogens) ED x 365 days/year (non-carcinogens)	RME CTE	Conventional human lifespan. Intakes for carcinogens are averaged over the duration of exposure. Equal to the exposure duration (in days).	USEPA, 1989 USEPA, 1989
FI = Fraction Ingested 1.0 (unitless)	RME and CTE	Conservatively assume 100 percent of daily soil incidental ingestion occurs on-site.	Professional Judgment
DAF = Dermal Absorption Fraction **Chemical-specific**	RME and CTE	Chemical-specific.	USEPA, 2004
IR = Incidental Soil Ingestion Rate 200 mg/day 100 mg/day	RME CTE	Default USEPA soil ingestion rates for children.	USEPA, 2011
AF = Soil-to-Skin Adherence Factor 0.2 mg/cm^2 f/	RME and CTE	Mean adherence factor for arms, hands, legs, and feet for daycare children, playing both indoors and outdoors.	USEPA, 2014
ET = Exposure Time 8 hours/day	RME and CTE	Assumed 8 hours/day outdoors.	Assumed
PEF = Particulate emission factor 3.23E+09 m^3/kg g/	RME and CTE	Calculated using site-specific Q/C term and default parameters listed in USEPA 1996a and 2002a.	USEPA, 1996a, Equation 10, and 2002a
Q/C = Inverse of mean concentration at center of source 87.37 g/m^2-s per kg/m^3 h/	RME and CTE	Q/C value of 0.5 acre source area of Zone VIII, Philadelphia. Philadelphia is the nearest eastern seaboard city to Washington, D.C. for which a Q/C is derived.	USEPA, 1996a, Table 3.
IRveg = Ingestion Rate for Home-Produced Vegetables (kg/kg-day)	RME and CTE	RME=0.0065 CTE=0.0011	USEPA, 2011
FIveg = Fraction of Home-Produced Vegetables from site	FIveg	RME=25% CTE=25%	Assumed

Table 7-4. Exposure Factors for the Child Resident Exposure Scenario

Exposure Variable	Scenario a/	Rationale	Reference
Legend: *a/ RME = Reasonable Maximum Exposure; CTE = Central Tendency Exposure* *b/ kg = kilogram* *c/ days/yr = days per year* *d/ cm^2 = square centimeters* *e/ mg/day = milligrams per day* *f/ mg/cm^2 = milligrams per square centimeter* *g/ m^3/kg = cubic meters per kilogram* *h/ g/m^2-s per kg/m^2 = grams per square meters – second per kilograms per cubic meters*			

Table 7-5. Exposure Factors for the Construction Worker Scenario

Exposure Variable	Scenario a/	Rationale	Reference
BW = Body Weight 80 kg [b/]	RME and CTE	Standard reference weight for adult males.	USEPA, 2014
EF = Exposure Frequency 225 days/yr [c/] 125 days/yr	RME CTE	Assumes year-round weekday exposure. Assumed.	USEPA, 2014 Assumed
ED = Exposure Duration 1 year 0.5 year	RME CTE	Upper bound time at construction site. Average time at construction site.	Assumed
SA = Surface Area 3,470 cm^2 3,470 cm^2 [d/]	RME CTE	Skin surface area for head, hands, forearms	USEPA, 2014
AT = Averaging Time 25,550 days (carcinogens) ED x 365 days/year (non-carcinogens)	RME CTE	Conventional human lifespan. Intakes for carcinogens are averaged over the duration of exposure. Equal to the exposure duration (in days).	USEPA, 1989 USEPA, 1989.
FI = Fraction Ingested (unitless) 1.0 0.20	RME CTE	RME conservatively assumes 100 percent of daily soil incidental ingestion occurs on-site. CTE = assumes 1/5 of time spent at this site	Professional judgment
DAF = Dermal Absorption Fraction Chemical-specific	RME and CTE	Chemical-specific.	USEPA, 2004
IR = Incidental Soil Ingestion Rate 330 mg/day [e/] 50 mg/day	RME CTE	Default soil incidental ingestion rate for workers. Assumed one-half of default adult soil ingestion rate	USEPA, 2002a USEPA, 2014
AF = Soil-to-Skin Adherence Factor 0.12 mg/cm^2 [f/] 0.12 mg/cm^2	RME CTE	Activity and body part-specific weighted based on exposed body parts. Activity and body part-specific weighted based on exposed body parts.	USEPA, 2014
ET = Exposure Time 8 hours/day	RME and CTE	Based on 100 percent of working day spent.	Professional Judgment
PEF = Particulate emission factor 3.23E+09 (m^3/kg) [g/]	RME and CTE	Calculated using site-specific Q/C term and default parameters listed in USEPA 1996a and 2002.	USEPA, 1996a, Equation 10, and 2002
Q/C = Inverse of mean concentration at center of source 87.37 g/m^2-s per kg/m^3 [h/]	RME and CTE	Q/C value of 0.5 acre source area of Zone VIII, Philadelphia. Philadelphia is the nearest eastern seaboard city to Washington, D.C. for which a Q/C is derived.	USEPA, 1996a, Table 3.

Table 7-5. Exposure Factors for the Construction Worker Scenario			
Exposure Variable	**Scenario a/**	**Rationale**	**Reference**
Legend: a/ RME = Reasonable Maximum Exposure; CTE = Central Tendency Exposure b/ kg = kilogram c/ days/yr = days per year d/ cm^2 = square centimeters e/ mg/day = milligrams per day f/ mg/cm^2-day = milligrams per square centimeter-day g/ m^3/kg = cubic meters per kilogram h/ g/m^2-s per kg/m^2 = grams per square meters – second per kilograms per cubic meters			

Table 7-6. Other Exposure Factors

COPC	Soil-Plant Uptake Equation or Factor[1]	Reference	Oral Absorption Factor Used[2]	Oral Absorption Factor Notes	Sufficiently Volatile Compound to Assess for Vapor Intrusion?[4]
Aluminum	0.004	RAIS/ORNL	1		No
Antimony	ln(Cp) = 0.938 * ln(Cs) - 3.233	USEPA, 2005a	0.15		No
Arsenic	Cp = 0.03752 * Cs	USEPA, 2005a	1		No
Beryllium	ln(Cp) = 0.7345 * ln(Cs) - 0.5361	USEPA, 2005a	0.007		No
Cadmium	ln(Cp) = 0.546 * ln(Cs) - 0.475	USEPA, 2005a	0.025		No
Chromium	Cp = 0.041 * Cs	USEPA, 2005a	0.025		No
Cobalt	Cp = 0.0075 * Cs	USEPA, 2005a	0.45	See reference in note 3, below	No
Copper	ln(Cp) = 0.394 * ln(Cs) + 0.668	USEPA, 2005a	1		No
Iron	0.004	RAIS/ORNL	1		No
Lead	ln(Cp) = 0.561 * ln(Cs) - 1.328	USEPA, 2005a	1	Some studies have shown oral absorption values of 0.3, 0.5, and 0.12 (USEPA 2004 RAGS Part E)	No
Magnesium	1	RAIS/ORNL	1		No
Manganese	Cp = 0.079 * Cs	USEPA, 2005a	1	Some studies report an oral absorption value of 0.004 (USEPA 2004 RAGS Part E)	No
Mercury	0.9	RAIS/ORNL	1		Yes
Nickel	ln(Cp) = 0.748 * ln(Cs) - 2.223	USEPA, 2005a	0.04		No
Selenium	ln(Cp) = 1.104 * ln(Cs) - 0.677	USEPA, 2005a	1	Some studies report an oral absorption value range of 30-80% (USEPA 2004 RAGS Part E)	No
Thallium	0.004	RAIS/ORNL	1		No
Vanadium	Cp = 0.00485 * Cs	USEPA, 2005a	0.026		No
Zinc	ln(Cp) = 0.554 * ln(Cs) +	USEPA, 2005a	1		No

Table 7-6. Other Exposure Factors

COPC	Soil-Plant Uptake Equation or Factor[1]	Reference	Oral Absorption Factor Used[2]	Oral Absorption Factor Notes	Sufficiently Volatile Compound to Assess for Vapor Intrusion?[4]
	1.575				
Benz[a] anthracene	ln(Cp)= 0.5944 * ln(Cs) - 2.7078	USEPA, 2005a	1		No
Benzo[a] pyrene	ln(Cp)= 0.9750 * ln(Cs) - 2.0615	USEPA, 2005a	1		No
Benzo[b] fluoranthene	Cp = 0.310 * Cs	USEPA, 2005a	1		Yes
Benzo[k] fluoranthene	ln(Cp)= 0.8595 * ln(Cs) - 2.1579	USEPA, 2005a	1		No
Dibenz[a,h] anthracene	Cp = 0.13 * Cs	USEPA, 2005a	1		No
Indeno[1,2,3-cd] pyrene	Cp = 0.11 * Cs	USEPA, 2005a	1		No
Phenanthrene	ln(Cp)= 0.6203 * ln(Cs) - 0.1665	USEPA, 2005a	1		No

Notes: Of the COPCs, dermal absorption factors are available only for arsenic (0.03), cadmium (0.001), and PAHs (0.13), as described in the text section 7.2.2.4.2
Cs=Concentration in soil (mg/kg)
Cp=Concentration in plant tissue (mg/kg dry weight)

1. *Plant uptake equations (in dry weight) from USEPA, 2005a (Tables 4a and 4b); plant uptake factors from RAIS/ORNL, 2014*
2. *From Nov 2013 RSL table (USEPA, 2013), except where noted*
3. *Reported as 5-45% in humans (Handbook on the Toxicology of Metals. 3rd edition. Norberg et al., 2007)*
4. *USEPA, 2002b*

Table 7-7. Non-Cancer Toxicity Values

COPC	Chronic Oral Reference Dose (RfD) (mg/kg-day)	Primary Target Organ(s)	Uncertainty Factor(UF)/ Modifying Factor (MF)	Oral Absorption Efficiency for Dermal [5]	Absorbed RfD for Dermal (mg/kg-day)	Source [1]	Inhalation Reference Concentration (RfC) (mg/m^3)	Primary Target Organ(s)	Uncertainty Factor(UF)/ Modifying Factor (MF)	Source[1]
Aluminum	1.00E+00	nervous system	UF=100; MF=1	1	1.00E+00	PPRTV, from RSL table and USEPA, 2006a	5.00E-03	nervous system	UF=300; MF=1	PPRTV, from RSL table and USEPA, 2006a
Antimony	4.00E-04	hematological	UF = 1000; MF=1	0.15	6.00E-05	IRIS	NA			
Arsenic	3.00E-04	cancer: skin	UF = 3; MF=1	1	3.00E-04	IRIS	1.50E-05		NA	RSL table
Beryllium	2.00E-03	GI	UF = 300; MF=1	0.007	1.40E-05	IRIS	2.00E-05	beryllium sensitization and progression to chronic beryllium disease	UF=10; MF=1	IRIS
Cadmium	1.00E-03	kidney	UF = 10; MF=1	0.025	2.50E-05	IRIS	NA			IRIS
Chromium VI	3.00E-03	no effects observed	UF = 300 MF = 1	0.025	7.50E-05	IRIS	1.00E-04	respiratory effects	UF=300; MF=1	IRIS
Chromium III	1.50E+00	no effects observed	UF = 100; MF=1	0.013	1.95E-02	IRIS	NA			
Cobalt	3.00E-04	thyroid	UF=3000; MF=1	1	3.00E-04	PPRTV, from RSL table and USEPA, 2008b	6.00E-06	respiratory effects	UF=300; MF=1	PPRTV, from RSL table and USEPA, 2008b
Copper	4.00E-02	GI	NA	1	4.00E-02	HEAST, from RSL table	NA			
Iron	7.00E-01	GI	UF=1.5; MF=1	1	7.00E-01	PPRTV, from RSL table and USEPA, 2006b	NA			
Lead	NA	neurotoxicity, developmental delays, hypertension, impaired hearing acuity, impaired hemoglobin synthesis, and male reproductive impairment		1		NA[2]	NA			

Table 7-7. Non-Cancer Toxicity Values

COPC	Chronic Oral Reference Dose (RfD) (mg/kg-day)	Primary Target Organ(s)	Uncertainty Factor(UF)/ Modifying Factor (MF)	Oral Absorption Efficiency for Dermal [5]	Absorbed RfD for Dermal (mg/kg-day)	Source [1]	Inhalation Reference Concentration (RfC) (mg/m^3)	Primary Target Organ(s)	Uncertainty Factor(UF)/ Modifying Factor (MF)	Source[1]
Magnesium	NA	NA		1		not available in IRIS or RSL table	NA			
Manganese	1.40E-01	nervous system	UF = 1000; MF=1	1	1.40E-01	IRIS	5.00E-05	nervous system	UF = 1; MF=1	IRIS
Mercury[6]	3.00E-04	immune system	UF = 1000; MF=1	1	3.00E-04	IRIS	3.00E-04	nervous system	UF=30; MF=1	IRIS
Nickel[7]	2.00E-02	body weight	UF=300; MF=1	0.04	8.00E-04	IRIS	NA			
Selenium	5.00E-03	selenosis (liver, hair, nail effects)	UF=3; MF=1	1	5.00E-03	IRIS	NA			
Thallium[3]	NA	NA		1		Screening PPRTV	NA			
Vanadium	5.00E-03	kidney	UF=100; MF=1	0.026	1.30E-04	IRIS/RSL table[4]	NA			
Zinc	3.00E-01	hematological	UF = 3; MF=1	1	3.00E-01	IRIS	NA			

Notes: 1. Nov 2013 RSL Table or currently available in IRIS or specific references as noted.
2. HHRA will use the Integrated Exposure-Uptake Biokinetic Model (IEUBK) to evaluate soil lead concentrations, although the USEPA Office of Solid Waste recommends that soil lead levels less than 400 mg/kg are generally safe for residential use.
3. Screening chronic provisional RfD for soluble thallium (USEPA, 2012a) is available, but as a screening PPRTV, is not used in this HHRA, for the reasons outlined in the text (reference: USEPA, 2012. Provisional Peer-Reviewed Toxicity Values for Thallium and Compounds. Final, 10-25-2012).
4. The vanadium RfD is from the November 2013 RSL table, with the following explanation provided: The oral RfD toxicity value for Vanadium, used in this website, is derived from the IRIS oral RfD for Vanadium Pentoxide by factoring out the molecular weight of the oxide ion. Vanadium Pentoxide has a molecular weight of 181.88. The two atoms of Vanadium contribute 56% of the MW. Vanadium Pentoxide's oral RfD of 9E-03 mg/kg-day multiplied by 56% gives a Vanadium oral RfD of 5.04E-03 mg/kg-day. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/usersguide.htm).
5. Oral reference doses are converted to dermal reference doses by multiplying by the oral absorption efficiency (USEPA, 2004); oral absorption efficiency from USEPA RSL table (November, 2013), noted as being from U.S. EPA 2004 (Exhibit 4-1) (as in the RSL tables, if the oral absorption is >50% then it is set to 100% for the calculation of dermal toxicity values).
6. RfD for mercuric chloride
7. RfD for nickel soluble salts

1

Table 7-8. Cancer Toxicity Data

COPC	Oral Cancer Slope Factor (CSF) (mg/kg-day)$^{-1}$	Oral Absorption Efficiency for Dermal [3]	Absorbed CSF for Dermal (mg/kg-day)$^{-1}$	CSF Weight of Evidence	Source [1]	Inhalation Unit Risk (UR) (ug/m^3)$^{-1}$	Source[1]	Inhalation UR Weight of Evidence
Aluminum	NA		NA			NA		
Antimony	NA		NA			NA		
Arsenic	1.5	1	1.5	A (Human carcinogen - based on sufficient evidence from human data)	IRIS	4.30E-03	IRIS	A (Human carcinogen - based on sufficient evidence from human data)
Beryllium	NA		NA			2.40E-03	IRIS	B1 (Probable human carcinogen - based on limited evidence of carcinogenicity in humans)
Cadmium	NA		NA			1.80E-03	IRIS	B1 (Probable human carcinogen - based on limited evidence of carcinogenicity in humans)
Chromium VI	NA		NA			1.20E-02	IRIS	A (Human carcinogen) (Inhalation route)
Chromium III	NA		NA			NA		
Cobalt	NA		NA			9.00E-03	PPRTV, from RSL table and USEPA, 2008b	Likely to be carcinogenic to humans by the inhalation route[4]
Copper	NA		NA			NA		
Iron	NA		NA			NA		
Lead	NA		NA			NA		
Magnesium	NA		NA			NA		
Manganese	NA		NA			NA		
Mercury	NA		NA			NA		
Nickel	NA		NA			NA		
Selenium	NA		NA			NA		
Thallium	NA		NA			NA		
Vanadium	NA		NA			NA		
Zinc	NA		NA			NA		
Benzo(a) anthracene	7.30E-01	1	7.30E-01	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals) (from IRIS)	RSL table[2]	NA		
Benzo(a)pyrene	7.30E+00	1	7.30E+00	B2 (Probable human carcinogen - based on sufficient evidence of	IRIS	NA		

Table 7-8. Cancer Toxicity Data

COPC	Oral Cancer Slope Factor (CSF) $(mg/kg\text{-}day)^{-1}$	Oral Absorption Efficiency for Dermal [3]	Absorbed CSF for Dermal $(mg/kg\text{-}day)^{-1}$	CSF Weight of Evidence	Source [1]	Inhalation Unit Risk (UR) $(ug/m^3)^{-1}$	Source[1]	Inhalation UR Weight of Evidence
				carcinogenicity in animals) (from IRIS)				
Benzo(b)fluoranthene	7.30E-01	1	7.30E-01	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals) (from IRIS)	RSL table[2]	NA		
Benzo(k)fluoranthene	7.30E-02	1	7.30E-02	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals) (from IRIS)	RSL table[2]	NA		
Dibenz(a,h)anthracene	7.30E+00	1	7.30E+00	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals) (from IRIS)	RSL table[2]	NA		
Indeno(1,2,3-c,d) Pyrene	7.30E-01	1	7.30E-01	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals) (from IRIS)	RSL table[2]	NA		
Phenanthrene	NA	1	NA	D (Not classifiable as to human carcinogenicity)	IRIS	NA		

Notes: 1. USEPA RSL table dated November 2013

2. Noted in RSL table (Nov. 2013) as from: Environmental Criteria and Assessment Office

3. Oral slope factors are converted to dermal slope factors by dividing by the oral absorption efficiency; oral absorption efficiency from USEPA RSL table (November, 2013), noted as being from U.S. EPA 2004 (Exhibit 4-1) (as in the RSL tables, if the GIABS is >50% then it is set to 100% for the calculation of dermal toxicity values).

4. Under the 2005 Guidelines for Carcinogen Risk Assessment (U.S. EPA, 2005), cobalt sulfate (soluble) is described as “likely to be carcinogenic to humans by the inhalation route,” based on both the limited evidence of carcinogenicity in humans and sufficient evidence of carcinogenicity in animals. From: USEPA, 2008b. Provisional Peer Reviewed Toxicity Values for Cobalt (CASRN 7440-48-4). Superfund Health Risk Technical Support Center, National Center for Environmental Assessment, Office of Research and Development.

NA=not provided in IRIS or RSL table (USEPA sources) or COPC not known to be carcinogenic

Table 7-9. Risk Summary for Residential EUs

	Incidental Ingestion Pathway		**Dermal Contact Pathway**		**Outdoor Dust Inhalation Pathway**		**Home-Grown Vegetable Ingestion Pathway**		**Total Estimated Hazard Index or Cancer Risk**	
	CTE	**RME**	**CTE**	**RME**	**CTE**	**RME**	**CTE**	**RME**	**CTE**	**RME**
Non-Cancer Hazard Indices - AOI 9										
Current *Surface Soils (0 - 2 feet bgs)*										
Current Outdoor Worker	0.01	0.2	NA	NA	0.002	0.004	NA	NA	0.01	0.2
Current Resident (Adult)	0.05	0.3	NA	NA	0.06	0.2	0.01	0.1	0.1	0.6
Current Resident (Child)	0.5	**3.5**	NA	NA	0.06	0.2	0.02	0.3	0.6	**4.0**
Future *Mixed Soils (0 - 10 feet bgs)*										
Future Outdoor Worker	0.01	0.2	NA	NA	0.002	0.004	NA	NA	0.01	0.2
Future Resident (Adult)	0.05	0.3	NA	NA	0.05	0.2	0.01	0.1	0.1	0.6
Future Resident (Child)	0.5	**2.9**	NA	NA	0.05	0.2	0.02	0.3	0.6	**3.3**
Future Construction Worker	0.01	0.6	NA	NA	0.002	0.004	NA	NA	0.009	0.6
Estimated Incremental Cancer Risks - AOI 9										
Current *Surface Soils (0 - 2 feet)*										
Current Outdoor Worker	NA	NA	NA	NA	2.2E-9	1.5E-8	NA	NA	2E-9	2E-8
Current Resident (Adult)	NA	NA	NA	NA	1.0E-7	4.6E-7	NA	NA	1E-7	5E-7
Current Resident (Child)	NA	NA	NA	NA	5.1E-8	1.4E-7	NA	NA	5E-8	1E-7

Table 7-9. Risk Summary for Residential EUs

	Incidental Ingestion Pathway		Dermal Contact Pathway		Outdoor Dust Inhalation Pathway		Home-Grown Vegetable Ingestion Pathway		Total Estimated Hazard Index or Cancer Risk	
	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Future *Mixed Soils (0 - 10 feet)*										
Future Outdoor Worker	NA	NA	NA	NA	2.2E-9	1.8E-8	NA	NA	2E-9	2E-8
Future Resident (Adult)	NA	NA	NA	NA	1.0E-7	5.3E-7	NA	NA	1E-7	5E-7
Future Resident (Child)	NA	NA	NA	NA	5.2E-8	1.6E-7	NA	NA	5E-8	2E-7
Future Construction Worker	NA	NA	NA	NA	1.4E-10	7.0E-10	NA	NA	1E-10	7E-10
Notes: NA=pathway not applicable to receptor; pathway not non-carcinogenic or not carcinogenic; or no dermal absorption values are recommended. Numbers are rounded in this table, and thus, may not be precisely additive.										
Non-Cancer Hazard Indices - Spaulding-Rankin										
Current *Surface Soils (0 - 2 feet)*										
Current Outdoor Worker	0.02	0.5	0.002	0.007	0.003	0.009	NA	NA	0.02	0.5
Current Resident (Adult)	0.1	0.7	0.002	0.01	0.1	0.3	0.05	1	0.3	**2.1**
Current Resident (Child)	1	**7.9**	0.01	0.08	0.1	0.3	0.1	**2.2**	1	**10**
Future *Mixed Soils (0 - 10 feet)*										
Future Outdoor Worker	0.001	0.5	0.01	0.03	0.003	0.008	NA	NA	0.01	0.5
Future Resident (Adult)	0.1	0.7	0.002	0.01	0.1	0.3	0.1	1	0.3	**2**
Future Resident (Child)	1	**7.5**	0.01	0.06	0.1	0.3	0.1	**2.2**	**1**	**10**
Future Construction Worker	0.02	1	0.001	0.006	0.003	0.008	NA	NA	0.02	1

Table 7-9. Risk Summary for Residential EUs

	Incidental Ingestion Pathway		Dermal Contact Pathway		Outdoor Dust Inhalation Pathway		Home-Grown Vegetable Ingestion Pathway		Total Estimated Hazard Index or Cancer Risk	
	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Estimated Incremental Cancer Risks - Spaulding-Rankin										
Current *Surface Soils (0 - 2 feet)*										
Current Outdoor Worker	6.0E-8	8.9E-6	7.4E-8	1.1E-6	6.5E-9	6.8E-8	NA	NA	1E-7	1E-5
Current Resident (Adult)	5.7E-7	1.1E-5	1.7E-7	1.4E-6	3.0E-7	2.0E-6	8.0E-7	4.1E-5	2E-6	6E-5
Current Resident (Child)	3.1E-6	3.5E-5	4.9E-7	2.9E-6	1.5E-7	6.1E-7	7.4E-7	2.5E-5	4E-6	6E-5
Future *Mixed Soils (0 - 10 feet)*										
Future Outdoor Worker	4.6E-8	6.4E-6	5.7E-8	8.1E-7	6.7E-9	6.2E-8	NA	NA	1E-7	7E-6
Future Resident (Adult)	4.4E-7	8.0E-6	1.3E-7	1.0E-6	3.1E-7	1.9E-6	6.2E-7	3.0E-5	2E-6	4E-5
Future Resident (Child)	2.4E-6	2.6E-5	3.8E-7	2.1E-6	1.6E-7	5.6E-7	5.7E-7	1.8E-5	3E-6	5E-5
Future Construction Worker	2.9E-9	8.5E-7	3.6E-9	3.2E-8	4.2E-10	2.5E-9	NA	NA	7E-9	9E-7
Non-Cancer Hazard Indices - Spaulding-Rankin Outliers (Maximums)										
Current *Surface Soils (0 - 2 feet)*										
Current Outdoor Worker	0.08	1	0.03	0.05	0.01	0.02	NA	NA	0.1	1
Current Resident (Adult)	0.5	**2.2**	0.04	0.07	0.3	0.7	0.4	**4.3**	1	**7.4**
Current Resident (Child)	**5.4**	**24**	0.2	0.5	0.3	0.7	0.7	**8.8**	**6.7**	**34**

Notes: NA=pathway not applicable to receptor; pathway not non-carcinogenic or not carcinogenic; or no dermal absorption values are recommended.

Future *Mixed Soils (0 - 10 feet)*										
Future Outdoor Worker	0.005	1.9	0.3	0.5	0.01	0.02	NA	NA	0.3	2.4
Future Resident (Adult)	0.7	**2.9**	0.05	0.09	0.4	0.9	0.4	**5.1**	**1.6**	**9.0**
Future Resident (Child)	**7.1**	**31**	0.3	0.6	0.4	0.9	0.8	**10**	**8.6**	**43**
Future Construction Worker	0.1	**6.1**	0.03	0.06	0.01	0.02	NA	NA	0.1	1
Estimated Incremental Cancer Risks - Spaulding-Rankin Outliers (Maximums)										
Current *Surface Soils (0 - 2 feet)*										
Current Outdoor Worker	9.6E-07	5.4E-05	1.2E-06	6.8E-06	3.3E-08	1.9E-07	NA	NA	2E-06	6E-05
Current Resident (Adult)	9.2E-06	6.7E-05	2.7E-06	8.5E-06	1.5E-06	5.5E-06	1.3E-05	**2.5E-04**	3E-05	**3.3E-04**
Current Resident (Child)	4.9E-05	**2.2E-04**	7.9E-06	1.7E-05	7.6E-07	1.7E-06	1.2E-05	**1.5E-04**	7E-05	**3.9E-04**
Future *Mixed Soils (0 - 10 feet)*										
Future Outdoor Worker	9.6E-07	5.4E-05	1.2E-06	6.8E-06	4.7E-08	2.7E-07	NA	NA	2E-06	6E-05
Future Resident (Adult)	9.2E-06	6.7E-05	2.7E-06	8.5E-06	2.2E-06	7.9E-06	1.3E-05	**2.5E-04**	3E-05	**3.4E-04**
Future Resident (Child)	4.9E-05	**2.2E-04**	7.9E-06	1.7E-05	1.1E-06	2.4E-06	1.2E-05	**1.5E-04**	7E-05	**3.9E-04**
Future Construction Worker	6.0E-08	7.1E-06	7.5E-08	2.7E-07	2.9E-09	1.1E-08	NA	NA	1E-07	7E-06
Notes: NA=pathway not applicable to receptor; pathway not non-carcinogenic or not carcinogenic; or no dermal absorption values are recommended.										

7.3 Quantitative HHRA – Southern AU EU

7.3.1 Overview

This section presents the quantitative HHRA for the Southern AU EU.

7.3.1.1 Objectives and Scope

The objectives of the HHRA for the Southern AU EU are the same as those for the residential EUs, that is, to ensure that all potential human health risks that may remain at this location are evaluated by conducting a site-specific quantitative risk assessment. For the receptors present, the HHRA estimates the magnitude of exposure to COPCs, identifies potential exposure pathways, and quantifies exposures. This information, in conjunction with toxicity information for the COPCs, is used to quantitatively estimate the risks posed to human receptors associated with exposure to the COPCs in soil at each residential site. This HHRA was conducted in accordance with the *Final SVFUDS Site-Wide Human Health Risk Assessment Work Plan* (USACE, February 2014). This HHRA does not address explosive hazards that may exist due to the presence of ordnance; those hazards are addressed separately in the MEC Hazard Assessment (Section 7.6). USEPA RAGS Part D (USEPA, 2001) table formats were used in the HHRA text and appendices when applicable.

7.3.1.2 Summary of Data Used in the Risk Assessment

The sample data sets used in this HHRA are described in Section 7.2.1.2. Data for the Southern AU EU are summarized in tables in Appendix E-1.

7.3.1.3 COPC Selection Process

The COPC selection process is described in Section 7.2.1.3. The COPCs for the Southern AU EU are shown in Table 7-10.

7.3.1.4 Additional Screen for Outlier Locations

As described in Section 7.2.1.4, where an outlier was determined, that sample location was removed from the data set and the EU was separately evaluated in this HHRA using the remaining samples. For the Southern AU EU, eight samples from six discrete locations were identified as outliers. Each of these six discrete outlier locations is evaluated separately for risk (i.e., a risk determination is made about that discrete location) in this HHRA. The COPCs for the outlier locations are shown in Table 7-11.

The referenced tables are presented at the end of Section 7.3.

7.3.2 Exposure Assessment

The objectives of the exposure assessment are to characterize the exposure setting, identify potentially exposed populations and potential exposure pathways, and quantify the exposures to potential human receptors at the site. The potentially exposed populations, exposure media, and exposure pathways are presented in the CSM.

7.3.2.1 Conceptual Site Model

The development of a CSM for this HHRA was described in Section 7.2.2.1. The CSM for the Southern AU EU takes into account that the area is an active university campus with no full time permanent residences and is defined by previous areas of investigation at this location. Suspected sources and types of contaminants present, contaminant release and transport mechanisms, and affected media are described in more detail in Section 1.6. Previous investigations at the SVFUDs have shown that past activities have impacted surface and subsurface soil. There are no surface water and sediment locations at this EU.

7.3.2.2 Potential Receptors

Potential human receptors are defined as individuals who may be exposed to site-related contaminants in environmental media. Consistent with USEPA (1989) guidance, current and reasonably anticipated future land uses were considered in the receptor selection process.

7.3.2.2.1 Southern AU EU

This EU is defined by previous areas of investigation conducted at AU. It is an active university campus with no full time permanent residences, and the EU boundary defines an area with common receptors and exposure pathways. The Southern AU EU combines the area addressed in the USEPA 2000 HHRA, and POI AU and portions of POIs 24 and 53 addressed in the USACE 1995 and USEPA 1999 HHRAs. However, the southeastern reaches of the POI AU and USEPA 2000 footprints are not included as that acreage is covered under the previously completed OU-4 AU Lot 18 and AU PSB HHRAs (see Section 7.1.1).

As a currently active university campus, current groups that may contact surface soil include:

- Outdoor workers (i.e., landscapers and maintenance); and
- Student recreational users (as associated with a 4-year college student).

Future exposures to surface/subsurface soil for the following receptors are evaluated:

- Outdoor workers;
- Student recreational users;
- Construction workers, and
- Adult and child residents, if residences were to be built on the AU campus.

7.3.2.3 Potential Exposure Pathways

Two different soil exposure intervals were evaluated. The current potential residential receptors were evaluated using an exposure interval of 0 to 2 feet bgs, to represent routine landscaping, gardening, and outdoor play activities. The soil exposure interval for future potential receptors includes mixed soils from 0 to 10 feet bgs, which includes the 0 to 2 foot interval to which current receptors could be exposed. This exposure interval takes into account soil mixing that may occur due to construction.

Outdoor workers and students spending time outdoors could be exposed to surface soil (0 to 2 foot interval) by incidental soil ingestion, dermal contact, and inhalation. The vegetable ingestion exposure pathway is included for the 0 to 2 foot depth for current students and for the 0 to 10 foot depth for future students to account for any gardening that may be occurring on campus, although the frequency of consumption of home-produced vegetables on the campus is uncertain.

In the future, construction workers, outdoor workers, and students using outdoor areas could be exposed to mixed surface/subsurface soil (0 to 10 foot interval) by incidental soil ingestion, dermal contact, and inhalation outdoors. Also, possible future exposures to mixed surface/subsurface soil for students and future residents are evaluated, and include the exposure pathways of incidental soil ingestion, dermal contact, inhalation outdoors, home-grown vegetable ingestion, and inhalation of vapors indoors for the COPCs that meet the USEPA criteria for volatility.

7.3.2.4 Exposure Assumptions

As described previously in Section 7.2.2.4, USEPA (1992, 1995) typically requires two types of exposure evaluations: an RME and an average, or CTE, estimate. All exposure factors used in the Southern AU EU HHRA are the same as those listed in Section 7.2.2.4 for the residential EUs, with the addition of a student scenario, which applies many of the same factors as used for an adult resident. For a college student, a four-year exposure period is assumed for both the RME and the CTE scenarios.

Exposure factors for the student scenario may be found in Table 7-12.

7.3.2.5 Estimation of Intake

The calculation of CDIs, taking into account appropriate exposure variables, is described in Section 7.2.2.5.

7.3.3 Toxicity Assessment

The toxicity assessment approach and parameters are the same as those for the residential EUs presented in Section 7.2.3. The toxicity values used in this HHRA are listed in Tables 7-7 and 7-8.

7.3.4 Risk Characterization

Following USEPA (1995) guidance, the risk characterization step integrates the toxicity and exposure assessment outputs into quantitative expressions of risk. Table 7-13 presents the estimated risks for the Southern AU EU and Table 7-14 presents the estimated risks for the AU outlier locations.

Risk calculations for the AU EU may be found in Appendix Tables E-7.3A though E-7.3G. Each individual COPC-specific HI is shown in Appendix E-8. The risk results listed below describe the COPC-specific HIs from Appendix E-8 only when they are greater than one.

The target organ assessments are shown in Appendix E-8. Target organ analysis for the COPCs in the Southern AU EU indicates that the majority of non-cancer COPCs have different target organs, except for aluminum and manganese, for which the RfDs are both based on nervous system effects. If the target organ-specific HI for aluminum and manganese is less than or equal to one, there are unlikely to be nervous system effects.

7.3.4.1 Non-Cancer Hazard Assessment Southern AU EU (excluding outlier locations)

The approach to non-cancer hazard assessment is the same as that for the residential EUs, described in Section 7.2.4.1. For the Southern AU EU current scenarios, all total HIs are less than or equal to one.

- Current outdoor worker:
  - CTE HI=0.01; RME HI=0.2.
- Current student:
  - CTE HI=0.1; RME HI=0.5.

For the Southern AU EU future scenarios, non-cancer results are summarized below. Only cobalt has an HI greater than one, for the future child resident scenario:

- Future outdoor worker:
  - CTE HI=0.01; RME HI=0.2.
- Future student:
  - CTE HI=0.1; RME HI=0.6.
- Future adult resident:
  - CTE HI=0.1; RME HI=0.9.
  - The total RME HI for nervous system effects (aluminum and manganese) is 0.2, indicating that these effects are not likely for potential future resident adults exposed to soil at the Southern AU EU.
- Future child resident:
  - CTE HI=0.7; RME HI=4.8.
  - Total COPC-specific RME HI for cobalt = 2.5 (Appendix Table E-8.3D).
    - The CTE total HI for cobalt for this receptor, using more realistic exposure assumptions, is 0.3. Based on a statistical comparison to background (USACE, 2013f), cobalt at AU is greater than background.
  - The total RME HI for nervous system effects (aluminum and manganese) is equal to 0.6, indicating that these effects are not likely for potential future resident children exposed to soil at the Southern AU EU.
- Future construction worker: CTE HI=0.01; RME=0.8.

7.3.4.2 Carcinogenic Risk Characterization Southern AU EU (excluding outlier locations)

The carcinogenic risk characterization process is the same as described for the residential EUs in Section 7.2.4.2. Table 7-13 presents the estimated cancer risks for the Southern AU EU and Appendix E-8 shows the COPC-specific estimated risks.

For all current and future scenarios, the estimated carcinogenic risks for the Southern AU EU are within or less than USEPA's acceptable incremental risk range. The calculation of a combined adult/child carcinogenic risk (as presented in Appendix E-4) indicates that these results are in the same order of magnitude as the separately calculated child and adult risks.

7.3.4.3 AU Outlier Locations Risk Characterization

Each outlier location has one or two associated samples (see Appendix E-2). To evaluate potential risks at the six AU outlier locations (see Figure 5 of the Risk Assessment Work Plan), hazard indices and cancer risks were calculated using CTE and the RME exposure assumptions with the maximum detected outlier concentration (regardless of the location or depth of the sample), as well as with the next highest concentration (tables labeled as "AU Outlier Locations - Concentration Next to Maximum" in the Appendix E-7 tables). For both outdoor worker and student scenarios, it was assumed that current and future soil contact with the outlier locations would be the same. Table 7-14 presents the estimated risks for the maximum detected AU outlier concentrations for the CTE and the RME scenarios (risk calculation tables E-7.4A though E-7.4E in Appendix E-7). Although unacceptable risks may be associated with the maximum available outlier concentration, this does not necessarily mean that each outlier location is associated with unacceptable risks. Therefore, the specific risks associated with each outlier location are discussed in the following summary, however, the results for the outlier concentration next to maximum (second highest result) are only discussed if the maximum detected outlier concentration resulted in an unacceptable risk. At the six outlier locations, only beryllium and iron have the same target organ, the gastro-intestinal (GI) system. Because iron is an essential element, and, in general, is not a focus of the HHRA, and because each of the other COPCs has a different target organ, target organ analysis did not need to be further assessed for the six outlier locations.

Non-Cancer Hazards

For the maximum detected value from all of the AU outlier locations, the non-cancer results are as follows:

- Outdoor worker: CTE HI=0.03; RME HI=0.5.
- Construction worker: CTE HI=0.03; RME HI=1.8, although all individual COPC-specific total HIs across all exposure pathways for this receptor are < 1.
- Student: CTE HI=0.4; RME HI=1.
- Future adult resident:
    - CTE HI=0.6; RME HI=4.7, based primarily on an RME vegetable ingestion pathway HI=3.7. Except for mercury, all individual COPC-specific total HIs across all pathways for this receptor are <1. Mercury (from SV-AU05 at a concentration of 9.74 mg/kg) has a COPC-specific RME total HI=3.5 for this receptor (Appendix Table E-8.4B) based primarily on the vegetable ingestion exposure pathway, although the CTE HI for mercury is <1.
    - The next highest mercury concentration is from the only other outlier location with mercury as a COPC, SV-04, with a mercury concentration of 2.3 mg/kg; applying that concentration to the future adult resident scenario results in a COPC-specific RME total HI< 1 for mercury (Appendix Table E-8.4B).
- Future child resident:
    - CTE HI=2.7; RME HI=17, based primarily on an RME soil ingestion pathway HI=9.0 (mainly from cobalt, iron, and vanadium) and an RME vegetable ingestion pathway HI=7.7 (mainly from mercury).
        - Cobalt (54.5 mg/kg) has a COPC-specific RME total HI=2.5 across all exposure pathways, iron (135,000 mg/kg) has a COPC-specific RME total HI=2.7 across all exposure pathways, and vanadium (627 mg/kg) has a COPC-specific RME total HI=1.8 across all exposure pathways (all from the AU-03 and SV-AU-03 outlier location) (Appendix Table E-8.4C). The CTE total HI for cobalt for this receptor, using more realistic exposure assumptions, is 0.6 and for vanadium is 0.4. The CTE total HI for iron for this receptor, using more realistic exposure assumptions, is 0.6. Also, iron is an essential element and is not considered an important non-cancer hazard.
        - Mercury (9.74 mg/kg from the SV-AU-05 location) has a COPC-specific

RME total HI=7.5 across all exposure pathways, although the CTE total HI for mercury is <1 (Appendix Table E-8.4C).

- Using the next highest outlier concentrations for cobalt (32.7 mg/kg), iron (46,900 mg/kg), mercury (2.3 mg/kg), and vanadium (105 mg/kg) (concentrations from several different outlier locations), results in a total HI=4.6 for the future child resident. Although all individual COPC HQs are $\leq$1, the COPC-specific total HI for cobalt across all exposure pathways for this receptor is =1.5, slightly higher than 1. The potential hazards associated with this slight exceedance in soil at this single location are likely to be minimal.

Cobalt, iron, and vanadium at the AU-03 and SV-AU-03 outlier location are associated with non-cancer HIs greater than 1. For the reasons noted above, further action at the AU-03 and SV-AU-03 outlier location based on iron is not proposed. However, further action based on cobalt and vanadium at the outlier location AU-03 and SV-AU-03 should be considered.

In addition, mercury at the SV-AU-05 outlier location results in an HI greater than 1. Therefore, further action for mercury at the outlier location SV-AU-05 should be considered.

Cancer Risks

Using the maximum detected value from all of the Southern AU EU outlier locations, the estimated incremental cancer risks are based primarily on the carcinogenic PAHs, which are COPCs at the Baker-03 and SV-Baker-03 outlier location only:

- For the outdoor worker, student, and construction worker scenarios, the estimated incremental cancer risks do not exceed the level of concern (1×10^{-4}).
- For the theoretical future resident adult, using the Southern AU Baker-03 and SV-Baker-03 outlier location concentrations, the total estimated RME cancer risk is 1.8×10^{-4}, due primarily to PAHs.
- For the theoretical future resident child at the Southern AU EU Baker-03 and SV-Baker-03 outlier location concentrations, the total estimated RME cancer risk is 1.5×10^{-4}, due primarily to PAHs.

The carcinogenic PAHs at the Southern AU EU Baker-03 and SV-Baker-03 location are associated with a potential for unacceptable incremental cancer risk. Therefore, further action for carcinogenic PAHs at this location should be considered.

Note that for these outlier locations, which consist of only one or two samples, statistical comparisons to background cannot be made.

7.3.4.4 Results of the Vapor Intrusion Model

Mercury and benzo(b)fluoranthene are COPCs with sufficient volatility to consider with respect to vapor intrusion (as described in more detail in Appendix E-5). The potential HIs due to vapor intrusion calculated by the Johnson-Ettinger model are less than 1 for mercury, and the carcinogenic risks for benzo(b)fluoranthene are below the level of concern. The model is designed as a screening-level tool with many conservative assumptions, such as assuming a small house size, which would tend to over-estimate exposures for larger buildings, such as those that exist on the AU campus. The potential carcinogenic risks associated with vapor intrusion for benzo(b)fluoranthene are below the USEPA acceptable incremental cancer risk range.

7.3.4.5 Qualitative Assessment of Indoor Dust Inhalation

The USEPA IEUBK lead model guidance uses, as a default, 30% of the outdoor air lead concentration to calculate indoor air concentrations. Based on this infiltration rate, which would result in 30% lower indoor air concentrations of COPCs, and the low risk results for outdoor dust inhalation, it is not likely that dust infiltration to indoor air will result in risks of concern.

7.3.5 Uncertainty Discussion

All HHRAs involve the use of assumptions, judgments, and imperfect data to varying degrees resulting in uncertainties in the final estimates of risk. These uncertainties are generally associated with each step of the process (USEPA, 1989). The parameters used in the HHRA are characteristically conservative and tend to over-estimate potential site-related risks. This uncertainty section qualitatively discusses the inherent and site-specific uncertainties associated with the HHRAs for residential and American University EUs.

1. Data Evaluation and Identification of COPCs:

    - Representative soil sampling at a site is based on the assumption that a sufficient number of samples have been collected to adequately characterize the site. However, not every sample was analyzed for every constituent and this represents an uncertainty in characterizing the site.
    - All data used from all investigations were validated in accordance with USEPA procedures. All data were found to be usable for making project decisions (no rejected results were used).
    - The generic screening levels used for selection of COPCs are appropriately conservative. However, the assumptions that form the RSLs may not be appropriate for each site. In addition, some of the screening values are based on PPRTVs, which adds uncertainty to their derivation, as discussed in more detail below.

2. Exposure Assessment:

    - Overall, the selection of conservative exposure assumptions for the RME scenario results in upper bound (i.e., high end) estimates of exposures and risks, while it is most likely that the majority of the population have lower exposures and risks. However, the presentation of these high end exposure and risk estimates are balanced by the presentation of CTE (i.e, average) exposures and risks, which are more realistic for each site.
    - The possible existence of the condition known as pica (i.e., the deliberate ingestion of soils) in children, as opposed to incidental ingestion of soil, could result in an under-estimate of risks for children.
    - USEPA (2002a) does not provide guidance on estimating dust emissions from lawn mowing, leaf blowing, soil tilling, or similar activities, therefore, outdoor workers were assumed to be exposed to the same level of dust as were residents. The PEF used was selected to be consistent with the USEPA risk assessment guidance documents for Superfund. For a small site, the USEPA default PEF was appropriate to estimate the exposure for an outdoor worker. However, site-specific PEFs may be higher than the

default level based on site-specific activities. Therefore, outdoor worker exposures to dusts at the sites may have been underestimated; however, outdoor workers would have sporadic and infrequent exposures.

- The Johnson and Ettinger Model was developed for use as a screening level model and, consequently, is based on a number of simplifying assumptions regarding contaminant distribution and occurrence, subsurface characteristics, transport mechanisms, and building construction. The following parameters add uncertainty to the vapor intrusion assessment (USEPA, 2002b; USEPA, 2005b): mixing height, building air exchange rate, crack width, soil properties, and chemical properties. The use of default values, although appropriate for a typical residence, adds uncertainty to the assessment.
- Oral absorption factors are not available for all COPCs. In some cases an oral absorption factor of 1 was used in the vegetable ingestion pathway, which may overestimate uptake of the metal from vegetables.
- Arsenic can exist in a variety of forms in soils. The form of arsenic in soil could influence its bioavailability and its toxicity. Risk assessments and regulatory guidelines make the simplifying and conservative assumption that all arsenic in soil is present as inorganic arsenic (arsenate or arsenite), estimate risks based on total arsenic content, and assume 100% bioavailability. However, arsenic has reduced bioavailability in soil, thereby affecting its toxicity. This reduction in bioavailability is primarily a function of the presence of less soluble mineral phases and ionic forms that are strongly adsorbed to soil particles or co-precipitated with other elements in soil (NAVFAC, 2000). Arsenic bioavailability from soil is not taken into account in this HHRA review or in previous HHRAs. That is, all arsenic in soil at the SVFUDS is assumed to be 100% bioavailable, which would tend to greatly overestimate the risk due to soil ingestion of arsenic. Note that on December 31, 2012, an Office of Solid Waste and Emergency Response (OSWER) Directive was released recommending a relative bioavailability factor of 60% for arsenic in soil (in the absence of site-specific data) (USEPA, 2012b); the previous USEPA default value was 100%.
- Generic plant uptake factors or equations were used to estimate the concentrations of COPCs in vegetables grown at the site. However, bioaccumulation from soil to plants is dependent on multiple factors, including soil pH, metal species present in the soil, plant species, part of the plant measured/consumed, etc. Thus, the predicted concentrations in vegetables presented here are subject to uncertainty. Also, it is assumed that all types of vegetables (e.g., leafy, root, or fruit) have the same uptake fraction, even though some may have lower or higher uptake fractions.
- The RME vegetable ingestion pathway assumptions are conservative. In particular, it is assumed that all receptors at the residential and Southern AU EUs obtain 25% of their vegetables from a home garden, although not all Spring Valley receptors have home vegetable gardens.

3. Toxicity Assessment:

- All published toxicity values have associated uncertainties, which are commonly addressed by USEPA with the application of uncertainty or modifying factors. For example, for the chromium III RfD, the following uncertainty and modifying factors are applied: an uncertainty factor of 100 representing two 10-fold decreases in the daily dose that account for both the expected inter-human and interspecies variability to the toxicity of the chemical in lieu of specific data, and a modifying factor of 10 to reflect database deficiencies including the lack of a study in a non-rodent mammal and lack of unequivocal data evaluating reproductive impacts.

- The use of PPRTVs for aluminum, cobalt, iron, and vanadium: PPRTVs are derived for use in the Superfund Program after a review of the relevant scientific literature, an internal review, and an independent external peer review by three scientific experts. This review process is less rigorous than that which occurs for toxicity values published in IRIS. Thus, although the PPRTVs aluminum, cobalt, iron, and vanadium are not "screening" values and are used in the HHRA, they have additional uncertainties associated, as outlined in the individual PPRTV documents for aluminum, cobalt, iron, and vanadium.
- For cobalt, confidence in the principal study is low-to-medium (USEPA, 2008b). In the key study used as the basis of the RfD, there were several deficiencies, including the fact that only a single dose level was evaluated, and therefore a no observed adverse effects level (NOAEL) for the thyroid effect (decreased iodine uptake) was not identified. USEPA (2008b) noted that, although other studies regarding the cobalt/thyroid impact were available, the critical details of these studies were unavailable for their assessment. Therefore, USEPA (2008b) concluded that a temporal relationship between oral cobalt exposure and increased severity of thyroid effects in humans (or experimental animals) was not clear, based upon available data. Thus, USEPA (2008b) set a low confidence level in the provisional subchronic and chronic RfDs results. In addition, the USEPA (2008b) PPRTV document does not discuss the fact that the RfD is close to the range of typical dietary exposures to cobalt.
- PPRTVs that are classified as "screening" are considered less well-supported and are approved for use only in a screening assessment (USEPA, 2013a). The PPRTV for thallium, for which only a screening PPRTV was available, is not used in the HHRA. The lack of a toxicity value for thallium means that the potential risks due to exposure to thallium in soil are not quantified, potentially leading to an under-estimate of risk. The potential effects of exposure to thallium in soil are outlined in the risk characterization section.
- The assumption that chromium in soil is chromium III and the use of the chromium III toxicity values adds uncertainty to the toxicity assessment. However, in previous investigations, chromium VI has been analyzed, but has not often been detected. It is a reasonable assumption that chromium in soil is chromium III; there are no known sources of chromium VI based on AUES activities. Further, Kimbrough et al., 1999, concluded that most naturally occurring chromium is trivalent (III). Therefore, it is likely that trivalent chromium is the predominant species at the site.
- COPCs without toxicity values were not quantified in the HHRA, therefore, total site risks may be underestimated.

4. Risk Characterizations:

- There are uncertainties associated with summing risks or hazard indices for several substances (i.e., the assumption of dose additivity), however, the risks are not necessarily additive; e.g., the risks could be synergistic or even antagonistic. The potential for interactions between multiple chemicals, multiple pathways and other combinations was not evaluated quantitatively.

- The chemical risk calculations include the risk associated with exposure to all COPCs evaluated at a site. When the non-carcinogenic hazard quotient is greater than 1, potential target organ effects were considered. Only those chemicals that affected the same target organ, as indicated by the critical study for calculating the RfD, were considered to have a cumulative toxicity. This assumption may tend to underestimate the hazard, should a chemical effect multiple target organs not represented in the critical study or should there by synergistic effects among the COPCs.

7.3.6 <u>Conclusions and Recommendations</u>

Southern AU EU (excluding outlier locations)

Based on the results of the HHRA for the Southern AU EU, the estimated non-cancer HI was greater than one for the future resident child RME scenario for cobalt in soil (HI=2.5), and a statistical comparison to background shows that cobalt in soil at this EU is greater than background. Consequently, further action at the Southern AU EU based on cobalt is warranted.

However, cobalt is an essential element in the diet and is a natural element found throughout the environment. There is also considerable uncertainty associated with the provisional toxicity value used to estimate the cobalt non-cancer hazards, as described in more detail in Section 7.3.5, and the RME scenario uses very conservative assumptions, resulting in an estimate of exposure for the 95th percentile of the potentially exposed population; note that the CTE HI (using average exposure assumptions) for cobalt for the future resident child scenario at the Southern AU EU was $\leq$1.

For these reasons, while further action based on cobalt is warranted, USACE proposes a cobalt HI of $\leq$2 as an appropriate RAO. For the derivation of the cobalt RfD, a very large uncertainty factor of 3000 was applied to the oral RfD, reflecting toxicity data limitations and to ensure protectiveness. USEPA's confidence in the principal study behind the RfD is low to medium, and the practical implication is that the RfD is set at such a low value that true risk tends to be exaggerated. When this extra low RfD value is combined with the RME scenario (which uses very conservative assumptions resulting in an estimate of exposure at the high end for exposed receptors), the resulting risk estimates may be artificially high. However, the COPC-specific RME estimated non-cancer HI was >2 for cobalt in soil for the future resident child scenario, and accordingly, using this proposed RAO, further action based on cobalt is recommended

With regard to cancer risks, all estimated incremental cancer risks are below the level of concern.

<u>**Based on these results, for the Southern AU EU (excluding outlier locations), cobalt is a COC that poses unacceptable risks, and follow-on actions are required to address it.**</u>

Outlier Locations within the Southern AU EU

For the outlier locations at the Southern AU EU, several locations are associated with unacceptable risks:

- Mercury at the SV-AU-05 outlier location results in an RME HI greater than 1, based on future adult and child residential use, and it is considered a COC.

- Vanadium at the AU-03 and SV-AU-03 outlier location results in an RME HI greater than 1, based on future child residential use, and it is considered a COC.
- Although iron resulted in an HI greater than one at the AU-03 and SV-AU-03 outlier location, because iron is an essential element, further action for the Southern AU EU outlier locations based on iron is not proposed.
- Cobalt at the AU-03 and SV-AU-03 outlier location resulted in an HI greater than 2 based on the future child resident scenario, and it is considered a COC.
- At the BAKER-03 and SV-BAKER-03 Southern AU outlier location, for the theoretical future resident adult, the total estimated RME cancer risk is 1.8 x 10^{-4}, and for the theoretical future resident child, the total estimated RME cancer risk is 1.5 x 10^{-4}, based mostly on the carcinogenic PAHs in the vegetable ingenstion pathway. Although no individual COC exceeds 1 x 10^{-4}, the carcinogenic PAHs at this outlier location are considered to be COCs.

Based on these results, for the Southern AU EU outlier locations, mercury, vanadium, cobalt, and the carcinogenic PAHs are COCs that pose unacceptable risks, and follow-on actions are required to address them.

Table 7-10. Chemicals of Potential Concern for Southern AU EU

COPC	**Southern AU EU** (with outliers removed)
Aluminum	YES
Antimony	YES
Arsenic	YES
Cobalt	YES
Iron	YES
Magnesium	YES
Manganese	YES
Mercury	YES
Nickel	YES
Thallium	YES
Vanadium	YES
Benzo(a)anthracene	YES
Benzo(a)pyrene	YES
Benzo(b)fluoranthene	YES

Notes:
COPCs were determined in the initial screen in the Addendum 1 to the Pre-2005 HHRA Review report (USACE, 2013f).
YES means this chemical is a COPC for this EU.

Table 7-11. Chemicals of Potential Concern in Outlier Samples for Southern AU EU

COPC	***Outlier Sample Location Name*** SV-04 (1 sample)	SV-AU-05 (1 sample)	AU-10 (1 sample)	SV-12A (1 sample)	AU-03 and SV-AU-03 (2 samples)	BAKER-03 and SV-BAKER-03 (2 samples)
Aluminum				YES	YES	
Antimony			YES		YES	YES
Beryllium				YES		
Cobalt	YES		YES	YES	YES	
Iron			YES	YES	YES	
Magnesium				YES	YES	
Mercury	YES	YES				
Thallium					YES	
Vanadium			YES	YES	YES	
Benzo(a)anthracene						YES
Benzo(a)pyrene						YES
Benzo(b)fluoranthene						YES
Benzo(k)fluoranthene						YES
Dibenz(a,h)anthracene						YES
Indeno(1,2,3-c,d)pyrene						YES
Phenanthrene						YES

Notes:
COPCs were determined in the initial screen in the Addendum 1 to the Pre-2005 HHRA Review report (USACE, 2013f).
YES means this chemical is a COPC for this outlier location.

Table 7-12. Exposure Factors for the AU Student Exposure Scenario

Exposure Variable	Scenario [a/]	Rationale	Reference
BW = Body Weight 80 kg [b/]	RME and CTE	Standard reference weight for adult males.	USEPA, 2014
EF = Exposure Frequency 350 days/yr [c/] 160 days/yr	RME CTE	Assumes year-round exposure with one 2-week vacation. Mean exposure frequency.	USEPA, 1991 Assumed based on 8 months March-October, 5 days/week
ED = Exposure Duration 4 years 4 years	RME CTE	Normal time period at university Normal time period at university	Assumed
SA = Surface Area 6,032 cm^2 6,032 cm^2 [d/]	RME CTE	Skin surface area for head, forearms, hands, lower legs, and feet.	USEPA, 2014
AT = Averaging Time 25,550 days (carcinogens) ED x 365 days/year (non-carcinogens)	RME CTE	Conventional human lifespan. Intakes for carcinogens are averaged over the duration of exposure. Equal to the exposure duration (in days).	USEPA, 1989 USEPA, 1989
FI = Fraction Ingested 1.0 (unitless)	RME and CTE	Conservatively assume 100 percent of daily soil incidental ingestion occurs on-site.	Professional Judgment
DAF = Dermal Absorption Fraction Chemical-specific	RME and CTE	Chemical-specific.	USEPA, 2004
IR = Incidental Soil Ingestion Rate 100 mg/day [e/] 50 mg/day	RME CTE	Assumed same as adult residential incidental soil ingestion rate.	USEPA, 2014
AF = Soil-to-Skin Adherence Factor 0.07 mg/cm^2 [f/]	RME and CTE	Mean adherence factor for face, arms, hands, legs, and feet for gardening activities.	USEPA, 2014
ET = Exposure Time 8 hours/day	RME and CTE	8 hours/day outdoors.	Assumed
PEF = Particulate emission factor 3.23E+09 (m^3/kg) [g/]	RME and CTE	Calculated using Equation 10 and site-specific Q/C term and default parameters listed in USEPA 1996a and 2002.	USEPA, 1996a, Equation 10, and 2002
Q/C = Inverse of mean concentration at center of source 87.37 g/m^2-s per kg/m^3 [h/]	RME and CTE	Q/C value of 0.5 acre source area of Zone VIII, Philadelphia. Philadelphia is the nearest eastern seaboard city to Washington, D.C. for which a Q/C is derived.	USEPA, 1996a, Table 3.
IRveg = Ingestion Rate for Home-Produced Vegetables (kg/kg-day)	RME and CTE	RME=0.0032 CTE=0.0006	USEPA, 2011

Table 7-12. Exposure Factors for the AU Student Exposure Scenario			
Exposure Variable	**Scenario** [a/]	**Rationale**	**Reference**
FIveg = Fraction of Home-Produced Vegetables from site	FIveg	RME=25% CTE=25%	Assumed

Legend:
a/ RME = Reasonable Maximum Exposure; CTE = Central Tendency Exposure
b/ kg = kilogram
c/ days/yr = days per year
d/ cm^2 = square centimeters
e/ mg/day = milligrams per day
f/ mg/cm^2 = milligrams per square centimeter
g/ m^3/kg = cubic meters per kilogram
h/ g/m^2-s per kg/m^2 = grams per square meters – second per kilograms per cubic meters

Table 7-13. Risk Summary Tables for the Southern AU EU *(excluding outlier locations)*

	Incidental Ingestion Pathway		Dermal Contact Pathway		Outdoor Dust Inhalation Pathway		Home-Grown Vegetable Ingestion Pathway		Total Site Hazard Index or Total Estimated Site Cancer Risk	
	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Non-Cancer Hazard Indices - AU										
Current *Surface Soils (0 - 2 feet bgs)*										
Current Outdoor Worker	0.01	0.2	0.001	0.002	0.0008	0.002	NA	NA	0.01	0.2
Current Student	0.1	0.3	0.001	0.003	0.05	0.1	0.007	0.04	0.1	0.5
Future *Mixed Soils (0 - 10 feet bgs)*										
Future Outdoor Worker	0.009	0.2	0.0009	0.002	0.002	0.005	NA	NA	0.01	0.2
Future Construction Worker	0.01	0.8	0.0009	0.002	0.002	0.005	NA	NA	0.01	0.8
Future Student	0.1	0.4	0.001	0.003	0.06	0.2	0.01	0.05	0.1	0.6
Future Adult Resident	0.1	0.4	0.001	0.003	0.06	0.2	0.02	0.4	0.1	0.9
Future Child Resident	0.6	**3.8**	0.008	0.02	0.06	0.2	0.04	0.8	0.7	**4.8**
Incremental Cancer Risks - AU										
Current *Surface Soils (0 - 2 feet bgs)*										
Current Outdoor Worker	5.0E-8	2.9E-6	6.0E-8	4.2E-7	2.6E-9	2.5E-8	NA	NA	1E-7	3E-6
Current Student	1.5E-7	8.4E-7	3.9E-8	1.1E-7	4.1E-8	1.5E-7	1.2E-7	1.8E-6	4E-7	3E-6
Future *Mixed Soils (0 - 10 feet bgs)*										

Table 7-13. Risk Summary Tables for the Southern AU EU *(excluding outlier locations)*

	Incidental Ingestion Pathway		**Dermal Contact Pathway**		**Outdoor Dust Inhalation Pathway**		**Home-Grown Vegetable Ingestion Pathway**		**Total Site Hazard Index or Total Estimated Site Cancer Risk**	
	CTE	**RME**	**CTE**	**RME**	**CTE**	**RME**	**CTE**	**RME**	**CTE**	**RME**
Future Outdoor Worker	4.9E-8	2.4E-6	5.8E-8	3.5E-7	3.2E-9	2.9E-8	NA	NA	1E-7	3E-6
Future Construction Worker	2.9E-9	3.7E-7	3.6E-9	1.4E-8	2.0E-10	1.2E-9	NA	NA	7E-9	4E-7
Future Student	1.5E-7	6.9E-7	3.8E-8	8.7E-8	5.0E-8	1.7E-7	3.1E-7	2.8E-6	5E-7	4E-6
Future Adult Resident	3.8E-7	2.9E-6	1.3E-7	4.4E-7	1.5E-7	8.6E-7	4.9E-7	1.1E-5	1E-6	1E-5
Future Child Resident	1.9E-6	9.3E-6	3.9E-7	8.9E-7	7.5E-8	2.6E-7	8.5E-7	8.4E-6	3E-6	2E-5

Notes: Bold=greater than USEPA acceptable incremental cancer risk

Table 7-14. Risk Summary for Southern AU Outlier Locations										
	Incidental Ingestion Pathway		**Dermal Contact Pathway**		**Outdoor Dust Inhalation Pathway**		**Home-Grown Vegetable Ingestion Pathway**		**Total Site Hazard Index or Total Estimated Site Cancer Risk**	
Non-Cancer Hazard Indices – AU Outlier Locations										
	CTE	RME	CTE	RME	CTE	RME	CTE	RME	CTE	RME
Outdoor Worker	0.03	0.5	NA	NA	0.002	0.003	NA	NA	0.03	0.5
Future Construction Worker	0.03	**1.8**	NA	NA	0.002	0.003	NA	NA	0.03	**1.8**
Student	0.2	0.8	NA	NA	0.06	0.1	0.1	0.5	0.4	1
Future Adult Resident	0.2	0.8	NA	NA	0.06	0.1	0.3	**3.7**	0.6	**4.7**
Future Child Resident	**2.0**	**9.0**	NA	NA	0.06	0.1	0.6	**7.7**	**2.7**	**17**
Incremental Cancer Risks – AU Outlier Locations										
Outdoor Worker	1.7E-7	9.7E-6	9.4E-7	5.3E-6	5.5E-9	3.1E-8	NA	NA	1E-6	2E-5
Future Construction Worker	1.1E-8	1.3E-6	5.9E-8	2.1E-7	2.3E-9	8.4E-8	NA	NA	7E-8	2E-6
Student	5.5E-7	2.4E-6	6.1E-7	1.3E-6	8.5E-8	1.9E-7	2.7E-6	3.2E-5	4E-6	4E-5
Future Adult Resident	1.7E-6	1.2E-5	2.1E-6	6.6E-6	2.5E-7	9.3E-7	8.1E-6	**1.6E-4**	1E-5	**1.8E-4**
Future Child Resident	8.9E-6	3.9E-5	6.2E-6	1.4E-5	1.3E-7	2.8E-7	7.5E-6	9.6E-5	2E-5	**1.5E-4**
*Notes: Bold=greater than USEPA acceptable incremental cancer risk (**based on PAHs**)*										

7.4 Arsenic Within the SVFUDS

7.4.1 <u>Derivation and Protectiveness of 20 mg/kg</u>

A soil cleanup goal or removal goal for arsenic of 20 mg/kg (or ppm [parts-per-million]) was jointly proposed by the Partners. The endpoint is the soil arsenic concentration above which remediation is recommended. This concentration is considered protective of human health and the environment. The Scientific Advisory Panel, established to assist the community in understanding the overall approach to technical issues affecting Spring Valley, recommended adoption of this removal goal, saying that "the level should not pose a health hazard to the community and should not threaten the natural ecological systems of northwest Washington, DC" (Scientific Advisory Panel Report, May 29, 2002 Meeting).

The removal goal of 20 mg/kg is a consensus approach of the Partners. For comparison purposes, the highest background sample collected (was 18 mg/kg and a previously calculated non-cancer Soil Screening Level (SSL), corresponding to an HI of one based on a child resident receptor, was 23.5 mg/kg. The 20 mg/kg level is conservative in that it does not make use of any bioavailability factors. That is, the amount of arsenic that becomes available (reaches the target organ or systemic circulation) to an organism's body, is assumed to be 100%, but studies show this percentage to be much lower in actual practice. USEPA (2012b) recommends a default bioavailability of 60% for arsenic in soil; this factor was applied in the screening evaluation described below.

A screening evaluation of the 20 mg/kg removal goal for carcinogenic and non-carcinogenic risks posed to adult and child residents was completed, using the same exposure pathways and CTE and RME assumptions used in this HHRA, with the addition of a 60% bioavailability from soil factor (see tables in Appendix E-7). The results indicate that the non-cancer HIs for an arsenic concentration of 20 mg/kg in soil are less than or equal to one, and the estimated carcinogenic risks for 20 mg/kg arsenic in soil are within USEPA's acceptable range of 1E-04 to 1E-06, indicating that unacceptable risk levels are not associated with 20 mg/kg arsenic in soil, as shown in Table 7-15.

Table 7-15. Risks Associated with 20 mg/kg Arsenic in Soil

Resident Adult	CTE Hazard Quotient	RME Hazard Quotient		CTE Incremental Cancer Risk	RME Incremental Cancer Risk
Incidental Ingestion Pathway	0.01	0.05		8.5E-07	6.2E-06
Dermal Pathway	0.003	0.001		1.2E-05	1.3E-06
Inhalation Pathway	NA	NA		4.1E-08	1.5E-07
Vegetable Ingestion Pathway	0.000005	0.00005		3.8E-07	7.4E-06
Adult Resident HI Total =	0.01	0.06	**Adult Incremental Cancer Risk Total =**	**1E-05**	**2E-05**
Resident Child	CTE Hazard Quotient	RME Hazard Quotient		CTE Incremental Cancer Risk	RME Incremental Cancer Risk
Incidental Ingestion Pathway	0.1	0.5		4.5E-06	2.0E-05
Dermal Pathway	0.004	0.07		4.0E-05	2.7E-06
Inhalation Pathway	NA	NA		2.0E-08	4.5E-08
Vegetable Ingestion Pathway	0.00001	0.0001		9.3E-06	1.2E-04
Child Resident HI Total =	0.1	0.6	**Child Resident Incremental Cancer Risk Total =**	**1E-05**	**1E-04**
Construction Worker	CTE Hazard Quotient	RME Hazard Quotient		CTE Incremental Cancer Risk	RME Incremental Cancer Risk
Incidental Ingestion Pathway	0.002	0.03		2.8E-09	2.0E-07
Dermal Pathway	0.003	0.005		1.9E-07	4.1E-08
Inhalation Pathway	NA	NA		6.6E-10	4.8E-09
Construction Worker HI Total =	**0.004**	**0.04**	**Construction Worker Incremental Cancer Risk Total =**	**2E-07**	**2E-07**
Outdoor Worker	CTE Hazard Quotient	RME Hazard Quotient		CTE Incremental Cancer Risk	RME Incremental Cancer Risk
Incidental Ingestion Pathway	0.002	0.03		8.8E-08	5.0E-06
Dermal Pathway	0.09	0.2		6.1E-06	3.4E-05
Inhalation Pathway	NA	NA		8.7E-10	5.0E-09
Outdoor Worker HI Total =	**0.1**	**0.2**	**Outdoor Worker Incremental Cancer Risk Total =**	**6E-06**	**4E-05**

7.4.2 Elevated Arsenic Left in Place

As described more completely in the *EE/CA for Arsenic in Soil* (USACE 2003b), in limited situations, soil containing arsenic in concentrations greater than the 20 mg/kg removal goal has been left in the root zones of trees or where access and other construction limitations made soil removal difficult or unsafe. The option to leave up to 43 mg/kg arsenic in the soil has been exercised in specific situations representing challenging soil excavation logistics. This decision was always based on discussion and concurrence between the property owner, the USEPA, DDOE, and USACE representatives.

Health officials agree that arsenic in soil up to 43 mg/kg is acceptable and still protective in these limited circumstances. The 43 mg/kg standard is based on the USEPA emergency removal concentration for arsenic in soil, as discussed in the USEPA Region 3 Emergency Removal Guidelines, *Hazard Evaluation Handbook, A Guide to Removal Actions, USEPA 903/B-97-006* (USEPA Region 3, 1997a). This is a risk-based value for a residential surface soil scenario corresponding to a cancer risk of 1 in 10,000.

Figure 7-5 shows the 40 residential properties, 1 DC lot, and 3 AU lot locations where a property owner used the 43 mg/kg arsenic option to save trees or to avoid significant disturbance to the grounds. At least one grid or partial grid on each property was left in place containing arsenic in concentrations between 20 mg/kg and 43 mg/kg. However, some properties had multiple grids and some had an individual sample location (under walkways or concrete decks, for example), with these concentration ranges.

7.4.3 Arsenic Under City Streets

In some cases, arsenic contamination on a private or public property extended to the paved city streets beyond the property. The SVFUDS investigation process did not typically sample beneath paved city streets since there is little receptor access to these areas, and therefore, in general, little risk posed by the arsenic in the soil. However, to fully assess whether arsenic remaining beneath paved city streets could pose risks, an evaluation of a construction worker receptor, who would potentially disturb these soils to repair the street or install utilities, was conducted.

Table 7-16 presents estimated cancer and non-cancer risk levels for a construction worker with limited exposures during intermittent repair work, using a concentration of 100 mg/kg arsenic in soil (see tables in Appendix E-7). The same CTE and RME assumptions are used as in the HHRA presented in previous sections, including the CTE assumption that a construction worker would be exposed for 0.25 years, representing a repair project that lasts 3 months in the same general areas. The RME exposure duration is assumed to be one year, which may be an over-estimate for typical road projects. The evaluation indicates that arsenic up to 100 mg/kg in the soil could be encountered by a construction worker without exceeding the acceptable USEPA levels for cancer and non-cancer risks.

A review of the 68 properties where one or more soil samples were collected adjacent to a city street indicates that of the 228 soil samples, only 14 contained arsenic greater than 20 mg/kg and only three of those concentrations were greater than 43 mg/kg, with the highest arsenic concentration detected being 46.6 mg/kg. In addition, a recent sampling investigation associated with a DC Water and Sewer Authority (DC WASA) water main rehabilitation project indicated that of the 46 samples collected from 23 separate locations within the SVFUDS, none of them exceeded 11 mg/kg (DC WASA, 2014).

There remains some uncertainty regarding arsenic levels in these soils because sampling beneath paved city streets was not typically conducted. However, based on sampling results in multiple locations leading up to the streets and the recent samples collected by DC WASA from beneath the streets, the existence of areas of arsenic greater than 100 mg/kg under the streets does not appear likely.

Table 7-16. Construction Worker Risks Associated with 100 mg/kg Arsenic in Soil

	Non-Cancer Hazard			**Estimated Cancer Risk**	
Construction Worker	CTE Hazard Quotient	RME Hazard Quotient		CTE Incremental Cancer Risk	RME Incremental Cancer Risk
Incidental Ingestion Pathway	0.01	0.2		1.4E-08	9.9E-07
Dermal Pathway	0.01	0.02		9.5E-07	2.1E-07
Inhalation Pathway	NA	NA		3.3E-09	2.4E-08
Construction Worker HI Total =	**0.02**	**0.2**	**Construction Worker Incremental Cancer Risk Total =**	**1E-06**	**1E-06**

7.5 External Studies

The SVFUDS is located in a suburban neighborhood where stakeholders, during the course of the RI and EE/CA activities, have been concerned about possible past and present exposures to contamination associated with past DoD activities. Therefore agencies and organizations external to USACE have conducted health consultations, studies and exposure studies to evaluate such scenarios. It should be noted that these external studies focused on the potential for health impacts to the community prior to completion of RI, TCRA, and NTCRA activities previously described; that is, for the most part these studies did not take into account all of the mitigation/removal activities being conducted by USACE. Reference to the external studies is provided for background and informational purposes only.

7.5.1 ATSDR Health Consultations

The ATSDR has conducted seven focused health consultations related to the SVFUDS and three exposure investigations (ATSDR, 1997a, 1997b, 2000a, 2000b, 2001a, 2001b, 2002, 2003a, 2003b, and 2005). Consultations and exposure investigations were requested in response to community concerns with arsenic exposure in soil, indoor air quality, and overall community health. ATSDRs Public Health Evaluation for the Spring Valley Community published in 2005 provided the first community-wide health evaluation. The community health evaluation concluded that residents in Spring Valley have not and will not experience adverse health effects due to AUES activities. At the request of USACE, ATSDR is in the process of evaluating two exposure scenarios at 4825 Glenbrook Road: construction workers who built the home and the family who lived in the home. Table 7-17 reviews the seven consultations and three exposure studies completed by ATSDR.

7.5.2 Johns Hopkins Bloomberg School of Public Health Scoping Studies

Starting in March 2006, health researchers with the Johns Hopkins Bloomberg School of Public Health (JHSPH) conducted a health scoping study for the SVFUDS project area under contract with the DC DOH. This study was initiated in response to community concerns regarding the completeness of the 2005 ATSDR Health Evaluation. The study, published in 2007, found that the overall health of Spring Valley residents is very good (JHSPH, 2007).

In July 2013, JHSPH researchers released an additional health scoping study report for the SVFUDS project area, under contract with the DDOE (formerly DC DOH). The purpose of the study was to follow up on issues raised in the 2007 study report and document any community concerns and potential health impacts from the SVFUDS. The report noted that the overall health of Spring Valley residents continues to be very good and mortality rates continue to be below the U.S. average for most causes (JHSPH, 2013).

Table 7-17. ATSDR Health Consultations and Exposure Studies

Date / Title	Brief Description
2005 / Public Health Evaluation for the Spring Valley Community	At the request of DC DOH and attorneys representing community members, ATSDR conducted a public health evaluation for the SVFUDS. ATSDR's overall assessment indicated that most people in Spring Valley had not and would not experience adverse health effects due to AUES activities because exposure point concentrations were not high enough to result in adverse health effects.
2003 / Evaluation of Indoor Air Sampling 4625 Rockwood Parkway	At the request of USEPA Region 3, ATSDR reviewed indoor air and soil gas sampling data to determine if exposure to chemical substances detected in indoor air posed an immediate or long-term health hazard to residents at 4625 Rockwood Parkway. ATSDR identified elevated levels of carbon monoxide likely attributed to an HVAC system problem and recommended additional soil gas sampling to rule out any other potential causes of adverse health effects.
2003 / Follow-up Report on Levels of Arsenic in Urine	At the recommendation of the Spring Valley Science Advisory Panel, ATSDR conducted a follow-up to the 2002 exposure investigation by taking samples during investigation at a time of presumed maximal exposure activities. No significant exposures were identified by ATSDR.
2002 / Report on Levels of Arsenic in Urine and Hair	In response to a DC DOH request, ATSDR conducted an exposure investigation examining individuals in the SVFUDS for possible exposure to arsenic contamination in their yards. Urine and hair arsenic levels were tested, and household dust was analyzed for arsenic in each of the homes. ATSDR determined that participants showed low levels of arsenic exposure; however, could not determine whether exposure was from soil or dietary intake. ATSDR concurred that USACE should remove soil with elevated arsenic.
2001 / Levels of Arsenic in Hair at Child Development Center	In response to parent concerns of exposure to elevated levels of arsenic in soil at the AU CDC, ATSDR tested hair samples of children and adults at the CDC. ATSDR reported that all hair arsenic levels detected were within the ranges reported for unexposed populations and concluded that none of participants in the exposure investigation had hair arsenic levels that indicated unusual exposure to arsenic.
2001 / The Public Health Significance of Arsenic in Soil at the AU CDC	At the request of USACE, ATSDR reviewed the results of follow-on soil sampling and concluded that USACE children and staff at the AU CDC should not experience any adverse health effects from previous exposure to arsenic in soils at the playground. In addition, ATSDR concurred that the arsenic levels in soil at the CDC should be reduced to background levels.
2000 / Assessment of Soil Sampling Results at the AU CDC	At the request of USACE, ATSDR evaluated initial sampling results at AU's CDC. ATSDR concluded there were likely no adverse effects, concurred with USACE that further sampling to characterize the area was necessary, and recommended actions to reduce potential exposures to arsenic in soils.
2000 / Assessment of Arsenic in Creek Sediment at Four Residences in Spring Valley	At the request of the USEPA Region 3, ATSDR evaluated the public health significance of arsenic concentrations identified in creek sediments at four properties in Spring Valley. ATSDR derived a comparison value of 20 mg/kg at which no adverse health effects are expected to occur. All concentrations fell below the comparison value; therefore ATSDR concluded no adverse health effects were expected to occur.
1997 / Assessment of Soil Sampling Results at the American University	At the request of the D.C. Public Health Commissioner, ATSDR conducted a Health Consultation to review sample data and evaluate increased risk of adverse health effects at the AU or vicinity. No adverse health effects were identified in the soil samples; however, ATSDR noted that ordnance, laboratory or storage vessels may remain buried at the AU or in the vicinity that may hold explosives or noxious agents that could pose serious health threats if unearthed.
1997 / Public Health Actions Needed at American University Experiment Station	This Health Consultation concluded that the full range of potential hazards may not have been identified or addressed and made four types of recommendations to maximize public awareness and safety: communication and coordination, prevention, surveillance, and response.

7.6 MEC Hazard Assessment

7.6.1 Overview

7.6.1.1 Introduction

The MEC Hazard Assessment (MEC HA) methodology was used to assess potential explosive hazards to human receptors at the SVFUDS. MEC HA is intended to evaluate the potential explosive hazard associated with an area, given current conditions and under various cleanup scenarios, land use activities, and land use control (LUC) alternatives. The *MEC Hazard Assessment Methodology, Interim* (USEPA, 2008), provides the methodology for assessing explosive hazards to human receptors at an area. The MEC HA interim guidance was developed by the Technical Working Group for Hazard Assessment, which included representatives from the DoD, the U.S. Department of the Interior, the USEPA, and various states and tribes.

The results of the MEC HA are used to evaluate potential munitions response alternatives. MEC HA risk characterization results can ultimately be inputs to the evaluation of the Protectiveness of Human Health and the Environment criterion in the Feasibility Study (FS). The risk characterization is used to communicate the magnitude of the risk at the location and the primary causes of that risk, and to aid in the development, evaluation, and selection of appropriate response alternatives. The MEC HA reflects the difference between chronic environmental contaminant exposure risk (as determined through the HHRA) and acute MEC explosive hazards.

USACE completed MEC HA scoring to assess potential explosive hazards to human receptors at the SVFUDS; the results were presented to the RAB in March 2013.

7.6.1.2 Purpose

The MEC HA meets CERCLA project requirements to conduct site-specific risk assessments for human health and the environment at sites involving MEC. The MEC HA provides a consistent framework for organizing information to be used in the decision process. It assists in managing uncertainty and ensures continuity of hazard management evaluations and decisions. The MEC HA supports the hazard management decision-making process by analyzing site-specific information to:

- Assess existing explosives hazards
- Evaluate hazard reductions associated with removal and remedial alternatives
- Evaluate hazard reductions associated with land use activity decisions

The SVFUDS MEC HA was conducted to provide the basis for the evaluation and implementation of effective management response alternatives in an FS. However, the MEC HA does not provide a quantitative assessment of MEC hazards and is not used to determine whether or not further action is necessary at a site.

7.6.2 MEC HA Description

7.6.2.1 Description

MEC HA is a qualitative hazard assessment that provides an assessment of the acute explosive hazards associated with remaining MEC at a site by analyzing site-specific conditions and human issues that affect the likelihood that a MEC accident will occur. The method focuses on hazards to human receptors and does not directly address environmental or ecological concerns that might be associated with MEC.

An explosive hazard can result in immediate injury or death; therefore, risks from explosive hazards are evaluated either as being present or not present. If the potential for an encounter with MEC exists, then the potential that the encounter may result in injury or death also exists. Conversely, if the potential presence of MEC can be ruled out as a result of field investigations, then no explosive hazards are present, and a MEC HA is not necessary.

An explosive hazard exists at a site if there is a potentially complete MEC exposure pathway. A potentially complete MEC exposure pathway is present any time a receptor can come near or into contact with MEC and interact with the item in a manner that might result in its detonation. There are three elements of a potentially complete MEC exposure pathway: (1) a source of MEC, (2) a receptor, and (3) the potential for interaction between the MEC source and the receptor. All three of these elements must be present for a potentially complete MEC exposure pathway to exist.

7.6.2.2 Components

MEC HA scoring is organized around the following components:

- *Summary Information* - General information regarding the site.
- *Munitions/Explosive Information* – any MEC and/or bulk explosives present at the site.
- *Current and Future Activities* - Current land use activities as well as planned future activities, if any.
- *Remedial-Removal Action* - General information regarding remediation/removal alternatives being considered for the site, including Land Use Controls (LUCs) such as fencing, signage, and deed restrictions.
- *Post-Response Land Use* - Land use activities associated with remediation/removal alternatives being considered for the site.

7.6.2.3 Input Factors

The MEC HA uses input data based on historical documentation, field observations, and the results of previous studies and removal actions. Potential MEC hazards are evaluated qualitatively for each assessment area by evaluating three primary factors:

- *Severity*: the potential consequences of the effect on a human receptor should a MEC item detonate;
- *Accessibility*: the likelihood that a human receptor will come into contact with a MEC item; and
- *Sensitivity*: the likelihood that a MEC item will detonate if a human receptor interacts with the item.

To complete the scoring for each assessment area, the input factors were reviewed and suitable categories (LUCs, subsurface MEC cleanup, etc.) were selected based on historical documentation and field observations. The input factors for the MEC HA method are highlighted below (USEPA, 2008c). The specific inputs for the SVFUDS MEC HA scoring are presented in Appendix F, where the complete Excel-based worksheets are contained.

Energetic Material Type: This factor describes the general type of energetic material (e.g., high explosives, or propellants) associated with the munition(s) known or suspected to be present.

The six categories for this factor range from the most to least potentially hazardous; the category selected is based on the energetic material with the greatest potential explosive hazard known or suspected to be present.

Location of Additional Human Receptors: Human receptors other than the individual who causes a detonation may be exposed to fragmentation hazards from the detonation of MEC. This factor describes whether or not there are additional human receptors located within the assessment area.

Site Accessibility: The site accessibility factor describes how easily human receptors can gain access to the assessment area and takes into account the various barriers to entry that might be present.

Potential Contact Hours: This factor accounts for the amount of time receptors spend within the assessment area during which they might come into contact with MEC and intentionally or unintentionally cause a detonation. Both the number of receptors and the amount of time each receptor spends in the assessment area are used to calculate the total "receptor-hours/year."

Amount of MEC: This input factor describes the relative quantity of MEC anticipated to remain within the assessment area as a result of past munitions-related activities. For example, a greater quantity of MEC is assumed to be present in a former target area than at a former firing point.

Minimum MEC Depth Relative to the Maximum Receptor Intrusive Depth: This factor indicates whether the MEC are located at depths that might be reached by the anticipated human receptor activities.

Migration Potential: The migration potential factor addresses the likelihood that MEC in the assessment area might migrate by natural processes (e.g., erosion or frost heave) thereby increasing the chance of subsequent exposure to potential human receptors.

MEC Classification: This factor accounts for how easily a human receptor might cause a detonation of the MEC and relates directly to the MEC sensitivity. The category selection is made using the MEC with the highest potential sensitivity known or suspected to be present and, where uncertainty exists, conservative assumptions are made and documented.

MEC Size: This factor indicates how easy it is for a typical human receptor to move the MEC item(s) present within the assessment area.

7.6.2.4 Output

Once the categories and scores for all input factors are defined for each assessment area, the related scores for each category are totaled to calculate an overall MEC HA score for each assessment area. The total possible minimum and maximum MEC HA scores, the associated hazard levels for these scores, and the relative explosive hazard designation, are shown in Table 7-18. The total MEC HA scores and associated hazard levels are qualitative references only and should not be interpreted as quantitative measures of explosive hazard, or as the sole basis for determining whether or not further action is necessary at a site.

Table 7-18. Hazard Level Scoring Rankings Table			
Hazard Level	**Maximum MEC HA Score**	**Minimum MEC HA Score**	**Associated Relative Explosive Hazard**
1	1,000	840	Highest potential explosive hazard conditions
2	835	725	High potential explosive hazard conditions
3	720	530	Moderate potential explosive hazard conditions
4	525	125	Low potential explosive hazard conditions

7.6.3 Application of MEC HA at the SVFUDS

At the SVFUDS, the MEC HA was organized around the past activities most likely to result in MEC at the site. These include:

- Ballistically Fired Testing (e.g., Range Fan);
- Statically Fired Testing (e.g., Circular Trenches); and
- Disposal (e.g., 52nd Court, OU-4 AU Lot 18). This has been further divided into 'known' and 'possible' disposal areas.

7.6.3.1 Ballistically Fired Testing

The SVFUDS Range Fan (see Section 1.5 and Appendix B Range Fan Memorandum for Record) was developed based on ballistically fired testing activities at the AUES. A typical range fan comprises the following component areas:

- The Firing Point
- The Range Safety Fan (or Safety Buffer)
- The Function Test Range (Impact Area)

Past practices involved firing 3-inch and 4-inch Stokes mortars and 8-inch Livens projectiles from the Spaulding-Rankin area firing point to the impact areas. Figure 7-6 shows the delineation of each area, differentiating the function test range impact areas for the Livens and Stokes. Note that for scoring the MEC HA, the function test range category was considered to be most appropriate for the SVFUDS impact areas. A function test range is utilized for the testing of munition functioning and typically includes research and development of new munitions. Quantities are often limited and the munition is often removed from the range for further analysis. These factors were important considerations in the MEC HA scoring for the impact areas (usually where most MEC is expected to be found).

For the MEC HA evaluation, the safety fan or safety buffers (blue shading on Figure 7-6) were evaluated separately for each munition (Stokes and Livens). The impact areas for the Livens (pink shading) and Stokes mortars (purple shading) were scored separately. Descriptions for each of the assessment areas, and how the MEC HA scoring was approached, are summarized in Table 7-19 below.

Table 7-19. Ballistically Fired Testing Areas

Area	Description	Comment
Firing Point	Spaulding-Rankin Area	Area has been thoroughly investigated; no MEC HA score required
Range Safety Buffer	3" and 4" Stokes mortars combined	**Prepare single MEC HA score** for combined areas
Range Safety Buffer	8" Livens Projectiles	**Prepare single MEC HA score** (includes fenced portion of Dalecarlia Woods)
Function Test Range	Impact area for Stokes	**Prepare single MEC HA score** for combined areas
Function Test Range	Impact area for Livens	**Prepare single MEC HA score** (includes AOI 12, designated as a Livens target area)

The MEC HA scores are summarized in Table 7-23 below. The specific inputs for the SVFUDS MEC HA scoring are presented in Appendix F, where the complete Excel-based worksheets are contained. The worksheets, organized by the components described in Section 7.6.2.2, and the input factors described in Section 7.6.2.3, provide the rationale for each input selection.

7.6.3.2 Statically Fired Testing

Static firing means the remote firing of fixed or stationary munitions, as opposed to those fired ballistically. Five areas of the AUES were identified through historical records as being static fire test areas (primarily Livens and 75 mm projectiles). These include:

- POIs 39, 11, 10
- POI 9
- POI 1 (Sedgwick Trenches)
- POI 13 (52nd court Circular Trenches)
- POIs 21, 22, and 23 (concrete bunkers at Spaulding/Rankin)

Figure 7-7 shows these areas.

With regard to MEC HA scoring, the static test fire areas would not typically represent MEC concerns in that the testing process would have monitored and controlled individual items. Any munition item not properly firing would be identified in real time; none of the items would be left behind (i.e., still existing at the Site). Therefore, no MEC HA scoring would be required.

However, similar to the findings at the initial 52nd Court trenches (POI 13 disposal area), static testing activities may suggest the presence of DMM in munitions burial pits near the testing locations, identifying areas for possible further geophysical investigation. Figure 7-7 also shows the geophysical investigation coverage in the vicinity of the static fire test areas.

To identify possible munitions burial pits, a distance of 150 ft, representing a practical distance workers may have walked to bury DMM generated through the static testing, was determined by reviewing the geophysical findings at POI 2 (possible pit associated with POI 1-Sedgwick Trenches). The rationale is that these static fire test areas may be analogous to the 52nd Court (POIs 13/14) scenario. POI 2 in particular may represent a disposal of DMM or other material associated with the POI 1 Sedgwick Trenches. At POI 2, DGM has been completed and a potential pit has not been ruled out, but at this time, the property owner has not allowed intrusive work to thoroughly characterize the area.

Descriptions for each of the five assessment areas, and how the MEC HA scoring was approached, are summarized in Table 7-20 below.

Table 7-20. Statically Fired Testing Areas

Area	Description	Comment
Static Fire area-POI 39, 11, 10	**POI 39, 11, 10**--POI 39 is believed to have been used as a static test fire area for munitions containing chemical agent (contains POIs 10 and 11 within)--POI 10 is a possible static test site or observation dugout and POI 11 is ground scars. Seven statically fired 75 mm shells have been located in the POI 39 area.	No MEC HA score required, but assess for possible munitions disposal pits
Static Fire area-POI 9	**POI 9**--Possible remote static firing location. Approximately 350 feet east of POIs 39,11,10. Many MD items have been found here.	No MEC HA score required, but assess for possible munitions disposal pits
Circular trenches-Sedgwick Street	Sedgwick trenches **(POI 1)**-- Livens and 75 mm shells with agent were statically fired in the center of the circular trenches.	No MEC HA score required, but assess for possible munitions disposal pits
Circular trenches-52nd Court	52nd Court trenches **(POI 13)**-- Livens and 75 mm shells with agent were statically fired in the center of the circular trenches. The associated disposal pit **(POI 14)** has been excavated.	Area has been thoroughly investigated; no MEC HA score required

Table 7-20. Statically Fired Testing Areas		
Area	**Description**	**Comment**
Concrete bunkers at Spaulding - Rankin area	**POIs 21, 22, 23**---POI 21 was a two-chambered shell pit used to test the physical properties of explosives, smokes, and CWA. POI 22 was a shell pit, now incorporated into the utility room of the current house, and POI 23 was a three-chambered shell pit used to test the physical properties of explosives and CWA.	Area has been thoroughly investigated; no MEC HA score required

7.6.3.3 Disposal Areas (Known)

Five areas have been identified as 'known' disposal areas based on the findings of various investigations. These include portions of:

- Glenbrook Road Area (4801 and 4825)
- 52nd Court Trenches (POI 14)
- Lot 18 (AU)
- 5000 Block of Sedgwick (POIs 5 and 6)
- 4000 Block of Quebec (POI 18)

Figure 7-8 shows these areas. With the exception of the ongoing work at 4825 Glenbrook, these areas have already been thoroughly investigated and, where required, remediated. Descriptions for each of the five assessment areas, and how the MEC HA scoring was approached, are summarized in Table 7-21 below.

Table 7-21. Known Disposal Areas		
Area	**Description**	**Comment**
Glenbrook Road area	Properties at 4801 and 4825 Glenbrook Road	4801 area has been thoroughly investigated; no MEC HA score required. MEC HA previously completed for 4825.
52nd Court trenches	**POI 14--**disposal pit associated with POI 13 circular trench static fire testing. POI 14 has been excavated.	Area has been thoroughly investigated; no MEC HA score required
Lot 18 area	Lot 18 area--much MD but no MEC found; Lot 18 has been excavated.	Area has been thoroughly investigated; no MEC HA score required

Table 7-21. Known Disposal Areas

Area	Description	Comment
5000 Block Sedgwick Street	**POIs 5 & 6**--POI 5 is possible pit and POI 6 is a possible target or test site referred to on a 1918 topographic map as a "TARGET" area. 3" Stokes MEC found. Multiple MD items found in small pit. This may represent cleanup of ballistic firing; it is within the Stokes impact areas, but includes many 75mm MD items not associated with ballistic firing (they may be kick-out from nearby static testing).	Area has been thoroughly investigated; no MEC HA score required
4000 Block Quebec Street	**POI 18**--POI 18 was identified as small crater scars, possible former impact area. MEC items found include approximately 60 fuzes or detonators in box and part of thermite grenade.	Area has been thoroughly investigated; no MEC HA score required

7.6.3.4 Disposal Areas (Possible)

Three areas of the SVFUDS have been identified as 'possible' disposal areas (see Figure 7-8) based on the findings of various investigations. These include:

- The AU PSB
- AOI 13 area
- Fordham Road Property (possible munitions burial pit)

These are considered 'possible' disposal areas based on a weight of evidence assessment, but it is not certain that they contain buried munitions. There is little specific information upon which to run the MEC HA, and therefore, a generic MEC HA that conservatively assumed a worst case disposal area/burial pit scenario was completed. Should additional sufficient information become available for any of these areas, a MEC HA score specific to that area will be prepared.

Figure 7-8 shows the areas. Descriptions for each of the three assessment areas, and how the MEC HA scoring was approached, are summarized in Table 7-22 below.

Table 7-22. Possible Disposal Areas

Area	Description	Comment
Generic Disposal Area/Burial Pit	Any disposal area or burial pit	**Prepare Generic MEC HA score** (for worst case disposal area/burial pit because no specific info is available)
AU Public Safety Building	Active building on AU. OU-4 AU Lot 18 excavations extended to the building, but no digging beneath it. One MEC item, a burster tube for a 75mm projectile that appeared to contain residual energetics, was found close to bldg.	Use Generic MEC HA score unless more information becomes available to prepare specific MEC HA score
AOI 13	13 residential properties containing multiple 1918 ground scars, including POI 26 – small crater scars. 3 AUES bldgs are within AOI 13 and northern edge of Range Fan passes through part of it.	Use Generic MEC HA score unless more information becomes available to prepare specific MEC HA score
Fordham Road Property	**POI 2**--Possible location of a pit that may have been used for disposal of munitions or other material associated with Sedgwick Trench, similar to 52nd Court (POIs 13/14) scenario	Use Generic MEC HA score unless more information becomes available to prepare specific MEC HA score

7.6.4 <u>MEC HA Summary and Conclusions</u>

As discussed in the sections above, MEC HA for the SVFUDS was organized around ballistically fired testing, statically fired testing, and disposal activities. The specific inputs for the SVFUDS MEC HA scoring are presented in Appendix F, where the Excel-based worksheets indicate the rationale for the input and provide additional information to support the scoring.

Table 7-23 presents the MEC HA results for the activities scored. For each of the component areas, the current use and two response alternatives were scored. Section 7.6.2.2 discusses how the MEC HA is organized around current site activities and potential remediation/removal alternatives being considered for the site.

The first score evaluates the current assessment area conditions. Response Alternative 1 evaluates the impact of placing LUCs on the assessment area and Response Alternative 2 evaluates a surface and subsurface cleanup of munitions. Note that there are no surface munitions currently on any of the assessment areas, but the MEC HA model assumes there are in order to score the cleanup scenario.

It is important to emphasize that the MEC HA provides the basis for the evaluation and implementation of effective management response alternatives in an FS. The MEC HA scores are qualitative references only and should not be interpreted as quantitative measures of explosive hazard, or as the sole basis for determining whether further action is necessary at a site.

7.6.4.1 Ballistically Fired Testing Area Conclusions

The MEC HA approach was to score the ballistically fired testing areas as described in Table 7-19. However, since no ballistically fired MEC was found in the Stokes Range Safety Buffer (combined buffers for 3” and 4” Stokes), a MEC HA score could not be generated, as MEC HA requires a munition type (based on investigation findings) to derive a score. The only MEC finds in the Stokes Range Safety Buffer area (see Figure 7-6) were from burial areas unrelated to ballistic firing.

Table 7-23 indicates that the Livens Range Safety Buffer scored a hazard level category of 4 (low potential explosive hazard conditions) based on current use activities. This is partly due to portions of this area being within the fenced Dalecarlia Woods where access is limited.

The Function Test Ranges or impact areas for both the Livens and the Stokes mortars received a MEC HA score of 3 (moderate potential explosive hazard conditions) based on current use activities. The moderate potential explosive hazard conditions that this score represents for this documented impact area suggests that follow-on actions may be required to mitigate unacceptable explosive hazards that could exist on the properties within the impact areas.

7.6.4.2 Statically Fired Testing Area Conclusions

The static test fire areas do not typically represent MEC concerns in that the testing process would have monitored and controlled individual items and any munition item not properly firing would be identified in real time. None of the items would be left behind (i.e., still existing at the Site) and therefore, no MEC HA scoring was required. However, similar to the findings at the initial 52nd Court trenches (POI 13 disposal area), static testing activities may suggest the presence of munitions burial pits near the testing locations.

The potential for remaining munitions burial pits suggests that follow-on actions may be required to mitigate unacceptable explosive hazards associated with possible munitions burial pits in the test areas and the 150 ft investigation or buffer zones around the known static fire test areas (see Figure 7-7).

7.6.4.3 Disposal Area Conclusions

The known disposal areas have been thoroughly investigated and no MEC HA score was required. For the possible disposal areas, there was little specific information upon which to run the MEC HA, and therefore, a generic MEC HA that conservatively assumed a worst case disposal area/burial pit scenario was completed.

As Table 7-23 indicates, the generic MEC HA score was a 3 (moderate potential explosive hazard conditions) based on current use activities. The unknowns associated with the three possible disposal areas (AU PSB, AOI 13, and POI 2 / Fordham Road area) and the moderate potential explosive hazard conditions they represent (using conservative assumptions) suggest that follow-on actions may be required to mitigate unacceptable explosive hazards that could exist in these three areas (see Figure 7-8).

Table 7-23. MEC HA Scoring Summary

	Safety Buffer (Livens)		**Function Test Range Impact Area (3" & 4" Stokes)**		**Function Test Range Impact Area (Livens)**		**Generic Disposal Area**	
	Hazard Level Category	**Score**	**Hazard Level Category**	**Score**	**Hazard Level Category**	**Score**	**Hazard Level Category**	**Score**
Current Use Activities	4	505	3	710	3	640	3	670
Response Alternative 1: LUCs	4	440	3	645	3	575	3	605
Response Alternative 2: Sub-surface Cleanup	4	345	4	435	4	300	4	405

1

7.7 Munitions Response Site Prioritization Protocol

As required by section 2710(b) of title 10 of the U.S. Code (codified under 32 CFR Part 179), the SVFUDS has been delineated into three MRSs (see Section 1.5.6) for purposes of applying the Munitions Response Site Prioritization Protocol (MRSPP). The MRSPP is required by section 311(b) of the National Defense Authorization Act for Fiscal Year 2002 to assign relative priorities for conducting response actions at each location where MEC or MC are known or suspected. Although many areas of the SVFUDS have already undergone or are undergoing removal/remedial actions, MRS delineation and prioritization are still required in order to comply with the Rulemaking.

The MRS priorities resulting from MRSPP evaluations are briefly summarized below. The detailed MRSPP scoresheets are presented in Appendix F. Note that MRS ratings are on a scale of 1-8, with 1 being the highest priority and 8 being the lowest.

- MRS 01 – Burial Pits/Field Test Areas: The compilation of multiple POIs and AOIs, as well as the Range Fan, covers 120.1 acres (see Figure 1-9). The priority for MRS 01 is "3," as shown on Table 29 of the scoresheet in Appendix F. This rating is based on the Chemical Warfare Materiel Hazard Evaluation (CHE) module total of 78, which equates to a rating of C (on a scale of A-G). This rating reflects several factors, including but not limited to the fact that CWM mixed with unexploded ordnance has been found in the subsurface, there is an incomplete barrier around the MRS, the property is not controlled by DoD, and the site is in a densely populated area.

- MRS 08 – Battery Vermont: A 906-acre range fan that originates on Sibley Memorial Hospital property on the western corner of the SVFUDS and extends west across the Potomac River into Virginia. The range was used by the U.S. Government from 1861 to 1865 as part of the Civil War temporary defenses to protect Washington DC from Confederate attacks. Battery Vermont did not engage in any combat and there is no documentation of any firings from the battery, and no reports of any munitions found. The MRS was given an alternate rating of "No Known or Suspected Hazard," for all three modules – Explosive Hazard Evaluate (EHE), CHE, and Health Hazard Evaluation (HHE). The scores for Tables 1 and 11 are zero, because there is no evidence of munitions or CWM, and Tables 2-9 and 12-19 are omitted per Army guidance as a result. Tables 21-26 for the HHE module are omitted because the ratings for the EHE and CHE modules are "No Known or Suspected Hazard."

- MRS 09 – 4825 Glenbrook Road: The 0.4-acre residential property where a remedial action is ongoing to remove contaminated soil and MEC/CWM from the burial pit(s). The priority for MRS 09 is "3," as shown on the scoresheet in Appendix F. This rating is based on the CHE module total of 80, which also equates to a rating of C (on a scale of A-G). Like MRS 01, the score reflects several factors, including that CWM mixed with unexploded ordnance has been found in the subsurface, the property is not controlled by DoD, and the site is in a densely populated area.

MRS priorities will be reviewed for MRSs 01 and 09 at least annually to reflect any new information that becomes available. MRSPPs will be revised upon completion of a response action, further delineation of the MRSs, or if site conditions change (e.g., UXO containing high-explosive filler is discovered, MEC or CWM is found on the surface, a barrier to an MRS gets installed, etc.). When all objectives set out in the decision documents have been achieved and no further action, aside from long-term management and recurring reviews, is necessary, both MRSs will be given the alternate rating of "No Longer Required".

The rating for MRS 08, Battery Vermont, is not anticipated to change since there is no evidence of contamination and the project has been designated as No DoD Action Indicated (NDAI). Note that if DoD-related contamination is discovered in the future, it will be re-evaluated and reopened, as appropriate, and a revised MRSPP evaluation will be conducted, as necessary.

7.8 Groundwater HHRA

7.8.1 Summary

A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

7.9 Screening Level Ecological Risk Assessment

7.9.1 Summary

Pursuant to CERCLA, risk assessors perform qualitative or quantitative appraisals of actual or potential effects of a hazardous waste site on plants or animals. A SLERA supplements the overall characterization of the site and serves as part of the baseline used to develop, evaluate, and select appropriate remedial alternatives for ecological receptors. Accordingly, the SVFUDS SLERA, conducted to evaluate the ecological impacts of soil, sediment, surface water, and groundwater contaminants at the SVFUDS, was completed by USACE in July 2010 (USACE, 2010b). The findings of that report are summarized in this section; the entire report is included as Appendix D.

The primary objective of the SLERA was to evaluate whether unacceptable adverse risks are or may be posed to ecological receptors as a result of hazardous substance releases. The SLERA was conducted in accordance with the *Work Plan for Screening Level Ecological Risk Assessment* (USACE, 2007f). Available literature on the toxicology of Chemicals of Potential Ecological Concern (COPECs) to wildlife populations was used to characterize ecological receptors in the SVFUDS.

7.9.1.1 Environmental Setting of the SVFUDS

The SVFUDS area was characterized with respect to operational, physical, chemical, and ecological characteristics, and the current and anticipated future land uses. Methods used to characterize ecological resources included a site visit by a biologist for the identification of existing wildlife and vegetative communities. The ecological conditions at the SVFUDS include both natural and semi-natural areas where ecological receptors may occur. Throughout the SVFUDS, there are small woodland streams that are surrounded by native vegetation. These areas, although small in size, provide habitat for ecological receptors, including such species as birds and some mammals (i.e., raccoons), and amphibians and reptiles. The western portion of the area is forested native vegetation that provides suitable habitat for a number of species, including birds, mammals (i.e., raccoons and white tailed deer), amphibians, and reptiles. Representative ecological habitats, based on the site visit and a review of local area resources, are shown in Figure 7-9.

7.9.1.2 Sampling Data

The surface soil, surface water and sediment, and groundwater data used for the SLERA were selected to provide spatial coverage of SVFUDS as well as to reflect available data (and parameters) from previous investigative areas of concern. Figure 7-10 indicates the general locations of the data points used in the SLERA.

7.9.1.3 Contaminant Fate and Transport Mechanisms

Pathways for migration of contaminants were identified. Potentially affected media included soils, sediment, surface water and groundwater. In general, exposure to groundwater by most terrestrial species is limited, but may be released to surface water resulting in exposures; therefore, as an extremely conservative evaluation, groundwater was considered an exposure pathway at the site. For the SLERA, the highest contaminant concentrations measured at the Site were documented for each medium and used in the screening of COPECs.

7.9.1.4 Ecotoxicity and Potential Receptors

Based on current land uses at and near the SVFUDS, ecological receptors selected are generally adapted to urban environments. Terrestrial wildlife may include species able to utilize disturbed open spaces and/or wooded areas within and adjacent to the site. For most terrestrial receptors, soil exposure intervals are limited to the upper one foot of the soil column, though some burrowing species and deep-rooted plants can be exposed to deeper soils. Terrestrial plants and soil invertebrates may be affected by contamination in soil; these potential ecological receptors were evaluated in the SLERA by comparison to applicable soil screening levels and, indirectly by their role as food for higher level receptors.

Potential effects on the organisms that live in sediment and surface water were semi-quantitatively evaluated in the SLERA by screening sediment and surface water chemical concentrations against values reflecting potential toxic effects for receptors in these media. Wildlife species that may be exposed to sediment and surface water, but primarily live in terrestrial habitats, termed “semi-aquatic” for the SLERA, were also evaluated. Surface water contaminant concentrations were included in the SLERA to the extent that terrestrial and semi-aquatic species are exposed to surface water (e.g., as drinking water).

The receptors were selected to represent the trophic levels and characteristics of the area being assessed. Based on available information, specific receptor species were selected to be representative of terrestrial and semi-aquatic ecological populations potentially exposed to COPECs. Consideration was given to special-concern (i.e., threatened or endangered) species potentially present at the site when selecting receptor species. Within the SVFUDS, no threatened, endangered, or locally sensitive species are known to occur. The species listed by the United States Fish and Wildlife Service (USFWS) that are known to occur within the area, include the Hays Spring Amphipod *(Stygobromus hayi)*, and the Bald Eagle *(Haliaeetus leucocephalus)*. None of these species have been documented within the project area. There are four additional species that are listed within the DC, but that do not occur within the area.

Vegetation in the area consists of deciduous hardwood forested areas, urban landscaped areas, and small streams and associated deciduous vegetation. Plant species were evaluated indirectly by evaluating the soil at the site. Plants were also evaluated as an exposure medium (i.e., food source) for wildlife receptors. Likewise, invertebrates were indirectly assessed by evaluating the soil exposure, and were also evaluated as an exposure medium (i.e., food source) for higher trophic level organisms. Similarly, aquatic and sediment-dwelling receptors were evaluated semi-quantitatively by comparison of maximum detected concentrations to screening values that reflect potential toxic effects for these receptors.

7.9.1.5 Complete Exposure Pathways

For an exposure pathway to be complete, a contaminant must be able to travel from the source to ecological receptors and to be taken up by the receptors via one or more exposure routes. If an exposure pathway is not complete for a specific contaminant (i.e., ecological receptors cannot be exposed to the contaminant), that exposure pathways was not evaluated further. Potentially complete exposure pathways were evaluated in the SLERA for higher trophic level ecological receptors that are more likely than lower trophic level receptors to accumulate environmental chemicals. These receptors evaluated include: deer mice, box turtles, American robins, Cooper’s hawks, raccoons, red foxes.

7.9.1.6 Assessment and Measurement Endpoints

The assessment endpoints for the SLERA were the survival, growth, and reproduction of aquatic and terrestrial wildlife populations (associated with suitable habitat) that may have been affected by previous actions in the SVFUDS. Assessment endpoints were provided for terrestrial and semi-aquatic populations at three trophic levels. Each animal’s exposure was evaluated in the SLERA based on individual habitats. The possible receptors were divided into broad classes of herbivores, omnivores, and carnivores, and are further divided into mammals, birds, and reptiles/amphibians. In accordance with USEPA guidance, representative species that are likely to occur in the area and for which sufficient data on diet and other habitat characteristics are available, can be used to conduct the SLERA. The representative species at SVFUDS include the deer mouse, American robin, box turtle, raccoon, and the red fox.

7.9.1.7 Screening and Identification of Chemical Stressors

COPECs were identified through the initial screening step and were carried through the risk assessment process. The screening process compared the maximum detected concentrations in soil, sediment, surface water, and ground water to a screening value. For soil screening, several screening values were utilized to evaluate the risks to various groups of organisms. Different values were used for plants, for terrestrial invertebrates, and other wildlife. Based on the screening criteria, some chemicals were eliminated from further analysis, and the remaining COPECs were retained for exposure estimates and receptor effect levels. Toxicity information pertinent to each identified receptor was gathered for all available COPECs. To quantify the ecotoxicity (i.e. exposure-response) it was necessary to evaluate the likelihood of toxic effects in different groups of organisms.

7.9.1.8 Exposure Estimate and Risk Calculation

To estimate exposures for the SLERA calculation, only potentially complete exposure pathways were evaluated. For the potentially complete exposure pathways, a 95% UCL of the mean was calculated as a more realistic representation of current site conditions. For other potentially complete exposure pathways where there were fewer data points, the maximum measured contaminant concentration for each environmental medium was used to estimate exposures. A quantitative screening-level risk was estimated using the exposure estimates and screening ecotoxicity values. For the SLERA, conservative assumptions were used to calculate screening level hazard quotients. These highly conservative assumptions resulted in an overestimation of the risk to the ecological receptors. Due to the conservative nature of the SLERA and based on an evaluation of COPECs with site-specific background concentrations, no site-specific COCs were identified from the list of preliminary COCs presented.

7.9.2 SLERA Summary and Conclusions

Based on the data presented, the SLERA provided adequate information to conclude that ecological risks are negligible at the SVFUDS and there is no need for additional ecological risk assessment or remediation on the basis of ecological risk. The area is largely residential, commercial, and institutional with only a small portion of the area available as suitable habitat for ecological receptors. No threatened, endangered, or locally sensitive species are known to occur at the SVFUDS and the ecological receptors that are known to occur in the area do not warrant further evaluation.

7.10 Uncertainty

Sections 7.2 and 7.3 provided HHRA-specific discussions of uncertainty associated with HHRA conclusions. However, there is also uncertainty associated with some of the other elements discussed in this RI report. In some cases, background information is insufficient to accurately locate an area. For example, as described in Tables 1-1 and 1-2, the location of Major Tolman's field (AOI 18 / POI 38) could not be determined with certainty. Known data gaps also result in uncertainty, such as a property in the 3700 block of Fordham Road, where geophysical surveys were conducted that identified one potential burial pit or trench and 27 single item anomalies. However, access to perform the intrusive investigation of the anomalies has not been granted by the property owner.

Uncertainty is associated with locating the ground scars and the subsequent shifting of them to improve positional accuracy. As described in Section 2.1.1.2, shifting was a function of improved technology and the increased georeferencing capability allowing for correction of misalignments of the ground scars. Based on GIS software statistical calculations of realignment errors, the 1918, 1927, and 1928 historic aerials are considered to be consistently and more accurately positioned in relation to each other, while the 1922 aerial was more difficult to georeference (an average shift of 75 feet).

Other specific issues of uncertainty include the sufficiency of the sampling to characterize the SVFUDS, the potential for burial areas to remain in the neighborhood, and the limitations associated with use of one of the primary investigation tools, DGM. These are further discussed in more detail below.

7.10.1 Sampling Sufficiency

More than 99% of all properties (residential properties and commercial lots) within the SVFUDS have received some level of soil sampling. Much of this is screening-level sampling based on assessing arsenic concentrations across the SVFUDS. The few areas where sampling has not occurred is primarily due to right-of-entry issues with the property owner (that is, the owner will not allow USACE to sample the property). In these cases, USACE has made multiple attempts to obtain access agreements.

Figure 7-11 presents an overview of soil sampling within the SVFUDS. The green shading indicates areas that received some type of soil sampling. While the majority of these samples have been for arsenic analysis only, more than 500 samples were analyzed for a wide variety of parameters, including the CWM ABPs. The parameters analyzed for many of these samples reflected the AUES activity performed in that area, as described in the 2003 EE/CA (USACE, 2003b) under which much of the sampling was conducted. There are few areas on the figure that are not shaded green. However, it is important to emphasize that many samples cannot be shown on the figure due to issues of map scale. For example, the 4801, 4825 and 4835 Glenbrook Road properties, or the athletic fields and Lot 18 area of AU, have had a considerable density of samples for many analytical parameters not shown on the figure. The specific numbers, locations, and analyses for these samples are contained in the individual investigation reports addressing those areas (Appendix C includes these reports in their entirety).

Figure 7-12 presents an additional view of soil sampling coverage. The approximately 38,000 dots shown represent discrete soil samples, or sub-samples where compositing was conducted to form an individual sample in accordance with the 2003 EE/CA arsenic screening procedure. Due to issues of map scale, not all sample dots could be shown (e.g., areas of dense sampling such as OU-3, or grid sampled areas completed at a 10 foot spacing). USACE conservatively estimates that approximately 17,000-20,000 soil samples have been collected within the SVFUDS since the OSR FUDS RI, beginning approximately 1993.

In addition, to characterize the groundwater, many monitoring wells have been installed and sampled on multiple occasions. The groundwater investigation is ongoing. The Groundwater RI Summary Report (Appendix G) will be provided at a later date.

With regard to the issue of whether there remain significant areas of the SVFUDS that should be sampled, CERCLA does not require that a responsible party sample all areas of a site. Rather, to assess the nature and extent of potential contamination, distinctions between historically impacted and unimpacted areas are made, as has been done with the establishment of the POIs and AOIs. The USEPA RI guidance makes clear that sampling everywhere is neither possible nor recommended, and using site history to focus samples is standard practice.

The need for further sampling of relevant media would be driven by potential sources of contamination. The primary potential sources of contamination, based on the review of the past history of AUES operations and the CSM development are the burial pits identified at 4825 and 4801 Glenbrook Road, 52nd Court, and the OU-4 AU Lot 18 disposal area. As these areas were discovered through excavations or geophysics, the procedure was to thoroughly characterize the surrounding area with soil sampling and additional geophysics as warranted, with the intent of not only removing buried items, but characterizing the possible contamination in the soils; each of these areas has been (or, in the case of 4825 Glenbrook Road, is in the process of being) excavated to unimpacted soil and backfilled with clean soil. Therefore no additional soil sampling is considered to be necessary for these areas.

The Range Fan is an additional possible source area. However, based on the large portions of this area intrusively investigated for MEC and MD, and the lack of significant soil contamination associated with any munitions finds related to the Range Fan, no additional soil sampling is warranted there.

With the exception of the ongoing groundwater investigation where contamination from a discrete source can migrate elsewhere, soil contamination at one discrete burial area is not associated with another burial area in terms of migrating contaminants. The assumption of spatial dependence between two discrete burial areas and therefore a need to sample the acreage between them is not a reasonable technical approach. This is particularly true with naturally occurring constituents such as metals, which may vary widely in concentration simply based on soil type. Where there is reasonable information, evidence, or data, USACE's approach has been to investigate further. For portions of the SVFUDS where there is no evidence of past operations having impacted an area, and where contaminants are unlikely to be able to migrate (as is the case with soil contamination associated with burial pits), no comprehensive sampling has been conducted. Although even in those areas, as described above, even in this situation, considerable screening level sampling has occurred.

7.10.2 Potential for Remaining Burial Areas

Section 7.6.3.4 describes three remaining possible disposal or burial areas. These are considered 'possible' disposal areas based on a weight of evidence assessment, but it is not certain that they contain buried munitions. The reason these areas were identified is that their possible presence was suggested by the results of nearby investigations (as in the case of the AU Public Safety Building), or by inferences made based on the knowledge of past AUES operations (as in the Fordham Road situation), or by review of photogrammetry including ground scars or test pits (such as AOI 13).

The overall approach to the SVFUDS investigations has been to apply such rationale and logic to ensure that critical areas are not overlooked. The primary tool to achieve this is the DGM survey. The completion of DGM surveys in areas where past operations suggest that disposal or burials may have occurred, and the elaborate DGM analysis, described in Section 4.1.2, that provides detailed evaluation of individual anomalies and whether they might represent pits or trenches that could be burial areas, is the primary means of determining whether burial pit remain in the SVFUDs.

There will always be a level of uncertainty associated with this issue, however, as stated above, where there is reasonable information, evidence, or data, USACE's approach will be to evaluate the need for further action.

7.10.3 DGM Uncertainty

Uncertainty in geophysics with respect to near surface geophysics employed at SVFUDS, results from several factors. There is uncertainty in the detection of MEC or MD due to the limitations of the geophysical detectors used. Instruments are limited in what physical parameters they can and cannot detect. For example, electromagnetic instruments can detect the presence of metals within soil, but cannot detect glass. Magnetic instruments can only detect ferrous metals. The depth sensitivity of various detectors adds uncertainty in that most can detect small objects only at shallow depths. Geological site conditions can increase uncertainty by impacting the effectiveness of the detector. For example the instrument may be impeded by clayey soil. Conversely, naturally occurring rocks with magnetic properties may obscure metallic objects of interest or may actually be targeted for excavation (i.e., result in false positives).

Errors in measurements are possible. For any site, there is some level of background noise or interference that may obscure the signal generated by an object of interest, which may limit the ability to detect small or deep objects. Noise can be limited to a very small amount generated by the detector itself or it can be caused by external sources such as overhead power lines or radio transmitters.

Errors in position measurements cause another type of uncertainty. Various navigation systems have inherent error associated with them, usually ranging from a less than an inch to a few feet, and this can be affected by site conditions such as slopes, obstructions, or tree-canopy (which can block GPS satellite signals). Related to this are errors resulting from the spacing of measurements, or the transect spacing and along-track spacing. Although most surveys are designed so that there is overlap in the geophysical footprint, objects of interest may be buried between transects and could be less detectable for this reason. Lower quality of data in a survey due to vegetation or steep slopes where a detector cannot be operated as methodically as a flat surface, can add to uncertainty.

Errors in processing the geophysical data are possible. The threshold (minimum instrument response considered to be representative of objects of interest) could be set too high resulting in small or deep items being ignored. There may be inconsistency caused by variations in the experience of the data processors handling the raw data. Most geophysical responses are not unique, meaning more than one configuration of subsurface materials may cause nearly identical geophysical responses. For example, several small metallic objects may cause the same response as a single large item, or a small, shallow object could cause the same response as a deep, large objects.

Intrusive investigation of every single anomaly would generally solve many of these issues. However, this is not practical and is rarely done. Interpretation of DGM data by experienced geophysicists is done to focus on those anomalies most likely to be the ones of interest (i.e., munitions related), thereby saving resources and increasing efficiency of operations. The interpretation of data and generation of 'dig' lists also becomes a source of uncertainty. The accuracy of the locations of historical site features previously described, such as ground scars, impacts the ability to find and intrusively investigate geophysical anomalies of interest, and uncertainty is associated with imprecise or incomplete knowledge of historical features and past records of military operations. Unless 100% coverage of a site is practical, DGM surveys are designed based on knowledge of past operations so that the survey can be properly focused on the most likely areas of interest.

8.0 SUMMARY AND CONCLUSIONS

8.1 Summary

This section summarizes the key findings from Sections 5.0 and 7.0, and presents recommendations for future work at the SVFUDS.

8.1.1 Nature and Extent of Contamination

8.1.1.1 HTW/MC/CWM

The determination of the nature and extent of HTW/MC/CWM contamination for the SVFUDS is based on the findings summarized in Sections 5.1, 5.2, and 5.4. The results of the investigation and characterization, and removal activities define the nature and extent.

The investigation and characterization activities were completed as standalone reports performed at discrete areas of the SVFUDS. Several discrete areas of the SVFUDS have proceeded through quantitative HHRAs, including those discussed in Section 7.1.1, and any conclusions indicating remaining risk have been addressed in follow-on investigation or removal actions such that characterization of those discrete areas was considered to be complete. The more recent supplemental sampling was assessed in the Addendum to the Pre-2005 HHRA Review document (see Section 7.1.2.2) and the results have been incorporated into the quantitative HHRA included in this RI report (Sections 7.2 and 7.3).

Removal actions at the SVFUDS have been concurrent with other investigations, being expedited through the TCRA and NTCRA process. The nature and extent of contamination in the areas of removals has been bounded through the removal actions, with soil excavations continuing until clean confirmation samples are obtained. No additional sampling or removal actions are currently required to complete the nature and extent characterization of the SVFUDS.

The groundwater investigation is ongoing. A Groundwater RI Summary Report is included as Appendix G. A separate Groundwater RI will be provided at a later date.

8.1.1.2 MEC/MD

For the OSR FUDS investigation, some 492 properties within the 661 acres of the SVFUDS, with focus on the identified POIs, were geophysically surveyed with an objective to locate burial pits and trenches. However, it is not practical to geophysically survey 100% of a site the size of the SVFUDS. Therefore, sound rationale for the selection of properties was crucial to determining the nature and extent of MEC or MD contamination (Figure 5-6 indicates types and locations of MEC/MD found). Since 2001, a structured classification scheme to prioritize properties for geophysical investigations has been followed. While this process has provided high quality geophysical data of all key areas based on historical review of past practices and likelihood of MEC or MD being present, the presence of individual munitions-related items in the SVFUDS will remain a possibility. Section 8.1.3 provides recommendations to address this possibility in certain scenarios.

The details of the investigation and characterization, geophysical investigation, and removal activities that define the nature and extent are contained in key standalone documents. Table 8-1 shows the organization of key documents by activity type, and where discussion of their findings can be found in this RI report.

Table 8-1. Summary of Key SVFUDS Documents by Activity Type		
Activity Type	**List of Documents***	**Section 5.0 Discussion**
Initial Investigations and Characterization	Table 1-3	5.1
Follow-on Investigations and Characterization	Table 1-4	5.2
Geophysical Investigations	Table 1-5	5.3
Removal Actions	Table 1-6	5.4

* - All of these documents are contained in their entirety in Appendix C.

8.1.2 <u>Risk Assessment</u>

Risk assessment for the SVFUDS required integration of multiple risk-related issues on a site-wide basis to form a comprehensive understanding of risk remaining within the SVFUDS. In addition to quantitative HHRAs completed, other risk-related elements that contribute to understanding risk within the SVFUDS included:

- The derivation and protectiveness of 20 mg/kg arsenic as the soil cleanup goal;
- An evaluation of arsenic potentially remaining in soil beneath city streets;
- External health-related studies (prepared by others); and a
- Screening Level Ecological Risk Assessment.

8.1.2.1 Risk-related Elements

An evaluation of the 20 mg/kg arsenic removal goal for carcinogenic and non-carcinogenic risks posed to adult and child residents indicated that the risks for children and adults are within USEPA's acceptable range.

Cancer and non-cancer risk levels were evaluated for a construction worker with limited repair work exposure to arsenic contaminated soils beneath city streets. The evaluation concluded that arsenic concentrations up to 100 mg/kg in the soil could be encountered by the construction worker without exceeding the acceptable USEPA risk levels. Based on a review of the 68 properties where one or more soil samples were collected adjacent to a city street, only 14 of the 228 samples contained arsenic greater than 20 mg/kg and the highest arsenic concentration (46.6 mg/kg) did not pose unacceptable risks to a construction worker.

The ATSDR and JHSPH, agencies and organizations external to USACE, conducted health consultations and exposure studies to evaluate possible past and present exposures to contamination associated with past SVFUDS activities. The primary health scoping study (conducted by JHSPH) noted that the overall health of Spring Valley residents continues to be very good and mortality rates continue to be below the U.S. average for most causes.

In addition to human health, ecological risks were assessed in the SLERA, which evaluated whether unacceptable adverse risks are, or may be posed, to ecological receptors as a result of hazardous substance releases. The SVFUDS area was characterized with respect to operational, physical, chemical, and ecological characteristics, and the current and anticipated future land uses. Based on the data presented, the SLERA provided adequate information to conclude that ecological risks are negligible and that there is no need for additional ecological risk assessment or further action on the basis of ecological risks.

8.1.2.2 Quantitative HHRAs

The comprehensive risk screening process described in Section 7.1.2 included review of the previous (pre-2005) HHRAs to assess whether they remain protective, supplemental additional soil sampling to address data gaps, and identification of specific areas where further risk assessment was warranted. This screening resulted in the quantitative HHRAs conducted on the AOI 9, Spaulding-Rankin, and Southern AU EUs, which estimated the magnitude of exposure to COPCs, identified potential exposure pathways, and quantified exposures to estimate the risks posed to human receptors associated with exposure to the soil at each of the EUs. Table 8-2 summarizes the key findings of the quantitative HHRAs for the three EUs.

For the residential AOI 9 EU, non-cancer HIs and incremental cancer risks are below a level of concern. Therefore, further assessment or action at the AOI 9 EU is not required.

For the residential Spaulding-Rankin EU, cobalt was determined to be a COC that poses unacceptable risks and follow-on actions are required to address it.

For the Southern AU EU (excluding outlier locations), cobalt was determined to be a COC that poses unacceptable risks and follow-on actions are required to address it.

For the much smaller outlier locations at the Southern AU EU, three locations are associated with risks: mercury (one location) and vanadium and cobalt (one location) in soil are associated with non-carcinogenic risks, and carcinogenic PAHs in soil (one location) are associated with carcinogenic risks that exceed USEPA’s risk range. Thus, these chemicals in soil at these outlier locations are COCs that pose unacceptable risks and follow-on actions are required to address them.

Table 8-2. Summary of Risk Assessment Findings

Exposure Unit	Conclusion	Risk Driver (soil)
AOI 9	No Further Action	None
Spaulding-Rankin	Unacceptable non-carcinogenic risk	Cobalt
Southern AU (excluding outlier locations)	Unacceptable non-carcinogenic risk	Cobalt
Southern AU Outlier Locations	Unacceptable non-carcinogenic risk	Mercury, Vanadium, and Cobalt
	Unacceptable carcinogenic risk	Carcinogenic PAHs

In addition to these HHRAs addressing soil, a Groundwater RI that will include a quantitative HHRA focusing on groundwater will be provided at a late date.

8.1.3 <u>Hazard Assessment</u>

Section 7.6 presents the MEC hazard as determined by using the MEC HA methodology. The MEC HA is the ‘explosive hazard’ component of an HHRA, assessing potential explosive hazards to human receptors at the SVFUDS. The methodology evaluates the potential explosive hazard associated with an area, given current conditions and under various cleanup scenarios, land use activities, and LUC alternatives.

At the SVFUDS, the MEC HA was organized around the past activities most likely to result in MEC at the site, including ballistically fired testing, statically fired testing, and disposal (known and possible). Table 8-3 summarizes the MEC HA for current use conditions, indicating that three of the four activities scored result in a MEC HA hazard level category of 3 (moderate potential explosive hazard conditions). The MEC HA provides the basis for the evaluation and implementation of effective management response alternatives in an FS, but the scores are qualitative references only and should not be interpreted as quantitative measures of explosive hazard, or as the sole basis for determining whether or not further action is necessary at a site.

Table 8-3. Summary of MEC HA Findings

Area	*Current Use Conditions*	
	Hazard Level Category	**Associated Relative Explosive Hazard**
Safety Buffer for Livens	4	Low potential explosive hazard conditions
Function Test Range for Stokes	3	Moderate potential explosive hazard conditions
Function Test Range for Livens	3	Moderate potential explosive hazard conditions
Generic Disposal Area	3	Moderate potential explosive hazard conditions

Table 8-3 indicates that the Livens Range Safety Buffer scored a hazard level category of 4 (low potential explosive hazard conditions) based on current use activities. This reflects that few MEC items would be expected in a buffer area. The Function Test Ranges or impact areas for both the Livens and the Stokes mortars received a MEC HA score of 3 (moderate potential explosive hazard conditions) based on current use activities. The moderate potential explosive hazard conditions that this score represents for this documented impact area suggests that follow-on actions may be required to mitigate unacceptable explosive hazards that could exist on the properties within the impact areas.

The static test fire areas do not typically represent MEC concerns in that the testing process would have monitored and controlled individual items and any munition item not properly firing would be identified in real time. However, similar to the findings at the initial 52nd Court trenches (POI 13 disposal area), static testing activities may suggest the presence of munitions burial pits near the testing locations. The potential for remaining munitions burial pits suggests that follow-on actions may be required to mitigate unacceptable explosive hazards associated with possible munitions burial pits in the test areas or the 150 ft investigation or buffer zones around the known static fire test areas.

For the possible disposal areas, a generic MEC HA that conservatively assumed a worst case disposal area/burial pit scenario was completed and the resulting score was a 3 (Table 8-3). The unknowns associated with the three possible disposal areas (AU PSB, AOI 13, and POI 2 / Fordham Road area) and the moderate potential explosive hazard conditions they represent (using conservative assumptions) suggest that follow-on actions may be required to mitigate unacceptable explosive hazards that could exist in these three areas.

8.1.4 Fate and Transport

Based on the quantitative HHRAs, the COCs are mercury, vanadium, and dibenz(a,h)anthracene (a carcinogenic PAH) in soil. However, these were identified as COCs only for the Southern AU EU, and only in outlier locations, meaning they are very narrowly limited in extent around a few samples with elevated concentrations of those chemicals.

The fate and transport of metals is highly complex, governed by pH and redox environments, soil composition, extent of soil saturation, and soil organic content. Metals, in general, are immobile under the subsurface conditions at the SVFUDS, where approximately 90 percent of the SVFUDS is underlain by saprolitic, clay-rich soils, and slightly acidic to neutral soil pH and oxidizing conditions are expected. Metals do tend to leach into groundwater based upon the specific metal's affinity to soil and groundwater. Generally, the solubility of metals tends to increase proportionate to increased acidity, and decrease under alkaline conditions. Organic matter may also result in metals sorbing to soil and sediment making them insoluble in groundwater.

PAHs are a concern because they are complex molecules that do not easily biodegrade and are therefore persistent in the environment for long periods of time. PAHs in general do not easily dissolve in water. They are present in air as vapors or stuck to the surfaces of small solid particles. When present in soil or sediments, PAHs tend to remain bound to the soil particles and dissolve only slowly into groundwater or the overlying water column.

Arsenic and perchlorate have been found in the groundwater at levels of concern at various times in different locations, including in wells located in close proximity to 4801 Glenbrook Road and 4825 Glenbrook Road. The arsenic contaminated soil at 4801 Glenbrook Road has been removed, and is in the process of being removed at 4825 Glenbrook Road; therefore, migration to groundwater is not considered to be a continuing concern.

8.2 Conclusions

Nature and extent of HTW/MC/CWM and MEC and MD has been characterized for the SVFUDS as described above. Human health and ecological risks, and explosive hazards have been assessed. DQOs, as developed for site-specific efforts, and as generally applied on an activity-specific basis, have been achieved.

8.2.1 Data Limitations

Data limitations are described in the uncertainty sections (Section 7.2.5, 7.3.5, and 7.10). In some cases, limitations are based on the inability of USACE to access private property to complete investigations or the inadequacy of available background or historical information upon which to base investigative decisions. With regard to characterizing the SVFUDS for nature and extent of MEC or MD, the primary limitation is the impracticality of conducting geophysics on 100% of the 661 acre SVFUDS, and while the process to select properties for geophysical investigation is thorough and based on solid technical rationale, the potential for MEC and MD items to be present remains.

8.2.2 Recommendations

Recommendations focus on unacceptable risks posed by HTW/MC/CWM contaminated soil as determined by the quantitative HHRA, and unacceptable explosive hazards posed by potentially remaining MEC. Figure 8-1 presents the locations of areas recommended for follow-on actions as described below. The specific nature of the follow-on actions will be determined through the alternatives analysis conducted for the FS.

Regarding HTW/MC/CWM contamination, the following is recommended:

- **Conduct an FS to address unacceptable non-carcinogenic risks in soil in the Spaulding-Rankin EU.**
- **Conduct an FS to address unacceptable non-carcinogenic risks in soil at the Southern AU EU (excluding outlier locations), and carcinogenic and non-carcinogenic risks in soil in three outlier locations in the Southern AU EU.**

Regarding MEC contamination, the following is recommended:

- **Conduct an FS to address potential unacceptable explosive hazards associated with munitions possibly remaining within the impact areas of the Function Test Ranges for the 3" Stokes, 4" Stokes, and the 8" Livens.**
- **Conduct an FS to address potential unacceptable explosive hazards associated with possible munitions burial pits in the buffer zones and test areas of the Static Test Fire areas.**
- **Conduct an FS to address potential unacceptable explosive hazards associated with possible munitions disposal burial pits associated with the Possible Disposal Areas (AU PSB, AOI 13, and POI 2 / Fordham Road area).**

Table 8-4 presents recommendations for each POI, AOI, and the Range Fan, providing a comprehensive overview of the site-wide characterization and recommendations for the SVFUDS. The table incorporates the areas recommended above for follow-on actions into the appropriate POI, AOI, or Range Fan designation to further organize the site-wide RI findings by the SVFUDS delineated areas described in Section 1.5. Note that some recommendations are shown more than once, as areas such as AOI 9 and the Range Fan overlap.

8.2.3 Recommended Remedial Action Objectives

Based on the quantitative HHRAs, the COCs are cobalt, mercury, vanadium, and carcinogenic PAHs in soil. Combining the COCs, the affected media, the exposure pathways, and the project goals, the SVFUDS site-wide RAOs should include:

- Prevent direct contact with mercury or vanadium-contaminated soil having a non-carcinogenic HI exceeding 1,
- Prevent direct contact with cobalt-contaminated soil having a non-carcinogenic HI exceeding 2,
- Prevent direct contact with PAH-contaminated soil having a cancer risk in excess of 1 x 10^{-4}, and
- Reduce the potential for encountering MEC.

The areas recommended for follow-on actions in Section 8.2.2 will be evaluated through the FS process to identify alternatives for achieving these remedial action objectives.

Table 8-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
POI 1 / Circular Trenches	AOI 9, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with possible POI 1 munitions burial pits.**
POI 2 / Possible Pit	AOI 9, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with the POI 2 Possible Disposal Area.**
POI 3 / Small Crater Scars	AOI 9, Range Fan, Within MRS 01	Within POI 1 buffer zone **(see POI 1 recommendation)**.
POI 4 / Possible Pit	AOI 9, Range Fan, Within MRS 01	Within POI 1 buffer zone **(see POI 1 recommendation)**.
POI 5 / Possible Pit	AOIs 9, 21, Range Fan, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with the Function Test Ranges (Impact Areas) for the 3" Stokes, 4" Stokes, and the 8" Livens.**
POI 6 / Possible target or Test Site	AOIs 9, 21, Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
POI 7 / Possible Test Area	AOIs 9, 21, 24, Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
POI 8 / Possible target or Test Site	AOIs 9, 21, Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
POI 9 / Possible Firing or Observation Stalls	AOIs 21, Range Fan, Within MRS 01	**FS to address potential unacceptable explosive hazards associated with possible POI 9 munitions burial pits.**
POI 10 / Possible Target or Test Site	POIs 11, 39, AOIs 21, 24, Range Fan, Within MRS 01	**Within POI 39. FS to address potential unacceptable explosive hazards associated with possible POI 10 munitions burial pits.**
POI 11 / Scattered Ground Scars	POIs 10, 39, AOIs 21, 24, Range Fan, Within MRS 01	Within POI 39 **(see POI 10 recommendation)**.
POI 12 / Possible Graded Area	AOIs 8, 21	No Further Action
POI 13 / Circular Trenches	POI 14, AOIs 11, 21	No Further Action
POI 14 / Pit	POI 13, AOIs 11, 21	No Further Action
POI 15 / Ground Scar	AOI 21	No Further Action
POI 16 / Chemical Persistency Test Area	AOI 21	No Further Action
POI 17 / Possible Pit	Range Fan, Within MRS 01	No Further Action
POI 18 / Small Crater Scars	Range Fan, Within MRS 01	No Further Action
POI 19 / Old Mustard Field	None	No Further Action
POI 20 / Ground Scar	AOIs 3, 22, 24	No Further Action
POI 21 / Two-chambered shell pit	POIs 22, 23, AOIs 22, 24, Within MRS 01	**FS to address the unacceptable non-carcinogenic risks associated with soil COC at the Spaulding-Rankin property**
POI 22 / Shell pit	POIs 21, 23, AOIs 22, 24, Within MRS 01	Within Spaulding-Rankin property **(see POI 21 recommendation)**

Table 8-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
POI 23 / Three chambered shell pit	POIs 21, 22, AOIs 22, 24, Within MRS 01	Within Spaulding-Rankin property **(see POI 21 recommendation)**
POI 24 / Probable Pit	POI 53, AOIs 5, 17, Within MRS 01	No Further Action for 4835 Glenbrook Road. Work at 4825 Glenbrook Road is being addressed in a separate RA.
POI 25 / Possible Trenches	AOI 3, Range Fan, Within MRS 01	No Further Action
POI 26 / Small Crater Scars	POI 53, AOI 13, Within MRS 01	**Within AOI 13. FS to address potential unacceptable explosive hazards associated with the AOI 13 Possible Disposal Area.**
POI 27 / Probable Ditch or Trench	None	No Further Action
POI 28 / Probable Ditch or Trench	None	No Further Action
POI 29 / Ground Scar	AOI 14	No Further Action
POI 30 - 36 / Training Trenches	AOI 25	No Further Action
POI 37 / Mill Creek	None	No Further Action
POI 38 / Bradley Field/Major Tolman's Field	AOI 18	No Further Action
POI 39 / Static Test Fire Area	POIs 10, 11, AOIs 21, 24, Within MRS 01	Contains POIs 10 and 11 **(see recommendations for those areas).**
POI 40 / Ohio Hall	None	No Further Action
POI 41 / History Building	None	No Further Action
POI 42 Physiological Laboratory	None	No Further Action
POI 43 / Gun Pit	POIs 21, 22, 23, 53, AOI 4, Range Fan, Within MRS 01	No Further Action
POI 44 / Chemical Research Laboratory	None	No Further Action
POI 45 / Explosives Laboratory	None	No Further Action
POI 46 / Canister Laboratory	None	No Further Action
POI 47 / Bacteriological Laboratory	None	No Further Action
POI 48 / Dispersoid Laboratory	None	No Further Action
POI 49 / Pharmacological Laboratory	None	No Further Action
POI 50 / Concrete Gun Pit	None	No Further Action
POI 51 / Fire and Flame Laboratory	POI 53	No Further Action
POI 52 / Electrolytic Laboratory	POI 53	No Further Action
POI 53 /Baker Valley	POIs 24, 26, 43, 51, 52, AU, AOIs 4, 5, 13,17, 22,24, 26, Range Fan, Partially within MRS 01	No Further Action except for overlap of POI AU and AOI 13, and Spaulding-Rankin property **(see recommendations for those areas)**.
POI AU	POI 53, AOIs 17, 22, 24, 28, Within MRS 01	**FS to address unacceptable non-carcinogenic risks in soil at POI AU, and carcinogenic and non-carcinogenic risks in soil in the three outlier locations within POI AU.**

Table 8-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
		FS to address potential unacceptable explosive hazards associated with the Public Safety Building Possible Disposal Area.
AOI 1 / "X" Feature	Range Fan, Within MRS 01	No Further Action
AOI 2 / Rick Woods Burial Pit	POI 20	No Further Action
AOI 3 / Gunpowder Magazine Area	POIs 43, 53, Range Fan, Within MRS 01	No Further Action
AOI 4 / Livens Gun Pit	POI 53, AOIs 17, 22, 24, 28, Within MRS 01	Within Spaulding-Rankin property **(see POI 21 recommendation)**
AOI 5 / 4825/4835 Glenbrook Road	POI 24, AOI 17, Range Fan, Partially within MRS 01	No Further Action for 4835 Glenbrook Road. Work at 4825 Glenbrook Road is being addressed in a separate RA.
AOI 6 / Dalecarlia Impact Area	AOI 17	No Further Action
AOI 7 / The Rockwood Six	POI 12, AOI 21	No Further Action
AOI 8 / Possible Graded Area	POIs 1-8 AOI 24, Range Fan, Within MRS 01	No Further Action
AOI 9 / Sedgwick Ground Scars	POI 24, AOI 17, Partially within MRS 01	**See POI 1 and POI 5 recommendations.**
AOI 10 / Westmoreland Recreation Center	None	No Further Action
AOI 11 / 52nd Court Pit and Trenches	POIs 13, 14, AOI 21	No Further Action
AOI 12 / Livens Battery Impact Area	Range Fan, Within MRS 01	Within Function Test Range Impact Area **(see POI 5 recommendation)**.
AOI 13 / Quebec / Woodway 13 Properties	POIs 26, 53, Range Fan, Within MRS 01	**See POI 26 recommendation.**
AOI 14 / Sharpe Bunker on Seminary	POI 29	No Further Action
AOI 15 / Dog Wallows	None	No Further Action
AOI 16 / Westmoreland Circle Impact Area	None	No Further Action
AOI 17 / $800,000 Burial Site	POIs 24, 53, AU, AOIs 5, 26	No Further Action
AOI 18 / Major Tolman's Field	POI 38	No Further Action
AOI 19 / Tenleytown Station	None	No Further Action
AOI 20 / Slonecker-Johnson Ground Scars	None	No Further Action
AOI 21 / Weaver Farm	POIs 5-16, 39, AOIs 8, 9,11,12, 24, Range Fan, Partially within MRS 01	No Further Action except for overlap of POIs 9, 39, and AOI 12 **(see recommendations for those areas)**.
AOI 22 / Mercury Detection Areas	POIs 20- 23, 25, 53, AU, Partially within MRS 01	No Further Action for this HTW-only AOI except for overlap of POI AU **(see POI AU recommendation)**.
AOI 23 / Railroad Sidings	None	No Further Action
AOI 24 / Antimony Detection Areas	POI 7, 10, 11, , 20-23 25, 39, 53, AU, AOI 9, Partially within MRS 01	No Further Action except for overlap of POI 7, 39, AU, and AOI 13 **(see recommendations for those areas)**.
AOI 25 / Camp Leach Trenches	POIs 30-36	No Further Action

Table 8-4. Recommendations for POIs/AOIs/Range Fan

AOI or POI Number	Related Areas	Recommendations
AOI 26 / 4801 Glenbrook Road	POI 53, AOI 17, Partially within MRS 01	No Further Action
AOI 27 / Third Circular Trench	None	No Further Action
AOI 28 / Hamilton Hall Burial Pit	POI AU, Partially within MRS 01	No Further Action
Range Fan	POIs 3-11, 17, 18, 25, 39, 43, 53, AOIs 2, 4, 5, 6, 9, 12, 13, 22, 24, Within MRS 01	For the Function Test Ranges (Impact Areas) for the 3” Stokes, 4” Stokes, and the 8” Livens, **see recommendations for POIs 5, 6, 7, 8, and AOI 12.**
		No Further Action for the Firing Point and the Range Safety Buffers for the 3” Stokes, 4” Stokes, and 8” Livens, except for the overlap of POIs 9, 39, AOI 13, and the Spaulding-Rankin property **(see recommendations for those areas)**.

Notes: Bold text with shading indicates recommendations to conduct an FS. Bold text without shading indicates a reference back to a related area (i.e., area is covered under a previous recommendation to conduct an FS).

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Appendix A: Figures

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Appendix B: Technical Memoranda and Signed Documents of Record *(Presented on DVD only)*

B-1 Technical Memoranda

- **SVFUDS Boundary – Northeast and Southeast Area Review**
- **SVFUDS Cut and Fill Contour Map Analysis**
- **Procedure for Evaluation of Tentatively Identified Compounds in the SVFUDS**
- **Proposed Analysis and Classification Scheme for Selection and Ranking of Point Source Anomalies as Determined from Geophysical Data Acquired within the SVFUDS**
- **Three Phased Investigation and Development of DQOs for SVFUDS Livens Battery Pit and Stokes Mortar Gun Placement, Range Fan, and Impact Areas**

B-2 ARB Memoranda

B-3 Arsenic Contaminated Soil Removal Completion Letters

B-4 AOI Consensus Memoranda and Reports

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Appendix C: Key Investigation or Removal Reports

(Presented on DVD only)

Appendix C-1: Initial Investigation and Characterization Key Documents
Appendix C-2: Follow-on Investigation and Characterization Key Documents
Appendix C-3: Geophysical Investigations Key Documents
Appendix C-4: Removal Actions Key Documents

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Appendix C-1:
Initial Investigation and Characterization Key Documents

- **Remedial Investigation Report for the Operation Safe Removal – Formerly Used Defense Site (USACE, 1995)**
- **Engineering Evaluation/Cost Analysis, Captain Rankin Area Shell Pits, OSR FUDS (USACE, 1994)**
- **Remedial Investigation Report for Spaulding and Captain Rankin Areas, OSR FUDS (USACE, 1996)**
- **USEPA Region III Draft Risk Assessment Report, Army Munitions Site, Spring Valley (USEPA, 1999)**

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Appendix C-2:
Follow-on Investigation and Characterization Key Documents

- **Engineering Evaluation/Cost Analysis - 4801, 4825, and 4835 Glenbrook Road (USACE, 2000)**
- **Site-Specific Anomaly Removal Report 4801 Glenbrook Road (USACE, 2005)**
- **Post Removal Action Report. Non-Time Critical Removal Action for 4801 Glenbrook Road (USACE, 2006)**
- **Property Closeout Report for 4801 Glenbrook Road (USACE, 2011)**
- **Site-Specific Investigation Report – 4835 Glenbrook Road (USACE, 2013)**
- **USEPA HHRA for AU Property, OU-3 (USEPA, 2000)**
- **Post Removal Action Report – Time Critical Removal Action for AU Child Development Center (USACE, 2003)**
- **Site Specific Removal Report Small Disposal Area (USACE, 2004)**
- **Site Specific Anomaly Removal Report AU Lots (USACE, 2005)**
- **Post Removal Action Report - Time Critical Removal Action (TCRA) for AU Athletic Fields and Other Critical AU Lots (USACE, 2010)**
- **Site Specific Anomaly Investigation Report AU Lot 18 (USACE, 2008)**
- **Site-Specific Investigation Report – AU Public Safety Building (Phase 1 and Phase 2 Investigations) (USACE, 2013)**
- **Report of Sampling Results, AU Area G Ground Scar (USACE, 2012)**
- **Ground Disturbances Site Inspection Report for AU (USACE, 2011)**
- **Indoor Air Sampling Report for 5065 Sedgwick Street (USACE, 2004)**
- **Basement Sub-Slab Soil Gas Sampling Report - 4621 and 4625 Rockwood Parkway (USACE, 2006)**
- **Engineering Evaluation / Cost Analysis for Arsenic in Soil (USACE, 2003)**
- **Final Evaluation of Remaining Sampling Requirements, Spring Valley FUDS (USACE, 2012)**
- **Parameters Report for the Development of the AUES List of Chemicals (USACE, 2008)**

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Appendix C-3:
Geophysical Investigations Key Documents

- **Site Specific Anomaly Investigation Report for Anomalies at Nine Properties on Sedgwick Street, Quebec Street, 52nd Street, Fordham Road, 49th Street, and Warren Street (USACE, 2006)**
- **Site Specific Anomaly Investigation Report for Anomalies at Seven Properties on Sedgwick Street, Woodway Lane, and 48th Street – OU- 4 and OU-5 (USACE, 2005)**
- **Site Specific Anomaly Investigation Report for 3822 Fordham Road (USACE, 2011)**
- **Site Specific Anomaly Investigation Report for 3949 52nd Street (USACE, 2012)**
- **Site Specific Anomaly Investigation Report for 4703 Woodway Lane (USACE, 2011)**
- **Site Specific Anomaly Investigation Report for 4710 Woodway Lane (USACE, 2011)**
- **Property Closeout Report for 4710 Quebec Street (USACE, 2006)**
- **Site Specific Anomaly Investigation Report for 4720 Quebec Street (USACE 2010)**
- **Site Specific Anomaly Investigation Report for 4740 Quebec Street (USACE, 2011)**
- **Site Specific Anomaly Investigation Report for 4900 Quebec Street (USACE, 2012)**
- **Final Remedial Investigation Evaluation Report (USACE, 1998)**
- **Site Specific Anomaly Investigation Report for 5010 Sedgwick Street (USACE, 2010)**
- **Site Specific Anomaly Investigation Report for 5024 Sedgwick Street (USACE, 2011)**
- **Site Specific Anomaly Investigation Report for 5027 Sedgwick Street (USACE 2010)**
- **Site Specific Anomaly Investigation Report for 5036 Sedgwick Street (USACE, 2011)**
- **Site Specific Anomaly Investigation Report for 5041 Sedgwick Street (USACE, 2010)**
- **Site Specific Anomaly Investigation Report for 5047 Sedgwick Street (USACE, 2010)**
- **Site Specific Anomaly Investigation Report for 5053 Sedgwick Street (USACE, 2010)**
- **Site Specific Anomaly Investigation Report for 5058 Sedgwick Street (USACE, 2003)**
- **Site Specific Anomaly Investigation Report for 5100 Tilden Street (USACE, 2010)**
- **Site Specific Anomaly Investigation Report for the AU Bamboo Area (USACE, 2006)**
- **Site Specific Anomaly Investigation Report for AU Kreeger Hall Area Anomalies (USACE, 2007)**
- **Site Specific Anomaly and Trench Investigation Report for AU Kreeger Hall (USACE, 2012)**
- **Geophysical Investigation Report for Grids G4, H4, I4, H5, and I5 Dalecarlia Woods Area (USACE, 2011)**
- **Geophysical Investigation Report for Grids G6, H6, I6, and G7 Dalecarlia Woods Area (USACE, 2011)**
- **Investigation of Anomalies Report for Dalecarlia Woods Area (USACE, 2012)**

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Appendix C-4:
Removal Actions Key Documents

- **Post Removal Action Report – Time Critical Removal Action for Child Development Center (USACE, 2003)**
- **Post Removal Action Report: Time Critical Removal Action (TCRA) – AU Athletic Fields and Other Critical AU Lots (USACE, 2010)**
- **Post Time Critical Removal Action for Arsenic Contaminated Properties (USACE, 2003)**
- **Post Removal Action Report Time Critical Removal Action Tier II Arsenic Contaminated Properties (USACE, 2004)**
- **Arsenic Phytoextraction Laboratory Feasibility Study: 2004 Final Report (USACE, 2007)**
- **Arsenic Phytoextraction Field Verification Study: 2004 Final Report (USACE, 2007)**
- **Arsenic Phytoextraction Field Verification Study: 2005 Final Report (USACE, 2007)**
- **Arsenic Phytoextraction Field Verification Study: 2006 Final Report (USACE, 2008)**
- **Arsenic Phytoextraction Field Verification Study: 2007 Final Report (USACE, 2009)**
- **Arsenic Phytoextraction Field Verification Study: 2008 Final Report (USACE, 2011)**

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Appendix D: Completed HHRAs and Screening Documents

(Presented on DVD only)

- **Human Health Risk Assessment, American University Lot 18, Final, (USACE 2008).**
- **Human Health Risk Assessment, 4835 Glenbrook Road, Revised Final, (USACE 2009).**
- **Screening Level Ecological Risk Assessment for the SVFUDS, (USACE 2010)**
- **Human Health Risk Assessment, 4825 Glenbrook Road, Final, (USACE 2011).**
- **Human Health Risk Assessment, AU Public Safety Building, Final, (USACE 2013).**
- **Evaluation Document for the Spring Valley FUDS, Final (USACE, 2012).**
- **Pre-2005 Human Health Risk Assessment Review, Final (USACE 2013).**
- **Addendum 1 to the Final Pre-2005 Human Health Risk Assessment Review, Final (USACE 2013).**
- **Data Tables from Samples Used in Addendum 1 to the Final Pre-2005 Human Health Risk Assessment Review.**
- **Site-Wide HHRA Work Plan, Final (USACE 2014).**

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Appendix E: HHRAs for Residential EUs and American University EU

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Appendix E-1:
Occurrence and Distribution of COPCs

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Appendix E-2:
COPC Screening Tables

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Appendix E-3:
ProUCL Output

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Appendix E-4:
Age-Adjusted Carcinogenic Risk Tables

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Appendix E-5:
Vapor Intrusion Model

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Appendix E-6:
IUEBK Model

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Appendix E-7:
Risk Calculation Tables

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Appendix E-8:
COPC-Specific and Target Organ Tables

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Appendix F: MEC HA Scoresheets and MRSPP Scoresheets

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Appendix G: Groundwater Summary Report

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