RAAP 050506\05002

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

FINAL MASTER WORK PLAN

AUGUST 2003

PREPARED BY:

URS

5540 Falmouth Street, Suite 201
Richmond, Virginia 23230
(804) 965-9000 main
(804) 965-9764 fax

ARCHITECT-ENGINEER SERVICES
CONTRACT NO. DACA31-00-D-0011
DELIVERY ORDER NO. 0027

ATK
ALLIANT TECHSYSTEMS

Radford Army Ammunition Plant
Route 114, P.O. Box 1
Radford, VA 24143-0100
USA

February 20, 2004

Mr. Robert Thomson
U. S. Environmental Protection Agency
Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Subject: Master Work Plan, Final, August 2003 and
Work Plan Addendum 18, RCRA Facility Investigation at SWMU 41, Final December 2003
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Per your February 11, 2004 approval of the subject documents, two additional copies of each will be forwarded under separate cover to your office.

Please coordinate with and provide any questions or comments to myself at (540) 639-8266, Jerry Redder of my staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 639-8641.

Sincerely,

C. A. Jake

C. A. Jake, Environmental Manager
Alliant Ammunition and Powder Company, LLC

Enclosure

c: Russell Fish, P.E., EPA Region III

Thursday 2/27/2004 faxed to Dorsen Renne, URS

Durwood Willis
Virginia Department of Environmental Quality
P. O. Box 10009
Richmond, VA 23240-0009

Mark Leeper
Virginia Department of Environmental Quality
P. O. Box 10009
Richmond, VA 23240-0009

E. A. Lohman
Virginia Department of Environmental Quality
West Central Regional Office
3019 Peters Creek Road
Roanoke, VA 24019

04-815-23
JMcKenna/JJRedder

Tony Perry
U.S. Army Environmental Center
5179 Hoadley Road, Attn: SFIM-AEC-ERP
Aberdeen Proving Ground, MD 21010-5401

Katie Watson
Engineering & Environment, Inc.
7927 Camberley Drive
Powell, TN 37849

Dennis Druck
U.S. Army Center for Health Promotion and Preventive Medicine
5158 Blackhawk Road, Attn: MCHB-TS-HER
Aberdeen Proving Ground, MD 21010-5403

John Tesner
Corps of Engineers, Baltimore District
ATTN: CENAB-EN-HM
10 South Howard Street
Baltimore, MD 21201

bc: Administrative File
J. McKenna, ACO Staff
Rob Davie-ACO Staff
C. A. Jake
J. J. Redder
Env. File

Coordination: J. McKenna
J McKenna

04-815-23
JMcKenna/JJRedder

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

Date: February 11, 2004

In reply
Refer to 3HS13

CERTIFIED MAIL
RETURN RECEIPT REQUESTED

Commander,
Radford Army Ammunition Plant
Attn: SIORF-SE-EQ (Jim McKenna)
P.O. Box 2
Radford, VA 24141-0099

C.A. Jake
Environmental Manager
Alliant Techsystems, Inc.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24141-0100

Re: Radford Army Ammunition Plant
New River Ammunition Storage Depot
Draft revised *Master Work Plan*
Document submittal and review

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's August, 2003 draft revised *Master Work Plan* for the investigation of the Radford Army Ammunition Plant (RFAAP) and the New River Ammunition Storage Depot (NRASD). Based upon our review, the draft revised *Master Work Plan* for the investigation of RFAAP and the NRASD is approved. In accordance with Part II. (E)(5)of RFAAP's Corrective Action Permit, the *Master Work Plan* is now considered final. Please forward two copies of the final *Master Work Plan* to EPA for our files.

If you have any questions, please call me at 215-814-3357.

Sincerely,

Robert Thomson

Robert Thomson, PE
Federal Facilities

cc: Russell Fish, EPA
Leslie Romanchik, VDEQ-RCRA
Mark Leeper, VDEQ-CERCLA

McKenna, Jim

m: McKenna, Jim
nt: Thursday, January 15, 2004 7:18 AM
To: 'Thomson.Bob@epamail.epa.gov'; John.E.Tesner@nab02.usace.army.mil
Cc: darren_renne@urscorp.com; james_o_spencer@urscorp.com; Redder, Jerome; McKenna, Jim; msleeper@deq.state.va.us
Subject: RE: SWMU 54 Presentation, Tuesday, 20 January @ 0930

For SWMU 54 there are no EPA actions pending after the October 10, 2002 EPA approval letter. Based on this approval letter, RFAAP sent final report covers for WPA 13 on December 6, 2002. Also there was DEQ approval letter of November 5, 2002.

On another topic, the RFAAP Master Work Plan RFAAP submitted on September 4, 2003 still hasn't been approved. We revised it to address BTAG comments and resubmitted it for approval.

Jim McKenna
IMPORTANT NOTE: When replying to this message cut and paste Jim_McKenna@ATK.com into the address line. Please do not hit reply. Thanks.

-----Original Message-----
From: Thomson.Bob@epamail.epa.gov [mailto:Thomson.Bob@epamail.epa.gov]
ent: Wednesday, January 14, 2004 3:20 PM
: John.E.Tesner@nab02.usace.army.mil
c: darren_renne@urscorp.com; james_o_spencer@urscorp.com; Jerome_Redder@ATK.COM; Jim_McKenna@ATK.com; msleeper@deq.state.va.us
Subject: Re: SWMU 54 Presentation, Tuesday, 20 January @ 0930

Just a follow-up, the latest correspondence I have in the EPA working files for this site is an October 10, 2002 approval of Work Plan addedum 13. I am assuming that this is correct, unless I hear otherwise.

Rob

John.E.Tesner@nab02.usace.army.mil
01/14/2004 01:52 PM
To: msleeper@deq.state.va.us, Bob Thomson/R3/USEPA/US@EPA, Jim_McKenna@ATK.com, Jerome_Redder@ATK.COM
cc: darren_renne@urscorp.com, james_o_spencer@urscorp.com
Subject: SWMU 54 Presentation, Tuesday, 20 January @ 0930

ATK
ALLIANT TECHSYSTEMS

Radford Army Ammunition Plant
Route 114, P.O. Box 1
Radford, VA 24141
USA

September 4, 2003

Mr. Robert Thomson
U. S. Environmental Protection Agency
Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Subject: Final Master Work Plan, August 2003,
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is one certified copy of Final Master Work Plan, August 2003 Radford Army Ammunition Plant for your files. Your additional two copies will be sent under separate cover as well as additional copies to the Virginia Department of Environmental Quality (VDEQ), U.S. Army Environmental Center, U.S. Army Center for Health Promotion and Preventive Medicine.

This report has been revised to address USEPA Biological Technical Assistance Group (BTAG) of May 28, 2002. Note closure on these comments was first achieved during a conference call held on July 17, 2003. Our responses to these comments are attached. In a subsequent conversation with Mr. Jim McKenna, you indicated to send this as a final document. Please note that the Final Master Work Plan, August 2003 replaces the Final Master Work Plan, September 2002.

Please coordinate with and provide any questions or comments to myself at (540) 639-8266, Jerry Redder of my staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 639-8641.

Sincerely,

C. A. Jake

C. A. Jake, Environmental Manager
Alliant Ammunition and Powder Company LLC

Enclosure

w/o enclosure

c: Russell Fish, P.E., EPA Region III

Durwood Willis
Virginia Department of Environmental Quality
P. O. Box 10009
Richmond, VA 23240-0009

Mark Leeper
Virginia Department of Environmental Quality
P. O. Box 10009
Richmond, VA 23240-0009

03-815-138
JMcKenna/JJRedder

E. A. Lohman
Virginia Department of Environmental Quality
West Central Regional Office
3019 Peters Creek Road
Roanoke, VA 24019

Tony Perry
U.S. Army Environmental Center
5179 Hoadley Road, Attn: SFIM-AEC-ERP
Aberdeen Proving Ground, MD 21010-5401

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Engineering & Environment, Inc.
7927 Camberley Drive
Powell, TN 37849

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Aberdeen Proving Ground, MD 21010-5403

John Tesner
Corps of Engineers, Baltimore District
ATTN: CENAB-EN-HM
10 South Howard Street
Baltimore, MD 21201

bc:
Administrative File
J. McKenna-ACO Staff
Rob Davie-ACO Staff
C. A. Jake
J. J. Redder
Env. File

Coordination: J McKenna
J. McKenna

03-815-138
JMcKenna/JJRedder

Concerning the following:

Final Master Work Plan, August 2003
Radford Army Ammunition Plant

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

SIGNATURE:
PRINTED NAME: Anthony R. Skinner
TITLE: LTC, CM, Commanding
Radford AAP

SIGNATURE:
PRINTED NAME: Anthony Miano
TITLE: Vice President Operations
Alliant Ammunition and Powder Company, LLC

03-815-138
JMcKenna/JJRedder

Attachment 1
Response to USEPA BTAG Comments dated 28 May 2003
for
Master Work Plan

The responses to USEPA Biological Technical Assistance Group (BTAG) comments have been revised to incorporate discussions/agreements completed during teleconference discussions with the BTAG on 15 and 17 July 2003.

EPA BTAG Comment 1

Section 7.1.2, Identification of Ecological Chemicals of Potential Concern, on page 7-2 states that contaminants of potential concern (COPC) will be identified by comparison of maximum site concentration to approved BTAG screening values and/or by simple food-web modeling. In the screening ecological risk assessment (ERA), both a direct toxicity screen and conservative food chain modeling should be performed to identify COPCs. BTAG recommends that for evaluation of direct toxicity to invertebrates, maximum media concentration be compared to BTAG screening values. In addition to this direct toxicity screen, food chain modeling should be performed on individual receptors for chemicals known to bioaccumulate in the food chain. All bioaccumulative compounds need to be assessed in the food chain exposure evaluation. The list of bioaccumulative compounds that the Region III BTAG considers is on Table 4-2 in Bioaccumulative Testing and Interpretation for the Purpose of Sediment Quality Assessment, Status and Needs, EPA-823-R-00-001, February 2000. If a compound found on your site is on this list, it must be considered in the food chain evaluation.

Army Response

The comment is noted.

The following text will be revised, Section 7.1.2 Identification of Ecological Chemicals of Potential Concern - the first paragraph will read:

"The purpose of selecting COPCs is to identify site-related chemicals that have the potential to adversely affect ecological resources. COPCs will be identified by comparison of maximum site concentrations to approved Region III BTAG screening values and/or by simple food-web modeling for bioaccumulative compounds. It should be noted that BTAG screening values (USEPA, 1995) are for direct contact only. Bioaccumulative compounds (including, but not limited to those as identified in *Bioaccumulative Testing and Interpretation for the Purpose of Sediment Quality Assessment, Status and Needs, EPA-823-R-00-001, February 2000*) found at the site will be considered in the food chain evaluation. Initial screening of analytical data will be conducted using media specific screening values considered protective of wildlife. Chemicals will be selected as COPCs if one of the following conditions are met: if maximum detected concentrations exceed screening values for ecological receptors, if the chemical is non-detect and the detection limit exceeds the screening value, and/or if no screening value is identified. COPCs identified in this step will be carried through to the risk characterization step of the screening level RA, however non-detect COPCs will only be discussed in the Uncertainty Analysis section of the SLERA."

EPA BTAG Comment 2
On pages 7-2 and 7-3, it states that media specific screening values will be derived from various federal and state sources as well as relevant and current scientific literature. When available, only Region III BTAG screening values should be used in the screening ERA to assess direct exposure to ecological receptors. In general, when a BTAG value is not available, we recommend carrying a compound through the screening level assessment and providing justification for dropping or retaining the compound for further evaluation in the ecotoxicological and fate and transport discussions that will be provided in the baseline problem formulation.

> **Army Response**
> As directed by EPA, Region III BTAG Screening Values will be used to identify COPCs in the Screening Level Ecological Risk Assessment (SLERA) despite the following limitations:
>
> - Region III BTAG Screening Values are draft;
> - Derivation/calculation of some of the values is not clearly provided in the document; and
> - No updates have been issued to reflect increased knowledge base in the area since their compilation in 1995. Consequently these values do not reflect the current advances in risk assessment.
>
> In order to account for these limitations and to ensure that the SLERA screening process is adequately conservative but realistic, the Master Work Plan will incorporate values from sources identified in the following paragraph in subsequent steps of the risk assessment.
>
> The second paragraph of Section 7.1.2 Identification of Ecological Chemicals of Potential Concern - will be revised to read as follows:
>
> "Media specific values will be used to better characterize exposure and risk in subsequent steps of the risk assessment. Values will be derived from various Federal and State sources as well as relevant and current scientific literature. Screening values may include sources such as *Region III BTAG Screening Values (1995), Federal Standards for Ambient Water Quality Criteria (AWQC), Virginia Criteria for Surface Water (2002), Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment, 2002), Great Lakes Research Threshold Effect Levels (TEL) (Smith et. al. 1996) for freshwater habitats, USEPA surface soil screening levels (USEPA 2000b), USEPA Region V Ecological Data Quality Levels (EDQL) (USEPA, 1999), and ORNL screening levels for surface water, sediment, and soil; Efroymson et al., 1977, Jones and Suter, 1997, Suter and Tsao, 1996, and Efroymson, Will, and Suter, 1997*".

EPA BTAG Comment 3
On page 7-3 it states that site-specific metal concentrations will be compared to background concentrations as part of the risk management phase of the site evaluation. It is unclear from this paragraph when this comparison would be performed. During the screening ERA (Steps 1 and

2), background data should not be used to eliminate contaminants from further consideration. Screening is a risk-based process and should not consider background at this point. Where there are elevated background concentrations of chemicals of potential concern that may present an unacceptable risk to the environment, the risk from these chemicals should be quantified, if possible, in the risk assessment, and addressed in the baseline ERA problem formulation (Step 3).

Army Response
Steps 1 and 2 in the 8-Step risk assessment process and the refinement step for preliminary COPCs, Step 3a will be completed as part of the SLERA. This allows the SLERA to review the assumptions used in the initial media screening and consider background data in order to identify media with metals concentrations at or below the natural site-specific background. Since natural environments exist in symbiotic balance with their media, it is not inherently logical or correct to assume risk or quantify "unacceptable risk" in environments that contain natural concentrations of metals. If throughout the SLERA screening process, it is determined that metals concentrations are elevated over natural background or are likely present in a specie not found naturally, then risk from these constituents will be quantified. Potential risk due to metals that are naturally elevated regionally will be identified and discussed.

The text will be revised to read as follows:

- Section 7.0 Ecological Risk Assessment – the fourth paragraph will read: *"Steps 1 and 2 in the 8-Step risk assessment process and the refinement step for preliminary COPCs, Step 3a will be completed as part of the screening level RA. Steps 1 and 2, involve characterizing the environmental setting, identifying known or suspected contaminants, evaluating the transport pathways to ecological receptors, selecting assessment endpoints, selecting and comparing site data to conservative screening values and/or food-web modeling. Step 3a refines the contaminants of ecological concern (COPCs) identified in Steps 1 and 2. Collectively, these results will determine if additional ecological risk evaluation is necessary."*

- Section 7.0 Ecological Risk Assessment – the fifth paragraph will read: *"The remainder of Step 3 and Steps 4 through 7 include a baseline assessment and evaluation of SWMUs identified during the screening-level assessment which need a detailed risk investigation. Step 3 develops a focused problem formulation by using a refined list of contaminants of ecological concern (COPCs) to refine exposure pathways, the Ecological Conceptual Site Model (ECSM), assessment endpoints, and measurement endpoints. Step 4 involves establishing a study design and data quality objectives (DQO) based on the problem formulation.* Step 5 verifies that the sampling plan designed in Step 4 is appropriate and implementable at the site. Step 6 is the implementation of the sampling plan and analysis of the data. Step 7, the Risk Characterization, is conducted following the completion of all site investigations and integrates data on exposure and effects with the assessment endpoints established during the problem formulation."

- Section 7.1.2 Identification of Ecological Chemicals of Potential Concern - the referenced paragraph will read: *"Site-specific metal concentrations will be compared to background concentrations at the end of the risk characterization step, as part of the risk management* *step. This evaluation will result in the elimination of metals from the risk management process that are not attributable to site-related activities."*

- Section 7.1.6 Screening-level Results and Conclusions - the first paragraph will read: *"Steps 1 and 2 in the 8-Step risk assessment process and the refinement step for preliminary COPCs, Step 3a, will be completed as part of the screening level risk assessment.* The screening-level RA will provide exposure estimates based on conservative assumptions and determinations of which contaminants and exposure pathways may pose a risk to ecological receptors. The screening-level RA will also provide conclusions and recommendations regarding ecological risk at the site. The RA group and BTAG will use these data to make ecological risk management decisions concerning each SWMU. The scientific/management decision point reached from the screening-level RA will include one of the following: "

EPA BTAG Comment 4

Page 7-3 also states that it is likely that some of the COPCs retained during the initial screening pose minimal risk to wildlife due to the highly conservative nature of the initial screening process. Therefore, a review of the assumptions used in the initial screening will identify the need for refinement comparisons to more realistic screening values. As stated earlier, only BTAG values should be used to evaluate direct toxicity to ecological receptors. The refinement of the conservative assumptions used in the food chain modeling can be modified and re-evaluated as part of the baseline ERA.

Army Response

See response to comment 2 for a discussion of the Region III BTAG Screening Values.

Steps 1 and 2 in the 8-Step risk assessment process and the refinement step for preliminary COPCs, Step 3a will be completed as part of the SLERA. This will allow the SLERA to review the assumptions used in the initial media screening and refine the conservative assumptions used in the food chain modeling. The addition of Step 3a will focus the outcome of a SLERA, streamline the review process, and allow one document to function as the initial forum for ecological risk management decision making at an individual SWMUs.

See response to comment 3 for text revision.

EPA BTAG Comment 5

Section 7.1.3, Identification of Exposure Pathways and Potential Receptors for Analysis, on page 7-4 states that relevant and ecologically appropriate receptors will be evaluated in detail based on contaminants fate and transport and receptor life history. The next sentence states that owing to the invasive and successive nature of plant communities, plants as site receptors do not typically warrant a detailed examination of effects. This statement is incorrect. The impact of site contaminants on plants may warrant detailed examination; the selection of appropriate receptors is a site-specific decision.

Army Response

The SLERA will include an account of potential receptors at individual SWMUs, including plants. However, an important outcome of the SLERA will be to focus the risk assessment process on relevant and important risk issues in ecosystems, particularly where human industrial activities are not the obvious presiding factor.

The following text will be revised, Section 7.1.3 Identification of Exposure Pathways and Potential Receptors for Analysis - the referenced paragraph will read:

"Relevant and ecologically appropriate receptors will be evaluated in detail based on contaminants fate and transport and receptor life history. *For example, owing to the invasive and successive nature of plant communities, plants as site receptors are not always included in a detailed examination of effects. Vegetation communities will be considered as a potential receptor where appropriate.* "

EPA BTAG Comment 6

In Section 7.1.3 on page 7-4 it is also stated that if a no-observed adverse effect level (NOAEL) is not available for a chemical, a lowest observed adverse effect level (LOAEL) or LC50 will be used, and uncertainty factors will be applied as described in ERDEC (1994). BTAG recommends that the process shown on Figure 12 for Wentsel et. al. (1996) Tri-Service Guidance for Ecological Risk Assessments be used to derive a NOAEL from LOAELs and LC50s.

Army Response

The U.S. Army Center for Health Promotion and Preventative Medicine Technical Guide 254, *Standard Practice for Wildlife Toxicity Reference Values* (USACHPPM TG 254, 2000) provides current guidance for the derivation of NOAELs. The document generally incorporates the same uncertainty factors presented in the *Tri-Service Guidance for Ecological Risk Assessments* (Wentsel et al. 1996), although Wentsel et al. 1996 have a more refined (and preferred) approach for interspecies TRV extrapolation. These approaches will be used in the SLERA.

The following text will be revised, Section 7.1.3 Identification of Exposure Pathways and Potential Receptors for Analysis - the last paragraph will read:

"Toxicity values will be used to evaluate potential constituent effects to birds and mammals. Chemical-specific criteria will be developed in order to estimate the dose of a chemical at which no adverse effects are likely to occur in the selected indicator species based on simple food-web modeling. Where available, dietary No Observed Adverse Effect Levels (NOAELs) will be used to evaluate the potential for adverse effects to wildlife. In the absence of these values, the toxicity values from the scientific literature will be reviewed. *If a NOAEL is not available for a chemical, a Lowest Observed Adverse Effect Level (LOAEL) or LC_{50} will be used, and uncertainty factors will be applied to estimate a NOAEL as described in the Standard Practice for Wildlife Toxicity Reference Values, USACHPPM TG 254 (2000).* For interspecies extrapolations, the more refined approach in Wentsel et al. 1996 (Figure 12) will be used.

EPA BTAG Comment 7

Section 7.1.5, Screening-level Exposure Estimate and Risk Characterization, on page 7-5 states that the ecological exposure assessment will consist of two phases. The first phase will be based on conservative assumptions such as maximum media concentration and site use factor of one, while the second phase will be based on conservative yet more realistic exposure assumptions such as 95% upper confidence limit of the mean and a more realistic site use factor. According to current EPA guidance, only conservative assumptions discussed in the first phase should be used in the screening ERA (Steps 1 and 2). The second phase should not be performed as part of the screening ERA. The exposure assumptions can be modified to more realistic values (means) in the baseline ERA. However, realistic site use factors should not be used alone to eliminate contaminants in the baseline ERA, as this approach does not consider exposure from other sites.

Army Response
As discussed in response to comment 4, the SLERA will include both the screening of COPCs and serve as the starting point for the rationale for COPC exclusion from further investigation, if warranted (i.e. the refinement of COPCs as described in Step 3a of 8-Step process). As stated in this comment, these types of discussions may include, but are not limited to, several factors such as 95% UCL media concentrations, exposure area, and receptor area use.

Contaminant exposure from other sites is an inherent uncertainty in risk assessment, as such it will be considered as an uncertainty analysis section.

See response to comment 3 for text revisions.

EPA BTAG Comment 8
Section 7.1.5 on page 7-6 states that EPA Region III Guidance concludes that an environmental effects quotient (EEQ) ratio greater than one but less than 10 demonstrates a potential risk, an EEQ greater than 10 indicates a moderately high potential for risk, while an EEQ above 100 indicates extreme risk to ecological receptors. Neither current EPA Region III guidance nor 1997 ERAGS accepts that the magnitude of the EEQ reflects the magnitude of the potential for ecological risk. This discussion should be removed from the document.

Army Response
The comment is noted and the text will be removed from the document.

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

FINAL MASTER WORK PLAN

AUGUST 2003

PREPARED BY:

URS

5540 Falmouth Street, Suite 201
Richmond, Virginia 23230
(804) 965-9000 main
(804) 965-9764 fax

ARCHITECT-ENGINEER SERVICES
CONTRACT NO. DACA31-00-D-0011
DELIVERY ORDER NO. 0027

PREFACE

A two-stage approach has been developed to facilitate and streamline Resource Conservation Recovery Act (RCRA) site investigations at Radford Army Ammunition Plant (RFAAP) pursuant to the Permit for Corrective Action and Waste Minimization (October 2000). The approach consists of a single facility-wide Master Work Plan (MWP) and multiple site-specific Work Plan Addenda (WPA).

The MWP provides comprehensive discussions of standard procedures, protocol, and methodologies that are to be followed during execution of field investigations at RCRA sites within the RFAAP. The MWP is a generic plan designed to streamline site-specific WPA development, review, and approval.

Each WPA describes the site-specific information for each RCRA site, providing detailed data on past site operations, potential constituents of concern, sampling strategy, etc. Each addendum, through reference to the MWP, is developed as a concise document, focused on site-specific investigations.

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LIST OF ACRONYMS

°	Degree
%	Percent
ADD	Average Daily Dose
AOC	Area of Concern
ASTM	American Society for Testing and Materials
AWQC	Ambient Water Quality Criteria
BAF	Bioaccumulation Factor
BCF	Bioconcentration Factor
BGS	Below Ground Surface
BTAG	Biological Technical Assistance Group
Bw	Body Weight
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C_{FOOD}	Chemical Concentration in Food
Cm/sec	Centimeters Per Second
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CSF	Cancer Slope Factor
D_{FOOD}	Daily Dose From Food
DIUF	Deionized Ultra-filtered
DQO	Data Quality Objective
ECAO	Environmental Criteria and Assessment Office
ECSM	Ecological Conceptual Site Model
EDIP	Epikarst Dye Introduction Point
EEQ	Environmental Effects Quotient
Eos	Eosine
EPIC	Environmental Photographic Interpretation Center
ERA	Ecological Risk Assessment
FI	Ingestion Rate
Fl	Fluorescein
GOCO	Government-owned, Contractor-operated
GPS	Global Positioning System
HEAST	Health Effects Assessment Summary Tables
HHRA	Human Health Risk Assessment
HQ	Hazard Quotient
HSA	Horseshoe Area
HSP	Health and Safety Plan
HTRW	Hazardous, Toxic, and Radioactive Waste
HWMU	Hazardous Waste Management Unit
IAP	Installation Action Plan
IDM	Investigation-Derived Material
IEUBK	Integrated Exposure Uptake Biokinetic
IRIS	Integrated Risk Information System
LADD	Lifetime Average Daily Dose
LEL	Lowest Effect Levels
LOAEC	Lowest Observed Adverse Effect Concentration
LOAEL	Lowest Observed Adverse Effect Level
LOD	Limit of Detection
LOQ	Limit of Quantitation
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
MDC	Maximum Detected Concentration

VOLUME I
LIST OF ACRONYMS (continued)

MQO	Method Quality Objective
µg/dL	Micrograms Per Deciliter
µg/L	Micrograms Per Liter
µS/cm	Microsiemens Per Centimeter
MGD	Million Gallons Per Day
Mg/kg	Milligrams Per Kilogram
Mg/L	Milligrams Per Liter
MMA	Main Manufacturing Area
MQO	Method Quality Objectives
MSDS	Material Safety Data Sheet
MSL	Mean Sea Level
MWP	Master Work Plan
N	North
NCEA	National Center for Environmental Assessment
NOAEL	No Observed Adverse Effect Level
NRU	New River Unit
NSF	National Sanitation Foundation
OSHA	Occupational Safety and Health Administration
PCB	Polychlorinated Biphenyls
PFWWTP	Peppers Ferry Wastewater Treatment Plant
PPB	Parts Per Billion
PPE	Personal Protective Equipment and Clothing
PPM	Parts Per Million
PQL	Practical Quantitation Limit
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl Chloride
Py	Pyranine
QAP	Quality Assurance Plan
QC	Quality Control
RA	Risk Assessment
RAGS	Risk Assessment Guidance for Superfund
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RFAAP	Radford Army Ammunition Plant
RfD	Risk Reference Dose
RFI	RCRA Facility Investigation
RL	Reporting Limit
RME	Reasonable Maximum Exposure
RWT	Rhodamine WT
SARA	Superfund Amendments and Reauthorization Act
SCS	Soil Conservation Service
SHSO	Site Health and Safety Officer
SMDP	Scientific/Management Decision Points
SOP	Standard Operating Procedure
SRB	Sulforhodamine B
SSA	Site Screening Area
SSP	Site Screening Process
SVOC	Semi-Volatile Organic Compound
SWMU	Solid Waste Management Unit
TEL	Threshold Effect Levels
TIC	Tentatively Identified Compound

TRV	Toxicity Reference Value
UCL	Upper Confidence Limit
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VDEQ	Virginia Department of Environmental Quality
VI	Verification Investigation
VOC	Volatile Organic Compound
VOSHA	Virginia Occupational Safety and Health Administration
VPDES	Virginia Pollutant Discharge Elimination System
VPI	Virginia Polytechnic Institute
W	West
WP	Work Plan
WPA	Work Plan Addendum

VOLUME II
LIST OF ACRONYMS

ASTM	American Society for Testing and Materials
AWQC	Ambient Water Quality Criteria
CLP	Contract Laboratory Program
COR	Contracting Officer Representative
DBMS	Database Management System
DQO	Data Quality Objective
EICP	Extracted Ion Current Profile
FOL	Field Operations Leader
HSP	Health and Safety Plan
IDL	Instrument Detection Limit
LCS	Laboratory Check Sample
LIMS	Laboratory Information Management System
LOC	Level of Concern
LOD	Limit of Detection
LOQ	Limit of Quantitation
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
Mg/kg	Milligrams Per Kilogram
Mg/L	Milligram Per liter
MQO	Method Quality Objective
MS	Matrix Spike
MSD	Matrix Spike Duplicate
M/Z	Mass-to-Charge Ratio
NFG	National Functional Guideline
PCD	Project Controlling Document
PDC	Project Data Coordinator
PM	Project Manager
PQL	Practical Quantitation Limit
QA	Quality Assurance
QAP	Quality Assurance Plan
QC	Quality Control
QIP	Quality Improvement Process
RCRA	Resource Conservation and Recovery Act
RF	Response Factor
RFAAP	Radford Army Ammunition Plant
RL	Reporting Limit
RPD	Relative Percent Difference
RRT	Relative Retention Time
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedure
SOW	Statement of Work
SQL	Sample Quantitation Limit
SVOC	Semivolatile Organic Compound
TBC	To-Be-Considered
TOC	Total Organic Carbon
µg/kg	Micrograms Per Kilogram
µg/L	Micrograms Per Liter
USCS	United Soil Classification System
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
UXO	Unexploded Ordnance

LIST OF ACRONYMS (continued)

VOA	Volatile Organic Analyses
VOC	Volatile Organic Compound
WPA	Work Plan Addenda

VOLUME III
LIST OF ACRONYMS

°F	Degrees Fahrenheit
%	Percent
ACGIH	American Conference of Governmental Industrial Hygienists
ALR	Air Line Respirator
ANSI	American National Standards Institute
AOC	Area of Concern
BEI	Biological Exposure Indices
C	Ceiling Value
Ca	NIOSH Suspect Carcinogen
CGI	Combustible Gas Indicator
CGI/O_2	Combustible Gas Indicator/Oxygen
CFR	Code of Federal Regulations
CIH	Certified Industrial Hygienist
CPR	Cardiopulmonary Resuscitation
CRZ	Contamination Reduction Zone
CWM	Chemical Warfare Material
dBA	Decibels on the A-Weighted Scale
DEET	n,n-diethyltoluamide
EV	Electron-Volt
EZ	Exclusion Zone
FID	Flame Ionization Detector
FOL	Field Operations Leader
HAZCOM	Hazard Communication
HAZWOPER	Hazardous Waste Operations and Emergency Response
HBV	Hepatitis B Virus
HEPA	High-Efficiency Particulate Air
HIV	Human Immunodeficiency Virus
HSP	Health and Safety Plan
HTRW	Hazardous, Toxic, Radioactive Waste
HWMU	Hazardous Waste Management Unit
IDLH	Immediately Dangerous to Life or Health
IP	Ionization Potential
LEL	Lower Explosive Limit
LOP	Level of Protection
Mg/m^3	Milligram Per Cubic Meter
MSDS	Material Safety Data Sheet
NA	Not Applicable
ND	Not Determined
NIOSH	National Institute for Occupational Safety and Health
NRT	Near Real-Time
OE	Ordnance and Explosive
OSHA	Occupational Safety and Health Administration
OSIC	On-Scene Incident Commander
OVA	Organic Vapor Analyzer
PEL	Permissible Exposure Limit
PHSO	Project Health and Safety Officer
PID	Photoionization Detector
PM	Project Manager
PPE	Personal Protective Equipment
ppm	Parts Per Million
PVC	Polyvinyl Chloride

RFAAP	Radford Army Ammunition Plant
SHSO	Site Health and Safety Officer
SOP	Standard Operating Procedure
SOW	Statement of Work
STEL	Short-Term Exposure Limit
SWMU	Solid Waste Management Unit
SZ	Support Zone
TLV	Threshold Limit Value
TWA	Time-Weighted Average
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
WP	Work Plan
WPA	Work Plan Addenda

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1.0 INTRODUCTION

The purpose of this Master Work Plan (MWP) is to provide a set of operating instructions for completion of Radford Army Ammunition Plant (RFAAP) site investigations. It is comprised of procedures for planning, executing, controlling, and verifying the health and safety of contractors performing investigations at the Installation.

The MWP is a generic plan designed to facilitate Work Plan (WP) development, review, and approval. It is to be used in conjunction with site-specific work plan addenda (WPA) to delineate project activities and investigation objectives. Site descriptions of the Solid Waste Management Units (SWMUs), Hazardous Waste Management Units (HWMUs), and Areas of Concern (AOCs) to be investigated are provided in the Installation Action Plan (IAP) (US Army 2002). The MWP will also be used when conducting investigations (e.g., site screening assessments) at other areas not currently identified in the IAP, such as site screening areas (SSA). MWP provides a comprehensive discussion of standard procedures, protocols, and methodologies that are to be followed during execution of SWMU, HWMU, AOC, and SSA field investigations. The WPA describes the site-specific information for each SWMU, HWMU, AOC, and SSA, providing detailed data on past site operations, potential constituents of concern, sampling strategy and rationale. The addendum through reference to the MWP is developed as a concise document, focused on SWMU, HWMU, AOC, and SSA specific data needs. The MWP consists of three volumes: WP, Quality Assurance Plan (QAP), and Health and Safety Plan (HSP).

1.1 MASTER WORK PLAN

Volume I presents the Master WP and contains the specifications for investigative activities and comprises eight sections including:

- Installation Description;
- Environmental Setting - climate, physiography, land use/demographics, regional soils, regional geology, RFAAP geology, hydrogeology, surface water hydrology, groundwater usage, and ecology;
- Site Investigation Planning - objectives, WPA, health and safety, documentation, and standard operating procedures (SOPs);
- Site Investigation Program - sample management, subsurface investigation, surface water investigation, sediment investigation, active soil gas surveys, geophysical surveys, drum sampling, physical testing, aquifer testing surveying, general decontamination requirements, and investigative derived material (IDM);
- Human Health Risk Assessment - objective and general approach, data summary and selection of chemicals of potential concern, human health exposure assessment, toxicity assessment, and risk characterization;
- Ecological Risk Assessment (ERA) - problem formulation, exposure characterization and development of exposure pathway model, ecotoxicologic effects assessment, risk characterization, limitations and uncertainties; and
- Entry to Radford Army Ammunition Plant - logistical and safety concerns specific to the Installation.

1.2 MASTER QUALITY ASSURANCE PLAN

Volume II presents the Master QAP and contains the specification for quality assurance and control activities and comprises ten sections, including:

- **Introduction** - document organization, project objectives, and QAP distribution list;
- **Project Organization and Responsibilities** - key project personnel, lines of authority, and key points of contact;
- **Quality Assurance Objectives** - project quality objectives, chemical data measurements, and applicable or relevant and appropriate requirements;
- **Sampling Locations and Rationale** - general requirements;
- **Sample Management** - sample number and type, sample containers, sample preservatives, holding times, sample identification, documentation requirements, chain of custody requirements;
- **Analytical Procedures** - field testing and screening, laboratory procedures for chemical analyses, detection limits, and physical testing methods;
- **Calibration Procedures** - laboratory calibration, instrument/equipment testing, inspection, and maintenance, inspection/acceptance for supplies and consumables, and field equipment calibration and maintenance;
- **Internal Quality Control Checks** - laboratory quality control elements, special training requirements and certification, and field quality control samples;
- **Data Reduction, Validation, Reporting, and Management** - reporting limits, rounding rules, data reduction, data validation and usability, blank contamination assessment, reporting, documentation and records, record storage and handling, and data management;
- **Corrective Action** - routine, non-routine, quality improvement, problem prevention, and stop work protocols;
- **Quality Assessments** - document review, readiness reviews, field performance audits, and laboratory performance audits;

1.3 MASTER HEALTH AND SAFETY PLAN

Volume III presents the Master HSP and contains the specifications for health and safety and comprises nine sections including:

- **Project Organization** - health and safety personnel and responsibilities, subcontractor responsibilities, site personnel, visitors, and RFAAP project personnel;
- **Hazard Assessment and Hazard Control** - chemical toxicity hazards, physical hazards, and biological hazards;
- **Training Plan** - Occupational Safety and Health Administration (OSHA) hazardous waste operations training, site-specific and hazard information training, first aid and cardiopulmonary resuscitation

training, bloodborne pathogen training, hearing conservation training, hazard communication training, confined space training, additionally required OSHA training, buddy system training, daily safety meetings, and weekly safety meetings;

- **Medical Surveillance Plan** - planning;

- **Site Safety and Control** - site safety and site control;

- **Personal Protective Equipment and Clothing (PPE)** - levels of protection, protocols for changing levels of protection, respirator selection, and fit test;

- **Personnel and Equipment Decontamination** - Modified level D, level C, level B, level A, other decontamination/disposal procedures, decontamination during medical emergencies, and personnel decontamination sequence;

- **Monitoring Plan** - monitoring instruments, types of monitoring, action levels, noise monitoring, heat and cold stress monitoring, meteorological monitoring, calibration, and maintenance of monitoring equipment;

- **Emergency Response and Contingency Plan** - pre-emergency planning, emergency response responsibilities, emergency training, emergency site control and security, on-site emergency equipment, medical facilities, contingency plans, emergency response and decontamination procedures, and emergency contact/ notification system; and

- **Appendices** - Appendix A contains the SOPs for routine investigative activities.

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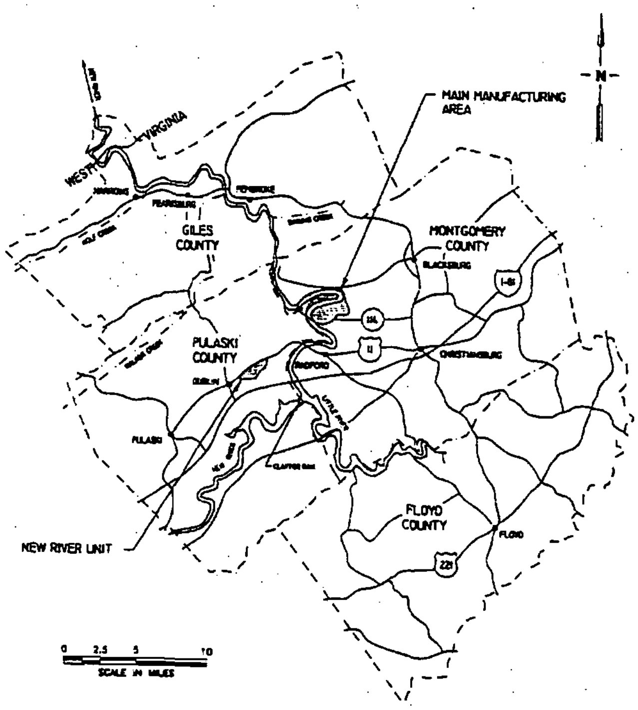
2.0 INSTALLATION DESCRIPTION

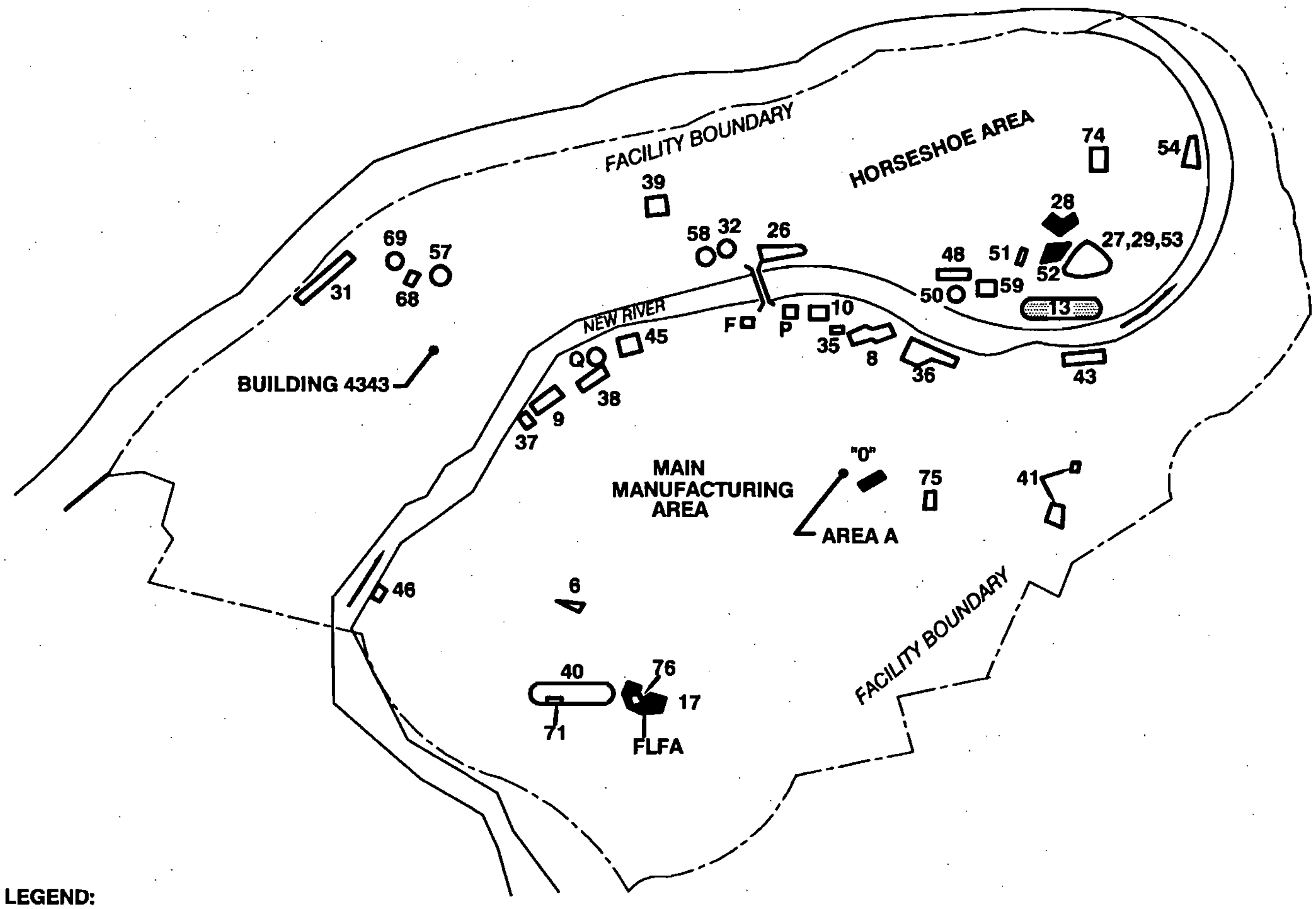
RFAAP is a government-owned, contractor-operated (GOCO) industrial complex located in Radford, Virginia. RFAAP is owned by the U.S. Department of the Army and is currently operated under contract by Alliant TechSystems, Inc.

RFAAP is located in the mountains of southwest Virginia in Pulaski and Montgomery Counties (Figure 2-1). The Main Manufacturing Area (MMA) is located approximately ten miles west of Blacksburg and 47 miles southwest of Roanoke. The New River Unit (NRU) is located approximately six miles west of the MMA, near the town of Dublin. This MWP is applicable to sites listed within Appendix A of the Installation RCRA Corrective Action Permit and sites at the New River Unit. Figure 2-2 shows the locations of SWMUs in the MMA. Figure 2-3 shows the site locations in the NRU.

RFAAP lies in one of a series of narrow valleys typical of the Valley and Ridge Province of the Appalachian Mountains. Oriented in a northeast-southwest direction, the valley is approximately 25 miles long, with a width of eight miles at the southwest end, narrowing to two miles at its northeast end. The plant lies along the New River in the relatively narrow northeast corner of the valley.

Figure 2-1
RFAAP and Vicinity Map
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia





LEGEND:

■ RFI SWMUS

□ VI SWMUS

SWMU = SOLID WASTE MANAGEMENT UNIT

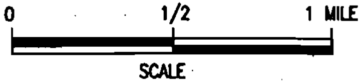
RFI = RCRA FACILITY INVESTIGATION

VI = VERIFICATION INVESTIGATION

RCRA = RESOURCE CONSERVATION AND RECOVERY ACT

TABLE OF SWMU'S

SWMU NUMBERS	SWMU NAME
SWMU 6	ACID WASTEWATER LAGOON
SWMU 8, 9, 35, 36, 37, 38 & AREA "A"	CaSO4 TREATMENT DISPOSAL AREA
SWMU 10	BIOPLANT BASIN
SWMU 13	WASTE PROPELLANT BURNING GROUND
SWMU 17	AIR CURTAIN DESTRUCTOR AND OPEN BURNING GROUND
SWMU 26	FLY ASH LANDFILL NO. 1
SWMU 27	CaSO4 TREATMENT DISPOSAL AREA
SWMU 28	CLOSED SANITARY LANDFILL
SWMU 29	FLY ASH LANDFILL NO. 2
SWMU 31	COAL ASH SETTLING LAGOONS
SWMU 32	INERT LANDFILL NO. 1
SWMU 39	WASTEWATER PONDS FROM PROPELLANT INCINERATOR
SWMU 40	LANDFILL NITRO AREA
SWMU 41	RED WATER ASH BURIAL GROUND
SWMU 43	SANITARY LANDFILL NO. 2
SWMU 45	LANDFILL NO. 3
SWMU 46	PROPELLANT BURIAL
SWMU 48	OILY WATER BURIAL AREA
SWMU 49	RED WATER ASH BURIAL GROUND
SWMU 50	CaSO4 TREATMENT/DISPOSAL AREA
SWMU 51	TNT WASTE ACID NEUTRALIZATION PITS
SWMU 52	CLOSED SANITARY LANDFILL
SWMU 53	ACTIVATED CARBON DISPOSAL AREA
SWMU 54	PROPELLANT BURNING ASH DISPOSAL AREA
SWMU 57	POND BY BUILDING 4931/4932
SWMU 58	RUBBLE PILE
SWMU 59	BOTTOM ASH PILE
SWMU 68	CHROMIC ACID TREATMENT TANKS
SWMU 69	POND BY CHROMIC ACID TREATMENT TANKS
SWMU 71	FLASH BURN PARTS AREA
SWMU 74	INERT LANDFILL NO. 3
SWMU 76	MOBILE USED OIL TANKS
AREA F	FORMER DRUM STORAGE AREA
AREA O	UNDERGROUND FUEL OIL SPILL
AREA P	BATTERY STORAGE AREA
AREA Q	CaSO4 TREATMENT DISPOSAL AREA
BUILDING 4343	BUILDING 4343
FLFA	FORMER LEAD FURNACE AREA



RFAAP
MASTER WORK PLAN

Date: *JUNE 2002*

URS Proj Number: *09604-263*

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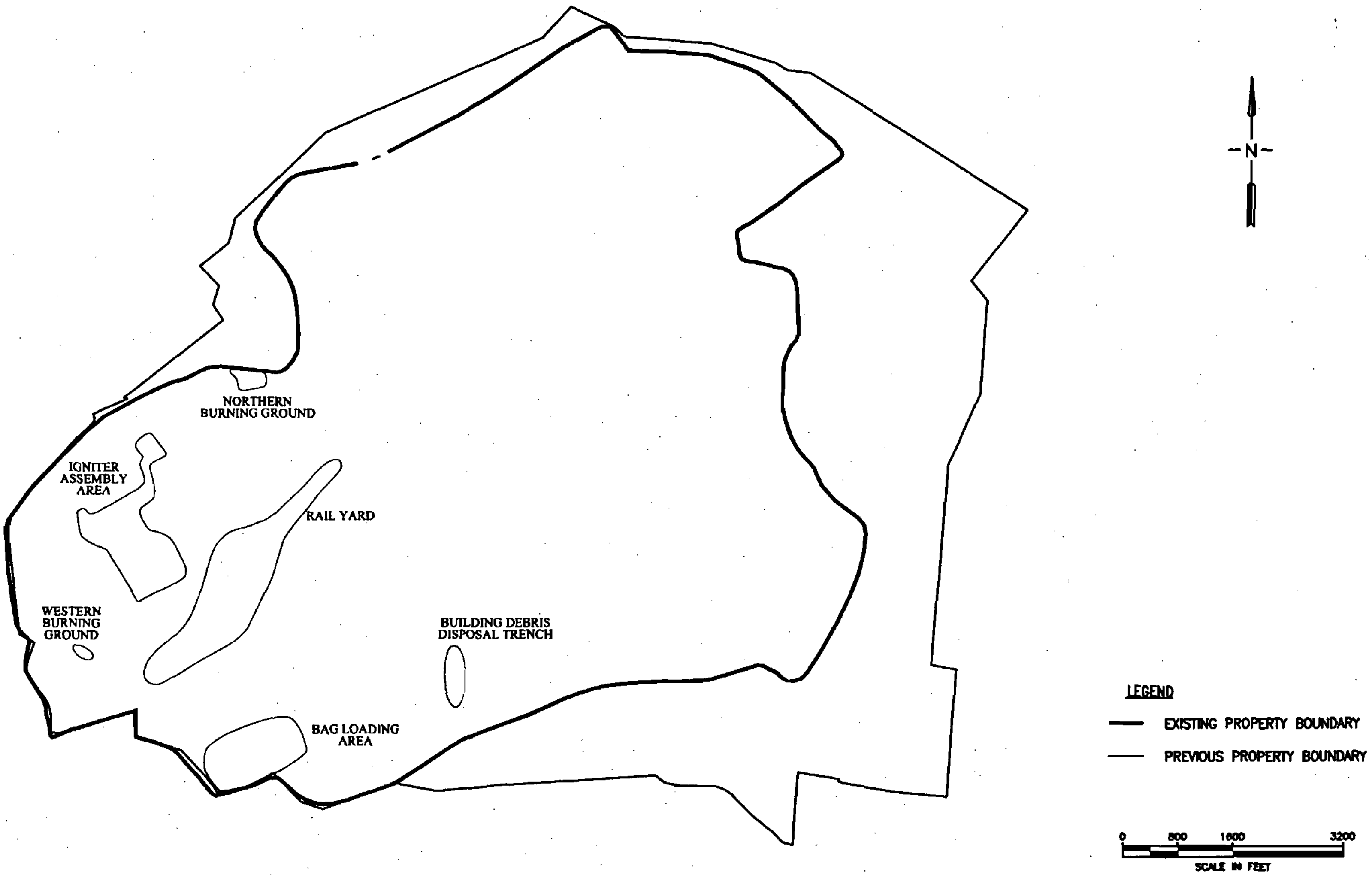
FIGURE 2-2

SITE LAYOUT AND SWMU LOCATION MAP MAIN MANUFACTURING AREA



SOURCE: IT CORP., WORK PLAN ADDENDUM NO. 12, 2002

RFAAP
MASTER WORK PLAN

Date: JAN. 2002

URS Proj Number: 09604-263

Scale: AS SHOWN

File Name: MWPFigure2-3.DWG

FIGURE 2-3

SITE LOCATION MAP
NEW RIVER UNIT

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3.0 ENVIRONMENTAL SETTING

3.1 CLIMATE

The climate of the area encompassing RFAAP is classified as "moderate continental." Moderately mild winters and warm summers characterize this climate. The prevailing winds are from the southwest, with a northerly component during the cold season. The average yearly wind speed is eight miles per hour (Dames & Moore 1992).

The average monthly temperature ranges from 29.6°F in January to 72°F in July, with an annual average temperature of about 52°F. Average monthly precipitation ranges from about 2.5 to 4.0 inches with an annual total precipitation between 36.9 and 41.5 inches (Virginia State Climatological Office 1995). Class A pan evaporation was measured in the Roanoke, Virginia, area at 43 inches per year. Lake evaporation was measured at 32 inches per year in the same area. Potential evapotranspiration has been calculated at 30 inches per year using the Thornthwaite method (Virginia State Climatological Office 1995). Based on these data, the net precipitation in the RFAAP area is estimated to be in the range of 6.9 and 11.5 inches annually. Snowfall in the RFAAP area averages 17 inches annually. Montgomery and Pulaski Counties lie in one of the areas of highest occurrence of dense fog in the United States. Dense fog can be expected to occur between 20 and 45 days per year.

3.2 PHYSIOGRAPHY

RFAAP lies within the Valley and Ridge province of the Appalachian physiographic division. The Valley and Ridge province is characterized by a series of long, narrow, flat-topped mountain ridges separated by valleys of varying widths. RFAAP is located within a valley.

The topography within the Installation varies from a relatively flat floodplain to elevated uplands in the extreme southeast section. The New River forms the RFAAP boundary on the north, with the elevation approximately 1,675 feet above mean sea level (MSL). The eastern boundary represents a transition from floodplain elevation of 1,680 feet MSL to an upland elevation of 1,900 feet MSL. The southern boundary traverses terrain consisting of creek bottoms and sharply rising summits. The western boundary follows the bluff line overlooking the New River to a point where the Norfolk and Western Railroad crosses the lower arm of the horseshoe area (HSA). This Facility displays an overall relief of 342 feet. In the HSA to the north and east, the New River has a narrow floodplain. The HSA exhibits rolling karst terrain, with three prominent terraces and escarpments, which are remnants of ancient New River floodplains.

RFAAP contains prominent karstic features including sinkholes, caves, and caverns. Karst landforms occur in carbonate rock formations as the result of the dissolution of rock by naturally occurring carbonic acid in rainwater migrating along bedding planes and fractures. As the rock is dissolved, solution features such as cavities and channels form beneath the surface. Occasionally, large cavities collapse producing a depression or sinkhole on the surface. Numerous sinkholes are apparent along the western and southern boundaries of the Facility.

3.3 LAND USE

Because of the steep terrain, the area surrounding RFAAP has not been highly developed. Land use has been mostly rural; the less rugged areas are primarily used for agriculture. The Jefferson National Forest is located approximately two miles north of the Facility. The majority of land in the New River Valley, which includes Montgomery, Pulaski, Giles, and Floyd Counties as well as the city of Radford, is forested. Thirty-eight percent (%) of the area of the New River Valley classifies as non-forest land, including agricultural land, developed land, and water acreage (NRVPDC 2001). The Blacksburg-Christiansburg-Virginia Polytechnic Institute (VPI) Water Authority owns four parcels of land adjacent to RFAAP.

3.4 REGIONAL SOILS

Soil surveys have been conducted by the Soil Conservation Service (SCS) to identify and map soil types present in the area of the RFAAP. SCS soil survey reports for Montgomery County (SCS 1985a) and Pulaski County (SCS 1985b) cover the RFAAP area.

3.4.1 Montgomery County

Two SCS soil map units underlie the portion of the MMA located within Montgomery County (area south of the HSA): the Unison-Braddock and Groseclose-Poplimento-Duffield.

The Unison-Braddock soil map unit underlies terrace and alluvial areas within the central and northern portions of the MMA (excluding the HSA). This soil map unit consists of deep, well-drained, gently sloping to moderately steep soils. The surface layer is fine sandy loam or loam, and the subsoil is clay. Rounded pebbles and cobbles are present in the surface and subsurface soil in some areas. Within Montgomery County, the Unison-Braddock soil map unit covers approximately 4% of the survey area. The main components of this map unit are Unison soils (34%) and Braddock Soils (15%), with remaining components consisting of minor soils. The Unison-Braddock soils have formed in old alluvium, and on stream terraces and alluvial fans.

The Groseclose-Poplimento-Duffield soil map unit underlies upland areas within the southernmost portion of the MMA. This soil map unit consists of deep, well drained, gently sloping to steep soils that have clayey subsoil. The Groseclose-Poplimento-Duffield soil map unit occurs on broad ridge tops and side slopes and has a loam or silt loam surface layer and clay subsoil. Sinkholes are common in some areas. The major components of this map unit are Groseclose soils (21%), Poplimento soils (15%), and Duffield soils (9%), with remaining components consisting of minor soils. The Groseclose-Poplimento-Duffield soils have formed in limestone, shale, and sandstone residuum and colluvium (SCS 1985a).

3.4.2 Pulaski County

The Braddock-Wheeling soil map unit underlies the HSA of RFAAP (SCS 1985b). This map unit consists of deep, nearly level to hilly soils that have a loamy surface soil and clayey or loamy subsoil formed in alluvium. Typically, these soils are present on low and high terraces. Within Pulaski County, the Braddock-Wheeling soil map unit covers approximately 3% of the survey area. The main components of this map unit are Braddock soils (40%), and Wheeling soils (12%), with the remaining portion of this map unit consisting of minor soils (SCS 1985b).

The Groseclose-Popimento-Frederick and Carbo-Lowell-Groseclose soil map units underlie the NRU. Both of these map units have formed from material weathered from limestone and shale and have clayey subsoil. The Groseclose-Popimento Frederick map unit, which covers approximately 17% of the county, underlies the southeastern portion of the NRU. This map unit is a deep soil and consists of approximately 22% Groseclose soils, 21% Poplimento soils, and 17% Frederick soils, with the remaining portion consisting of minor soils (SCS 1985b).

Soils associated with the Carbo-Lowell-Groseclose map unit cover approximately 22% of the county and underlie most of the NRU. This map unit is a moderately deep to deep soil consisting of approximately 25% Carbo soils, 20% Lowell soils, and 13% Groseclose soils, with the remaining portion consisting of minor soils (SCS 1985b).

3.5 RFAAP SOILS

As part of the Montgomery County and Pulaski County soil surveys, the SCS has prepared detailed maps and descriptions of the soil types underlying the MMA and NRU areas of RFAAP. The more detailed information from the SCS soil surveys has been incorporated into the Facility-Wide Background Study (IT 2002) prepared for the MMA and NRU and the Draft Current Conditions Report prepared for the HSA (IT 2001). The following sections describe the nature and occurrence of the specific soil types mapped in the MMA and NRU by the SCS (as described by the SCS soils surveys and IT Corporation (IT) reports).

3.5.1 Main Manufacturing Area

Figure 3-1 shows that 27 SCS soil types underlie the MMA. The text below summarizes the physical and chemical characteristics of these soil types (SCS 1985a, 1985b).

Berks-Clymer Complex (7 to 15% slopes). This complex comprises less than 1% of the soils at MMA. The soil map unit consists of well drained, strongly sloping soils situated on side slopes and ridge tops. The Berks-Clymer Complex consists of approximately 50% moderately deep Berks soils, 30% deep Clymer soils, and 20% other soils.

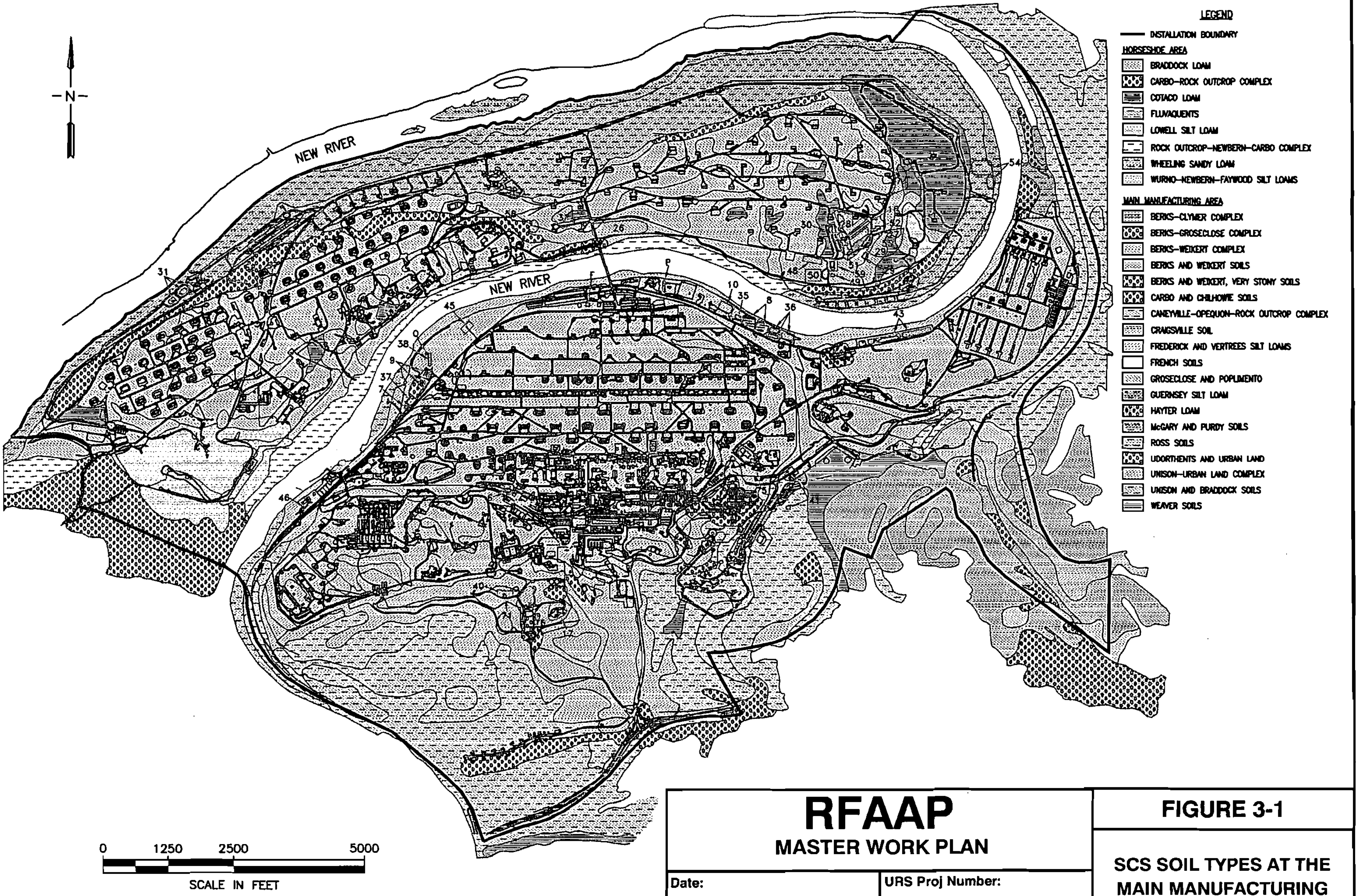
Reactions of complex soils range from extremely acid to strongly acid. Soils are moderately permeable and have a low to moderate organic content. The available water capacity for the Berks-Clymer complex is low and the surface runoff is high.

A typical profile of the Berks soil consists of a five-inch thick surface layer of very dark grayish brown and brown shaly silt loam underlain by a 17-inch thick subsoil of yellowish-brown shaly silt loam. The substratum is very shaly silt loam mottled in shades of brown, yellow, and red. Soft shale bedrock is typically present at a depth of approximately 27 inches, but may vary in depth from 20 to 40 inches.

Clymer soil in profile typically consists of a surface layer of yellowish-brown loam approximately nine inches thick underlain by 23-inches of subsoil, which consists of sandy loam mottled in shades of brown, yellow, and red. The substratum is approximately 17-inches thick and consists of sandy loam mottled in shades of brown, yellow, and red. Hard sandstone bedrock is typically present at a depth of 49 inches, but may vary in depth from 40 to 60 inches.

Berks-Groseclose Complex (2 to 15% slopes). This complex comprises less than 1% of the soils at the MMA and consists of well drained, gently to strongly sloping soils that are located on side slopes and ridgetops. The Berks-Groseclose Complex consists of 40% moderately deep Berks soils, 35% deep Groseclose soils, and 25% other soils.

Reaction of the complex soils ranges from extremely acid to strongly acid. Surface runoff for these soils is medium and organic matter content is low to medium. The available water capacity is low in the Berks soil and medium in the Groseclose soil. The permeability is moderate for the Berks soil and slow for the Groseclose soil. A typical profile of the Berks soil consists of a five-inch thick surface layer of very dark grayish brown and brown shaley silt loam underlain by a 17-inch thick subsoil of yellowish- brown shaley silt loam. The substratum is very shaley silt loam mottled in shades of brown, yellow, and red. Soft shale bedrock is typically present at a depth of approximately 27 inches, but may vary in depth from 20 to 40



SOURCE: FACILITY WIDE BACKGROUND STUDY REPORT (IT 2002)

RFAAP
MASTER WORK PLAN

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FIGURE 3-1

SCS SOIL TYPES AT THE MAIN MANUFACTURING AREA

inches. Generally, the Groseclose soil profile consists of a six-inch thick surface layer of brown silt loam underlain by a 29-inch thick subsoil of strong brown sticky and plastic clay mottled in shades of brown, yellow, and red. The substratum is clay loam mottled in shades of yellow, brown, and red below a depth of approximately 35 inches. Depth to bedrock is greater than 48 inches.

Berks-Weikert Complex (15 to 20% slopes). This complex comprises less than 1% of the soils at the MMA and consists of well-drained, moderately steep soil situated on side slopes. The Berks-Weikert complex consists of approximately 50% moderately deep Berks soils, 30% shallow Weikert soils, and 20% other soils.

Reaction of complex soils range from extremely acid to strongly acid. Organic matter content of these soils is low to moderate. Permeability is moderate for the Berks soil and moderately rapid for the Weikert soils. Surface runoff is high for the Berks soil and very rapid for the Weikert soil. Available water capacity for the complex is low (Berks) to very low (Weikert).

A typical profile of the Berks soil consists of a five-inch thick surface layer of very dark grayish brown and brown shaley silt loam underlain by a 17-inch thick subsoil of yellowish-brown shaley silt loam. The substratum is very shaley silt loam mottled in shades of brown, yellow, and red. Soft shale bedrock is typically present at a depth of approximately 27 inches, but may vary in depth from 20 to 40 inches.

Generally, the Weikert soil profile consists of a four-inch thick surface layer of dark brown shaley silt loam underlain by a nine-inch thick subsoil of yellowish-brown shaley silt loam. Soft shale bedrock is typically at 13 inches, but the depth may range from ten to 20 inches.

Berks and Weikert Soils (25 to 65% slopes). These soils comprise approximately 3% of the soils at the MMA and consist of well-drained soils on steep to very steep side slopes. The Berks and Weikert soil unit consists of approximately 50% moderately deep Berks soils, 25% shallow Weikert soils, and 25% other soils.

Reaction of the Berks and Weikert soils ranges from extremely acid to strongly acid. Both of these soils have a low to moderate organic matter content with very rapid surface runoff. Permeability is moderate for the Berks soil and moderately rapid for the Weikert soils. Available water capacity is low for the Berks soil and very low for the Weikert soil.

A typical profile of the Berks soil consists of a five-inch thick surface layer of very dark grayish brown and brown shaley silt loam underlain by a 17-inch thick subsoil of yellowish-brown shaley silt loam. The substratum is very shaley silt loam mottled in shades of brown, yellow, and red. Soft shale bedrock is typically present at a depth of approximately 27 inches, but may vary in depth from 20 to 40 inches.

Generally, the Weikert soil profile consists of a four-inch thick surface layer of dark brown shaley silt loam underlain by a nine-inch thick subsoil of yellowish-brown shaley silt loam. Soft shale bedrock is typically at 13 inches, but the depth may range from ten to 20 inches.

Berks and Weikert, Very Stony Soils (15 to 25% slopes). These soils comprise less than 1% of the soils at the MMA and consist of well-drained soils on moderately steep to very steep side slopes and ridge tops. The Berks and Weikert soil unit consists of approximately 50% moderately deep Berks soils, 25% shallow Weikert soils, and 25% other soils.

Reaction of the Berks and Weikert soils ranges from extremely acid to strongly acid. Both soils have a low to moderate organic content with very rapid runoff. Permeability is moderate for the Berks soil and moderately rapid for the Weikert soils. Available water capacity is low for the Berks soil and very low for the Weikert soil.

A typical profile of the Berks soil consists of a five-inch thick surface layer of grayish brown and brown very stony silt loam underlain by a 17-inch thick subsoil of yellowish- brown shaley silt loam. The substratum is very shaley silt loam mottled in shades of brown, yellow, and red. Soft shale bedrock is typically present at a depth of approximately 27 inches, but may vary in depth from 20 to 40 inches.

Generally, the Weikert soil profile consists of a four-inch thick surface layer of dark brown very stony silt loam underlain by a nine-inch thick subsoil of yellowish-brown shaley silt loam. Soft shale bedrock is typically at 13 inches, but the depth may range from ten to 20 inches.

Braddock Loam (2 to 30% slopes). Braddock soil comprises approximately 17% of the soils at the MMA and consists of soils situated on gentle to steep slopes on high terraces.

Reaction of Braddock soils ranges from very strongly acid to strongly acid. The organic matter content of this soil is moderately low and permeability is moderate. Available water capacity of the Braddock soil is moderate and surface runoff is medium. The Braddock soil does not have a seasonally high water table within 60 inches of the surface.

A typical profile of the Braddock soil consists of a seven-inch thick surface layer of dark yellowish brown loam underlain by a minimum 60-inch thick subsoil of yellowish-red clay and red clay. Depth to bedrock is greater than 60 inches.

Carbo and Chilhowie Soils (7 to 15% slopes). These soils comprise less than 1% of the soils at the MMA and consist of well drained and strongly sloping soils situated on side slopes and ridge tops. The Carbo and Chilhowie soil unit consists of approximately 40% moderately deep Carbo soils, 35% moderately deep Chilhowie soils, and 25% other soils.

Reaction of the Carbo soil ranges from very strongly acid to mildly alkaline. Reaction of the Chilhowie soil ranges from slightly acid to mildly alkaline. The organic matter content is low to moderate in the Carbo soil and low in the Chilhowie soil. Permeability of both soils is slow, with rapid surface runoff. Available water capacity is low in the Carbo soil and very low in the Chilhowie soil.

A typical profile of the Carbo soil consists of a seven-inch thick surface layer of yellowish-brown silty clay loam underlain by a 23-inch thick subsoil of very sticky and very plastic clay. The plastic clay is strong brown within the upper part of the subsoil and yellow brown in the lower part of the subsoil. Hard limestone and shale bedrock is typically at 30 inches, but the depth may range from 20 to 40 inches.

Generally, the Chilhowie soil profile consists of a two-inch thick surface layer of very dark grayish brown silty clay underlain by a 13-inch thick subsoil of yellowish-brown sticky and plastic clay. The substratum is olive brown very shaley clay approximately 15 inches thick. This clay is sticky and plastic. Hard-interbedded shale and limestone bedrock is typically present at 30 inches, but the depth may range from 20 to 40 inches.

Caneyville-Opequon-Rock Outcrop Complex (25 to 60% slopes). This complex comprises approximately 21% of the soils at the MMA in primarily undeveloped areas of the Facility. The Caneyville-Opequon-Rock Outcrop complex consists of approximately 30% Caneyville soils, 25% Opequon soils, 20% rock outcrop, and 25% other soils.

Reaction of the Caneyville soil ranges from strongly acid to neutral. Reaction of the Opequon soil ranges from medium acidic to mildly alkaline. The organic matter content is moderate for both soils with rapid surface runoff. Permeability is moderately slow in the Caneyville soil and moderately slow or moderate in the Opequon soil. Available water capacity is low in the Caneyville soil and very low in the Opequon soil.

A typical profile of the Caneyville soil consists of an eight-inch thick surface layer of brown silt loam underlain by a 24-inch thick subsoil of yellowish-red very plastic clay. Limestone bedrock is typically at a depth of 30 inches.

Generally, the typical Opequon soil profile consists of a four-inch thick surface layer of brown silt, clay loam underlain by an 11-inch thick subsoil of yellowish-brown sticky and plastic clay. The substratum is olive brown very shaley clay approximately 15 inches thick. This clay is sticky and plastic. Limestone bedrock is typically at a depth of 15 inches.

Carbo-Rock Outcrop Complex (10 to 45% slopes). This complex comprises approximately 3% of the soils at the MMA and consists of strongly sloping to steep soils and areas of exposed rock. The areas of exposed rock cover 10 to 50% of the surface area.

Reaction of the Carbo soils ranges from slightly acid to mildly alkaline. The organic matter content is low to moderate in the Carbo soil and permeability is slow. Permeability of the Carbo soil is slow and runoff is very rapid. Available water capacity for this soil is low.

A typical profile of the Carbo soil consists of a five-inch thick surface layer of yellowish brown silty, clay loam underlain by a 26-inch thick subsoil of strong brown clay. Limestone bedrock is typically at a depth of 31 inches. This soil map unit does not have a seasonally high water table.

Cotaco Loam (0 to 7% slopes). The Cotaco soil comprises approximately 3% of the soils at the MMA and consists of soils situated on nearly level to gently sloping terrace areas.

Reaction of Cotaco soils ranges from very strongly acid to strongly acid. The organic matter content of this soil is moderately low and permeability is moderate. Available water capacity of the Braddock soil is moderate and surface runoff is medium. The Cotaco soil has a seasonally high water table at a depth of 18 to 30 inches.

A typical profile of the Cotaco soil consists of a nine-inch thick surface layer of brown loam underlain by a minimum 60-inch thick subsoil of yellowish brown and brownish yellow loam and clay loam. Depth to bedrock is greater than 60 inches.

Craigsville Soils. This soil map unit comprises approximately 1% of the soils at the MMA and consists of well-drained, deep, and nearly level soils situated in flood plains.

Reaction of the Craigsville soil ranges from very strongly acid to strongly acid. The organic matter content of this soil is low to moderate. Available water capacity of the Craigsville soil is low and permeability is rapid.

A typical profile of the Caneyville soil consists of an eight-inch thick surface layer of dark yellowish brown cobbles and sandy loam underlain by a 22-inch thick subsoil of strong brown cobbles and sandy loam. The substratum below a depth of 30 inches is brown friable very cobbles, sandy loam.

Fluvaquents. The soil map unit comprises approximately 1% of the soils at the MMA and consists of soils found on narrow and nearly level floodplains along the New River.

Characteristics of the Fluvaquents soil are variable because of their location in the floodplain. The soil is typically unconsolidated, stratified alluvium, which has a widely variable texture. Many areas are gravelly, cobbles, or stony in the surface layer and gravelly or cobbles in the substratum. This soil map unit is susceptible to flooding.

Frederick and Vertrees Silt Loams (2 to 7% slopes). These soils comprise less than 1% of the soils at the MMA and consist of well-drained and gently to strongly sloping soils located on side slopes and ridgetops. These soils consist of approximately 40% Frederick soils, 35% deep Vertrees soils, and 25% other soils.

Reaction of the Frederick and Vertrees soils range from strongly acid to medium acid. The organic matter content is low to moderate in the Frederick soil and moderate in the Vertrees soil. Permeability is moderate in the Frederick soil and moderately slow in the Vertrees soil. Available water capacity is moderate in both soils.

A typical profile of the Frederick soil consists of a ten-inch thick surface layer of brown silt loam underlain by a 64-inch thick subsoil, which in the uppermost 18 inches consists of a strong brown clay loam. Yellowish-red sticky and plastic clay comprises the remainder of the subsoil; this clay is mottled in shades of brown and yellow between a depth of 48 to 74 inches. Depth to bedrock is greater than 60 inches.

The typical Vertrees soil profile consists of a ten-inch thick surface layer of dark brown and yellowish brown silt loam. A 64-inch thick subsoil of yellowish-red sticky and plastic clay mottled in shades of brown and yellow underlies this surface layer. Depth to bedrock is greater than 60 inches.

French Soils. The French soils comprise less than 1% of the soils at the MMA and consist of somewhat poorly drained, deep, and nearly level soils on flood plains. These soils are commonly flooded for brief period in winter and spring.

Reaction of French soils ranges from strongly acid to slightly acid. The organic matter content of French soils is low to moderate and permeability is moderate in the surface layer and rapid in the substratum.

A typical profile of the French soil consists of a four-inch thick surface layer of dark brown loam underlain by a 26-inch thick subsoil of dark yellowish-brown loam mottled in shades of gray, brown, and red. The substratum is very dark grayish brown gravelly sand. Depth to bedrock is greater than 60 inches.

Groseclose and Poplimento Soils (2 to 7% slopes). These soils comprise approximately 3% of the soils at the MMA and consist of well-drained gently sloping soils that are located on ridge tops. This map unit consists of approximately 45% deep Groseclose soils, 40% deep Poplimento soils, and 15% other soils.

Reaction of the Groseclose soils ranges from extremely acid to strongly acid. Reaction of the Poplimento soils ranges from strongly acid to slightly acid. Surface runoff for both soils is medium. Organic matter content is low to moderate in the Groseclose soil and low in the Poplimento soil. The available water capacity is medium for both soils. Permeability is slow in the Groseclose soil and moderately slow in the Poplimento soil.

The profile of the Groseclose soil typically consists of a ten-inch thick surface layer of brown loam underlain by a 29-inch thick subsoil of a yellowish-brown sticky and plastic clay mottled in shades of brown, yellow, and red. The substratum is typically plastic clay from 39 to 51 inches and clay loam from 51 inches to 72 inches. Depth to bedrock is greater than 48 inches.

Generally, the typical Poplimento soil profile consists of a 12-inch thick surface layer of dark brown and light yellowish brown silt loam underlain by a 43-inch thick subsoil of yellowish-brown, sticky and plastic clay. The clay subsoil is mottled shades of brown, yellow, green, and gray. The substratum is yellowish-brown shaley silty, clay loam mottled in shades of brown, yellow, green, and gray. Depth to bedrock is greater than 48 inches.

Guernsey Silt Loam (2 to 7% slopes). The Guernsey soils comprise less than 1% of the soils at the MMA and consist of moderately well drained, deep, gently sloping soils, which are situated on stream terraces.

Reaction of the Guernsey soils ranges from very strongly acid to mildly alkaline. The organic matter content of Guernsey soil is low and permeability is slow. A perched seasonal high water table occurs in this soil at a depth of 24 to 42 inches. A typical profile of the Guernsey soil consists of a ten-inch thick surface layer of dark brown silt loam underlain by a 43-inch thick subsoil. The subsoil typically consists of an upper layer of yellowish-brown silty clay loam and a lower layer of yellow-brown plastic clay. The substratum is very dark grayish brown gravelly sand. Depth to bedrock is greater than 50 inches.

Hayter Loam (2 to 7% slopes). The Hayter soils comprise less than 1% of the soils at the MMA and consist of well-drained, deep, gently sloping soils, which are situated on stream terraces.

Reaction of Hayter soils ranges from strongly acid to slightly acid. The organic matter content of the Hayter soil is low to moderate and permeability is moderately rapid. Available water capacity of the Hayter soil is moderate. A typical profile of the Hayter soil consists of a 14-inch thick surface layer of very dark grayish-brown loam underlain by a 41-inch thick subsoil. The subsoil is typically comprised of brown loam at a depth interval of 14 to 38 inches and brown cobbles and sandy, clay loam at a depth interval of 38 to 55 inches. The substratum is brown cobbles loam. Depth to bedrock is greater than 48 inches.

Lowell Silt Loam (2 to 30% slopes). The Lowell soils comprise less than 1% of the soils at the MMA and are gently to strongly sloping areas found on side slopes and ridge tops.

Reaction of Lowell soils ranges from very strongly acid to mildly alkaline. The organic matter content of the Lowell soil is moderately low and permeability is moderately slow. Available water capacity of the Lowell soil is moderate and surface runoff is slow. A typical profile of the Lowell soil consists of a 11-inch thick surface layer of dark yellowish brown silt loam underlain by a 27-inch thick subsoil of strong brown and reddish-yellow silty clay and clay. The substratum is yellowish brown shaley silt loam at depths greater than 60 inches. This soil map unit does not have a seasonally high water table within 60 inches of the surface.

McGary and Purdy Soils. This soil map unit comprises less than 1% of the soils at the MMA and consists of poorly to very poorly drained soils situated on flood plains and low terraces. The map unit consists of approximately 40% deep McGary soils, 35% deep Purdy soils, and 25% other soils.

Reaction of the McGary soils ranges from extremely acid to mildly alkaline. Reaction of the Purdy soils ranges from extremely acid to strongly acid. Surface runoff for both soils is medium and available water capacity is moderate. Organic matter content is low to moderate for the McGary and Purdy soils. Permeability is slow or very slow in both soils. A seasonally high water table is present in the McGary soil at a depth of 12 to 36 inches. In the Purdy soil, the depth of the seasonally high water table is 12 inches or less.

The profile of the McGary soil typically consists of a nine-inch thick surface layer of dark gray silt loam by a 28-inch thick subsoil of yellowish-brown sticky and plastic clay mottled gray and yellowish brown. The substratum is gray sticky and plastic clay that is mottled yellowish brown below a depth of 48 inches. Depth to bedrock is greater than 60 inches.

The Purdy soil profile typically consists of an 11-inch thick surface layer of very dark grayish brown and grayish brown loam underlain by a 23-inch thick subsoil of grayish brown sticky and plastic clay with yellowish-brown mottling. The substratum is mottled light gray and gray, sticky and plastic, clay loam below a depth of approximately 34 inches. Depth to bedrock is greater than 60 inches in the McCarty soil and greater than 48 inches in the Purdy soil.

Rock Outcrop-Newbern-Carbo Complex (30 to 65% slopes). This complex comprises approximately 2% of the soils at the MMA and consists of steep and very steep soils, and rock outcrop. The soil map consists of approximately 50% rock outcrop, 25% Newbern soils, 20% Carbo soils, and 5% other soils.

Reaction of the upper part of both soils profiles ranges from slightly acid to neutral. Reaction of the lower part of the profile for both soils ranges from neutral to moderately alkaline. The organic matter content is moderately low for both soils. Permeability is moderate in the Newbern soils and slow in the Carbo soils. Surface runoff is rapid or very rapid for both soils. Available water capacity is very low for the Newbern soils and low in the Carbo soils.

A typical profile of the Newbern soil consists of a seven-inch thick surface layer of yellowish brown silt loam underlain by an eight-inch thick subsoil of brownish yellow shaley silty clay loam. Unconsolidated shale is typically at a depth of 15 inches and hard shale is at a depth of 19 inches.

A typical profile of the Carbo soil consists of a five-inch thick surface layer of yellowish brown silty clay loam underlain by a 26-inch thick subsoil of strong brown clay. Limestone bedrock is typically at a depth of 31 inches.

Ross Soils. The Ross soils comprises approximately 1% of the soils at the MMA and consist of well-drained, deep and nearly level soils situated on levees adjacent to streams and in scour channels on flood plains.

Reaction of Ross soils range from slightly acid to moderately alkaline. The organic matter content of Ross soil is moderate to high and permeability is moderate. Available water capacity of the Ross soil is high and surface runoff is slow.

A typical profile of the Ross soil consists of a ten-inch thick surface layer of dark brown loam underlain by a 25-inch thick subsoil of dark brown loam. The substratum is brown loam below a depth of approximately 35 inches. Depth to bedrock is greater than 60 inches.

Udorthents and Urban Land. These soils comprise less than 2% of the soils at the MMA and consist of moderately well drained or somewhat poorly drained, shallow to deep, soils. This map unit ranges from nearly level and gently sloping to strongly sloping and moderately steep. Urban land consists of soils covered by streets, parking lots, buildings, and other structures. The map unit comprises of approximately 45% Udorthents, 30% Urban land, and 25% other soils.

Reaction of Udorthents soils ranges from extremely acid to moderately alkaline. The organic matter content of this soil is low to high and permeability ranges from slow to moderately rapid. A perched seasonal high water table occurs in this soil at a depth of 24 to 42 inches.

SCS has not provided a profile of the Udorthents soil because of its variability. In general, the surface layer ranges from five to 15 inches and is variable in color and texture. Underlying material generally extends to a depth of several feet.

Unison-Urban Land Complex (2 to 25% slopes). This complex comprises approximately 32% of the soils at the MMA and occurs on side slopes and ridgetops. The map unit consists of approximately 50% Unison soils, 25% Urban land, and 25% other soils.

Reaction of Unison soils ranges from strongly acid to medium acid. The organic matter content of this soil is low to moderate and permeability is moderate. Available water capacity of the Unison soil is moderate and surface runoff is medium. In disturbed areas, the above soil characteristics are extremely variable. A typical profile of the Unison soil in undisturbed areas consists of a 15-inch thick surface layer of dark brown and brown loam underlain by a 43-inch thick subsoil of yellowish-red sticky and plastic clay. The substratum is red sandy clay loam below a depth of approximately 58 inches. Depth to bedrock is greater than 60 inches. Urban land consists of soil covered by streets, parking lots, buildings, and other structures.

Unison and Braddock Soils (7 to 25% slopes). These soils comprise less than 1% of the soils at the MMA and occur on side slopes near the New River. This map unit consists of well drained and strongly sloping to moderately steep soils that are located on stream terraces and alluvial plains. The Unison and Braddock soil map unit consist of approximately 45% deep Unison soils, 40% deep Braddock Soils, and 15% other soils.

Reaction of Unison soils ranges from strongly acid through medium acid. Reaction of the Braddock soils ranges from very strongly acid to strongly acid. The organic matter content for both of these soils is low to moderate and permeability is moderate. Available water capacity of the Unison and Braddock soils is moderate and surface runoff is rapid.

A typical profile of the Unison soil in undisturbed areas consists of a 15-inch thick surface layer of dark brown and brown loam underlain by a 43-inch thick subsoil of yellowish red sticky and plastic clay. The substratum is red sandy clay loam below a depth of approximately 58 inches. Depth to bedrock is greater than 60 inches.

The Braddock soil profile typically consists of a 17-inch thick surface layer of dark yellowish brown and strong brown loam underlain by a 42-inch thick subsoil of sticky and plastic clay. The plastic clay is yellowish red within the depth interval of 17 to 28 inches and is dark red within the depth interval of 28 to 59 inches. The substratum is red sandy clay loam. Depth to bedrock is greater than 60 inches.

Weaver Soils. The Weaver soils comprise approximately 1% of the soils at the MMA and consist of moderately well drained and deep soils located in nearly level areas within flood plains.

Reaction of Weaver soils ranges from neutral to moderately alkaline. The organic matter content of the Weaver soil is low to moderate and permeability is moderate. Available water capacity of the Weaver soil is high and surface runoff is slow. A seasonally high water table exists in the Weaver soil at a depth of 18 to 30 inches. A typical profile of the Weaver soil consists of a ten-inch thick surface layer of dark brown silt loam underlain by a 39-inch thick subsoil of silt loam of variable color. The substratum is dark gray gravel sandy clay loam below approximately 49 inches. Depth to bedrock is greater than 40 inches.

Wheeling Sandy Loam. This soil map unit comprises approximately 9% of the soils of the MMA and consists of soils situated on nearly level terraces.

Reaction of the Wheeling soils ranges from strongly acid to medium acid. The organic matter content of this soil is moderately low and permeability is moderate. Available water capacity of the Wheeling soil is moderate and surface runoff is slow. The Wheeling soil does not have a seasonally high water table within 60 inches of the surface. A typical profile of the Wheeling soil consists of a ten-inch thick surface layer of dark brown sandy loam underlain by a 42-inch thick subsoil of dark brown sandy clay loam and sandy loam. The substratum is dark brown, gravelly sandy loam to minimum depth of 60 inches.

Wurno-Newbern-Faywood Silt Loams (15 to 35% slopes). These soils comprise approximately 2% of the soils at the MMA and consist of moderately steep and steep soils. This soil map unit consists of approximately 35% Wurno soils, 30% Newbern soils, 25% Faywood soils, and 10% of other soils. This soil map unit does not have a seasonally high water table.

Reaction of the upper part of the Wurno soil profile ranges from slightly acid to mildly alkaline. Reaction of the lower part of the Wurno soil profile ranges from neutral to mildly alkaline. Reaction of the upper parts of the Newbern soil profile range from slightly acid to neutral. Reaction of the lower parts of the Newbern soil profile range from neutral to mildly alkaline. Reaction of the Faywood soil ranges from strongly acidic to neutral.

Organic matter content for the Wurno and Newbern soils is moderately low. Organic matter content for Faywood soil is moderate. Permeability of Wurno and Newbern soils is moderate. Permeability of the Faywood soils is moderately slow. Available water capacity is very low for the soils and runoff is rapid.

A typical profile of the Wurno soil consists of a seven-inch thick surface layer of yellowish brown silt loam underlain by a six-inch thick subsoil of brownish-yellow very shaley silty clay loam. The substratum is partially weathered shale 13 inches thick. Bedrock is typically at a depth of 18 inches.

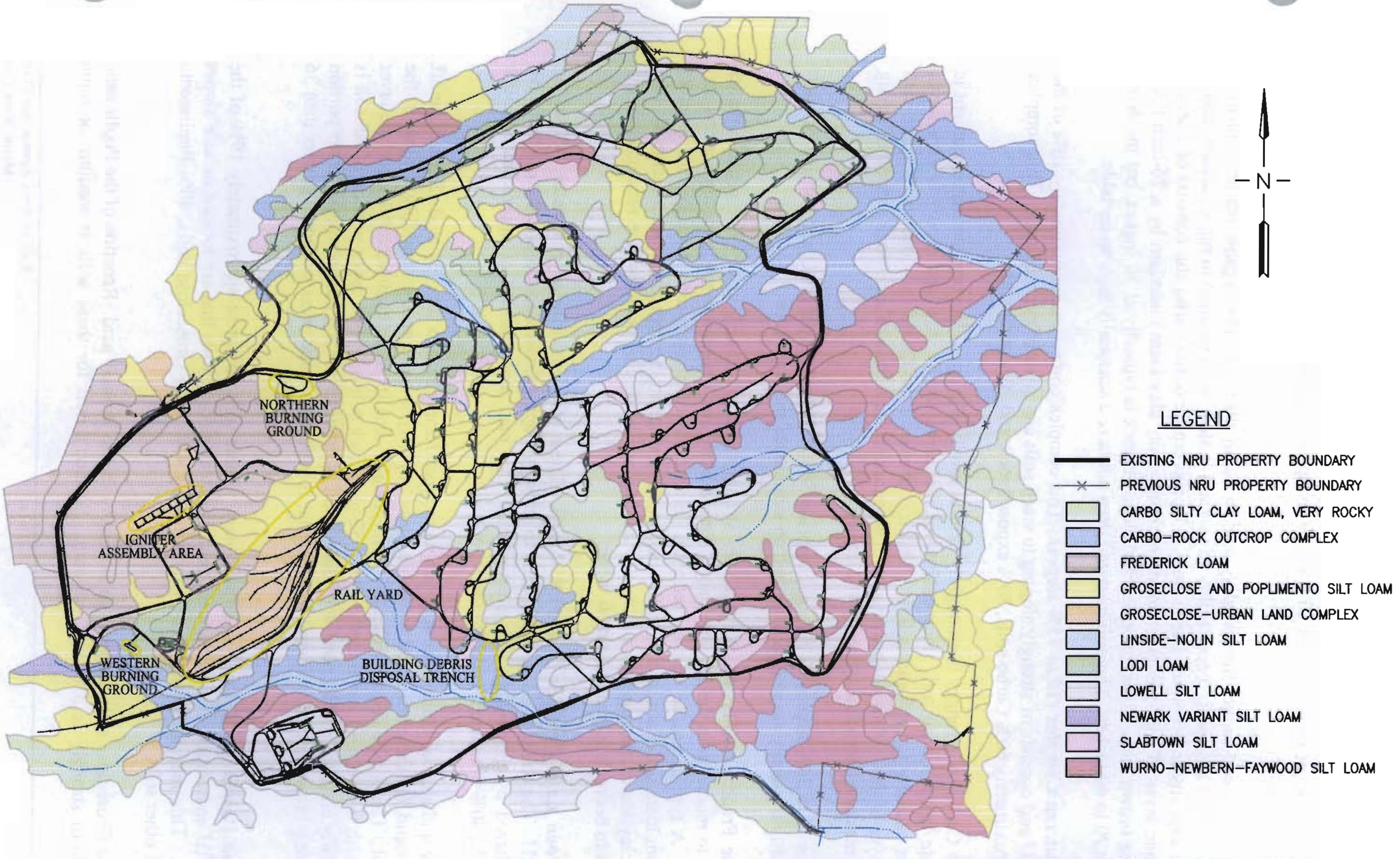
The Newbern soil profile typically consists of a five-inch thick surface layer of yellowish brown silty clay loam underlain by a 26-inch thick subsoil of strong brown clay. Limestone bedrock is typically at a depth of 31 inches.

A typical profile of the Faywood soil consists of a ten-inch thick surface layer of yellowish brown silt loam underlain by an 18-inch thick subsoil of yellowish brown silty, clay loam and silty clay. Bedrock is typically at a depth of 28 inches.

3.5.2 New River Unit

Figure 3-2 shows that 11 SCS soil types underlie the NRU. The text below summarizes the physical and chemical characteristics of these soil types (SCS 1985b).

Carbo Silty Clay Loam (7 to 30% slopes). These soils comprise approximately 12% of the soils at the NRU and consist of strongly sloping to steep soils situated on convex side slopes along drainage ways.



SOURCE: FACILITY-WIDE BACKGROUND STUDY REPORT (IT 2002)

RFAAP
MASTER WORK PLAN

Date: *JAN. 2002*	URS Proj Number: *09604-263*
Scale: *AS SHOWN*	File Name: *MWPFigure3-2.DWG*

FIGURE 3-2

SCS SOIL TYPES AT THE NEW RIVER UNIT

Rock outcrops cover approximately 1 to 10% of the mapped area. This soil map unit does not have a seasonally high water table.

Reaction of the Carbo soil ranges from slightly acid to mildly alkaline. The organic matter content is moderately low in the Carbo soil. Permeability of this soil is slow, with medium to rapid surface runoff. Available water capacity is low in the Carbo soil. A typical profile of the Carbo soil consists of a seven-inch thick surface layer of dark yellowish to strong brown silty clay loam underlain by a 26-inch thick subsoil of strong brown clay. Hard limestone and shale bedrock is typically at 30 inches, but the depth may range from 20 to 40 inches. This soil map unit does not have a seasonally high water table.

Carbo-Rock Outcrop Complex (10 to 45% slopes). This complex comprises approximately 10% of the soils at the NRU and consists of strongly sloping to steep soils and areas of exposed rock. This complex consists of approximately 60% Carbo soils, 30% exposed rock, and 10% other soils.

Reaction of the Carbo soils ranges from slightly acid to mildly alkaline. The organic matter content is low to moderate in the Carbo soil. Permeability of the Carbo soil is slow and runoff is very rapid. Available water capacity for this soil is low. A typical profile of the Carbo soil consists of a five-inch thick surface layer of dark yellowish brown silty clay loam underlain by a 26-inch thick subsoil of strong brown clay. Limestone bedrock is typically at a depth of 31 inches.

Frederick Loam (2 to 30% slopes). This soil comprises 9% of the soils at the NRU and consists of well-drained and gently to steeply sloping soils located on side slopes and ridge tops.

Reaction of the Frederick soils ranges from very strongly acid to strongly acid. The organic matter content is low to moderate in the Frederick soil. Permeability and available water capacity for this soil are moderate. A typical profile of the Frederick soil consists of a seven-inch thick surface layer of yellowish-brown loam underlain by a 53-inch thick subsoil, which in the uppermost portion consists of a strong brown clay loam. Strong brown silty clay and yellowish-red clay comprise the remainder of the subsoil. Depth to bedrock is greater than 60 inches.

Groseclose-Urban Land Complex (2 to 15% slopes). These soils comprise approximately 4% of the soils at the NRU. The complex consists of gently to strongly sloping Groseclose soils and areas that have been partly altered by grading or filling activities. This map unit consists of approximately 50% Groseclose soils, 40% urbanized, and 10% other soils.

Reaction of the undisturbed Groseclose soils ranges from extremely acid to strongly acid. Surface runoff is medium to rapid for these soils and available water capacity is medium. Permeability is slow in the Groseclose soil. The profile of the Groseclose soil typically consists of an eight-inch thick surface layer of dark yellowish brown silt loam underlain by a 52-inch thick subsoil. The upper portion of subsoil is strong brown silty clay, the middle portion of the subsoil is strong brown silty clay, and the lower portion consists of strong brown silty clay loam. Fill material is present in some areas to depths greater than 36 inches.

Groseclose and Poplimento Soils (2 to 30% slopes). These soils comprise approximately 19% of the soils at the NRU and consist of well drained, gently to steep sloping soils that are located on side slopes and ridgetops. This map unit consists of approximately 45% deep Groseclose soils, 40% Poplimento soils, and 15% other soils.

Reaction of the Groseclose soils ranges from extremely acid to strongly acid. Reaction of the Poplimento soils ranges from strongly acid to medium acid. Surface runoff for these soils is medium or rapid depending on the slope. Organic matter content is low to moderate in the Groseclose soil and low in the Poplimento soil. The available water capacity is medium for both soils. Permeability is slow in the Groseclose soil and moderately slow in the Poplimento soil.

The profile of the Groseclose soil typically consists of an eight-inch thick surface layer of dark yellowish brown silt loam underlain by a 52-inch thick subsoil. The upper portion of the subsoil is strong brown silty clay, the middle portion of the subsoil is strong brown silty clay, and the lower portion consists of strong brown silty clay loam. At depths greater than 54 inches, the substratum is yellowish-brown silty clay loam to a depth of at least 67 inches.

Generally, the typical Poplimento soil profile consists of a seven-inch thick surface layer of dark yellowish brown silt underlain by a 37-inch thick subsoil. The upper portion of the subsoil is strong brown silt loam, the middle portion is yellowish-brown and strong brown clay, while the lower part consists of reddish-yellow clay. The substratum extends to a depth of at least 60 inches and consists of reddish-yellowish and strong brown silty clay loam. Depth to bedrock is greater than 48 inches.

Linside-Nolin Silt Loams (0 to 2% slopes). These soils comprise approximately 3% of the soils at the NRU and consist of nearly level soils. This map unit consists of approximately 55% deep Linside soils, 35% Nolin soils, and 10% other soils.

The organic matter content for both of these soils is moderate. Available water capacity of the Linside and Nolin soils is high and surface runoff is very slow. Linside soils have a seasonally high water table of 18 to 30 inches. Nolin soils have a seasonal high water table of 36 to 72 inches.

A typical profile of the Linside soil consists of a ten-inch thick surface layer of dark yellowish brown silt loam underlain by a 28-inch thick subsoil consisting of mottled brown and gray silt loam and silty clay loam. The substratum is grayish brown silt loam to a depth of 60 inches or more. Depth to bedrock is greater than 60 inches.

The Nolin soil profile typically consists of a seven-inch thick surface layer of brown silt loam underlain by a 31-inch thick subsoil of brown silt loam. The substratum is dark yellowish brown silty clay loam to a depth of 60 inches or more. Depth to bedrock is greater than 60 inches.

Lodi Loam (2 to 30% slopes). This soil map unit comprises approximately 8% of the soils of the NRU and consists of gently to steeply sloping soils situated on convex side slopes and ridge tops.

Reaction of the Lodi soils ranges from very strongly acid to strongly acid. The organic matter content of this soil is moderately low and permeability is moderate. Available water capacity of the Lodi soil is moderate and surface runoff is medium. The Wheeling soil does not have a seasonally high water table within 72 inches of the surface. A typical profile of the Lodi soil consists of a seven-inch thick surface layer of yellowish-brown loam underlain by a 53-inch thick subsoil. The subsoil is yellowish brown loam in the upper portion, strong brown clay in the middle portion, and yellow and brownish-yellow clay loam in the lower portion. Depth to bedrock is greater than 60 inches.

Lowell Silt Loam (2 to 30% slopes). The Lowell soils comprise approximately 18% of the soils at the NRU and are gently to steeply sloping soils situated on side slopes and ridge tops. This soil map unit does not have a seasonally high water table within 60 inches of the surface.

Reaction of Lowell soils ranges from very strongly acid to mildly alkaline. The organic matter content of the Lowell soil is moderately low and permeability is moderately slow. Available water capacity of the

Lowell soil is moderate and surface runoff is slow. A typical profile of the Lowell soil consists of a 11-inch thick surface layer of dark yellowish brown silt loam underlain by a 27-inch thick subsoil of strong brown and reddish-yellow silty clay and clay. The substratum is yellowish-brown shaley silt loam at depths greater than 60 inches.

Newark Variant Silt Loam (0 to 2% slopes). The New Variant soils comprise less than 1% of the soils at the NRU and are nearly level soils situated along drainage ways.

Reaction of Newark Variant soils ranges from medium acid to mildly alkaline. The organic matter content and permeability of this soil are moderate. Available water capacity of the Newark Variant soil is moderate to high and surface runoff is very slow. A seasonal water table is present at a depth of six to 18 inches. A typical profile of the Newark Variant soil consists of a 21-inch thick surface layer of dark brown to light yellowish brown silt loam underlain by a 28-inch thick subsoil of brown silt loam with mottles. The substratum is gray clay and extends to depths greater than 60 inches. Depth to bedrock is greater than 60 inches. This soil map unit does not have a seasonally high water table within 60 inches of the surface.

Slabtown Silt Loam (2 to 15% slopes). The Slabtown soils comprise approximately 4% of the soils at the NRU and are gently to strongly sloping soils situated on concave toe and foot slopes and at the heads of drainage ways. This soil map unit does not have a seasonally high water table within 60 inches of the surface.

Reaction of Slabtown soil ranges from medium acid to mildly alkaline. The organic matter content of this soil is moderately low and permeability is moderately slow. Available water capacity of the Slabtown soil is high and surface runoff is medium or rapid. A seasonal water table is present at a depth of 18 to 36 inches. A typical profile of the Slabtown soil consists of a nine-inch thick surface layer of brown silt loam underlain by a 51-inch thick subsoil. The upper part of the subsoil is yellowish brown silt loam and gravelly silty clay loam and the lower part is yellowish-brown clay. Depth to bedrock is greater than 60 inches.

Wurno-Newbern-Faywood Silt Loams (75 to 30% slopes). These soils comprise approximately 12% of the soils at the NRU and consist of moderately steep and steep soils. This soil map unit consists of approximately 35% Wurno soils, 30% Newbern soils, 25% Faywood soils, and 10% of other soils.

Reaction of the upper part of the Wurno soil profile ranges from slightly acid to mildly alkaline. Reaction of the lower part of the Wurno soil profile ranges from neutral to mildly alkaline. Reaction of the upper parts of the Newbern soil profile range from slightly acid to neutral. Reaction of the lower parts of the Newbern soil profile range from neutral to mildly alkaline. Reaction of the Faywood soil ranges from strongly acidic to neutral. The organic matter content for the Wurno and Newbern soils is moderately low. Organic matter content for Faywood soil is moderate. Permeability of Wurno and Newbern soils is moderate. The permeability of the Faywood soils is moderately slow. Available water capacity is very low the three soils and runoff is rapid

A typical profile of the Wurno soil consists of a seven-inch thick surface layer of yellowish brown silt loam underlain by a six-inch thick subsoil of brownish-yellow very shaley silty, clay loam. The substratum is partially weathered shale 13 inches thick. Bedrock is typically at a depth of 18 inches.

The Newbern soil profile typically consists of a five-inch thick surface layer of yellowish brown silty clay loam underlain by a 26-inch thick subsoil of strong brown clay. Limestone bedrock is typically at a depth of 31 inches.

A typical profile of the Faywood soil consists of a ten-inch thick surface layer of yellowish brown silt loam underlain by an 18-inch thick subsoil of yellowish brown silty, clay loam and silty clay. Bedrock is typically at a depth of 28 inches. This soil map unit does not have a seasonally high water table.

3.6 REGIONAL GEOLOGY

The Valley and Ridge Physiographic Province of southwestern Virginia consists of closely spaced valleys and ridges that are directly related to folds in the underlying Paleozoic sequence of rocks, dating from 550 to 300 million years ago. Table 3-1 summarizes the geologic events affecting the Valley and Ridge Province. The history of the Paleozoic era includes a series of sea level transgressions and regressions as well as three orogenic (mountain building) events. The transgressions are recorded by the deposition of marine sediments (carbonates/dolostone), and clastic sediments evidence the regressions. The orogenic events are recorded by deformation (faulting, folding, and fracturing) in these rocks.

3.6.1 Stratigraphy of the Southern Appalachian Valley and Ridge Province

From the Cambrian through Ordovician periods, carbonates were primarily deposited in the area that became the Valley and Ridge province. These rocks record the presence of a shallow, warm sea, much like the present-day Caribbean, extending from eastern Canada through Alabama. A series of clastic (terrestrial) sedimentary rocks with minor amounts of carbonate were deposited from the Late Ordovician through Pennsylvanian periods.

Cambrian-aged carbonates and clastic rocks of the Elbrook Formation and similar rocks of Ordovician age underlie most of RFAAP. Much younger Mississippian-aged shales and mudstones of the McGary/Price Formations are present at the eastern border of RFAAP.

3.6.2 Structural History of the Southern Appalachian Valley and Ridge Province

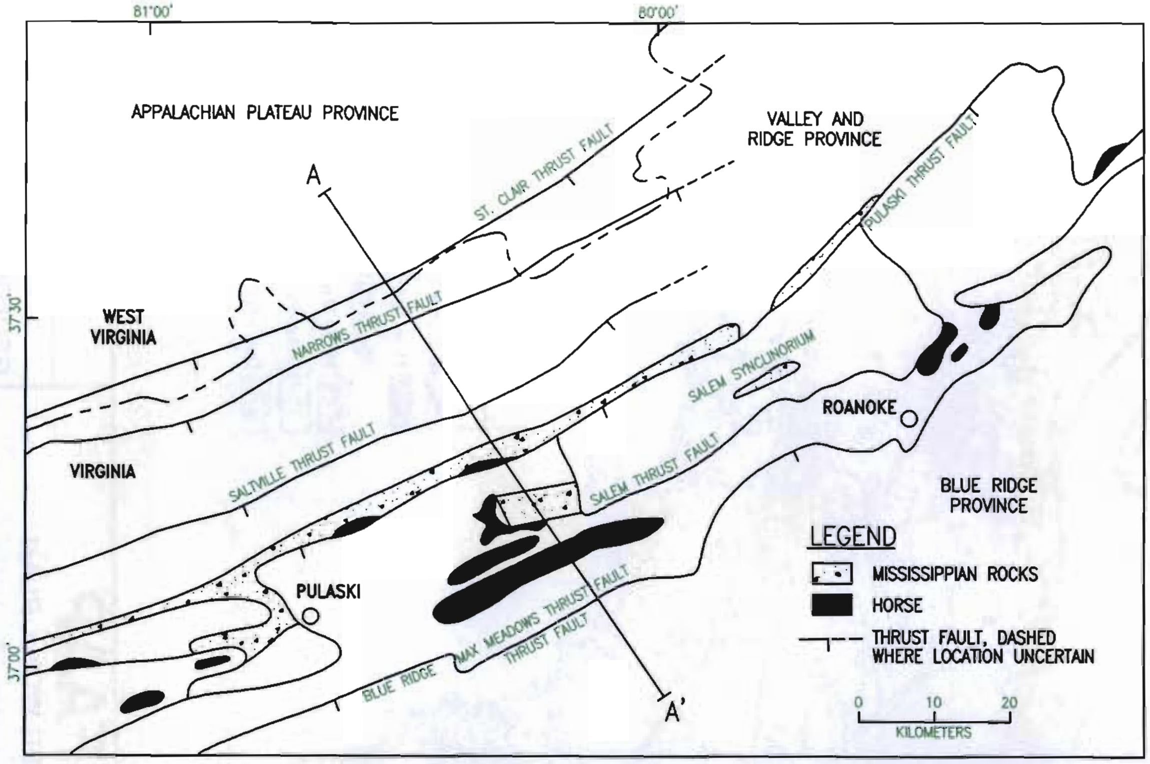
Most of the extensive folding and faulting observed in the southern Valley and Ridge province is attributed to compression during the Late Paleozoic Alleghanian orogenic event. This event was caused by the collision of North America with what is now Europe in the Mid-Pennsylvanian period.

Major thrust slices in the Valley and Ridge Province of southwestern Virginia include the Pulaski, Saltville, Copper Creek, and Clinchport thrust sheets. Faults have displacements on the order of tens of kilometers. Other major structural features include northeast-southwest trending folds and faults region. (Schultz 1988). Figure 3-3 shows the major thrust faults of the Valley and Ridge Province in the RFAAP The Pulaski thrust sheet, which is located in the area of RFAAP, is one of the several major, southeast dipping Alleghanian thrusts of the southern Appalachians. This thrust sheet has been traced along strike for approximately 500 kilometers. Estimates of the displacement near RFAAP range from 15 to 50 kilometers (Bartholomew 1979). At RFAAP, the Pulaski thrust emplaced older Cambrian rocks (Elbrook Formation) over younger Mississippian rocks (McCray/Price Formation). The maximum thickness of the overlying thrust sheet ranges from 1,500 to 4,000 meters. The fault surface is rarely exposed. When exposed, the type of exposure consists of fractured, veined and folded Cambrian dolomites, argillaceous dolomites and phyllites of the broken formations lying on soft and highly weathered, fractured, and foliated Mississippian rocks (Schultz 1983).

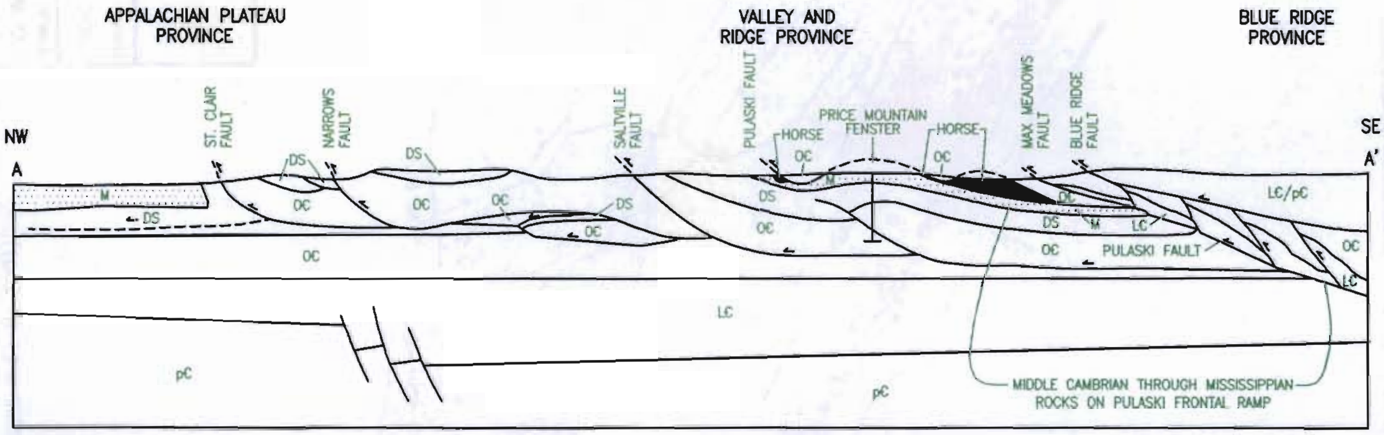
Figure 3-4 shows the geology of the Pulaski thrust sheet. Regional scale synclinoria are the dominant first-order structures of the Pulaski thrust sheet as shown on Figure 3-5.

Table 3-1
Summary of Geologic Events Affecting the Valley and Ridge Province
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

ERA	Period	Age, End of Period (Million Years Ago)	Formations Present in Province	Geologic Setting	Sedimentary Events	Structural Events
CENOZOIC	Tertiary	66.5	None	Stable plate interior	Constant erosion	Gentle uplift
MESOZOIC	Cretaceous Jurassic Triassic	248	None	Opening of Proto-Atlantic Ocean	Deposition of lacustrine and terrestrial sediments in basins to the east	Extensional rift valleys formed to the east
PALEOZOIC	Permian	286	None	Alleghanian orogeny--collision of North America with another landmass to the east	Deposition of clastic (terrestrial) sedimentary rocks with minor carbonates	Compressional deformation forms Valley and Ridge Province--extensive folding, faulting, and cleavage; Pulaski thrust occurs.
	Pennsylvanian	320	McCrady/ Price			
	Mississippian	360				
	Devonian	408	Brailler Fm	Orogeny		Compressional deformation forms Blue Ridge Mountains to the east.
	Silurian	438	None			
	Ordovician	505	Undivided Knox Group	Warm shallow sea; 15° from equator	Deposition of carbonates and minor clastics	
	Cambrian	590	Max Meadows Conococheague Fm Elbrook Fm Rome Fm			Unknown



MAJOR THRUST FAULTS OF SOUTHERN APPALACHIAN VALLEY AND RIDGE PROVINCE. PULASKI THRUST SHEET AND DISTRIBUTION OF MISSISSIPPIAN ROCKS.



CROSS SECTION A–A' SHOWING MAJOR FRONTAL TECTONIC RAMP OF PULASKI THRUST SHEET.

0 5 10
KILOMETERS

NO VERTICAL SCALE

LEGEND

M	MISSISSIPPIAN ROCKS
DS	SILURIAN AND DEVONIAN ROCKS
OC	LOWER CAMBRIAN ROME FORMATION THROUGH ORDOVICIAN ROCKS
LC	LOWER CAMBRIAN ROCKS
LC/pC	PRECAMBRIAN AND LOWER CAMBRIAN ROCKS
pC	PRECAMBRIAN ROCKS
■	HORSE DERIVED FROM PULASKI FRONTAL RAMP
←	THRUST FAULT, ARROW SHOWING SENSE OF MOVEMENT DASHED WHERE INFERRED
⊥	WELL

SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

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URS Proj Number: *09604-263*
Scale: *AS SHOWN*
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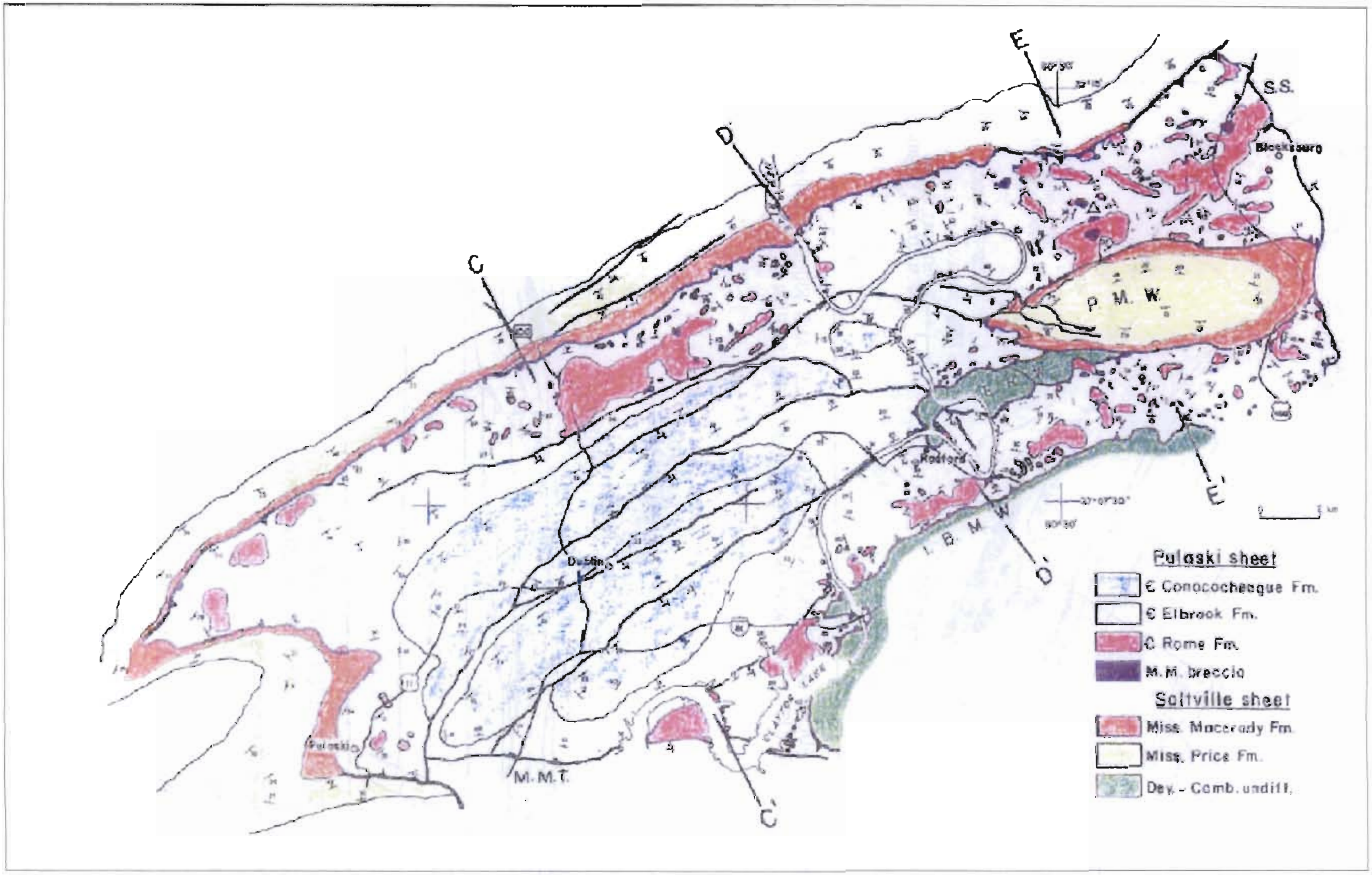
FIGURE 3-3

MAJOR THRUST FAULTS OF SOUTHERN APPALACHIAN VALLEY AND RIDGE PROVINCE



SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

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Date: JAN. 2002

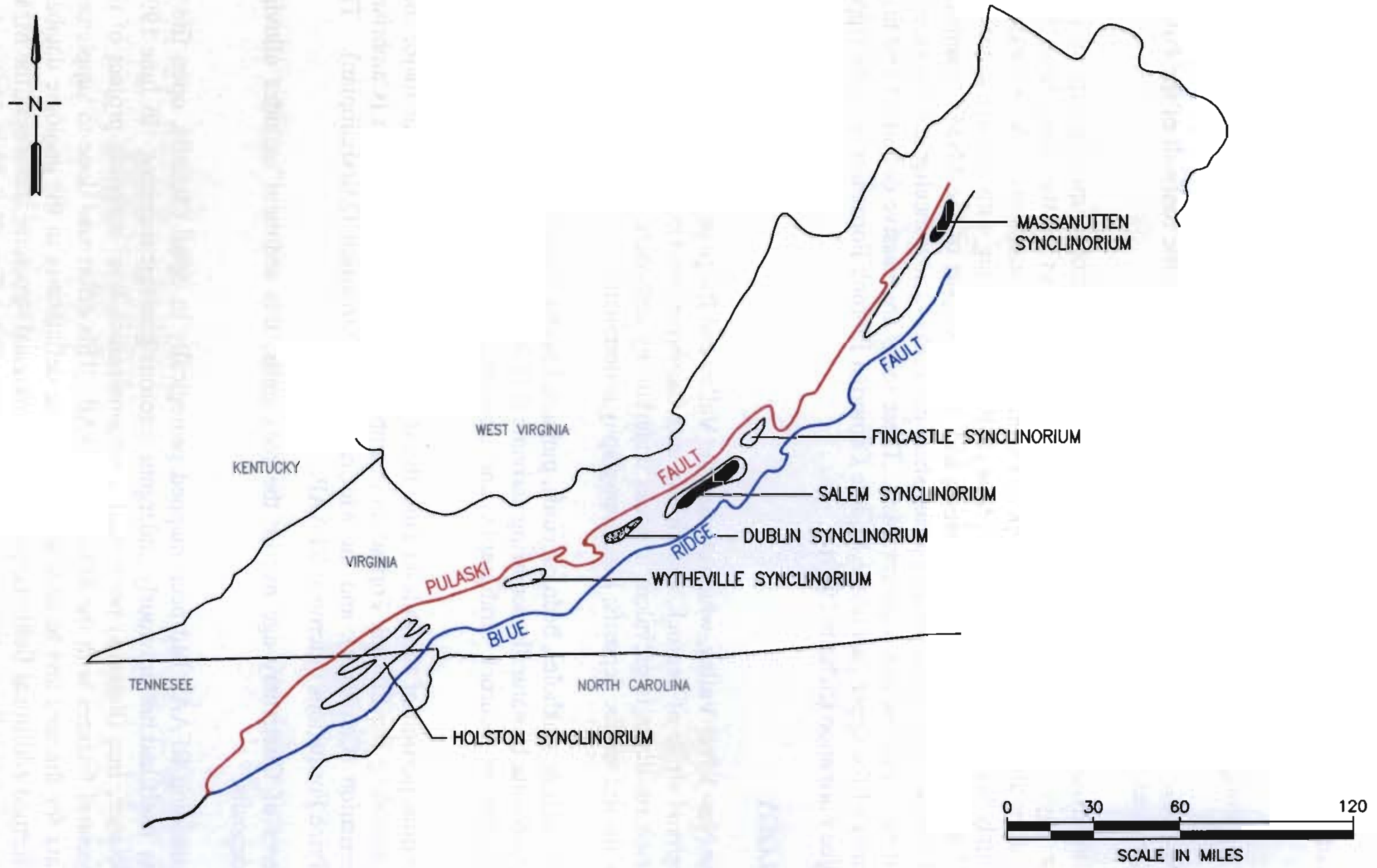
URS Proj Number: 09604-263

Scale: AS SHOWN

File Name: MWPFigure3-4.DWG

FIGURE 3-4

GEOLOGY OF THE PULASKI THRUST SHEET



SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

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URS Proj Number: 09604-263

Scale: AS SHOWN

File Name: MWPFigure3-5.DWG

FIGURE 3-5

LARGE-SCALE SYNCLINORIA WITHIN THE PULASKI THRUST SHEET

The Pulaski thrust sheet has undergone a four-fold deformational sequence. From relatively oldest to youngest this sequence includes:

1. Decollement thrusting along a footwall of Cambrian rocks;
2. Thrusting over a ramp that formed in folded and faulted rocks ranging in age from Cambrian to Mississippian;
3. Decollement thrusting along a footwall of Mississippian rocks; and
4. Folding and faulting of the emplaced Pulaski thrust sheet and of rocks of the footwall of the Pulaski thrust sheet (Saltville sheet) (Shultz 1983).

Rocks of the Pulaski thrust sheet consist of two distinctly different litho-tectonic units (groups of rock units that have similar physical characteristics). Rocks in the lower part of the sheet have high mechanical anisotropy, alternating high and low competency, and rheologic contrasts. These rocks are chiefly laminated and thinly bedded dolomites, argillaceous phyllites, alternating with massive dolomites and limestones of the Lower Cambrian Rome Formation and the lower part of the Middle Cambrian Elbrook Formation. The upper part of the Pulaski thrust sheet has rocks of low mechanical anisotropy, dominantly high competency, and low rheologic contrasts. These rocks are massive dolomites and thin- to thick-bedded limestones of the upper part of the Middle Cambrian Elbrook Formation and the Upper Cambrian Conococheague Formation (Schultz 1983).

3.7 RFAAP GEOLOGY

RFAAP is located in the New River Valley, which crosses the Valley and Ridge province approximately perpendicular to the regional strike of bedrock, and chiefly cuts Cambrian and Ordovician limestone or dolostone. Deep clay-rich residuum is prevalent in areas underlain by carbonate rocks. The valley is covered by river floodplain and terrace deposits; karst topography is dominant.

Karst features at RFAAP include sinkholes, bedrock voids, pinnacled bedrock, and springs formed by the dissolution of calcium carbonate by naturally occurring carbonic acid in rainwater. The greatest areas of karst features are controlled by bedrock stratigraphy and structure, and by the presence of major drainages.

RFAAP occupies the central portion of the Pulaski fault thrust sheet (Schultz 1988). Four major rock units underlie RFAAP including the Elbrook Formation (Cambrian), the Rome Formation (Cambrian), the Conococheague Formation (Cambrian), and the McCrady/Price Formation (Mississippian). The Elbrook and McCrady/Price Formations outcrop at RFAAP.

Unconsolidated sediments of Quaternary age overlie the rock units; this sediment includes alluvial, residual, and colluvial deposits.

Although the area surrounding RFAAP had been mapped geologically in detail (Schultz, open file in preparation), the Facility itself had not previously undergone rigorous geologic mapping. In June 1995, Parsons Engineering Science, Inc. (Parsons) performed a reconnaissance-level mapping project of the complex geological structural features with the MMA at RFAAP. This effort was done to supplement the existing geologic data for the area and to address site-specific deficiencies in the geologic database (Parsons 1996). IT performed additional field mapping of the geological structural features at the MMA in 2000 as part of the Current Conditions Report for the HSA (IT 2001). The IT field mapping effort including observing the geology of outcrops in the HSA and nearby surrounding areas for structural features including strike, dip, and fissure and joint set orientation. IT integrated data from their investigation, the Parsons mapping project, and both published and unpublished geology maps of the RFAAP area.

3.7.1 Geologic Map Units

The following sections describe the five geologic formations that underlie RFAAP.

3.7.1.1 Elbrook Formation

The Elbrook Formation is the major rock unit cropping out at RFAAP. This formation is composed of thickly bedded, blue-gray dolostone interspersed with blue-gray to white limestone; brown, green, and red shale; argillaceous limestone, and brecciated limestone (colors range from mottled light- to dark-gray and yellow-brown). Sinkholes, solution channels, pinnacled surfaces, and springs are common to the Elbrook. This Formation ranges from 1,400 to 2,000 feet thick. The strike of bedding in the Elbrook Formation is variable throughout the region. The general orientation of bedding is seen in the nearly east-west alignment of sinkholes at RFAAP and the surrounding area. Most sinkholes in the area are oval shaped and elongated with respect to the strike of the bedding; they most likely represent fractured or faulted zones within the underlying Elbrook Formation.

3.7.1.2 Rome Formation

The Rome Formation underlies the Elbrook Formation; however, the Rome does not outcrop at RFAAP. This Formation is composed of red and green shales, sandstone, dolostone, and limestone. The red shales commonly mark the basal unit. The thickness ranges from 1,000 to 2,000 feet.

3.7.1.3 Conococheague Formation

The Conococheague Formation overlies the Elbrook Formation and is composed of limestone, dolostone, and sandstone. It ranges in thickness from about 1,700 to 2,200 feet. This unit does not crop out within RFAAP.

3.7.1.4 McCrady/Price Formation

Mississippian rocks of the McCrady/Price Formation crop out east of the main plant area along Stroubles Creek. This Formation consists of mottled red and green shale and mudstone interspersed with brownish-green siltstone and sandstone. The McCrady/Price Formation may be up to 1,500 feet thick.

3.7.1.5 Max Meadows Tectonic Breccia

The Max Meadows tectonic breccia, which is evidence of the close proximity of the Pulaski fault surface, is abundant in the southeastern region of the HSA. This tectonic breccia consists of poorly sorted, angular to sub-rounded clasts of massive dolostones, laminated dolostones, and finely laminated, greenish-gray calcareous mudstones in a fine to very fine-grained matrix of crushed dolostones. Clasts range from less than one inch to more than three feet in length. The breccias are massive to crudely layered, and are well to poorly indurated. The breccia, which is most fine-grained along the fault contact (Schultz 1986), is an integral part of the highly deformed rocks along the base of the Pulaski thrust sheet.

3.7.2 Unconsolidated Sediments

Unconsolidated sediments (overburden) mantle the major portion of RFAAP. These include alluvial plain sediments deposited by the New River prior to entrenchment, residual deposits from in-place weathering of parent bedrock, and colluvial deposits developed by residual slope wash.

Alluvial plain deposits commonly line the New River and Stroubles Creek, some as recent floodplain material and some as geologically older terraces. Three terrace deposit types are evident within the HSA, which fine upward. Gravels and silty, clayey sands form the basal unit. Finer micaceous silts and clays overlie the basal unit. Sporadic cobbles and boulders (known as river jack) occur as lenses throughout the alluvial strata. Thickness of the alluvial deposits varies from a few feet to 50 feet, with an average of 20 feet (Parsons 1996).

Residual deposits (clays and silts) are a result of chemical and physical weathering of the parent bedrock. Residual deposits cover most of RFAAP. In most cases along the New River and in the HSA, these residual deposits underlie the alluvium, except where the residuum has been eroded to bedrock and replaced by alluvium. The depth of the overburden varies from a few feet to 70 feet (Parsons 1996).

Colluvial deposits generally form from mass wasting of slopes and escarpments. In general, these deposits are a heterogeneous mixture of alluvium, residuum, and rock debris that have moved from their original position. These deposits, which have variable thickness, are generally interbedded between the strata of alluvium and residuum.

3.7.3 Recent Faulting

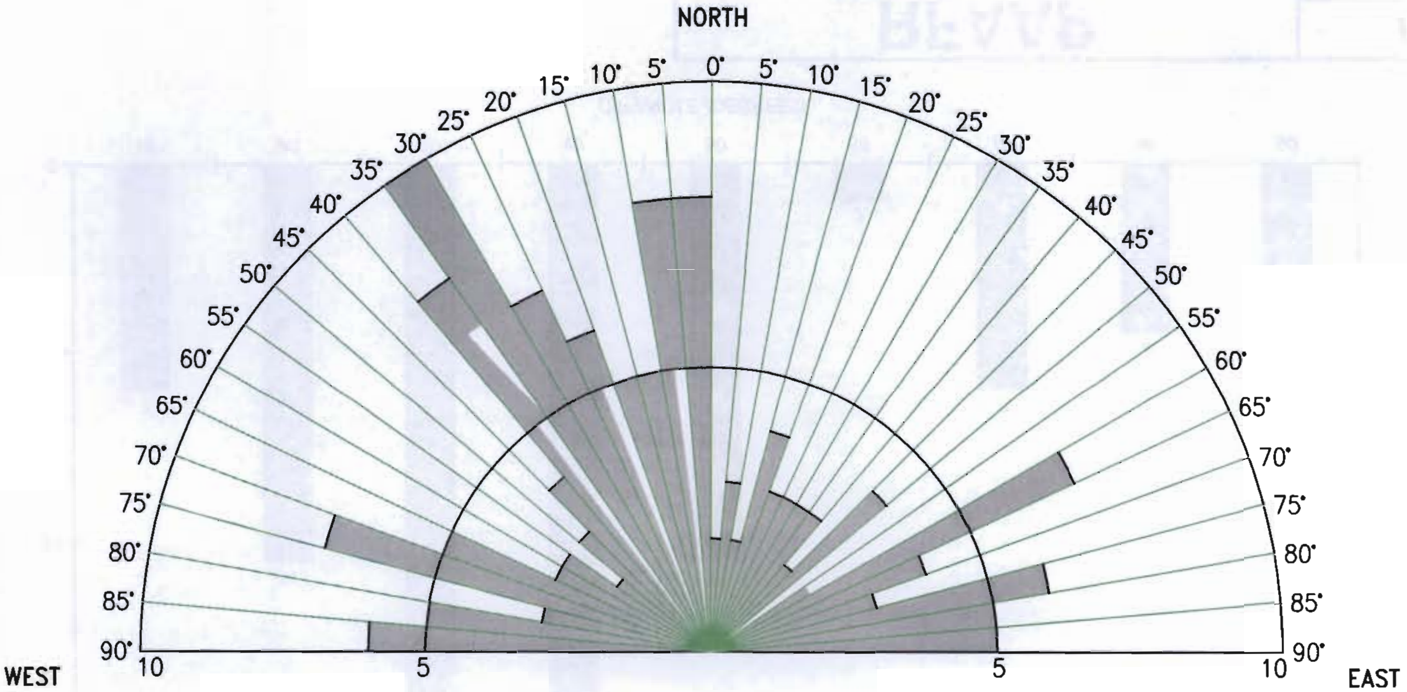
Evidence of recent faulting has not been observed near RFAAP. However, the Radford area has experienced seven earth tremors in the last 200 years with a recorded intensity of VI or higher on the Modified Mercalli Scale (USAEHA 1980). Several recent studies (Bollinger and Wheeler 1983; 1988) have delineated a low-level seismic zone in the central and northwestern part of the Valley and Ridge province in Giles County, VA. The largest recorded quake occurred in 1987, had a modified Mercalli Intensity of VIII, and was centered in Pearisburg, Virginia. Schultz and Southworth (1989) have shown that the largest slope failures in the folded Appalachians occur in the Giles County Seismic Zone, immediately northwest of RFAAP.

3.7.4 Bedrock Orientation

Bedrock orientation varies significantly at RFAAP because of the complex structural history of the Valley and Ridge Province in this area. IT and Parsons collected 159 strike measurements from outcrops at the MMA and nearby areas during their field mapping efforts. IT presented the compiled data on a rose diagram (Figure 3-6). The most predominant strike orientations are in four directions: N70°-75°W (70 degrees to 75 degrees west of north), N25°-35°W, N0°-10°W, and N60°-65°E (IT **2002).**

IT collected 86 dip measurements from outcrops at the MMA and nearby areas during the field mapping efforts (IT 2002). Figure 3-7 presents these data as a histogram and indicates that the predominant dip for bedrock measured at RFAAP. This figure indicates that the most predominant dip ranges measured are the following:

- 10° to 20° (11 measurements);
- 20° to 30° (22 measurements);



HORIZONTAL AXIS – NUMBER OF STRIKE DATA POINTS
159 STRIKE MEASUREMENTS

SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

RFAAP
MASTER WORK PLAN

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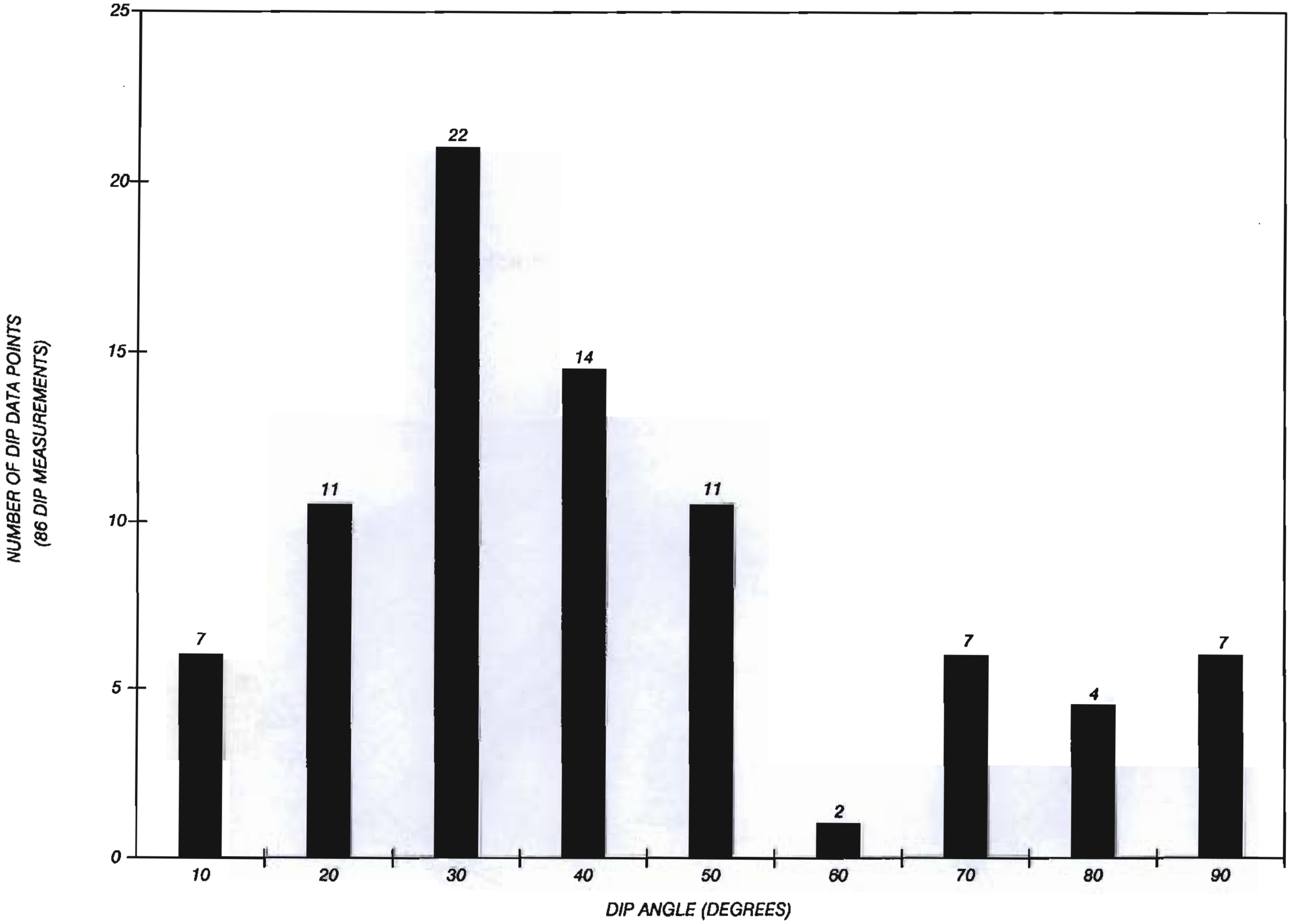
FIGURE 3-6

RFAAP AREA STRIKE DATA



SOURCE OF DATA: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

RFAAP

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Date: JAN. 2002

URS Proj Number: 09604-263

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File Name: MWPFigure3-7.DWG

FIGURE 3-7

RFAAP AREA DIP DATA

- 30° to 40° (14 measurements); and
- 40° to 50° (11 measurements).

3.7.5 Faults

Prominent deformation features include faults, folding, and fracture or joint set orientations. Figure 3-8 shows the numerous faults, photolineaments, and karst features in the RFAAP area, as presented by IT (2001) in the HSA Current Conditions Report. Most of the thrust faults, illustrated with the teeth on the upper plate (overriding plate) are predominantly east-west trending thrust faults. Other faults mapped are high-angle faults, with dip angles greater than 45 degrees.

Depending on the strike of the bedrock, the fissures or fractures are generally perpendicular to the strike. The compressional and/or tensional forces exerted on the rocks during the Allegheny Orogeny further complicate this relationship making it more difficult to interpret trends in fractures, joints, and joint-sets.

3.7.6 Photolineament Trends (Fracture Traces)

Fracture traces are linear features identified in aerial photographs that represent the surface expression of major fractures and/or zones of fracturing. Identifying lineament features, such as fracture traces, is important because fractures or fracture zones can act as preferential pathways for groundwater flow, increasing flow rates, and in some cases, redirecting flow away from an expected flow direction. Fractures are of particular environmental concern because they represent pathways through which contaminants may enter and move through an aquifer.

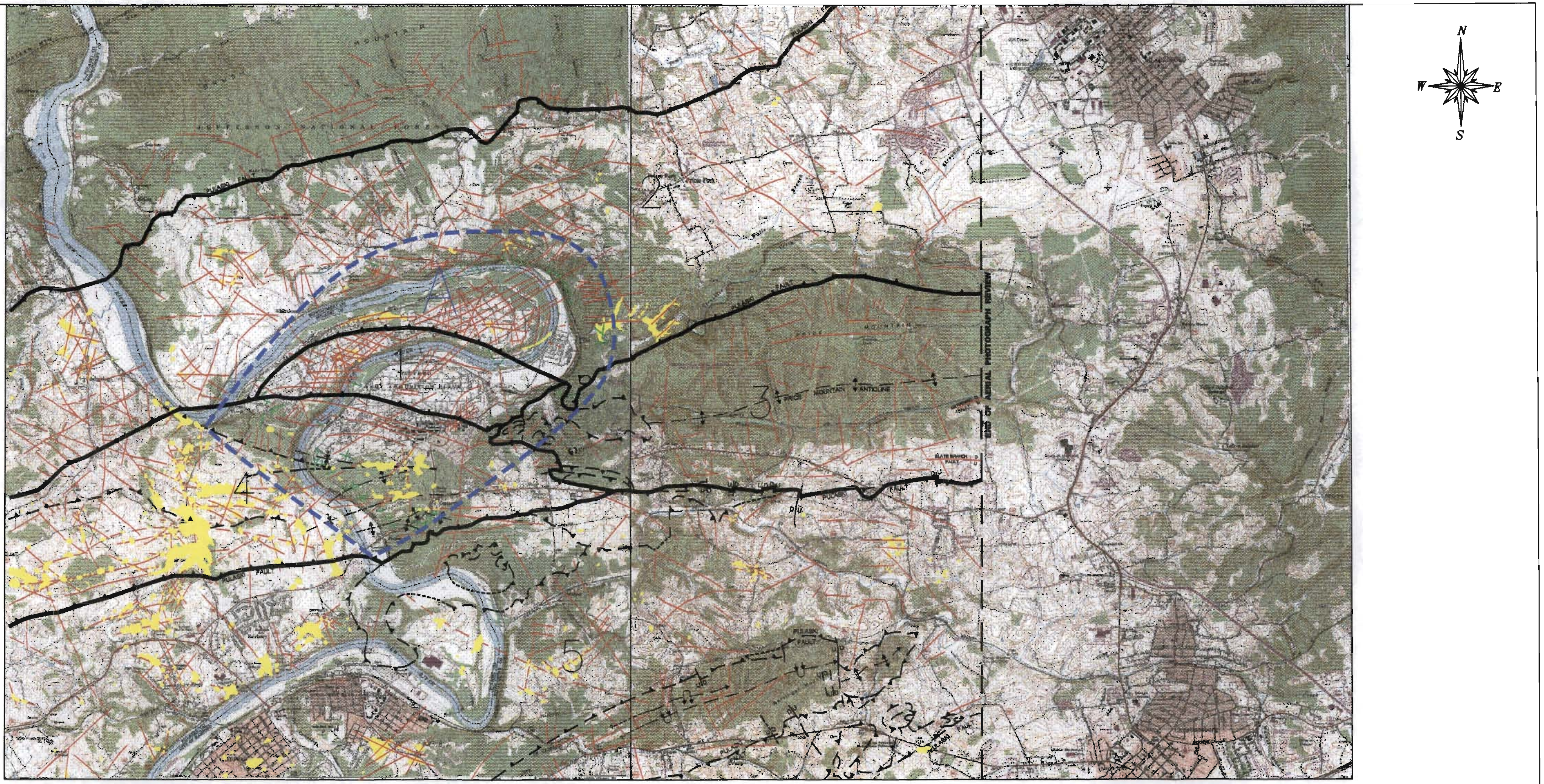
Photolineament studies were conducted by the U.S. Environmental Protection Agency (USEPA) (1992a) and IT (2001) to identify lineaments, fracture traces, faults, bedding plane orientations, and karst features in the area of RFAAP. These studies used aerial photographs and topographic maps to identify and map photogeologic signatures such as soil-tonal variations, vegetation and topographic alignments, bedding planes, karst features such as sinkholes, and other geologic structures.

The desktop study conducted by USEPA's Environmental Photographic Interpretation Center (EPIC) identified the following:

- 66 fracture traces in the area of RFAAP;
- Approximately 70 potential sinkholes in the MMA (excluding the HSA); and
- Approximately 100 potential sinkholes in the HSA.

IT conducted the photolineament study as part of the field geologic mapping effort completed for the HSA Current Conditions Report (IT 2001). This study used aerial photographs that predated and postdated the development of the Facility. The IT study also included a ground-truthing component. When supported by field data, the study differentiated between lineament features such as fissures and faults.

Figure 3-8 shows the features identified by IT from the photolineament study. There were 596 photolineaments measured in the study area, which included an area comprising five fault blocks. Photolineament data have a wide distribution reflecting the severe folding and faulting that occurred in this



EXPLANATION

FAULT, DASHED WHERE KNOWN OR INFERRED, DOTTED WHERE SUSPECTED OR CONCEALED

PHOTOLINEAMENT, DASHED WHERE INFERRED, DOTTED WHERE CONCEALED OR SUSPECTED

THRUST FAULT, TEETH ON UPPER PLATE, DASHED WHERE KNOWN OR INFERRED, DOTTED WHERE CONCEALED OR SUSPECTED

ANTICLINE

SYNCLINE

FRACTURE ORIENTATION

STRIKE AND DIP

STRIKE

SINKHOLE

OVERTURNED ANTICLINE

OVERTURNED SYNCLINE

ALL FAULTS, PHOTOLINEAMENTS, ANTICLINES ETC ARE COMPILED FROM PREVIOUS REFERENCES (PUBLISHED AND UNPUBLISHED), PHYSICALLY MAPPED FROM FIELD EVIDENCE OR INTERPRETED FROM AERIAL PHOTOS, TOPOGRAPHIC AND/OR GEOLOGIC MAPS.

SOURCES OF INFORMATION

1937 AND 1962 AERIAL PHOTOS

GEOLOGY OF BLACKSBURG QUADRANGLE BY M.J. BARTHOLOMEW AND W.D. LOWRY, 1979.

DRAFT GEOLOGY OF RADFORD NORTH, VIRGINIA QUADRANGLE BY M.J. BARTHOLOMEW AND A. SCHULTZ, 2000.

BLACKSBURG AND RADFORD NORTH, VIRGINIA 7 1/2 MINUTE U.S.G.S. QUADRANGLES, DATED: 1965, PHOTOREVISED: 1983 AND 1984 RESPECTIVELY.

SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

RFAAP MASTER WORK PLAN		FIGURE 3-8
Date: JAN. 2002	Prepared By: KDC/DR	STRIKE AND PHOTOLINEAMENT AREAS
Scale: AS SHOWN	File Name: 09604-263-155	

area. A rose diagram prepared by IT for the HSA Current Conditions Report shows the predominant photolineament trends are in area. A rose diagram prepared by IT for the HSA Current Conditions Report shows the predominant photolineament trends are in seven directions: N65°-70°W, N5°-10°W, N0°-5°E, N10°-15°W, N45°-50°, and N60°-65°E. Figure 3-8 shows these identified trends.

Figure 3-9 shows the broken-formations and the structural complexity in the RFAAP. This figure depicts the intense structural deformation as observed in bedrock outcroppings. The primary geologic control is the Pulaski thrust sheet and the numerous thrust imbrications that have occurred through successive tectonic events. Additional tectonic events have occurred that increases the number of faults and degree of folding. Because of the intense structural deformities, severe fracturing of the bedrock units has resulted in equally intense fracturing of the bedrock (IT 2001).

3.8 REGIONAL HYDROGEOLOGY

The Valley and Ridge topography consists of a series of ridges and valleys controlled by the structure and weathering characteristics of the different rock lithologies. Folded and faulted resistant rocks, such as sandstone, cherty limestone, dolostones, and conglomerate, generally underlie ridges. Less resistant rocks, such as limestone and shale, generally underlie valleys.

Local flow systems comprise approximately 95% of the groundwater flow in the Valley and Ridge province. These local systems are commonly restricted to depths shallower than 600 feet and generally lie between adjacent topographic divides that range from a few thousand feet to a few miles apart (Swain et. al. 1991).

The U.S. Geological Survey has identified three hydrogeologic terranes with the Valley and Ridge province of Virginia including:

1. Carbonate rocks with regolith of at least 50 thick, with both diffuse flow and conduit flow at shallow to intermediate depths less than 600 feet;

2. Carbonate rocks and sandstone with regolith up to 50 feet thick, with conduit and fracture flow at shallow depths less than 300 feet; and

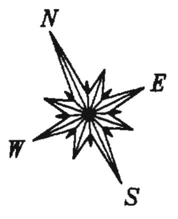
3. Clay-rich rocks with diffuse flow through clay-filled fractures at shallow depths less than 150 feet (Swain et. al. 1991).

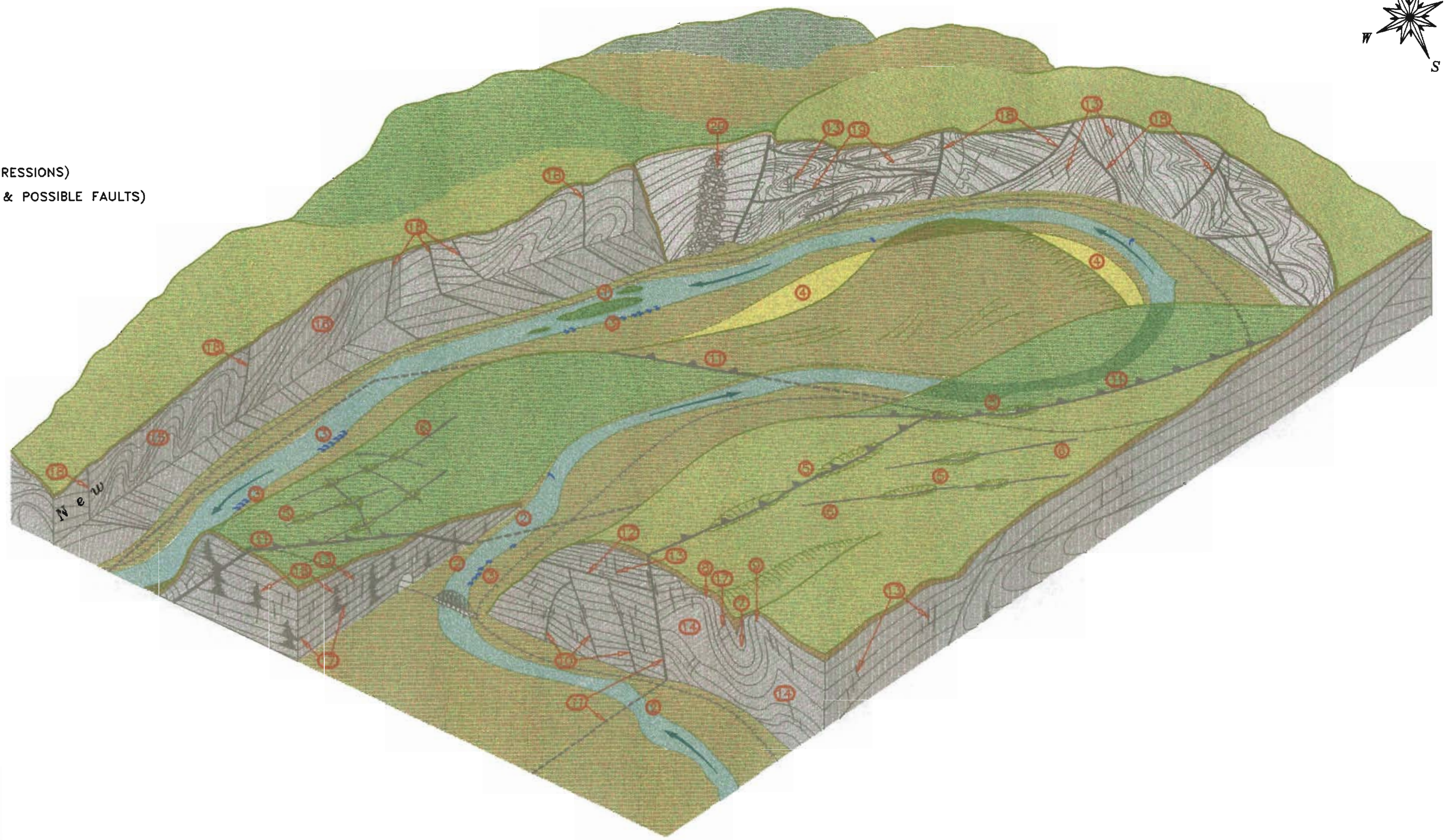
Parallel ridges and discharges to local streams generally restrict groundwater flow within the Valley and Ridge province. Local streams are normal to the axes of the intervening valleys and are tributaries to the main streams that flow along the axes of the valley. In places, main streams cut across or through the ridges. Thus, topography combined with ridge-cutting main streams effectively compartmentalizes groundwater flow into adjacent, but hydraulically isolated, shallow flow systems (Swain et. al. 1991).

In each local flow system, groundwater flows from ridge to valley until the water either discharges directly to local streams or is intercepted and routed down-valley by a layer or zone of rocks, which has well-developed secondary permeability (Swain et. al. 1991). Highly permeable layers or zones may consist of (1) coarse-grained carbonate rocks with well-developed secondary permeability or (2) permeable fracture zones that act as collectors or conduits (Parizek et. al. 1971). Generally, flow paths parallel to the axis of the valley are several times longer than flow paths perpendicular to the axis of the

LEGEND:

- ① ISLANDS
- ② RAPIDS
- ③ SPRINGS
- ④ TERRACE
- ⑤ SINKHOLES (BOWL-SHAPED DEPRESSIONS)
- ⑥ PHOTOLINEAMENTS (FRACTURES & POSSIBLE FAULTS)
- ⑦ SYNCLINE (ASYMMETRIC)
- ⑧ ANTICLINE (SYMMETRIC)
- ⑨ ANTICLINE (ASYMMETRIC
- ⑩ NORMAL FAULT
- ⑪ THRUST FAULTS
- ⑫ BEDDING PLANE FAULT
- ⑬ FISSURES IN ROCK





- ⑭ DUCTILE DEFORMATION
- ⑮ ASYMMETRIC FOLDS
- ⑯ INCLINED ISOCLINAL FOLDS
- ⑰ SECONDARY POROSITY – DISSOLUTION OF CARBONATES ALONG BEDDING PLANES AND FISSURES
- ⑱ FAULTS – PROBABLY NORMAL FAULTS, BUT NOT ABLE TO FIELD DETERMINE BECAUSE OF DEFORMATION OR LACK OF OUTCROP. GENERALLY PERPENDICULAR TO THRUST FAULTS.
- ⑲ DISHARMONIC FOLDING AND FAULTING
- ⑳ FAULT GOUGE SOLUTIONS ALONG FAULT ZONE

SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

RFAAP
MASTER WORK PLAN

Date: JAN. 2002	**Prepared By:** KDC/DR
Scale: N.T.S.	**File Name:** 09604-263-155

FIGURE 3-9

CONCEPTUAL GEOLOGIC AND HYDROGEOLOGIC MODEL

valley. Flow components that are parallel to the axis of the valley commonly discharge to a spring or a main stream that crosses the valley (Swain et. al. 1991).

Rocks of the Valley and Ridge province have low primary porosity and permeability. Within the uppermost 300 feet of these rocks, fracturing and dissolution have produced substantial secondary porosity and permeability. Wells commonly produce five to 500 gallons per minute from these secondary openings (Swain et. al. 1991). Carbonate rocks are the most prolific groundwater supplies, especially when they are associated with thick regolith (fragmented and unconsolidated material), which acts as an important storage reservoir. Regolith stores recharge that would otherwise be rapidly diverted to overland flow and slowly releases this water to underlying carbonate aquifers. The combination of regolith and mature epikarst zones provides a large storage component to the local and regional groundwater system (IT 2001). Figure 3-10 shows a conceptualized groundwater model in the Valley and Ridge Province.

Groundwater supplies in the Valley and Ridge Province are generally of good quality compared to surface water supplies (Parsons 1996). However, due to extended contact with minerals, many groundwater supplies contain higher levels of dissolved solids than the streams into which they discharge. Because of the sinkholes and underground voids in karst aquifers, there is potential for groundwater to be impacted by direct infiltration of contaminated surface water.

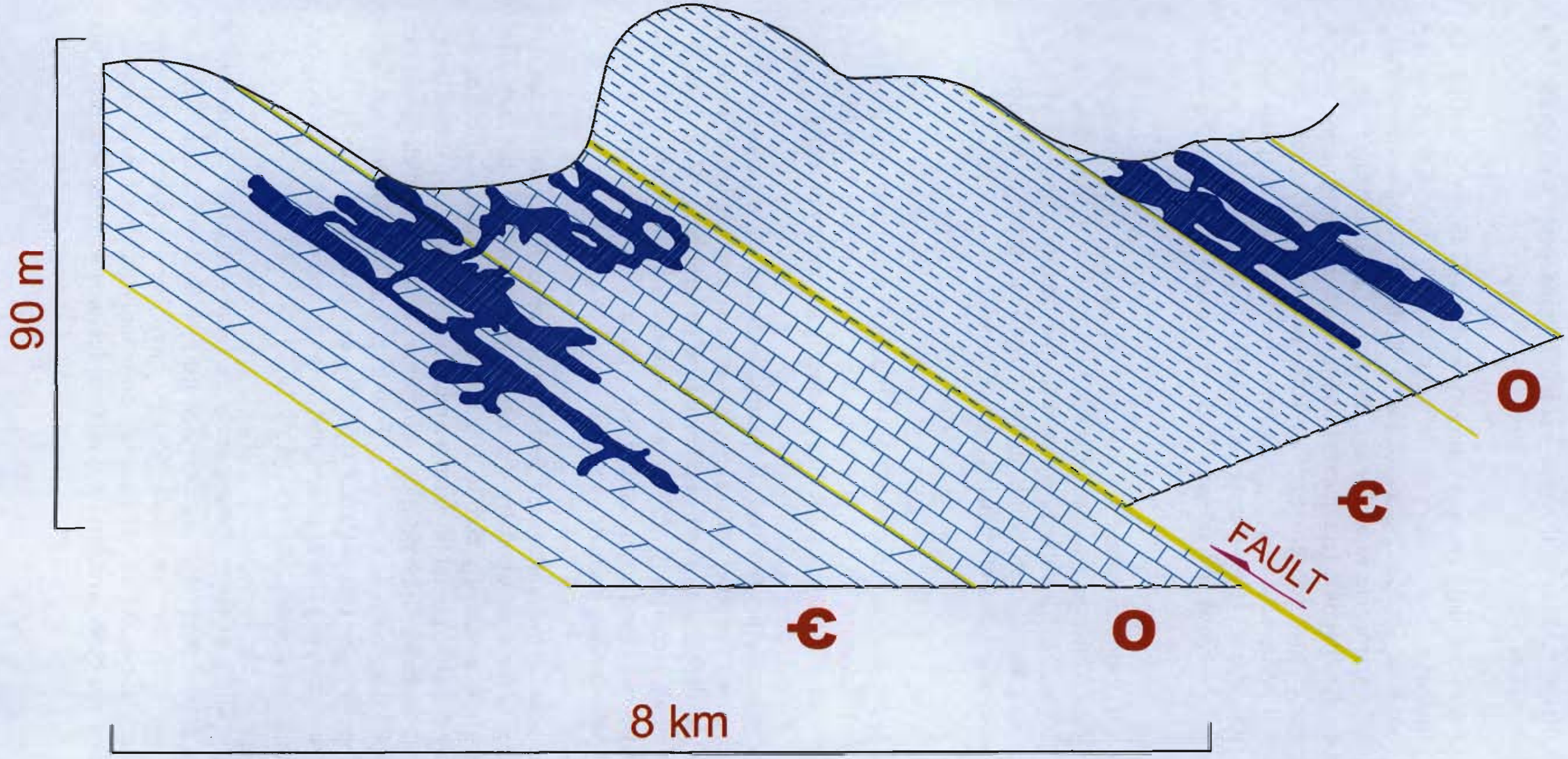
3.8.1 Carbonate Hydrogeology

Carbonate rocks in the Valley and Ridge Province in the area of RFAAP comprises a karst terrane, which is generally underlain by limestone and dolomite. Karst is a terrane with distinctive hydrology and landforms, which arises from a combination of high rock solubility producing secondary porosity.

The primary feature of karst is the erosion or net removal of aquifer materials by dissolution or by dissolution serving as the trigger mechanism for other processes. Most karst systems are of meteoric origin, circulating groundwater at shallow depths with short, residence time underground. Over time, the secondary permeability of carbonate rock increases with increased dissolution of aquifer materials creating preferential pathways for water movement in the subsurface. Surface karst features, such as sinkholes, and subsurface preferential pathways are intimately related.

The uppermost portion of karstified rocks in the Valley and Ridge Province is the epikarst zone (or subcutaneous zone). The epikarst zone is the dissolutionally weathered upper portion of the carbonate bedrock, which can range in thickness from essentially zero to 100 feet or more. Factors affecting the thickness of the epikarst zone include climate, glaciation history, patterns, and depth of groundwater circulation, bedrock characteristics, and the history of vegetation of the area. Epikarstic development can vary in intensity, with the degree of bedrock dissolution ranging from less than 1% to more than 50%. The percentage of bedrock dissolution with the epikarst zone typically decreases with depth. Voids within the epikarst zone are partially or completely full of sediments, with the percentage of the bedrock void volume filled ranging from less than 5% to more than 95% (Aley 1997).

Permeability rates within the sediment filling of the epikarstic zone are highly variable. Permeability rates of the sediment filling are often greater than might be expected from soils having similar textural characteristics; particularly, where silt and clay sediment fillings have been subjected to some desiccation. Silt and clay sediments subjected to desiccation commonly compact and develop compaction cracks. Compaction cracks, and other structural and textural features with the sediment fills often create



LEGEND:

- ▨ LIMESTONE
- ▦ DOLOSTONE
- ▤ SHALE
- € CAMBRIAN AGE ROCKS
- O ORDOVICIAN AGE ROCKS
- ⇄ FAULT SHOWING RELATIVE MOVEMENT
- ● GROUNDWATER STORED AND TRANSMITTED THROUGH FISSURES AND DISSOLUTION POROSITY

SOURCE:

SEBER, P.R., BRAHANA, J.V. AND HOLLYDAY, E.F. 1988.

SOURCE: DRAFT CURRENT CONDITIONS REPORT HORSESHOE AREA (IT 2001)

RFAAP
MASTER WORK PLAN

Date: JAN. 2002
URS Proj Number: 09604-263
Scale: AS SHOWN
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FIGURE 3-10

CONCEPTUALIZED GROUNDWATER MODEL IN THE VALLEY AND RIDGE PHYSI0GRAPHIC PROVINCE

zones of high permeability. Permeability rates through the sediment fills of the epikarstic zone are commonly orders of magnitude higher than those found in adjacent carbonate bedrock (Aley 1997).

The epikarst zone stores water and concentrates flow while it passes to the vadose zone (bulk rock mass) below the epikarst. At the base of the epikarst zone, groundwater flow is focused along a few major fissures. Major tectonic fissures provide leakage paths from the epikarst zone, and their preferential enlargement occurs from the base of the zone downward, resulting in hidden shafts. Such shafts represent headwaters draining the epikarst zone above to conduit drainage system developed deeper in the rock mass (Klimchouk 2000).

Aley (1997) has divided epikarstic zones into the three hydrological types based on their ability to store water.

Rapid-draining epikarsts. Significant storage of water is lacking in this type of epikarst. Saturation of the epikarst zone with water generally occurs for less than a few hours at a time. Dissolutional voids are relatively free of fine textured sediments in most cases. Areas commonly characterized by rapidly draining epikarst include (1) alpine karst areas, (2) areas with high topographic relief, and (3) areas where soluble purity of the carbonate bedrock is high and external sediment sources are low.

Seasonally saturated epikarsts. This type of epikarst routinely stores water seasonally or after major precipitation periods. Water storage in the epikarst typically persists for weeks or months at a time. Dissolutional voids are typically partially filled to almost completely filled with fine textured sediment. Some preferential flow paths, which contain appreciable air-filled void space, typically exist. Seasonally saturated epikarst zones typically form in areas characterized by: (1) humid conditions, (2) moderate relief, (3) an appreciable thickness of soil and residuum, and (4) the presence of perennial streams at lower elevations than most of the epikarst zone.

Perennially saturated epikarsts. This type of epikarst zone is perennially saturated with water. Areas commonly characterized by perennially saturated epikarsts include (1) humid areas, (2) areas of low to moderate relief, and (3) areas located along perennial streams. Voids in the bedrock are commonly most filled with fine textured sediments.

Karst aquifers may have diffuse and/or conduit type of groundwater flow (Swain et. al. 1991). Diffuse flow occurs under conditions in which most openings in the karstified rock intercommunicate and are full of water but have not been enlarged in specific zones by dissolution. Diffuse flow is slow by comparison to conduit flow and is frequently laminar; it may be turbulent if the rock openings are of sufficient diameter (five to 15 millimeters) and the velocity of water flow is higher (USEPA 1999).

Discharges from carbonate aquifers that have a substantial amount of diffuse flow respond slowly to rainfall. These aquifers have a low ratio between maximum and base flow discharge, typically 4:1 or less. The hardness of waters from diffuse flow is higher than for conduit flow. In addition, the hardness, turbidity, discharge, and temperature are less variable in diffuse flow when compared to conduit flow (Quinlin 1990).

Conduit flow occurs in carbonate rocks in karst terranes where dissolutional voids are relatively large (minimum diameter of five to 15 millimeters). These voids include enlarged fissures and tubular tunnels. Conduit flow is generally turbulent, but can be laminar in openings up to 500 millimeters in diameter if the velocity is sufficiently slow (USEPA 1999). This type of flow responds rapidly to rainfall and has a high ratio between the maximum discharge and the base flow discharge (typically 10:1 to 1,000:1). Water with conduit flow has low, but highly variable hardness. The turbidity, discharge, and temperature of these waters are also highly variable (Quinlan 1990).

Geomorphic factors, such as patterns of surface water drainage, strongly influence the development and nature of karst aquifers. In the Valley and Ridge Province, stream or rivers crossing more resistant bedrock tend to be high in elevation and have steeper gradients (e.g., New River) than streams or rivers crossing nonresistant bedrock (e.g., Tennessee River). Entrenchment of streams and rivers has a direct influence the gradient of aquifer. Thus, an increase in down cutting and gradient of a stream or river will result in an increased gradient in the aquifer, which will then cause additional mechanical and chemical erosion to occur within the aquifer (along bedding planes, fissures, etc.) (Swain et. al. 1991). In the area of RFAAP, the down cutting of the New River has lowered the groundwater base level over time.

The elevation of springs in the karst aquifer strongly controls the elevation of the water table. An entrenched river, such as the New River, typically controls spring elevations. The solution conduits that feed springs are typically so efficient in transmitting water, that they possess a low hydraulic gradient. Often, the potentiometric surface within or above the conduits lies slightly higher than the spring elevation. During low flow, hydraulic heads in the large conduits are typically lower than the heads in the surrounding smaller and less efficient fractures. Therefore, water flows towards the conduit from the surrounding narrow fissures and pores. This trend is often reversed during flood conditions, when large openings are subjected to sudden surges of water from the surface (Palmer 1984).

Geologic factors, such as tectonics, regional structures, bedding planes, faults, fissuring, etc. influence the storage and movement of groundwater within karst aquifers. Tectonics can have a major influence on hydraulic potential because it affects the balance of uplift and erosion. Regional structures are important for the control of folding and faulting. Anticline and syncline structures associated with tension and compression develop joint patterns reflecting these conditions. Percolating waters more readily penetrate joints and fractures under tension than under compression. Thus, anticlines and domes represent potentially important sites for aquifer recharge. On the other hand, synclinal troughs represent potentially important sites for flow convergence and accumulation of groundwater (IT 2001).

Bedding planes represent another controlling factor in movement of groundwater within the karst aquifer. Bedding planes can (1) link joint dominant routes for downward percolation in the vadose zone (unsaturated zone) and (2) allow for lateral movement of water in the phreatic zone (saturated zone). As the dip becomes steeper, bedding-plane partings can increasingly provide recharge routes. Water confined in major bedding planes between dense, thick sheets of rock may be led to great depths before cross-joints permit lateral movement (IT 2001).

Faults often act hydrogeologically like major joints. Because of their vertical and lateral continuity, faults can be an important feature in orientation of water flow in both the vadose and phreatic zones. However, many faults become barriers to groundwater flow because they are highly compressed or filled with secondary calcite (Ford et. al. 1990).

Because of the effects of fissuring and differential solution, permeability in bedrock may be greater in some directions than in others and in certain preferred stratigraphic horizons. In karst aquifers, dissolution features, and preferred fissuring patterns can override topographic control of groundwater flow on a local scale and cause anisotropic type of flow conditions. For example, trunk conduits (large dissolution voids) with a given karst system can act as the local discharge focus for tributaries, thereby causing local flow directions to diverge from a general trend associated with local topographic relief. Between adjacent karst systems in the same karst region, competitive advantage stemming from different geomorphic histories and allogenic (generated from elsewhere, usually at a distant place) inputs may also be significant in determining basin shape and drainage orientation (IT 2001).

The groundwater table in most karst regions is highly irregular and discontinuous, due to the great variation in the characteristics of the underground openings. Within most karst aquifers, conduits tend to form a branching system in which tributaries join to form larger passages with larger discharge. Water may stand at different elevations in nearby wells, and dry or poorly productive wells may occur in the same area as successful wells (Palmer 1990). Because of these and other complexities apparent in karst aquifers, some researchers deny the existence of a karst water table. However, perched zones and water table irregularities apparent in karst aquifers are also observed in other aquifer types. These irregularities are more pronounced and on a larger scale in soluble rock than in other materials. Therefore, the water table concept can be valid for karst regions, if applied regionally rather than on the scale of individual solution conduits or wells (Palmer 1990) and using wells completed to the same depth.

3.9 RFAAP HYDROGEOLOGY

Comprehensive detailed conceptual models for the hydrogeology of RFAAP are currently lacking. Most investigations in the MMA have focused on individual SWMUs; karst investigations (dye-tracing testing, etc.) have focused on the SWMU 17 area. An initial conceptual model of the hydrogeology of the HSA has been developed by IT in the HSA Current Conditions report (IT 2001).

3.9.1 Alluvium Water Table

This water table occurs primarily within the flood plain areas adjacent to the New River. In these areas, groundwater flow may occur within alluvium present above bedrock. A water table within alluvium has been identified both in the MMA (SWMUs 8, 10, 35, 36, 43, and 45) and HSA (SWMUs 13, 31, and 54).

Investigations by Dames & Moore (1992), Parsons (1996), and IT (2001) indicate that the water table surface within flood plain alluvium is at a relatively shallow depth of 15 to 25 feet at an elevation similar to the New River. In general, the observed saturated thickness of this water table ranges from featheredge to several feet (Dames & Moore 1992). Unconsolidated sediments generally fine upward and may include basal river jack deposits consisting of sand, gravel, and cobbles. Groundwater flow within the alluvium water table is toward the New River.

Permeability testing of flood plain alluvium sediments (coarse grained) in area of SWMUs 10 and 35 indicated intrinsic permeability values in the range of 1.7×10^{-4} to 2.2×10^{-3} centimeters per second (cm/sec) (Dames & Moore 1992). Slug testing conducted at the same locations yielded similar hydraulic conductivity results. Hydraulic data specific to the alluvial aquifer are lacking at other locations at RFAAP because monitoring wells are screened across the unconsolidated sediment/bedrock interface. Upland sediments (terrace deposits) at RFAAP may also contain groundwater, which is generally localized or in discontinuous perched zones.

3.9.2 Bedrock Aquifer

Hydrogeological conditions of the bedrock aquifer at RFAAP are complex because of (1) the intense structural deformation of the bedrock units and (2) the karst nature of the aquifer contained within limestone and dolostones underlying the Facility.

Groundwater within carbonate bedrock may be found within the epikarst zone (where present) and in underlying bedrock within fissures, bedding planes, and karst conduits. Fissures and bedding planes can become enlarged overtime through dissolution of the carbonate rock.

Geologic mapping and photolineament studies at RFAAP have shown that there is a significant potential for movement of water through solution features such sinkholes and for preferential movement of water with karst conduits and along fractures or faults.

Within RFAAP, sinkholes and photolineaments associated with sinkhole development are areas for groundwater recharge (see Figure 3-8). These sinkholes are the result of solutional widening of fractures or fissures with the underlying carbonate bedrock. These photolineaments can be zones of high secondary porosity due to fissured and solutionally enhanced carbonate rock, and therefore, sinkholes can form along these aligned structures.

Specific investigations of groundwater movement through these types of features at RFAAP have been limited to investigations associated with SWMU 17 in the MMA. Within other areas of RFAAP, monitoring wells were originally placed to sample groundwater and positioning is biased towards SWMUs to detect releases from these SWMUs. Significant spatial data gaps therefore exist in the groundwater elevation data. Thus, it is difficult to assess regional and local gradient characteristics and specific pathways of groundwater movement, especially in the highly deformed and karstic bedrock.

Groundwater levels in the bedrock aquifer at RFAAP can be responsive to heavy precipitation within a short time (less than 24 hours) and may rise several feet. This situation demonstrates that the karst aquifer underlying RFAAP can be characterized by conduit flow and illustrates the direct connection between the groundwater and surface water that could impact the quality of groundwater for domestic use. This rapid response occurs in many areas of RFAAP, especially in areas where surface water infiltrates through sinkholes (Parsons 1996).

Water levels from 91 monitoring wells throughout RFAAP were measured during the first quarter of 1995. Parsons Engineering Science (Parsons 1996) used these data to develop a facility-wide map of groundwater gradient. This map indicated a groundwater gradient toward the New River and away from areas of higher elevation. Some wells at the Facility displayed unusually shallow or deep water levels compared with other nearby wells. Parsons Engineering Science (Parsons) hypothesized that these differences may be the result of intercepted perched groundwater zones or influence by karst features, such as sinkholes or conduits, which exert a strong local influence and are not reflective of the overall unconfined water table. The map and resulting interpretations developed by Parsons may be misleading because they used data from wells installed in various monitoring zones and depths (shallow alluvial, deep alluvial, and bedrock wells). Spatial gaps in monitoring points at the Facility also make it difficult to accurately characterize groundwater gradients (and flow paths) on a facility-wide scale.

Parsons conducted hydrogeological investigations at SWMU 17 in the MMA, which is situated in two large sinkholes. The intent of these investigations was to characterize the effect of structural and solution features in bedrock on groundwater flow. Monitoring wells installed by Parsons Engineering Science were designed to intercept the "regional water table" associated with the New River. Parsons conducted a dye-trace study through dye placement into two injection wells located in each sinkhole associated with SWMU 17.

The Parsons dye-trace study indicated that a spring (SPG 3), which discharges directly to the New River, is hydraulically connected to the sinkhole in which SWMU 17 occupies. Dye placed in this sinkhole traveled 4,800 feet to the spring in approximately 24 hours. The flow path identified by the dye trace closely parallels a west-northwest to east-southeast trending fracture trace. This fracture can be extended to connect both the dye injection point and the dye resurgence point. Parsons concluded that, these conditions suggested that a direct conduit exists between SWMU 17 and SPG 3, which was likely caused by solution opening along a subsurface fracture. Under low flow conditions, estimates of the travel time of groundwater flow calculated by Parsons for this conduit ranged from 2,905 to 3,716 feet per day. Under high flow conditions, the travel time estimated by Parsons was approximately 4,800 feet per day (Parsons 1996).

Groundwater conditions in the HSA have been characterized in the Current Conditions Report (IT 2001) using previously installed monitoring wells. This current conditions report will be updated periodically and continue to be a primary resource for describing groundwater conditions in the HSA and RFAAP.

It is not completely understood how the Pulaski Fault affects groundwater movement at the Facility. The fault is not a simple planar feature, but rather a zone of regional deformation. At some areas, the location of the fault surface can be identified by the presence of lithologic unconformities. However, at RFAAP and most other localities, the proximity of the fault surface is generally indicated by the abundance of the Max Meadows tectonic breccia. This breccia displays distinct weathering characteristics that appear to be the result of intergranular dissolution. The breccia develops extensive solution cavities, which can allow for rapid conduit flow of the groundwater.

3.9.3 Springs

Parsons (1996) and IT (2001) have conducted spring surveys along the New River at the MMA in conjunction with hydrogeological studies of SWMU 17 and the HSA, respectively. IT conducted the more thorough survey, which included a thermal flyover survey and field survey. The IT field survey included the identification of spring locations, measurement of water quality parameters at the springs and the New River, and measurement of spring flow rates.

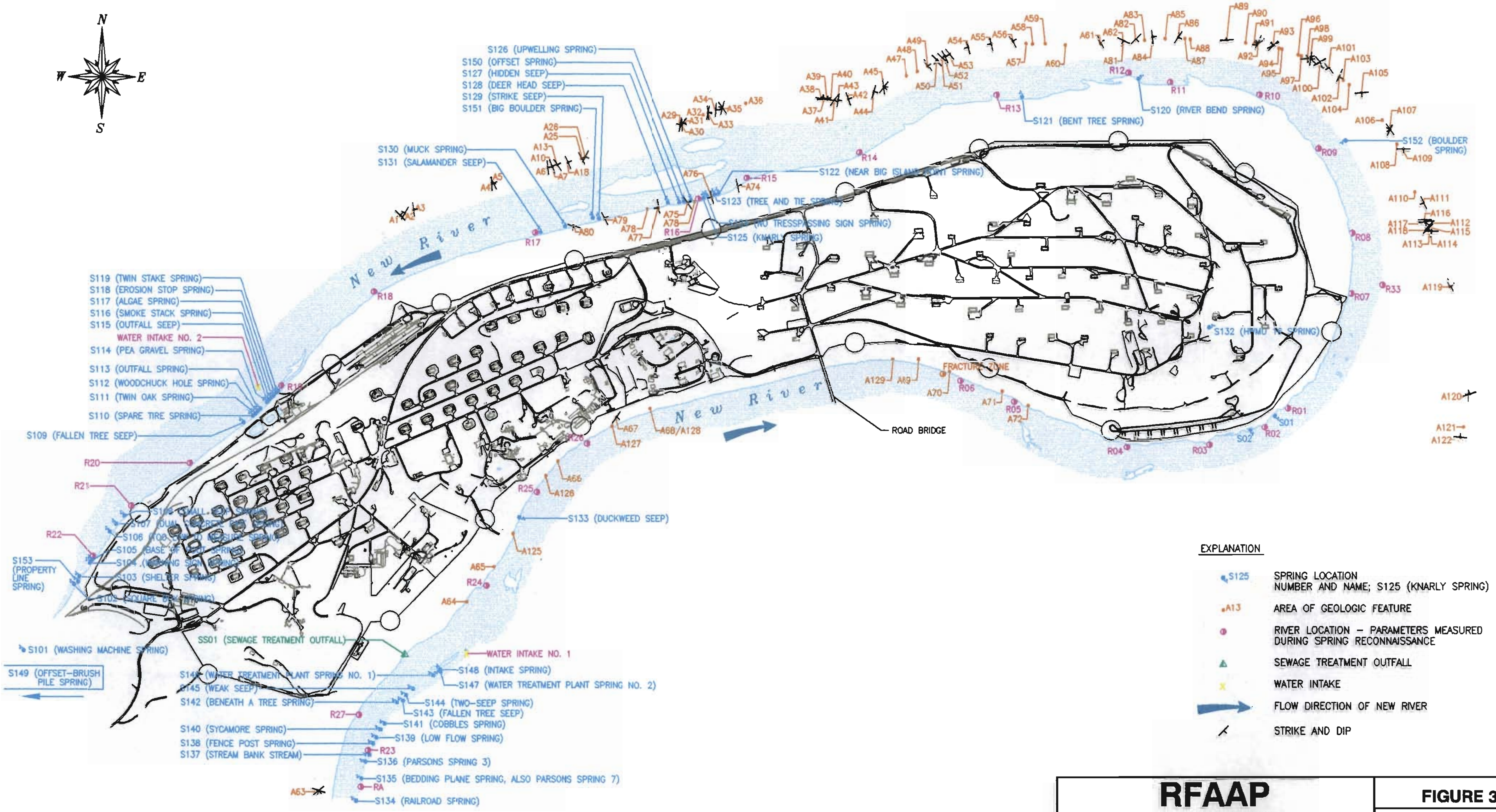
Figure 3-11 shows the locations of the springs identified in the MMA. IT identified 34 springs in the HSA, with 33 of the springs located along the New River. The other spring is located at HWMU 16. Most of the springs found are grouped together in one of three areas on the north side of the HSA, along the New River. Fifteen other springs have been identified along the opposite side of the New River from the HSA in the main plant area.

The 15 springs identified on the New River's southern shoreline, opposite the HSA, are located between the railroad bridge and Water Intake No. 1. Some of these springs were identified by Parsons (ES 1994). Three offsite springs were found offsite during the IT survey. Spring S152 is located across the New River near the northeast corner of the HSA. Springs S101 and S149 are located downstream of the RFAAP property line boundary (IT 2001).

Most of the springs at RFAAP are near the water level of the New River, especially during low flow periods, making them difficult to find other than during low river stage. Statistical analysis of water quality measurements at the New River and identified springs yielded the following mean values:

River Locations:

- pH – 6.93;
- Specific conductance – 131 microsiemens per centimeter (µS/cm);
- Dissolved oxygen – 10.03 milligrams per liter (mg/L); and
- Temperature – varies depending on the season.



0 1400

1 INCH = 1400 FEET

RFAAP

MASTER WORK PLAN

Date: JAN. 2002

Prepared By: KDC/DR

Scale: AS SHOWN

File Name: 09604-263-155

FIGURE 3-11

LOCATION OF SPRINGS,/SEEPS, RIVER MEASUREMENT POINTS, AND OTHER GEOLOGIC FEATURES

Spring Locations:

- pH – 6.67;
- Conductivity – 437 µS/cm;
- Dissolved oxygen – 5.01 mg/L; and
- Temperature – varies depending on the season (IT 2001).

Higher dissolved oxygen values in the river are caused by the aeration in the swift currents. Specific conductance of the springs was higher than river because of the dissolution of carbonate minerals caused by water migrating through the bedrock (IT 2001). Very few large-flow springs were identified in the IT survey. Ten springs had estimated flows greater than 20 gallons per minute of the springs; the remaining springs had lower rates, with many of these springs identified as seepage areas with rates of flow too low to measure (IT 2001).

The springs at RFAAP represent discrete local groundwater discharge points from the carbonate bedrock aquifer. These springs are interpreted to be associated with the complex tectonic history of the RFAAP area. Fracture traces were mapped at the downstream property line and at Water Intake No. 2 (see Figure 3-8). The area between the Railroad Bridge and Water Intake No. 1 is bounded between two faults. The downstream property line spring cluster at RFAAP and the cluster of spring down slope of SWMU 31 are interpreted to be associated with thrust fauting and associated structural complexities. Similarly, the spring cluster down slope of SWMU 39 is associated with structural complexities, with strike and dip measurements indicating a series of alternating synclines and anticlines in this area. Faulting was observed on the other side of the river, but was not traceable to the HSA side of the river (IT 2001).

The many fractures in the highly deformed bedrock rock also influence groundwater flow at RFAAP. These fractures provide diffuse paths for water to migrate through, instead of discrete discharge through springs. This fracture system may be acting as an enhanced slow-flow (diffuse) system where water is migrating through the many fractures, recharging the river below the river levels (IT 2001).

3.10 SURFACE WATER HYDROLOGY

The New River is the most significant surface water feature within RFAAP. The Facility is built within and adjacent to a prominent meander loop of this river. Within RFAAP, the river width varies from 200 to 1,000 feet, but averages approximately 400 feet. The river flow varies due to water management at Claytor Dam, approximately nine miles upgradient (south) from RFAAP. Downstream from the Claytor Dam, typical flows of the New River range between 3,200 and 8,000 million gallons per day (MGD). During typical flow conditions, the depth is approximately four to six feet; however, pools may be ten feet deep. There are 13 miles of river shoreline within the RFAAP boundaries.

Five profiles of the New River were prepared by IT as part of the Current Conditions Report for the HSA. The river profile measurements had a wide range of cross-sectional areas, velocities, and depths throughout the HSA. The width of the river ranged from 425 to 725 feet. The average velocity for the profiles ranged from 0.6 to 3.7 feet per second. The average flow through a cross-sectional area ranged from 1,460 to 3,970 cubic feet per second (IT 2001).

Consistent with a karst setting, the results of the profiling suggested that the New River bed appears to be both a losing and gaining river along different reaches of the river. IT indicated that additional investigations and analysis will be required to confirm this hypothesis.

The headwaters of the New River are in northwestern North Carolina, near the Tennessee state border. In the RFAAP area, the New River flows northwesterly cutting cliffs through the bedrock. The path of the New River, which is generally perpendicular to the ridgelines of the Valley and Ridge province, indicates that the river existed prior to the Paleozoic folding of these rocks. In some areas, this river has eroded 4,000 feet of rock. During the Paleozoic, the erosion rate of the river was higher than the uplift rate of the rocks. This produced the entrenched river channel present today. The New River may be the oldest river in North America, estimated to be 350 million years old.

Stroubles Creek is the largest local tributary of the New River and flows through the southeast sector of RFAAP. Several branches that originate on and off the Facility feed this creek. Flow within Stroubles Creek and its tributaries consist primarily of storm water runoff. Groundwater discharging from the karst bedrock may also supply significant stream flow. Manmade, surface drainage ways at RFAAP also influence local drainage. The direction of surface drainage flow within RFAAP is ultimately toward the New River. Prior to entering the Facility, branches of Stroubles Creek flow through rural areas and through the town of Blacksburg.

The Blacksburg Municipal Wastewater Treatment Plant discharges approximately 5.4 MGD of wastewater into the New River upstream of where Stroubles Creek empties into the river (Blacksburg Municipal Wastewater Treatment Plant, February 2002). Industrial and domestic wastewater is discharged into the New River from Peppers Ferry Wastewater Treatment Plant (PFWWTP). This discharge is located within RFAAP. Currently this plant discharges approximately 4.5 MGD of water into the New River (PFWWTP, February 2002). RFAAP operates under Virginia Pollutant Discharge Elimination System (VPDES) permit number VA0000248, and discharges approximately 19 MGD into the New River. The effluent consists of various treated process water, wash water, cooling water, runoff, sanitary wastewater, and storm water.

Water used at RFAAP is taken from the New River. Separate water systems are provided for the MMA and the HSA. Intake No. 1 is located approximately two miles upstream of the mouth of Stroubles Creek. Intake No. 2 is located approximately six miles downstream of the mouth of Stroubles Creek. Upstream of RFAAP, the New River serves as a source of drinking water for the towns of Blacksburg and Christiansburg.

3.11 ECOLOGY

The Virginia Department of Game and Inland Fisheries (1999) conducted the most recent Installation-wide biological survey at RFAAP. Major objectives of this survey were to sample flora and fauna, identify and delineate the major habit community types, and provide management recommendations for both community types and threat-endangered or species of concern.

Eight community types were identified at RFAAP:

- Bottomland Forest;
- Calcareous Forest;
- Cliffs;
- Grasslands;

- Oak Forest;
- Pine Plantation;
- Successional Forest; and
- Water.

Endangered plants or animals were not observed at RFAAP during the biological survey. Five state-listed rare plants were observed at RFAAP during the survey: *Clematis coattails, Cystoptris tennesseensis, Hasteola suaveolens, Sagittaria rigida,* and *Eleocharis intermedia*. State-threatened animals located at RFAAP include the invertebrate *Speyeria idalia* and the birds *Ammodramus henslowii* and *Lanius ludovicianus*.

An earlier comprehensive inventory of the mammals, birds, reptiles, aquatic invertebrates, trees, and plants found on the Installation, and of fish inhabiting the New River where it flows through the Installation, was conducted in 1976 during the RFAAP installation assessment (USATHAMA 1976). Information from that assessment was summarized in previous documents (Dames & Moore 1992).

Many of the reptiles, mammals, and birds listed in the assessment (USATHAMA 1976) are believed to breed on the Installation (Personal Communication with T. Thompson RFAAP Conservation Specialist 1995). However, indications are that some species, including ruffed grouse and upland plovers, have decreased in number or have disappeared from RFAAP. Foxes, which were once trapped to prevent rabies outbreaks (the last trapping program for foxes was conducted in 1966), were reintroduced to RFAAP as a control for groundhogs. Deer are common at RFAAP and bow hunting has been allowed at the Facility since 1991. Migratory waterfowl are found throughout the spring and winter near the New River because the Installation is on the Atlantic Flyway. Federally protected black vultures are present at RFAAP during certain times of the year. Between 1,500 and 3,000 of the migratory birds nest in thickets on the Facility (Washington Post 1995). Public fishing occurs in the New River where it flows through RFAAP.

The Virginia Department of Game and Inland Fisheries have identified the following flora and fauna as endangered or threatened for Pulaski and Montgomery Counties:

- Plant species - six endangered, three threatened;
- Mollusk species - one endangered, one threatened;
- Insect species - one endangered, four threatened;
- Bird species - three endangered; and
- The locally endangered mountain lion.

In addition, a fish, salamander, four bird species, and the river otter are identified as species of concern in the two counties in which RFAAP is located.

According to the RFAAP Installation Assessment (USATHAMA 1976), timber harvesting occurred at RFAAP in the past. The most recent harvest was conducted in 2002. Tree species at RFAAP include the short leaf pine, loblolly pine, eastern white pine, yellow poplar, and black walnut.

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4.0 SITE INVESTIGATION PLANNING

4.1 OBJECTIVE

Site investigation planning is performed to ensure investigation objectives are adequately addressed and task activities are performed accurately and completely. Routine activities are to be performed in accordance with MWP specifications, unless directed otherwise by RFAAP. The approaches for addressing site-specific investigations are to be included in WPA.

4.2 WORK PLAN ADDENDA

Project activities are to be executed in a manner commensurate with achieving project objectives as delineated by the RFAAP in site-specific delivery orders. Demonstration of effective cost, quality, and timeliness control is affected through the use of established requirements and specifications associated with definable features of work. The WPA is a tool that provides the mechanism for executing project activities for each definable feature of work.

This section provides the minimum addenda requirements necessary to ensure the quality and safety of work activities. Primary emphasis is given to the execution of project activities, quality control and quality assurance, and health and safety of contractors and subcontractors.

4.2.1 RFAAP Master Plans and Addenda

Project activities are governed by the RFAAP Master Plans, which specify the requirements for routine field investigation activities, quality control/assurance protocols, and health and safety. Because these documents contain specifications for standardized activities that have been approved for Facility use, repetition of standardized information is not required in addenda.

For example, the Installation description and environmental setting are contained in the RFAAP MWP. Because this information has been approved and is not subject to significant changes, it is not necessary to include it in site-specific addenda. Cost and quality benefits realized by the Installation through the use of this strategy include: (1) reduction in costs associated with WP development; (2) expedited review process resulting in faster deployment; (3) focused site-specific plans; and (4) technical variance control through the standardization of routine activities.

4.2.2 Addenda Development

WPA are typically developed within 30 days of contract award. Contractors should coordinate with the Installation to ensure the following information has been provided:

- **RFAAP IAP** (or applicable section) - provides characterization profiles for site-description;
- **RFAAP Master Work Plan** (or applicable sections) - contains SOPs for routine investigative activities;
- **RFAAP Master QAP** - contains the control activities required to verify the accuracy of project activities; and
- **RFAAP Master HSP** - contains Installation health and safety requirements including specific Installation health and safety requirements for contractors.

4.2.2.1 Organization

Addenda are to contain three primary sections: WP, QAP, and HSP. Sections 4.2.3, 4.2.4, and 4.2.5 provide guidance on individual section requirements.

Table 4-1 provides a comparison between the content to be generally included in the WP section of the WPA and the standard elements included in the MWP. Table 4-2 provides a comparison between the content to be generally included in the QAP section of the WPA and the standard elements included in the Master QAP. Table 4-3 provides a comparison between the content to be generally included in the health and safety section of the WPA and the standard elements included in the Master HSP.

4.2.2.2 Review Schedule

Generally draft and final addenda will be developed, approved, and distributed in accordance with Installation requirements. Revisions to draft addenda are to be submitted with a written response to comments to facilitate Installation review of revised text.

4.2.3 WPA Section I: Work Plan

This section of the WPA will generally include the following subsections:

- Introduction;
- Description of Current Conditions; and
- Field Investigation Program.

4.2.3.1 Introduction

This subsection of WPA will generally include the following elements:

- Introduction;
- Objectives and scope of project;
- Purpose of WPA and relationship to MWP, with a tabular summary;
- Organization of the WPA;
- Elements of the investigation program; and
- Documentation forms for WPA revisions and worker acknowledgement.

Table 4-1
Comparison of RFAAP Work Plan Addenda Section 1 Work Plan with Master Work Plan (Volume I)
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plan, Radford, Virginia

Work Plan Addenda Section 1 - Work Plan			Master Work Plan - Volume 1	
Sections		Content	Sections	Content
Introduction	1	- Purpose of WPA/relationship to MWP - Site specific objectives/scope of work - Organization of WPA - Elements of site investigation - Documentation for changes to MWP	1, 4	- Purpose of MWP/relationship to WPA - Organization of MWP
Description of Current Conditions	2	- Site description, history, and environmental setting - Description of nature and extent of contamination - Conceptual site model - Data gap analysis	2,3	- Installation description, history, and operations - Installation environmental setting - SWMU and AOC listing for installation
Field Investigation Program	3, App. A (SOPs)	- Overview of site investigation - Description of site-specific field activities - Identification of field methods and specifications - Reference MWP/SOPs for routine methods/specifications - Sampling strategy/rationale - Sample identification, media, location, and depth - Chemical and physical testing program - Plans/specifications for non-routine activities - SOPs from MWP pertaining to site investigation	5,6,7,8 and App. A (SOPs)	- Description of routine field activities - Description of routine field methods/procedures - Description of routine requirements/specifications - Description of methodology for risk assessments - Entry requirements for installation investigations - All SOPs

Table 4-2
Comparison of RFAAP Work Plan Addenda
Section 2 Quality Assurance Plan with Master Quality Assurance Plan (Volume II)
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plan, Radford, Virginia

Work Plan Addenda Section 2 - Quality Assurance Plan			Master Quality Assurance Plan - Volume II	
Sections		Content	Sections	Content
Introduction	1	- Purpose of QAP addenda/relationship to Master QAP - Organization of QAP addenda - Distribution list	1 (Master QAP), 4 (MWP)	- Purpose of Master QAP/relationship to WPA - Organization of Master QAP
Project Organization and Responsibilities	2	- Identification of key project personnel - Project organizational chart - Identification of key points of contact	2	- General descriptions of project personnel - Template for project organizational chart - Lines of authority - Information required for project key points of contact
Quality Assurance Objectives	3	- Project-specific data quality objectives - Project specific regulatory levels of concern - Project specific to-be-considered regulatory guidance	3	- Overview of project data quality objectives - Description/specifications for chemical data measurements - General types of regulatory levels of concern - General types of to-be-considered regulatory guidance
Sample Management	4	- Sample container, preservation, and holding time requirements - Site specific nomenclature for sample identification	5	- General discussion of sample containers and preservation - General discussion of holding time - General requirements for sample identification - Documentation requirements and chain of custody
Analytical Procedures	5	- Specification of analytical methods and procedures - Specifications for non-routine/specialized testing	6	- Description of field testing and screening - General discussion of selecting analytical methods - General discussion of LOD, MDL, SQL, LOQ, and RL - Identification of physical testing and methods
Internal Quality Control Checks	6	- Specification of method quality objectives - Site specific nomenclature for sample identification - Any amendments to Field Quality Control program specified in Master QAP	8	- Laboratory training requirements and certification - Field QC sample types - Field QC sample elements with required frequency/criteria
Data Reduction, Validation, Reporting, and Management	7	- Reporting units for solid/aqueous samples - Specification of MDLs and RLs for solid/aqueous samples - Any amendments to MWP reporting requirements	12	- Rounding rules - Data reduction and validation requirements/specifications - Blank contamination assessment requirements - Reporting requirements and specifications - Documentation/records requirements and specifications - Data management requirements

Notes:
LOD = Limit of Detection
MDL = Method Detection Limit
LOQ = Limit of Quantitation
RL = Reporting Limit
SQL = Sample Quantitation Limit

Table 4-3
Comparison of RFAAP Work Plan Addenda Section 3 Health and Safety Plan with Master Health and Safety Plan (Volume III) RCRA Facility Investigation Master Work Plan Radford Army Ammunition Plan, Radford, Virginia

Work Plan Addenda Section 3 - Health and Safety Plan			Master Health and Safety Plan - Volume III	
Sections		Content	Sections	Content
Introduction	1	- Purpose of HSP addenda/relationship to Master HSP - Organization of HSP addenda - Safety statement for contractor	1	- Objective and scope - Purpose of Master HSP/relationship to WPA - Organization of Master HSP - Site safety and health documentation
Training Plan	2	- Hazard information for installation and site - Project specific hazardous analysis - Required training for site work	3, 4	- Chemical toxicity hazards at RFAAP - Physical hazards at RFAAP - Biological hazards at RFAAP - Training requirements and procedures
Personal Protective Equipment and Clothing (PPE) and Decontamination	3	- Identification of site-specific PPE requirements - Amended personnel decontamination requirements, as appropriate	7	- Overview of PPE requirements - Levels of protection - Protocols for changing levels of protection - Respirator selection and fit test
Monitoring Plan	4	- Identification of required monitoring instrument(s) - Instrument calibration requirements - Action levels for monitoring and corresponding actions - Confined space entry and control requirements, as appropriate	9	- Discussion of monitoring instruments - Types of monitoring - General action level requirements - List of chemical compounds of concern and properties - Calibration and maintenance of monitoring equipment
Emergency Response Plan	5	- Contact information for the contractor (office and field)	10	- Pre-emergency planning - Emergency response responsibilities - Emergency training, site control, and security - Emergency phone numbers, contacts, and medical facilities - Onsite emergency equipment - Contingency plan

4.2.3.2 Description of Current Conditions

This subsection of WPA will generally include the following elements:

- Site background - description, history, and environmental setting with appropriate figures and tables;
- Description of the nature and extent of contamination from previous site-specific investigations;
- Conceptual site model; and
- Data gap analysis.

4.2.3.3 Field Investigation Program

Site-specific activities are to be described in terms of the specific investigation to be conducted. Reference to the RFAAP MWP is acceptable for routine activities that are to be performed in accordance with WP specifications. Variances to specifications are to be documented in WPA and approved by the Installation prior to commencement of on-site activities.

This subsection of WPA will generally include the following elements:

- Overview of field investigation program and components;
- Description of field investigation activities and identification of field methods and specifications with reference to the MWP and SOPs;
- Sampling strategy/rationale;
- Sample identification, media, location, and depth;
- Chemical and physical testing program;
- Supporting figures and tables, as appropriate; and
- Plans and specifications for non-routine field activities not discussed in the MWP and SOPs.

4.2.4 WPA Section II: Quality Assurance Plan

This section of the WPA will generally include the following subsections:

- Introduction;
- Project Organization and Responsibilities;
- Quality Assurance Objectives;
- Sample Management;
- Analytical Procedures;
- Internal Quality Control Checks; and

- Data Reduction, Validation, Reporting, and Management.

4.2.4.1 Introduction

This subsection of WPA will generally include the following elements:

- Introduction;
- Purpose of QAP addenda and relationship to Master QAP with a tabular summary;
- Organization of the document; and
- Distribution list for WPA.

4.2.4.2 Project Organization and Responsibilities

This subsection of WPA will generally include the following elements:

- Identification of key project personnel with a brief summary of qualifications;
- Project organizational chart; and
- Identification of key points of contact including project subcontractors.

4.2.4.3 Quality Assurance Objectives

This subsection of WPA will generally include the following elements:

- Project data quality objectives, including problem statement, identification of decision/study question, decision inputs, study boundaries, decision rules, acceptable decision error limits, and optimal data design; and
- Identification of regulatory levels of concern and to-be-considered regulatory guidance for soil, sediment, surface water, and groundwater at the site, as applicable.

4.2.4.4 Sample Management

This subsection of WPA will generally include the following elements:

- Requirements for sample containers, preservation, and holding times in tabular format; and
- Site-specific nomenclature for sample identification.

4.2.4.5 Analytical Procedures

This subsection of WPA will generally include the following elements:

- Specification of analytical methods and procedures; and
- For non-routine, specialized analytical methods, associated method detection limit studies and/or method validation studies will be appended to WPA.

4.2.4.6 Internal Quality Control Checks

This subsection of the WPA will include the following elements:

- Method quality objectives (MQO); and
- Project-specific amendments to the field QC elements specified in Volume II, Section 8.3 of the MWP, as appropriate.

4.2.4.7 Data Reduction, Validation, Reporting, and Management

This subsection of the WPA will include the following elements:

- Reporting units for solid and aqueous samples;
- Specification of method detection limits and reporting limits for solid and aqueous samples in tabular format; and
- Project-specific amendments to the reporting requirements identified in Volume II, Section 9.7 of the MWP, as appropriate.

4.2.5 WPA Section III: Health and Safety

This section of the WPA will generally include the following subsections:

- Introduction;
- Training Plan;
- Personal Protective Equipment and Clothing and Decontamination;
- Monitoring Plan;
- Emergency Response Plan; and
- Confined Space (as applicable).

4.2.5.1 Introduction

This subsection of WPA will generally include the following elements:

- Purpose of QAP addenda and relationship to Master QAP with a tabular summary; and
- Safety Statement - specifies the contractor's intent in regards to health and safety.

4.2.5.2 Training Plan

This subsection of WPA will generally include the following elements:

- Overview of training plan;
- Hazard information training as related to RFAAP and the site being investigated;
- Project-specific hazardous analysis: identification of physical, biological, and chemical hazards, with reference to Volume III of the MWP;
- Hearing and conservation training;

- Hazard communication training; and
- Confined space entry training and plan, as applicable.

4.2.5.3 Protective Equipment and Clothing and Decontamination

This subsection of WPA will identify PPE requirements for the site investigation, with reference to Volume III, Section 7.0 of the MWP, as appropriate. Amended personnel decontamination requirements to those specified in Volume III, Section 8.0 of the MWP is described in this subsection.

4.2.5.4 Monitoring Plan

This subsection of WPA will identify for a site-specific investigation the required monitoring instrument(s), calibration requirements, action levels, and corresponding actions, if an action level is exceeded.

4.2.5.5 Emergency Response Plan

This subsection of WPA will provide contact information (office and field) for the contractor conducting the field investigation. Other appropriate contact information is included in Volume III, Section 10 of the MWP.

4.3 DOCUMENTATION

Documentation requirements for site-specific investigations are provided in:

- Volume II, Section 5.0 of the MWP;
- SOP Series 10.0 (Documentation) included in Appendix A; and
- SOP Series 20.0 (Subsurface Investigation) included in Appendix A.

4.4 STANDARD OPERATING PROCEDURES

SOPs are included in Appendix A. These SOPs are designed to ensure that routine investigation activities at RFAAP are performed consistently using U.S. Army Corps of Engineers (USACE) and RFAAP approved specifications. In general, the following sources of information have been used to develop the SOPs and as reference in the MWP:

- USACE Engineer Manuals;
- USEPA methods and guidelines;
- Standards developed by the American Society for Testing and Materials (ASTM); and
- Other industry standards.

SOPs included in Appendix A are listed in Table 4-4 by their associated classification series.

Modifications to SOPs will be approved by RFAAP prior to implementation. Required site investigation procedures that are not included in the most current SOP listing will be included in WPA.

Table 4-4
SOP Classification Series
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

SOP SERIES	TITLE
10.0	**DOCUMENTATION**
10.1	Field Logbook
10.2	Surface Water, Groundwater, and Soil/Sediment Field Logbooks
10.3	Boring Logs
10.4	Chain-of-Custody Forms
20.0	**SUBSURFACE INVESTIGATION**
20.1	Monitoring Well Installation
20.2	Monitoring Well Development
20.3	Well and Boring Abandonment
20.4	Test Pits
20.5	Active Soil Gas Survey
20.6	Ground-Penetrating Radar Surveys
20.7	Resistivity and Electromagnetic Induction Surveys
20.8	Magnetic and Metal Detection Surveys
20.9	Piezometer Installation
20.10	Placement of Dye Detector Holders
20.11	Drilling Methods and Procedures
20.12	Direct Push Groundwater Sampling
30.0	**SAMPLING**
30.1	Soil Sampling
30.2	Groundwater Sampling
30.3	Surface Water Sampling
30.4	Sediment Sampling with Scoop or Tube Sampler
30.5	Sediment and Benthic Macroinvertebrate Sampling with Eckman Sampler or Ponar Sampler
30.6	Containerized Material
30.7	Sampling Strategies
30.8	VOC Sample Collection Using Sodium Bisulfate Preservation (Low Level) and Methanol Preservation (High Level)
30.9	Collection of Soil Samples By USEPA SW-846 Method 5035 Using Disposable Samplers
30.10	Collection of Wipe Samples
30.11	Lead Check Soil Screening Kit
30.12	Vibracore Deep Sediment Sampling
40.0	**FIELD EVALUATION**
40.1	Multiparameter Water Quality Monitoring Instrument
40.2	Water Level and Well-Depth Measurements
40.3	Slug Tests
40.4	Water Flow Measurements Using Water Flow Probe
50.0	**SAMPLE MANAGEMENT**
50.1	Sample Labels
50.2	Sample Packaging
60.0	**DATA MANAGEMENT**
70.0	**INVESTIGATION-DERIVED MATERIAL**
70.1	Investigation-derived Material
80.0	**DECONTAMINATION**
80.1	Decontamination
90.0	**AIR MONITORING EQUIPMENT**
90.1	Photoionization Detector (HNu Model PI-101 and HW-101)
90.2	Photoionization Detector (Microtip HL-200)
90.3	Personal Air Sampling Pump (GilAir)

5.0 SITE INVESTIGATION PROGRAM

The purpose of the site investigation is to identify sources and extent of contamination, pathways of contaminant migration, and potential remedial activities. Sampling locations will be selected in accordance with the Corrective Action Permit and applicable regulations. Locations will also be selected to provide representative samples of groundwater, surface water, soils, wastes, and sediments for use in identifying areas of concern. The following discussion outlines the rationale and procedures to be utilized during site investigation activities at RFAAP.

Site-specific chemicals of concern (COCs) will be identified from the site history, results of previous investigations, and permit requirements. Previous chemicals of concern have included semi-volatile organic compounds (SVOCs), volatile organic compounds (VOCs), explosives, and metals. COCs will establish health and safety concerns for investigation activities, and will govern the type and number of containers for each media.

Health and Safety requirements for work to be performed at RFAAP are outlined in the RFAAP Master HSP and in the *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2000). Addenda to the MWP will provide site-specific health and safety requirements per scope of work based on the RFAAP Master HSP. The contents of the RFAAP Master HSP will be enforced by the Site Health and Safety Officer (SHSO) at the task level and by the Project Health and Safety Officer at the project level.

5.1 SAMPLE MANAGEMENT

The following sections address pre-sampling and post-sampling protocol related to COCs, containers, sample labels, sample documentation, and sample packing and shipping.

5.1.1 Containers and Preservation

Sample container requirements will be specified in WPA for site-specific investigations. Specific container requirements for samples will be dependent on such project specific elements as the media sampled; the list of analytes; the method of analysis specified and data quality objectives.

Preservatives will be used for samples, as applicable, to retard hydrolysis of chemical compounds and complexes, to reduce volatility of constituents, and to retard biological action during transit and storage prior to laboratory analysis. Sample containers will be pre-preserved. Preservation requirements for samples collected during site-specific investigations will be specified in WPA.

In addition to chemical preservatives, samples for chemical analysis will be transported to the laboratory in temperature-controlled coolers. Double-bagged ice will be used to maintain the internal cooler temperature required for preservation. A temperature blank will be included in each shipping container to monitor the internal temperature.

5.1.2 Sample Labels

Sample label requirements are included in SOP 50.1 (Appendix A). Every sample will have a sample label uniquely identifying the sampling point and analysis parameters. Sample identification information will be printed on the label in a legible manner using indelible ink. Field identification information will be sufficient to enable cross-reference with the field notebook. The sample label will contain the following:

- Project name;
- Sample identification number;
- Date and time;
- Analyses to be performed;
- Preservatives (for water); and
- Initials of the sampler.

The information on the sample label will be double-checked prior to shipment to the contract laboratory. The sample label will be covered with clear tape that completely encircles the container so the label does not come off.

5.1.3 Packing and Shipping

Samples will be packed as soon as they are collected, to protect them from breakage during on-site handling and later during shipping. SOP 50.2 (Appendix A) has been developed to prevent sample breakage, sample tampering, and to contain the sample in event the of container breakage.

The following procedures will be followed immediately after sample collection:

1. Check cap for tightness. Ensure that clear tape covers the label and encircles the container;
2. Wrap sample container in bubble wrap or closed cell foam sheets;
3. Segregate highly contaminated samples from other samples prior to shipment. This includes samples containing or potentially containing high concentrations of tracer dye;
4. Enclose each sample in a clear, zip-seal plastic bag; and
5. Place sample containers in a cooler with ice (double-bagged).

The following procedures will be followed to prepare samples for shipment:

1. Place several layers of bubble wrap on the bottom of the cooler. Line the cooler with an open garbage bag, and place samples upright inside the garbage bag;
2. Double bag and seal loose ice to prevent melting ice from soaking the packing material. Place the bags of ice inside the garbage bag containing the samples; tie the garbage bag;
3. Pack shipping containers with packing material (closed-cell foam or bubble wrap). Place this packing material around the sample bottles or metal cans to avoid breakage during shipment;
4. Enclose sample documentation (chain-of-custody forms, etc.) in a waterproof plastic bag and the bag at the top of the cooler. If more than one cooler is being used, each cooler will have its own documentation;

5. Seal the coolers with signed and dated custody seals so that if the cooler were opened, the custody seal would be broken. Place clear tape over the custody seal to prevent damage to the seal;

6. Tape the cooler shut with packing tape over the hinges and place tape over the cooler drain; and

7. Ship samples via overnight delivery on the same day they are collected if possible.

5.2 SUBSURFACE INVESTIGATION

Subsurface investigations will generally involve drilling activities associated with sample collection and monitoring well installation.

5.2.1 Pre-Drilling Requirements

Necessary approvals for equipment, methods, and materials will be obtained from RFAAP prior to the arrival of drilling equipment on site. These include but are not limited to the following:

5.2.1.1 Permits

The contractor overseeing drilling operations will be required to obtain the necessary work permits from RFAAP for site work. Permits that will typically be required during for drilling include an area entry permit and in certain situations a hot work permit will be required (generally when using generators or similar equipment).

5.2.1.2 Clearance

Prior to the commencement of work, underground utilities will be marked out. Clearance of underground utilities will be arranged through RFAAP personnel. The work area will be delineated by use of a highly visible boundary.

5.2.1.3 Materials list

The contractor must submit a list of drilling materials and suppliers to be used on site. The Installation must approve the drilling materials and suppliers in accordance with approved geotechnical specifications (see SOP 20.1 in Appendix A).

5.2.1.4 Source Water Sample

The source of water to be used during drilling activities and/or well installation (e.g., grouting, and sealing) will be approved by the Installation prior to the execution of site investigations. This water source must be certified by laboratory analysis as free of investigation-related contaminants in accordance with the USACE materials requirements contained in EM 1110-1-4000 (as updated), unless directed otherwise by the Installation.

5.2.2 General Drilling Requirements

The following general requirements for drilling are applicable for site investigations:

- Drilling activities will be performed by a qualified drilling contractor under the direct supervision of a "site geologist" or equivalently trained personnel. This geologist should be experienced with USACE field investigations at hazardous, toxic, and radioactive waste (HTRW) sites;

- Site investigation activities will be documented in the field log book(s), as specified in SOPs 10.1 and 10.2 (Appendix A);

- Soil and rock borings will be logged as specified in SOP 10.3 in (Appendix A);
- Work will be conducted in accordance with WPA HSP developed for site-specific investigations including requirements for using PPE and air monitoring equipment;
- IDM will be managed according to the general requirements specified in Section 5.13 and SOP 70.1 (Appendix A);
- Sampling and down-hole equipment will be decontaminated as specified in Section 5.12 and SOP 80.1 (Appendix A);
- Soil sampling during drilling will follow those methods outlined in Section 5.2.8 and SOPs 20.11 and 30.1 in Appendix A, unless otherwise specified in WPA; and
- If a well is not to be installed, the boring will be abandoned at the termination depth as described in Section 5.2.7 and SOP 20.3 (Appendix A), as appropriate.

5.2.3 Drilling Methods

The objective of the selected drilling technique is to ensure that the drilling method provides representative data while minimizing down-hole contamination, cross-contamination, and drilling costs. Every effort will be made to avoid drilling procedures that introduce potential for cross contamination and/or high fluid losses during intrusive activities. The following considerations will be applied to prevent down-hole contamination:

- If lubrication is needed on the threads or couplings of down hole drilling equipment, it should be biodegradable and nontoxic. Vegetable oil/shortening or polytetrafluoroethylene (PTFE) tape may be used;
- Hydraulic fluids used in drilling equipment shall not contain polychlorinated biphenyls (PCBs);
- Fluids (including surface water runoff) will not be permitted to enter open boreholes; and
- The use of antifreeze in drilling equipment should be approved by the Installation prior to its use. Antifreeze should be used to prevent overnight freezing and not in drilling operation. Antifreeze added to drilling equipment to prevent overnight freezing would be completely purged prior to the equipment's use in drilling operations. Antifreeze without rust inhibitors and/or sealant may be used. The dates, reasons, quantities, and brand names of antifreeze used will be noted on the boring log.

5.2.3.1 General Considerations for Drilling Methods

Drilling methods that are appropriate for boring or monitoring well installation will depend on the subsurface geology most likely to be encountered in the boring. The geology for each site should be identified by reviewing previous investigation data (boring data, geophysics, etc.) from the site or nearby areas. Specific drilling methods that will be used to support site activities will be identified in WPA. SOP 20.11 in Appendix A describes drilling procedures for the various types of drilling methods discussed in the following sections.

Previous investigations at RFAAP have demonstrated highly variable subsurface conditions in both unconsolidated overburden and in bedrock, as described in Section 3.7. Controlling factors for the selection of a drilling method at a particular RFAAP site are generally:

- For unconsolidated material: the presence or absence of significant zones of very coarse and or loose alluvial materials, which contain cobbles and boulders (river jack); and
- For bedrock: the presence or absence of highly fractured bedrock or bedrock with karst solution features.

The following sections describe various types of drilling methods that have been or may be used at RFAAP. Potential advantages and disadvantages of each method are discussed to assist in the identification of appropriate drilling methods for site-specific investigations.

5.2.3.2 Hand Auger

Hand augering is generally appropriate for shallow borings and piezometers in unconsolidated sediments. Hand augering is most effective in clays and sands. The depth of penetration may be limited to 5 feet, or shallower if gravel, cobbles, or running sands is encountered. Sampling intervals will be described in site-specific WPA and will be commensurate with investigation objectives.

5.2.3.3 Direct Push

Direct push methods may be used in unconsolidated materials to obtain soil and/or groundwater samples from the subsurface with or without the assistance of other drilling methods. Direct push methods usually advance smaller diameter devices into the subsurface to collect media samples.

SOP 20.11 in Appendix A describes procedures for drilling with direct push methods.

Advantages of direct push drilling include:

- The ability to drill without the addition of fluids to the subsurface;
- A reduction in the volume of IDM generated through drilling because drill cuttings are not returned to the surface;
- Less site restoration necessary compared with other methods;
- Relatively rapid drilling is possible;
- Discrete zones of groundwater may be sampled;
- A variety of sampling devices may be used to collect soil and groundwater samples; and
- An ability to be used with core penetrometer systems.

Disadvantages of direct push drilling include:

- Limited ability to drill through difficult subsurface conditions and areas with debris unless high-powered sonic drilling equipment or similar techniques are used;
- Inability to penetrate bedrock; and
- Groundwater samples are typically considered screening level data.

5.2.3.4 Hollow Stem Auger

The dry, hollow-stem auger method is appropriate and preferred for drilling soil borings, monitoring wells, and piezometers in unconsolidated materials. Advantages of hollow-stem auger drilling include:

- The ability to drill without the addition of fluids to the subsurface; and
- Providing a stable borehole for collecting intact soil samples and installing monitoring wells (ASTM 2000k).

Disadvantages of this drilling method include:

- The difficulty in penetrating zones of cobbles and boulders, such as the river jack observed in alluvial strata at RFAAP; and
- Inability to penetrate bedrock (ASTM 2000k).

SOP 20.11 in Appendix A describes procedures for drilling with hollow-stem augers.

5.2.3.5 Direct Air Rotary

Direct rotary drilling with air (air rotary) is generally appropriate for drilling in unconsolidated sediment containing cobbles and boulders, when borehole stability is adequate for installation of a casing. It is also appropriate for drilling in consolidated and disrupted bedrock. Air rotary drilling may be used when borings are advanced into bedrock and has been frequently used at RFAAP sites where karst conditions exist. Advantages of this method include:

- Allows for stratigraphic characterization and identification of water bearing zones;
- Relatively rapid penetration of consolidated materials;
- The ability to drill without the addition of fluids to the subsurface; and
- The ability to be used where materials to be penetrated are sensitive to water, such as collapsible soils and/or rock (ASTM 1995a).

Disadvantages of air rotary include:

- The required use of a casing when borehole integrity is poor. In some cases, casing installation may be difficult for borings penetrating zones of unstable river jack;
- Inability to collect intact samples of rock without switching to another drilling method;
- Potential volatilization of contaminants; and
- Generation of air borne dust (ASTM 1995a).

Bedrock encountered at RFAAP may include competent, disrupted, or cavitized limestone of the Elbrook Formation. A roller-cone bit is preferred. When bedrock is too hard for a roller-cone bit, an air hammer will be used. If oil is used in the air stream to lubricate, it will be 100% natural and biodegradable.

An air line oil filter will be used during drilling. The filter will be changed per manufacturer's specifications during operation with a record kept (on the boring log) of this maintenance. No additive except approved water will be used for dust control and cuttings removal. Temporary casing may be required to stabilize the borehole walls.

WPA specifying air rotary methods will include:

- Specifications for the type of air compressor and lubricating oil to be used. A pint sample of each type of oil will be retained by the contractor, along with a record of oil loss (on the boring log), for evaluation in the event of future problems. The oil sample(s) may be disposed of upon contract/task completion; and
- Details for the use of down hole hammer/bit with emphasis upon those procedures to be followed to preclude residual groundwater sample contamination caused by the lubrication of the down hole equipment.

SOP 20.11 in Appendix A describes procedures for drilling with direct air rotary.

5.2.3.6 Direct Water Rotary

Direct rotary with water-based fluids (water rotary) is appropriate for drilling in unconsolidated sediment and hard rock. This method can be used in very coarse, unconsolidated sediments such as river jack under conditions when air rotary and hollow stem auger drilling methods are not feasible. Another advantage of water rotary is the ability to core rock and conduct *in situ* or pore fluid tests. Disadvantages of water rotary include:

- The introduction of water-based fluids into the subsurface;
- Potential influence of drilling fluid on groundwater sample quality;
- Increased effort for well development from fluid loss and well cake;
- Difficulty in identifying water bearing zones; and
- The inability to maintain circulation in certain conditions such as the karst bedrock conditions found in certain areas of RFAAP (ASTM 1995b).

The appropriate method of water rotary drilling uses materials that are not likely to alter the chemical character of the penetrated soils or rock. The water used for drilling will be from a supply tested and approved by the Installation prior to field efforts. If necessary, the thickening agent added to the water will be pure bentonite clay powder. A sample of the bentonite to be used during drilling will be submitted to the Installation prior to initiation of field efforts, along with documentation on manufacturing and origin of the material. Boreholes advanced with water rotary will be initiated without bentonite. If the formation does not yield sufficient clay to generate the proper fluid viscosity, then bentonite will be added as necessary. Proper fluid viscosity will ensure borehole stability and move cuttings to ground surface. Approved bentonite will be used for drilling boreholes.

Portable recirculation tanks should be used for water rotary operations to minimize the potential for cross-contamination and facilitate restoration of the work area. If sampling is required in the boring, split-spoon samples can be obtained by using a bit with an opening through which sampling tools can be inserted. After the borehole is advanced to the required depth or to the top of bedrock, the mud will be flushed from the borehole using approved water. Volumes of drilling fluid lost into the formation will be recorded at the time of drilling and flushing. Several considerations of water rotary methods addressed during the development of WPA include:

- Removal of the wall cake from outer perimeter of filter pack during development;
- Influence of drilling fluids on groundwater sample quality;
- Identification of discrete aquifers; and
- Proper procedures for well development are followed to ensure the validity of subsequent groundwater sample results.

Wire line casing advancement may be used with direct rotary drilling with water-based fluids. This method of drilling was used extensively during the Verification Investigation (VI) and RCRA Facility Investigation (RFI) drilling program conducted by Dames & Moore in 1991 and 1992 to core rock. The advantages of using this approach over direct water rotary without wire line casing advancement are:

- The large diameter-drilling rod used acts as a protective casing; and
- Drill rods do not need to be removed every time a coring bit is retrieved.

SOP 20.11 in Appendix A describes procedures for drilling with direct water rotary and wire line casing.

5.2.3.7 Drill-Through Casing Driver

Drilling-through casing driver is method of drilling that allows for drilling and simultaneous advancement of casing. For shallow borings, a single section of steel casing may be appropriate. When completing deeper borings, sections of casing must be welded together with boring advancement. Several variations of this method can be used including:

- Advancing the drill bit and casing as a unit;
- Driving the casing first following by drilling; and
- Advancing the drill bit in front of the casing and then driving the casing or allowing it to drop (using an eccentric bit).

The advantages of this method of drilling are the following:

- Borings can be completed in unconsolidated materials that may be difficult to drill with hollow stem auger or direct rotary methods;
- Rapid penetration rates;
- Lost-circulation problems are eliminated;
- Easy identification of water bearing zones;
- No drilling fluids are required for unconsolidated materials; and

- Monitoring wells may be installed inside temporary casing (Driscoll 1989).

Disadvantages of this method of drilling are the following:

- Potential dust generated from discharge of cuttings;
- Annulus between casing and borehole is generally too narrow to allow for placement of grout; and
- Additional cost of casing driver.

SOP 20.11 in Appendix A describes procedures for drilling through casing driver.

5.2.3.8 Sonic (Vibratory)

This drilling technique is a dual cased method that uses high frequency mechanical vibration to take continuous core samples of overburden soils and softer rock and advance casing into the subsurface. Core samples can be collected with a four-inch or eight-inch diameter core barrel, with advancement of up to a ten-inch diameter outer casing possible. The core barrel is advanced ahead of the outer casing during drilling and may be advance in increments of one to 30 feet. The advantages of sonic drilling include the ability to:

- Obtain large diameter, continuous and relatively undisturbed cores without the use of drilling fluid;
- Drill through difficult subsurface conditions such as very coarse unconsolidated material (e.g., river jack encountered at RFAAP) and construction debris;
- Drill and sample softer rock with high age of core recovery;
- Drill faster than most methods;
- Reduce the volume of IDM during drilling, as very few drill cuttings are returned to the surface; and
- Instrumentation can be placed inside the drill rods or casing while the borings is advanced.

Disadvantages of the sonic drilling method include:

- The addition of water or air (or both) is required for rock drilling;
- Extraction of casing can cause borehole smearing (with silt and clay); and
- Scarcity of equipment and expense of drilling.

5.2.3.9 Diamond Core Drilling

This method of drilling, used extensively during the VI and RFI conducted at RFAAP in 1991 and 1992, allows for retrieving intact cores of bedrock. Diamond core drilling conducted at RFAAP has been used in conjunction with the direct rotary, wire line casing advancement method described in Section 5.2.3.6. The primary advantages of this drilling method are:

- The ability to obtain intact samples for a more complete description of rock than other methods (see SOP 10.3 in Appendix A); and

- Ability to conduct various testing of rock samples.

The disadvantages of this type of drilling have been discussed and are the same as those discussed for water rotary.

SOP 20.11 describes procedures for diamond core drilling.

5.2.4 Summary of Drilling Methods

Dry hollow-stem auger drilling has been the preferred method for advancing soil and monitoring well borings in the unconsolidated overburden at RFAAP because it does not introduce fluids into the subsurface. However, the use of air rotary has been necessitated in previous investigations by the presence of river jack and other coarse material. In cases, where air rotary will not be an effective method of overburden drilling because of borehole instability, etc., sonic drilling or drill-through casing driver methods may be used. Sonic drilling may also be used when relatively undisturbed soil samples are desired at a site.

The preferred method for drilling in fractured bedrock or bedrock with solution features at RFAAP has been air rotary drilling. Water rotary (wire line casing method) has also been used for drilling in bedrock at RFAAP; particularly during the VI and RFI conducted by Dames & Moore in 1991 and 1992. Difficulties with this drilling method were encountered at sites with highly fractured bedrock or karst solution features; these difficulties included large quantities of fluid loss, lost circulation, and unstable boreholes. Rock coring (diamond core drilling) was conducted at locations where water-based rotary drilling was used. Wire line casing drilling may be appropriate at sites where rock cores are desired and bedrock conditions are known or expected to be amenable to this type of drilling.

Drill-through casing driver may also be used to drill through bedrock at RFAAP; particularly at sites, where bedrock stability is an issue and/or the use of air rotary may not be effective.

5.2.5 Borehole Logging

Boring logs will be prepared for each boring completed during a subsurface investigation. Each boring log should fully describe the subsurface environment and the procedures used to obtain this description. Logs should be recorded in the field directly on the boring log form and not transcribed from a field book. A geologist or other professional trained in the identification and description of soil/rock should conduct borehole logging and soil/rock identification and description

SOP 10.3 (Appendix A) describes the requirements and procedures for preparing boring logs at RFAAP and includes the following information:

- Material requirements;
- Required boring log information;
- Soil parameters for logging;
- Procedures for describing and identifying soil by ASTM Standard Practice D 2488;
- Rock parameters for logging;
- Procedures for describing and identifying rock;

- Procedures for logging refuse; and
- Submittal requirements.

5.2.6 Soil Boring

Soil borings will be advanced by the selected site-specific drilling method(s) as identified in WPA. Various drilling methods that may be used at RFAAP are discussed in Section 5.2.3 and procedures for these methods are described in SOP 20.11.

5.2.7 Test Pits

Test pit excavations are conducted to investigate and identify possible areas of contamination. Specific plans for test pit investigation and sampling will be outlined in WPA developed for site-specific investigations.

General procedures and requirements for conducting test pit investigations at RFAAP are outlined in SOP 20.4 (Appendix A), which includes the following information:

- Material requirements;
- Decontamination requirements;
- Site preparation guidance;
- Excavation and sampling guidelines; and
- Restoration guidelines.

5.2.8 Abandonment

Abandonment is the procedure by which a boring, piezometer, or well is permanently closed to prevent potential contaminant migration from the surface to the subsurface and within the subsurface strata.

In general, cement grout should be used for boring and well abandonment as specified in SOP 20.3 (Appendix A). Specialized narrow diameter soil borings (three inches or less) associated with direct push methods or hand augers may be abandoned, as appropriate, using bentonite pellets or chips as specified in SOP 20.3. The abandonment procedures and specifications included in SOP 20.3 reference:

- ASTM Standard Guide D 5299-92 (for decommissioning wells and other monitoring devices); and
- USACE guidance for monitoring well design, installation, and documentation at HTRW sites (USACE 1998).

The SOP to be used for boring/well abandonment includes the following information:

- Material requirements;
- Specifications for grout;
- Procedures for abandoning borings and wells;

- Site restoration requirements;
- Procedures for handling IDM;
- Notification and documentation requirements; and
- Replacement borings or wells associated with abandonment should be offset at least 20 feet from the abandoned site in a presumed up- or cross-gradient direction.

5.2.8.1 Borings

The term "boring" in the case of abandonment applies to a drilled hole made that is not completed as a well. This includes soil test borings, soil sampling borings, and deep stratigraphic borings. Whether completed to the planned depth or aborted prior to reaching that depth, borings should be abandoned within 12 hours of completion.

Boring abandonment should be conducting by grouting with a tremie pipe according to the procedures outlined in SOP 20.3 (Appendix A). Narrow soil borings with a diameter of less than three inches, advanced by a hand auger or direct push methods, may be sealed with bentonite pellets or chips, as appropriate, according to the procedures outlined in SOP 20.3.

5.2.8.2 Monitoring Wells and Piezometers

A number of techniques are available for abandoning monitoring wells and other monitoring devices including:

- Abandonment in place by grouting the well screen and casing in place;
- Removal of the well by pulling; and
- Overdrilling.

The particular method used for abandonment should be specified and rationalized in WPA developed for site-specific investigations. Several factors must be considered when selecting the appropriate abandonment technique including well construction, well condition, and subsurface conditions.

When possible, the preferred method for abandonment of wells is to remove existing well materials (by removal/pulling method or over drilling method) to accomplish the following:

- Reduce the potential for the formation of a vertical conduit to occur at the contact between the casing and annular seal;
- Reduce the potential for well materials interfering with the abandonment procedures; and
- Decrease the potential for reaction between the well materials and grout used for abandonment.

Procedures for well abandonment by the removal/pulling method or over drilling method are outlined in SOP 20.3 (Appendix A). In the event that it is not possible or desirable to remove the well materials, the well will be abandoned in place by grouting as described in SOP 20.3. This method of abandonment should include perforation of the screen and casing (see SOP 20.3).

5.2.8.3 Abandonment Considerations for Fractured Bedrock and Karst Aquifer Wells

Multi-cased wells completed into bedrock as screened wells, open wells, or open-lined wells may be abandoned with the outer casing left in place providing that the integrity of this casing and associated annular seal is good.

Borings or wells completed in karst zones may be difficult to abandon because of the potential presence of large conduits, which may make it difficult to fill the hole. Where large conduits exist or difficulties are encountered when abandoning a boring or well, packers can be used to isolate critical intervals for filling with grout above and below these zones.

5.2.9 Soil Sampling

Surface soil samples will generally be collected within the depth interval of zero to six inches below ground surface (BGS), except for samples for volatile organic compounds, which will be collected within the depth interval of six to 12 inches BGS. The vegetation and root mat will be removed prior to collecting surface samples. Subsurface soil samples will be collected at a depth below that of surface samples. Site-specific locations and depths for surface and subsurface soil samples will be identified in WPA.

Various sampling techniques may be used to collect surface soil samples including the scoop and trowel method (ASTM D5633). Other methods may be used in conjunction with the drilling techniques described in Section 5.2 to collect surface samples (or subsurface samples) including hand auger, soil corers advanced with a drill rig or direct push rig, and split spoon samples advanced with a drill rig. Sampling intervals and sampling techniques (split barrel, soil core, thin wall tube, etc.) will be described in site-specific WPA and will be consistent with investigation objectives.

General procedures to be followed for collecting surface and subsurface soil samples are outlined in SOP 30.1 (Appendix A). This SOP includes information that is consistent with ASTM and USACE standard practice guidelines for soil sampling. The following types of information are included in SOP 30.1:

- Material requirements;
- Sampling procedures;
- Site restoration guidelines;
- Documentation requirements; and
- Management of IDM.

SOP 20.11 in Appendix A identifies specific procedures for collecting soil samples using split-barrel, thin wall tube, soil core, and direct push methods.

5.2.10 Groundwater Investigations

Groundwater investigations at RFAAP will be conducted consistent with the 1998 USACE guidance for the design, installation, and documentation at HTRW sites and appropriate ASTM standard practices as referenced in the following sections.

5.2.10.1Monitoring Well Installation

Specifications for monitoring well construction and installation for a given site being investigated are to be included in the WPA. Four-inch diameter monitoring wells will be installed at RFAAP sites, unless otherwise specified in the WPA.

Well screen usage for a given site should be specified in WPA based on expected site conditions. Wells installed within overburden will have a screen. Bedrock wells may be installed with or without a screen depending on site-specific conditions such as the depth of water bearing zones, stability of bedrock, occurrence of karst zones, and construction of existing wells at the site being investigated.

Bedrock wells installed within karst zones or fractured bedrock should be completed as open-hole construction. If evidence of potential or severe borehole collapse (unstable bedrock) is indicated during drilling, casing and screen will be installed in the borehole as a removable lining. If desired, multiple flow zones may be monitored in an open bedrock well by installing a multiport well, which has monitoring/sampling intervals sealed off from the rest of the boring and from each other by packers.

Multi-cased wells or wells with an outer casing installed into competent bedrock should be specified for wells that are designed to monitor groundwater within bedrock. The installation of a multi-cased well or outer casing will isolate the zone(s) monitored from overburden and will minimize the potential for cross-contamination during and after drilling.

Well installation procedures consistent with the following guidelines are presented in SOP 20.1 (Appendix A):

- ASTM D 5092-90 (Standard Practice for Design and Installation of Groundwater Monitoring Wells in Aquifers);
- ASTM D 5717-95 (Standard Guide for Design of Groundwater Monitoring Systems in Karst and Fractured Rock Aquifers); and
- USACE Guidance for Monitoring Well Design, Installation, and Documentation at HTRW sites (USACE 1998).

The following types of information are included in SOP 20.1:

- Material and equipment requirements;
- Materials approval guidelines;
- Drilling requirements;
- Well construction and installation specifications and procedures;
- Documentation requirements;
- General sequence for monitoring well installations; and
- Management of IDM.

5.2.10.2 Monitoring Well Development

Well development is the process by which drilling fluids, solids, and other mobile particulates within the vicinity of the newly installed monitoring well are removed, while ensuring proper hydraulic connection to the aquifer. Development stabilizes the formation and filter pack sands around the well screen to ensure aquifer water moves freely to the well. Well development techniques that could potentially contaminate or alter the chemistry of the water-producing zones will be avoided.

The type of subsurface conditions encountered at a particular site at RFAAP will define the appropriate method of well development.

When monitoring wells are installed within overburden material and/or a uniformly fractured rock aquifer not exhibiting karst characteristics, a combination of mechanical surging and pumping (over pumping) is generally appropriate for well development. In general, over-pumping is the method of pumping the well at a rate higher than recharge occurs. Surging is typically accomplished by moving a tight-fitting surge block along the inside of the well screen; this action creates a vacuum.

When monitoring wells are installed within a karst aquifer containing heterogeneous high-permeability zones (fractures, conduits, voids, and other dissolution zones) and excessive amounts of sediment have entered the borehole, pre-development of the well (open borehole) will be required. Reverse-circulation airlifting should be used for pre-development. Because reverse-circulation airlift methods avoid forcibly exposing the annular space to air, reverse-circulation tools can be run throughout the entire water column in the wells being developed. After the excessive sediment has been removed by reverse-circulation airlifting, conventional pumping techniques may be used as appropriate to complete the well development.

Final development of monitoring wells should not be initiated sooner than 48 hours after or more than seven days beyond the final grouting of the well. Pre-development or preliminary development may be initiated prior to this 48-hour minimum period. Preliminary development may be conducted for open wells or for screened wells after installation of the well screen, casing, and filter pack but prior to installation of the annular seal. Pre-development is recommended when the natural formation will be used as a filter pack. Well development should be completed at least 14 days prior to sampling. SOP 20.2 (Appendix A) describes the requirements and procedures to be followed for development of monitoring wells at RFAAP and includes the following information:

- General materials requirements;
- Guidance for selection of a development method;
- Timing;
- A summary of procedures;
- Criteria for development;
- Documentation requirements; and
- Guidance for handling IDM.

5.2.10.3 Monitoring Well Sampling

In general, two different techniques may be used to sample groundwater from wells at RFAAP:

- Low-flow purging and sampling (Type I); and
- Conventional purging and low-flow sampling (Type II).

These two sampling techniques are intended to address the different groundwater conditions that may be encountered at RFAAP.

The Type I sampling technique will be used in the following situations:

- In wells where one discrete water-producing zone is encountered;
- In wells with no discrete water bearing zone and a low yield (less than 0.5 liters per minute); and
- In wells sampled during seasonal low groundwater conditions with greatly reduced yield.

The Type II sampling technique will be used in the following situations:

- In wells with potential or documented, multiple flow zones and where individual flow zones will not be evaluated; and
- In moderately producing wells (greater than 0.5 liters per minute) where no discrete flow zones were documented during drilling.

Groundwater sampling of newly installed wells will be performed no sooner than 14 days after completion of well development. Information from the borings, well completion records, and well development records should be reviewed prior to sampling a well to define the most appropriate sampling technique.

Due to the heterogeneous nature of the fracture and solution-enhanced fractured bedrock at RFAAP, monitoring well purging and sampling will need to be flexible. This flexibility is necessary to obtain representative samples that meet the data quality objectives (DQOs) specified in site-specific WPA.

The Type I and II methods of collecting groundwater samples from monitoring wells are described in SOP 30.2 (Appendix A); this SOP also describes the general requirements for materials, documentation of field activities, and management of IDM.

5.2.10.4 Piezometer Installation

For the purposes of this WP, a piezometer is defined as a well installation designed to measure and/or monitor groundwater level rather than to acquire environmental samples. The objective of the selected installation technique is to ensure that the piezometer provides representative data while minimizing subsurface contamination, cross-contamination, and installation costs.

Piezometers are open-ended or screened "pipes" installed in shallow water bearing zones. They may be placed in existing boreholes, driven below an open hole, or driven from the surface.

Site conditions will be considered when selecting installation and construction methods to prevent the potential for subsurface contaminate migration. Construction materials are typically polyvinyl chloride

(PVC), Teflon™, or stainless steel, depending on site conditions. Piezometers are typically of smaller diameters than wells and may be completed with or without sand packs, bentonite seals, or other construction parts.

Piezometers typically do not require development; however, some volume is usually purged to clear sediment that may have collected during installation. Piezometers to be used as introduction points for tracer dyes (see Section 5.9.3) should be developed using the same methods as monitoring wells.

General guidance for installation of piezometers is provided in SOP 20.9 (Appendix A). Piezometer specification will be included in WPA, as applicable.

5.3 SURFACE WATER INVESTIGATION

5.3.1 Surface Water Sampling

Factors that will need to be considered for selection of a surface water sampler include the width, depth, and flow of the surface water body, and whether the sample will be collected from the shore or a vessel. The most appropriate method(s) of sample collection and the appropriate depths of sampling (sampling strategies) will be specified in WPA.

Sampling will proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected upstream. In addition, if sediment samples are to be collected at the same locations as the surface water samples, the water samples must be collected first. Sampling will be performed in such a manner that minimizes disturbance of bottom sediments to ensure a representative sample.

Various methods may be used to collect samples of surface water and the method used will depend on the considerations discussed earlier. Some of the more common methods used to collect surface water samples from shallow depths include:

- Submergence of sampling containers;
- Dipper and pond sampler; and
- Peristaltic pump (for non-volatile parameters).

SOP 30.3 (Appendix A) describes the general requirements and procedures to be followed for collecting surface water samples at RFAAP and includes:

- General materials requirements;
- Considerations for sample collection;
- Sample location and timing;
- Sampling methods and procedures;
- Sample filtration; and
- Documentation requirements.

5.3.2 Surface Water Elevation Gauge

Surface water elevation (staff) gauges consist of calibrated steel posts driven vertically into a body of surface water to measure water level fluctuations. The installation procedures are as follows:

1. The gauge will be set where it can be attached to a secure location;
2. The gauge will be place such that the bottom of the gauge is resting on top of the streambed;
3. The water level will be recorded at the time of installation. A grease pencil will be used to mark the water level; and
4. The gauges will be surveyed by a Commonwealth of Virginia licensed surveyor concurrent with monitoring well/piezometer/soil-boring surveying. The surveyed point will be where the gauge is stationary. Water level elevations for each monitoring event will be converted to MSL (using stream gauge elevation [feet MSL] minus the water level reading [feet]).

Staff gauges will be surveyed to identify location coordinates and vertical elevation, as described in Section 5.10.

5.4 SEDIMENT INVESTIGATION

Factors that define the type of sediment water sampler to be used are primarily related to project objectives of surficial versus subsurface samples, site constraints of the water depth, sampling and sediment conditions, and cost-effectiveness of the sampler. The most appropriate method(s) of sample collection and the appropriate depths of sampling (sampling strategies) will be specified in WPA.

Sampling will proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected upstream. In addition, if surface water samples are to be collected at the same locations as the sediment samples, the surface water samples must be collected first. Sampling will be conducting using appropriate sampling devices that minimize disturbance and sample washing as the sample is retrieved through the liquid column.

Various methods may be used to collect samples of sediment and the method used will depend on the considerations discussed earlier. Some of the more common methods used to collect sediment include:

- Scoop or trowel method (exposed sediments or where surface water is six inches deep or less);
- Tube sampler (with or without hand auger); and
- Ekman or Ponar type of grab sampler.

SOPs 30.4 (scoop and tube sampler) and 30.5 (Ekman and Ponar sampler) in Appendix A describe the general requirements and procedures to be followed for collecting sediment samples at RFAAP and include:

- General materials requirements;
- Considerations for sample collection;
- Sample location and timing;

- Sampling methods and procedures;
- Documentation requirements; and
- Management of IDM.

5.5 GEOPHYSICAL SURVEYS

The use of geophysical techniques, if required, will be specified in site-specific WPA. Where possible, surface and down hole data will be integrated with existing geological information to form a synergistic interpretation. The contractor should consider these techniques for site-specific applicability to enhance the technical insight and cost-effectiveness of their efforts. Special applications may be useful in contaminant detection, epikarst thickness, depth to competent bedrock, detection of buried drums or debris, groundwater flow pathways, etc. When proposed for Contracting Officer Representative approval, the contractor will include the purpose, particular methods and equipment, selection rationale, methods and procedural assumptions, limitations (theoretical and site-specific), resolution, and accuracy, procedures for field standardization, calibration, and quality assurance.

The contractor will beta-test methods in one small representative area to verify that the selected methods in one small representative area to verify that the selected methods produce reasonable, defensible data. If the method does not meet the project's data quality objectives, the method(s) will be eliminated from the survey. The contractor shall also address the safety aspects of geophysical applications in their proposal. If geophysical techniques are used, the same topics will be addressed in the geotechnical report. Tables 5-1 and 5-2 present common surface and down hole geophysical lists survey techniques, including general purpose.

Several SOPs are included in Appendix A of the MWP that provide general descriptions and technical management guidance for the following types of geophysical surveys:

- Ground-penetrating radar (SOP 20.6);
- Resistivity and electromagnetic induction (SOP 20.7); and
- Magnetic and metal detection surveys (SOP 20.8).

Table 5-1
Geophysical Methods
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

METHOD	ELECTROMAGNETIC METHODS	ELECTRICAL METHODS	GPR Ground Penetrating Radar	ELECTRICAL RESISTIVITY	MAGNETICS	SEISMIC METHODS Refraction Tomography & Reflection	BOREHOLE METHODS
APPLICATIONS	• Gross soil lithology • Contaminant plumes • Boundaries of landfills, pits • Metal detection • Buried drums, USTs, • Utilities • Lateral, vertical variations • Fractures, faults, and karst	• Pipe and cable tracing • Shallow groundwater preferred flowpaths	• Buried drums, USTs, and utilities • Voids • Subsurface structures • Waste pits, trenches • Fractures, faults, and karst • Contamination plumes	• Soil and bedrock lithology • Contaminant plumes • Lateral and vertical variations • Water table • Bedrock topography • Fractures, faults, and large solution features	• Buried drums and USTs • Ordnance • Buried utilities • Abandoned wells	• Overburden thickness • Bedrock topography • Water table • Bedrock competence • Lithology • Fractures, faults, and epikarst	• Lithology • Fluid Properties • Fracture & fault orientation & magnitude • Estimate physical properties • Cross-hole investigations • Well casing integrity • Calibrate surface geophysics surveys • Vertical flow rates in boreholes
THEORY	Measures subsurface conductivity using low-frequency electromagnetic induction. Function of the electrical properties of subsurface materials and chemistry of pore fluids.	Measures the strength of electrical currents, either naturally occurring earth currents or currents applied to conductive targets.	Measures changes in the propagation of electromagnetic energy in the ground to produce an image of subsurface conditions.	Measures subsurface electrical resistivities (reciprocal of conductivity * 10,000) as a function of the physical mineralogical properties of soil and rock and the chemistry of pore fluids.	Measures the earth's magnetic field and anomalies caused by buried ferrous materials.	Measures seismic velocity of soil and rock. Function of soil and rock physical properties and density.	Measures electrical, thermal, radioactive properties, velocity, density, orientation, direction, and magnitude of borehole-intersected features and water quality parameters
METHODOLOGY	Hand carried, station, and/or continuous measurements are collected.	An applied current or signal is traced using an EM detector or voltmeter. Or naturally occurring currents are measured at soil voltage stations.	Antenna is pulled by hand or vehicle. Continuous measurements are collected.	Electrical current is forced into the ground through an expandable array of electrodes. Station measurements are collected.	Receiver is carried by hand. Station and/or continuous measurements are collected.	Energy is induced at the surface. Arrival of seismic wave is sensed by geophones and recorded by seismograph.	Borehole tools are lowered downhole. Data is recorded continuously or at specific depths.
INVESTIGATION DEPTH	Near surface to 200 feet; or 30 feet to several 1000's of feet.	Typically less than 10 feet.	Maximum depth 100 feet, but typically used for shallower profiling (zero to 20 feet).	Several hundred feet. Depth of investigation increases as electrode array is expanded.	0 to 60 feet.	Refraction: 0 to 100's of feet. Reflection: 30 to 100's of feet.	Vertical = depth of well Horizontal = zero to greater than 60 feet
LIMITATIONS	Interference caused by buried utilities, buildings, electrical power lines, electrical storms, and fences. Complex stratigraphy, more than two or three layers.	Interference from active electrical utilities. For pipe tracing, pipes must be conductive.	Highly site-specific. Not good in clayey, residuum soils or below the water table.	Sensitive to lateral resistivity variations. Electrode array length is several times the depth of investigation.	Reads only ferrous metals. Interferences caused by buried utilities, buildings, power lines, etc. Detectability varies with depth and size of target.	For the refraction method, velocity must increase with depth. Shallow reflection is highly site-specific.	Limitations vary with method used and whether used in an open hole or a cased well.
SURVEY COST	Low. Per station.	Low. Per station.	High. Per linear foot.	Medium. Per Array.	Low. Per station.	Medium-High. Per Array.	Varies. Per day.

Table 5-2
Borehole Geophysical Methods
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

METHOD	PROPERTIES MEASURED	POTENTIAL APPLICATION	REQUIRED HOLE CONDITIONS	OTHER LIMITATIONS
Spontaneous Potential (SP)	Electrical potential caused by salinity differences in borehole and interstitial fluids.	Lithology, correlation, shale content, water quality.	Open hole filled with conductive fluid.	Salinity difference required between borehole and interstitial fluid.
Single-Point Resistance (SPR)	Resistance of rock, saturating fluid, and borehole fluid.	High-resolution lithology, correlation, fracture location with differential SPR.	Open hole filled with conductive fluid.	Not quantitative, hole diameter effects significant.
Multi-Electrode Resistivity	Resistivity, in ohm-meters of rocks and saturated fluids.	Quantitative data on salinity of interstitial water, lithology, correlation.	Open hole filled with conductive fluid.	Normal resistivity spacing must be smaller than bed thickness to measure bed accurately.
Electrical Induction	Conductivity of rock and saturated fluids.	Quantitative data on salinity of interstitial water, water quality, lithology, correlation, monitoring formation fluid conductivity.	Open or non conductive casing.	Skin effects for highly conductive formations.
Natural Gamma, Spectral Gamma	Gamma radiation from natural or artificial radioisotopes.	Lithology related to clay (silt) content and permeability, spectral gamma identifies gamma emitting radioisotopes.	Any hole conditions except very large, or very thick casing and cement.	Very high count rates need to be corrected for dead time.
Gamma-Gamma Density	Total electron density.	Bulk density, porosity, moisture content, lithology, correlation.	Best results in uncased hole; qualitative through casing or drill stem.	Hole diameter effects.
Neutron	Hydrogen content, elemental spectra.	Saturated porosity, moisture content, activation analysis, lithology.	Best results in open hole; can be calibrated through casing.	Hole diameter and chemical effects.
Acoustic (Full Waveform Velocity)	Compressional shear and tube wave velocities.	In-situ engineering properties, porosity, fracture location and character, cement bond.	Open or cased fluid filled holes.	Does not "see" secondary porosity.
Acoustic Televiewer	Acoustic reflectivity of borehole wall.	Location, orientation, and character of fractures and solution openings, strike and dip of bedding.	Fluid filled borehole.	Heavy mud or mud-cake attenuates signal.
Optical Televiewer	Optical borehole wall imagery.	Location, orientation, and character of fractures and solution openings, strike and dip of bedding, casing inspection and well construction, mineralogy (color and light reflectance.	Air or clear fluid.	Optics diminish as hole is disturbed.
Caliper	Hole or casing diameter.	Hole diameter, corrections to other logs, lithology, fractures, hole volume for cementing, well construction.	Any conditions.	Deviated holes may skew measurement.
Fluid Temperature	Temperature of fluid near sensor.	Geothermal gradient, in-hole flow, location of injected water, correction of other logs, curring cement, plume identification.	Any conditions.	Best in undisturbed holes.
Water Quality	Several measurements available: fluid conductivity, pH, redox, salinity, pressure, sulphides, nitrates, chlorides, ammonia, copper.	Municipal water supply testing, environmental compliance, drinking water safety, plume identification.	Fluid filled hole.	Same sensors require regular maintenance and/or replacement.
Flow	Velocity of net flow in borehole.	In-hole flow, location and apparent hydraulic conductivity of permeable interval, leakage behind casing.	Fluid filled hole.	Spinners require higher velocities and centralization.
Magnetic Susceptibility	Magnetic field or some derivative.	Location of magnetic media.	Air or fluid, non-magnetic casing.	Most qualitative, but can be calibrated if borehole diameter is known.
Induced Polarization	Formation chargeability over a time or frequency domain.	Location of conductive zones.	Open fluid filled hole.	Best measurement requires relatively high current to be transmitted into formation.
Deviation	Inclination and bearing of borehole.	Subsurface geometry, location of specific targets.	Gyro required in magnetic cased holes.	Surface coordinates must be known for gyro.

Source: Mount Sopris Instrument Company, Inc. 2001 and (Keys 1997).

5.6 ACTIVE SOIL GAS SURVEY

Soil gas surveys are an effective screening tool for locating VOC-contaminated source areas in karst and fractured bedrock residuum. This system is also effective in mapping source areas and plumes within unconsolidated media. A large number of soil gas samples can be collected quickly and inexpensively. Thus, a large area can be evaluated for trends in VOC contamination in the subsurface. Soil gas is useful for defining optimum locations for subsequent soil borings and groundwater monitoring wells and for minimizing the number and cost of soil and groundwater samples needed to adequately define the source and extent of contamination. Soil gas results can also be useful in the interpretation of soil and groundwater sampling results.

5.6.1 Application

A soil gas survey involves sampling and analyzing gases in the interstitial spaces between soil particles in the unsaturated zone. VOCs in the soil or groundwater will volatilize to some degree and migrate through the soil column along preferential pathways, where they can be easily sampled as soil gas. However, VOC concentrations in soil gas do not correspond directly with concentrations in the soil or groundwater. The trends in contaminant concentration provide clues regarding the source and porous media migration of contaminants in the subsurface. Soil gas results should always be confirmed with soil or groundwater samples and are useful in determining subsequent soil and groundwater sample locations.

5.6.2 Limitations

Soil gas analysis cannot reliably predict contaminant concentrations in soil or groundwater. Many variables, some of which are poorly defined, or uncontrollable, may affect the relationship between contaminant concentrations in soil gas and in soil and groundwater. These variables include:

- **Physical and chemical properties of the VOCs**, such as vapor pressure, water solubility, density, and partitioning coefficients;
- **Properties of the unsaturated zone**, such as porosity, water content, soil organic matter, depth of the unsaturated zone, temperature gradient, and microbes;
- **Hydrogeologic properties**, such as groundwater flow, depth to groundwater, variations in groundwater depth, and lithology of the aquifer;
- **Characteristics of the release**, such as volume, duration, and depth;
- **Sampling techniques**, which affect the equilibria controlling VOC concentrations in the groundwater such as how the hole is drilled, purge volume, and sampling rate; and
- **Miscellaneous factors**, such as rainfall, background water quality, barometric pressure, wind, and proximity to surface water and pumping wells.

Soil gas sampling is best suited to sites with dry, porous soils, which have a larger volume of entrained gas and allow faster migration of VOCs than damp, clayey soils. Clay lenses, perched water, foundation walls, and other subsurface features are barriers to soil gas migration and may cause misleading results. VOCs in groundwater are most easily tracked if the depth to groundwater is relatively shallow and the aquifer is porous media. Soil gas sampling will be scheduled for dry weather, if possible. Rain saturates the soil column, displacing some soil gas and altering soil gas concentrations. Weather conditions during a sampling event cannot be controlled, but should be noted and taken into consideration during data analysis.

5.6.3 Selection of Sampling Locations and Depth

Sampling locations will be specified in site-specific WPA and may be selected based on available information on potential sources and the direction of groundwater migration. In many situations, a regularly spaced grid covering the area of interest will provide the best information. Grid spacing of 20- to 50-foot intervals is common, depending of the goal of the survey and the existing site conditions. Closer grid spacing provides information that is more detailed and is appropriate for locating potential sources of contamination. Wide spacing of sample locations is appropriate for general site screening to identify whether contamination is present. Samples may be located surrounding a potential source to ascertain whether a release has occurred. Sample points arranged in a line (rather than a grid) are appropriate in some situations, such as determining whether contamination is migrating off site.

Depth of sampling will be specified in site-specific WPA and selected based on the geology, hydrogeology, source depth, goals of the survey, and type of contamination expected. Sampling depths between two and 15 feet are possible (depending on soil conditions), but a depth of four to six feet is generally adequate to prevent significant effects on VOC concentrations from small surface spills or diffusion of soil gas into the atmosphere. Shallower samples at two to four feet are appropriate where groundwater is shallow or in paved areas (because paving minimizes both infiltration of spills and diffusion of soil gas into the atmosphere). Samples collected at depths greater than six feet may be needed if the contaminant source or the groundwater is especially deep or if clay lenses or other features prevent adequate vertical migration of soil gas. A confining layer separating two aquifer systems should not be breached. Significantly more time is required to collect samples at depths greater than 6 feet, which tends to negate some of the cost and speed advantages associated with soil gas techniques.

5.6.4 Sampling Procedures

SOP 20.5 (Appendix A) provides a general procedure for active soil gas sampling.

5.7 DRUM SAMPLING

Drums (and other sealed containers) with known or unknown contents potentially represent severely hazardous situations for sampling teams. Even when the original identity of the contents is reasonably certain, contents may be under pressure or in a decomposed state, and many materials readily react (sometimes violently) with air or water vapor in the atmosphere. Hazardous material specialists that have appropriate training and experience will inspect and sample unidentifiable drums. Specialist team members will use extreme caution and care when opening sealed drums or cans of unknown content for purposes of inspection and sampling.

Efforts will be made to ascertain the identity of the contents, through markings, history of activities at the site, and similarity and proximity to containers of known contents. Although the range of possible hazards will dictate which specific procedure will be followed, sampling activities will be consistent with SOP 30.6 (Appendix A). Predetermined procedures will be strictly followed as designated by the site-specific conditions.

5.8 PHYSICAL TESTING

When possible, physical testing of intact soil samples obtained during the field investigation should be conducted to characterize the encountered soil formations and their hydrogeologic properties. WPA for site-specific investigations will specify the physical testing requirements based on investigation objectives, site-specific conditions, etc.

The samples selected for physical testing will represent the range and frequency of soil types encountered within the study areas. Physical testing will be performed at a USACE-certified laboratory using ASTM methods and able to safely process hazardous and toxic samples, unless otherwise specified. Quality control samples will be sent to USACE Baltimore District Materials and Instrumentation Branch for analysis. The suite of tests, at a minimum should include sufficient testing to classify soils for engineering purposes (Unified Soil Classification System) by ASTM Standard D 2487 where applicable including:

- Moisture content (ASTM D 2216);
- Determination of particle-size distribution (ASTM D-422);
- Determination of Atterberg limits (ASTM D 4318); and
- Total organic content (ASTM D 2974).

Other tests may be conducted depending on investigation objectives such as:

- Porosity (ASTM D 854 and D 2937);
- Bulk density (ASTM D 4253);
- Capillary moisture relations (ASTM D 2325-68 and D 3152-72);
- Measurement of hydraulic conductivity (ASTM D 5084 and D 5856);
- Permeability (ASTM D 2434);
- Soil pH (ASTM D 4972-95a); and
- Cation exchange capacity (various methods).

5.9 AQUIFER TESTING

Aquifer tests, such as slug tests, pump tests, packer tests, and dye tests (for karst and fractured bedrock aquifers) are conducted to identify the approximate hydraulic properties of water bearing material. The properties that can be identified are specific to the test method used. The procedure for selection of aquifer test method(s) is a function of the following:

- The hydrogeology of the proposed test site;
- Testing conditions required by the test method;
- Requirements for observing the response of water levels to the test; and
- Site-specific investigation objectives.

ASTM Standard D 4043 provides guidance for development of site conceptual models and selection of a test method to identify hydraulic properties of porous media aquifers and fractured bedrock aquifers. Aquifer characteristics are important to evaluate the potential for contaminant migration and to identify potentially impacted areas.

5.9.1 Slug Tests

Slug tests are borehole scale aquifer tests that provide data that can be used to assess the approximate hydraulic conductivity of the screened porous media aquifer. Hydraulic conductivity data can be used in conjunction with data on effective porosity and hydraulic gradient to calculate estimated groundwater flow velocities in porous media. Aquifer characteristics are important to evaluate the potential for contaminant migration and to identify potentially impacted areas.

The slug test method involves causing a sudden change in head in a control well and measuring the water level response within that control well. Suddenly injecting into the well or removing from the well a known quantity of water may induce Head change. This is done by the rapid removal of a mechanical "slug" from below the water level, increasing or decreasing the air pressure in the well casing, or emplacement of a mechanical slug into the water column.

Initially, an appropriate test methodology should be chosen. The selection of the appropriate test method (rising or falling head) is dependent primarily on saturated screen length, the well diameter, aquifer fabric, and the estimated hydraulic conductivity. If the screen extends above the water table, a rising-head test (water removal or slug removal) should be used. The performance of a falling-head test (water or mechanical slug added) in this circumstance would overstate the hydraulic conductivity value, as the measured response would reflect the equilibration rate of previously unsaturated material; unsaturated materials would equilibrate faster than saturated materials (Bouwer 1989).

When the measured water level in a monitoring well is above the screened portion of the well, a falling-head test methodology should be employed. A rising-head test may also be performed if the initial water level reading (after the slug is removed) is above the screened interval.

Procedures for conducting falling-head slug tests and rising-head slugs are outlined in SOP 40.3 (Appendix A). The method (solution) used to analyze the slug test data will be primarily dependent on the site hydrogeologic conditions and conformity of these conditions to available model solutions for the type of condition observed.

5.9.2 Pumping Tests

Pumping tests are typically used to provide estimates of transmissivity and storativity values for the tested aquifer. Additionally, well performance parameters such as specific capacity and yield can be calculated from pumping tests. When conducted in fractured rock and karst aquifers, pumping tests can sometimes provide information on directions of groundwater flow.

Careful pre-design of pumping tests should be conducted prior to testing and consideration should be given to what type of data will be needed for the test. Geophysical surveys (surface or logging), packer tests, etc. may be necessary to provide appropriate subsurface data to design pumping tests for RFAAP sites when testing fractured rock and karst aquifers. Open hole bedrock wells will at a minimum, have a caliper log run prior to conducting packer and pump tests.

Several types of pumping tests may be conducted depending on site-specific conditions and project objectives including:

- Single well pumping test – no observation wells (note: limited parameters can be identified when compared with tests conducted with observation wells);

- Constant-rate test - with a single pumping well and multiple observation wells and/or piezometers; and

- Step-draw down test – with a single pumping well and multiple observation wells and/or piezometers.

Design specifications and pumping test plans (also for packer testing, etc.) will be included in WPA, when this type of aquifer test is proposed for site-specific investigations. These plans must include provisions for managing IDM.

5.9.3 Dye Tests

Karst features, such as solution cavities and zones of intense weathering and fracturing, identified in the limestone and dolostones bedrock in some areas at RFAAP, complicate groundwater flow. When site hydrology cannot be fully characterized due to the karst geology, a dye-trace study may be conducted to characterize groundwater flow, assess migration of contaminants in groundwater, and to identify receptors and future sampling locations.

5.9.3.1 Dye Selection

Groundwater tracing can be accomplished using a variety of tracers, including radioisotopes, chemicals, fluorescent dyes, bacterial tracers, and particulate tracers. Desirable properties in a groundwater tracer include:

- Easily detectable by the laboratory;

- Not detectable by the public;

- Should not react with the rock or soil matrix;

- Chemically stable over the length of the test;

- Not-commonly found in the environment;

- Non-toxic; and

- Relatively inexpensive.

These criteria are to some extent contradictory because no tracer will have each of these properties. Generally, the fluorescent dyes are the most cost-effective and reliable tracers.

Five types of fluorescent dyes are commonly used in groundwater tracing in the United States including:

- Eosine (Eos);

- Fluorescein (Fl);

- Pyranine (Py);

- Rhodamine WT (RWT); and

- Sulforhodamine B (SRB) (Aley 1999).

Each of the five of the dyes are anionic compounds and are thus less subject to adsorption onto clays and similar materials than are cationic dyes.

Dyes used for groundwater tracing are mixtures containing both dye and an associated diluent. Diluents enable standardization of the dye mixture to minimize difference among batches and allow for more ready dissolving in water. When conducting tracer studies, the common name of the dye, its color index, number, and the percentage of the dye in the mixture must be documented. Specific "as sold" dye mixtures used at RFAAP during previous investigations (ES 1994) include Fl, RWT, and Direct Yellow 95.

Table 5-3 identifies the characteristics of the five types of tracer dyes as related to the following:

- Color index and percentage of dye in "as sold mixtures";
- Relative magnitude of fluorescence intensity and magnitude;
- Detection limits for analytical testing and observation;
- Relative ability to absorb onto activated carbon and mineral materials; and
- Dye degradation in sunlight and influence of pH on fluorescence magnitude.

Relative Fluorescene Intensities. Each of the five fluorescent dyes has high detectability in water samples or in elute samples from activated carbon canisters (see Table 5-3). Fl has the highest fluorescence intensity followed by Eos, Py, SRB, and RWT.

Resistance to Adsorption and Other Losses. Factors that control dye absorption including pH, temperature, water quality, degree of water agitation, sediment concentration, sediment type, dye concentration, and dye type. In general, dye concentration is one of the most important variables. Dye concentration is one of the most important variables. In general, increased initial dye concentrations usually result in less percentage of dye lost to adsorbing materials. More dye usually required in turbid waters to achieve similar results to that for clear water (Aley 1999).

Organic materials adsorb much more dye than inorganic sediments. Studies conducted by Smart and Laidlaw (1977) indicated that Py has the most resistance to adsorption onto organic material followed by from least to most: SRB and Fl/RWT. Of the five dyes, Fl, Eos, and Py have good resistance to adsorption onto inorganic material, with Fl generally being the most resistant (see Table 5-3). RWT and SRB have lesser resistance to adsorption onto inorganic materials; this is particularly true when there is appreciable contact between such materials and water containing dyes (Aley 1999).

Table 5-3
Tracer Dye Characteristics
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Dye	CAS Number	Common Alternative Names	Color Index Identification and Approximate Percent of Dye in "As Sold Mixtures"				Relative Magnitude of Fluorescence Intensity (Ratios Relative to Rhodamine WT)		Fluorescence Magnitude in Standard OUL Eluent vs. Fluorescence Magnitude in OUL Reagent Water	
			Color Index Name	Color Index Number	Approximate Percent Dye in "As Solid Mixtures"					
					OUL Mixtures	Market Range	Emission in Peak Area in OUL Eluent	Emission in Peak Area in OUL Water	Emission Peak Height	Emission Peak Area
Eosine	17372-87-1	Eosin, Eosine OJ, and D&C Red 22	Acid Red 87	45380	75%	2 to 75%	7.36	4.50	199%	188%
Fluorescein	518-47-8	Uranine, Uranine C, Sodium Fluorescein, Fluorescein LT, and Fluorescene Yellow/Green	Acid Yellow 73	45350	75%	2 to 80%	27.08	48.15	-13%	-10%
Pyranine	6358-69-6	Solvent Green 7 (SG 7) and D&C Green 8	D&C Green 8	59040	77%	Unknown	3.25	Varies with the pH of the water at pH less than 9.5	NA	NA
Rhodamine WT	37299-86-8	Fluorescent Red	Acid Red 388	Not Assigned	20%	3 to 20%	1.00	1.00	107%	98%
Sulforhodamine B	3520-42-1	Sulfo Rhodamine B, Pontacyl Brilliant Pink B, Lissamine Red 4B, Kiton Rhodamine B, Amido Rhodamine B, and Fluoro Brilliant Pink	Acid Red 52	45100	75%	3 to 75%	1.14	1.17	157%	150%

Table 5-3 (Continued)
Tracer Dye Characteristics
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Dye	CAS No.	Common Alternative Names	Detection Limits					Dye Tracer Adsorption - Mineral Materials							
			Dye in Water, Instrument Analysis MDL (ppb)	Dye in Elutant; Instrument Analysis MDL (ppb)	Field Conditions		Dark Room Experienced Person	Kaolinite		Bentonite		Limestone		Ortho-quartzite	
					Experienced Person (ppb)	Field Conditions General Public (ppb)		Sediment Concentration (g/l)							
								2	20	2	20	2	20	2	20
Eosine	17372-87-3	Eosin, Eosine OJ, and D&C Red 24	0.005	0.040	135	13,500	10	NE		NE		NE		NE	
Fluorescein	518-47-10	Uranine, Uranine C, Sodium Fluorescein, Fluorescein LT, and Fluorescene Yellow/Green	0.0005	0.010	7	140	2	98	93	98	87	98	94	98	98
Pyranine	6358-69-8	Solvent Green 7 (SG 7) and D&C Green 10	NA	0.125	175	3,500	3	95	95	100	98	96	85	100	87
Rhodamine WT	37299-86-10	Fluorescent Red	0.007	0.155	125	2,500	50	89	67	92	79	93	66	98	90
Sulforhodamine B	3520-42-3	Sulfo Rhodamine B, Pontacyl Brilliant Pink B, Lissamine Red 4B, Kiton Rhodamine B, Amido Rhodamine B, and Fluoro Brilliant Pink	0.020	0.080	50	1,000	5	88	51	98	--	97	76	--	--

Table 5-3 (Continued)
Tracer Dye Characteristics
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Dye	CAS Number	Common Alternative Names	Ranking of Ability of Activated Carbon to Adsorb Dye in Field Situations and Release to Elution Protocol	Dye Degradation in Sunlight – As Measured by Fluorescence Magnitude (Water Depth 0.5 inches) - Initial Concentration of 1,000 ppb			Dye Degradation in Sunlight - As Measured by Fluorescence Magnitude (Water Depth 0.5 inches) - Initial Concentration of 100 ppb			Influence of pH on *Fluorescence Magnitude*	
				Percent of Initial Dye Remaining (Hours)			Percent of Initial Dye Remaining (Hours)			pH substantially decreased at pH less than	Fluorescence mostly eliminated at pH less than
				1 hour	3 hours	5 hours	1 hour	2 hours	3 hours		
Eosine	17372-87-3	Eosin, Eosine OJ, and D&C Red 24	2	2%	<1%	---	1%	<1%	---	4.0	2.5
Fluorescein	518-47-10	Uranine, Uranine C, Sodium Fluorescein, Fluorescein LT, and Fluorescene Yellow/Green	1	19%	<1%*	---	7%	<1%*	---	6.5	5.5
Pyranine	6358-69-8	Solvent Green 7 (SG 7) and D&C Green 10	5	68%	3%	---	3%	1%	---	9.5	6.5
Rhodamine WT	37299-86-10	Fluorescent Red	3	100%	100%	83%	97%	49%*	32%*	5.0	2.5
Sulforhodamine B	3520-42-3	Sulfo Rhodamine B, Pontacyl Brilliant Pink B, Lissamine Red 4B, Kiton Rhodamine B, Amido Rhodamine B, and Fluoro Brilliant Pink	4	100%	97%	95%	81%	70%	60%	3.5	2.0

Table 5-3 (Continued)
Tracer Dye Characteristics
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Notes:
OUL = Ozark Underground Laboratory
CAS = Chemical Abstract Service
MDL = Method Detection Limit
NA = Not Available
NE = Not Evaluated
* = Atypical peaks for the dye in question
g/l = Grams per liter
ppb = Parts per billion (micrograms per liter)
Source: (Aley 1999)

Field studies conducted by the Ozark Underground Laboratory (OUL) indicated that Fl has the most ability to adsorb to activated carbon samplers, and then be released to the eluting solution. The other four dyes have lesser abilities to adsorb in field situations ranking from decreasing adsorption ability: Eos, RWT, SRB, and Py (Aley 1999).

Percentages losses of tracer dyes in groundwater increase as:

1. Dye concentrations decrease;
2. Travel distance increases;
3. Travel times increase;
4. Organic matter increases;
5. Bacterial activity increases; and
6. Water follows dispersed, rather than concentrated, flow routes.

The fluorescence magnitude of tracer dyes is dependent on the pH of the solution in which the dye is present. Potential significant interference effects may occur for some dyes if the carrying waters of the tracing test are outside a pH range of 6.5 to 8.0 (see Table 5-3). Thus, the pH of the carrying waters for the test must be considered for appropriate dye selection and interference testing conducted as appropriate. Py is the most susceptible of the five dyes, with significant interference effects observed below a pH of 9.5. Carrying waters with a pH below 6.5 will likely have a significant interference effect on Fl (Aley 1999).

Losses in Surface Water: Photochemical Decay. Processes that remove, degrade, or destroy dyes from surface water include water and dye uptake by plants and dye degradation or destruction by photo-degradation. OUL has observed that each of the five of the dyes can be detected in the tissue of plants that are transpiring water, which contains tracer dyes (Aley 1999).

The rate of dye degradation in sunlight varies with generally RWT and SRB having the least degradation; Py generally has the next lowest rate of degradation followed by Eos and Fl, which tend to degrade more rapidly (see Table 5-3). Experimental data in Table 5-3 likely overestimates the actual degree of decay in the field, as most streams are deeper than the water depth used in the experiments (0.5 inches). Additionally, many streams are shaded. Additional factors to be considered are the following:

- Photochemical decay rates are typically an order of magnitude greater during sunny conditions than under cloudy conditions; and
- Photochemical decay does not occur at night (Aley 1999).

Dye detectors, when possible, should be shielded from sunlight and placed at locations where the water has been exposed to as little sunlight as possible; this is particularly important for the more photosensitive dyes such as Fl and Eos.

5.9.3.2 Selecting Dye Quantities

The selection of dye quantities is directly related to the expected recovery of dye. Observed recoveries for dye traces in karst aquifers where discharge occurs to springs generally range from 20 to 50% of the introduced dye, when the dye is introduced in the area of conduits. Dye recovery decreases to 1 to 10% when the point of introduction is a seasonally saturated epikarst zone. An order of magnitude decrease in recovery (0.1 to 1.0%) from this level is typical for an epikarst zone that is perennially saturated (Aley 1999).

When activated carbon samplers are used, Fl will generally require the least quantity for a successful trace followed by Eos, Py, RWT, and SRB. Most dye introductions require a few pounds of the "as sold" weights of tracer dyes. In karst areas, most dye introductions use one to five pounds of the selected dye, except when the point of introduction is into wells, borings, or backhoe pits. When introducing dye into wells, borings, or backhoe pits, dye quantities used typically range from five to ten pounds for Fl or Eos, and ten to 20 pounds for RWT. Tracing studies in non-karst areas typically require two to three times more dye than in karst areas (Aley 1999).

OUL has observed that the magnitude of the fluorescence peak associated with a particular dye trace tends increase with approximately the square of the amount of dye used. This relationship does not hold true when excessively large quantities of dye are used (Aley 1999).

5.9.3.3 Dye Introduction

Tracer dyes can be introduced into groundwater systems using a variety of methods. The method used will depend on the objectives of the test and the feasible approaches for the proposed test site.

In karst areas, sinkholes or surface streams that sink into the subsurface are obvious points for dye introduction. These type of sites are appropriate for delineating recharge areas for springs, but may be inappropriate for characterizing water movement from a waste site, particularly if the waste site is not proximate to these features (Aley 1999).

Backhoe trenches may be used as dye introduction points. The rate of leakage from trenches must be calculated prior to conducting tests to verify that the trace will be successful. OUL indicates that leakage rates greater than 0.04 gallons per minute are desirable (Aley 1999).

Epikarst dye introduction points (EDIPs) are appropriate when a waste unit overlies carbonate bedrock and contaminants of concern have been detected in the bedrock aquifer. With an EDIP, dyes are introduced at points, which bracket the waste unit or a portion of the unit. The introduction points consist of vertical borings that typically extend to a few feet below the top of bedrock. In general, the bottom ten feet of the EDIP is backfilled with clean gravel followed by the placement of an outer casing to the surface. The outer casing is grouted into place to seal the boring above the gravel zone. Prior to placement of dye, the EPIC must be tested to ensure that trace will be successful. In general, the rate of water acceptance should be five gallons per minute or more (Aley 1999).

Piezometers can be used as dye introduction points providing that their construction will allow for introduction of dye into targeted zones. The main consideration for use as an introduction point is the depth and interval of the screen. Positioning of screen intervals within the epikarst zone allows the piezometer to function as an EDIP. The introduction point (screened interval) can also be deeper in bedrock to target specific conduits, etc. It is important to test proposed piezometer introduction points for water acceptance to verify that they are appropriate for use in tracing tests.

Dyes tend to foam when they are added to water and agitated. When water levels are less than 15 feet below the top of the casing, foaming can be a problem in EDIP or piezometers. The introduction of dye through a tube inserted into the EDIP or piezometer will usually minimize foaming problems (Aley 1999).

The more water introduced with dye during a tracing study, the more efficiently it can be traced. OUL indicates that many successful dye introductions have used on the order of 1,000 to 4,000 gallons of water. The actual amount of water used will depend on site conditions and constraints. Sometimes, multiple dye introductions are necessary at hazardous waste sites because of constraints on the rate of introduction (Aley 1999).

Four of the five dyes are provided in powder form; RWT is provided in liquid form. In most cases, the easiest method to introduce the powder dyes is to first mix them with water. The dyes should be thoroughly mixed in a container of approximately 20-liter size by shaking until the mixture is free of lumps. Allowing the mixture to stand overnight will minimize foaming. In most cases, the tracer dye should be introduced as a slug along with approximately 10 to 15% of the water to be used for the test. The remaining water can then be introduced to flush the dye into and/or through the groundwater system (Aley 1999).

5.9.3.4 Placement of Samplers – Dye Detectors

Sampling for the five tracer dyes can be conducted with activated carbon samplers or with water samples. In most cases, primarily reliance should be placed on activated carbon samplers.

Activated carbon samples continuously absorb and accumulate the five dyes discussed in this MWP. In general, the samplers are inexpensive, easy to use, and adsorb tracer dyes in the presence of most common water contaminants. The activated carbon samples should contain coconut shell charcoal, which is generally considered the best carbon for detecting tracer dyes under field conditions.

Samplers in streams and springs should be placed where there is a reasonable current. Avoid placing the sampler at locations where swift current or accumulated debris will likely batter it. Stream velocities between 0.1 and 1.0 foot per second are the most desirable. If the stream or spring has a soft bottom, place the samplers where they are at least a few inches above the soft materials. Use of gumdrop samplers is ideal for these conditions; two independently anchored samplers should be used in case one of the samplers is lost during the sampling period (Aley 1999).

Pumping wells can be monitored with activated carbon samplers be placing a sampler in water derived from the well. A sampler holder constructed with pipe fittings can be used and attached to a hose bib. A flow rate of one gallon per minute is typically adequate if the water is continuously in contact with the activated carbon sampler. It is important to keep the samplers completely in the water being sampled; this can be accomplished by connecting a hose to the downstream end of the sampler holder (Aley 1999).

Monitoring wells or piezometers can be sampled by attaching an activated carbon sampler to the top of a disposable bailer with a clear or white, plastic cable tie. The sampler is then lowered to the center of the screened interval or to the middle of the saturated zone of the well. Activated carbon samplers will be prepared prior to insertion into the well to prevent the release of activated carbon powder to the well. The following procedure can be used:

1. Add samplers (up to 25) to a bucket containing one gallon of distilled or de-ionized water, slosh them round, and let stand for ten minutes;

2. Discard the used water from the bucket and add a second gallon of clean distilled or de-ionized water, slosh, and let stand for ten minutes;

3. Repeat the procedure with a third gallon of water; and

4. Store the samplers wet and in a plastic bag under refrigeration and use within one week (Aley 1999).

The general procedure for placement of dye detectors at RFAAP is presented in SOP 20.10 (Appendix A).

5.9.3.5 Frequency of Sample Placement/Collection

The frequency of sampler placement and retrieval depends on the specific objectives of the project and will therefore be specified in WPA. Frequent changing (less than once per week) is appropriate if the travel time is an important consideration. An accelerated schedule may be used in this case, such as daily for the first week and weekly thereafter. The sampling periods should be of equal length if dye concentrations will be compared for the different periods. The sampling interval should not be of such length that most of the detectable dye might discharge during a single sampling period (Aley 1999).

At highly contaminated sites, Eos and RWT dyes are more sensitive to decreased adsorption rates with increased exposure time of the samplers than is the case for Fl. Thus, more frequent sampling intervals (than once per week) may be appropriate in these situations (Aley 1999).

5.9.3.6 Maintaining Sample Integrity

In addition to appropriate sampling and chain-of-custody protocols, the following steps should be followed to maintain the integrity of activated carbon samplers:

1. Limit labeling of sample bags to the outside and do not use a colored pen or marker as these contain some of the tracer dyes in the ink;

2. Keep the collected samplers under refrigeration until analysis;

3. Use cold packs and cooler chests to keep samples cool during field and sample shipping. Avoid using real ice since it can cross-contaminate samples during melting; and

4. Do not wash samplers in chlorinated tap water.

5.9.3.7 Background Sampling

At least three background-sampling events will be executed in the dye-trace study area at each sampling station to assess ambient dye concentrations. Dyes related to automotive fluids and many industrial processes are found at or near hazardous waste sites. Parking lots and storm water runoff collection/discharge areas often contain Fl and Eos from antifreeze, brake, hydraulic, and transmission fluids.

5.10 SURVEYING

After installation and completion, newly installed wells and surface water elevation (staff) gauges will be surveyed to calculate location coordinates and vertical elevation. The RFAAP Coordinate System will be referenced, with locations surveyed to within ± 0.1 foot. Elevations of the ground surface and the top of the inner well casing will be reported within ±0.01 foot, using RFAAP vertical datum. The topographic survey will be completed as near to the time of last well completion as possible, but no longer than five weeks after well installation. Survey field data (as corrected), to include loop closure for survey accuracy, will be included within the geotechnical or final report. Closure will be within the horizontal and vertical limits given above.

Coordinates and elevations for soil borings and other sampling locations that do not need to be as accurate will be obtained using a hand-held global positioning system (GPS) unit, which will result in an accuracy of ±30 feet in X-Y coordinates. Alternately, coordinates will be estimated by using survey data from wells or other benchmarks surveyed according to the procedure above.

Survey data will be presented on one comprehensive map for each study area, as appropriate, and in tabular form. These data will clearly list the coordinates and elevation for each boring, well, and reference mark. Permanent and semi-permanent reference marks used for horizontal and vertical control will be described in terms of their name, character, and physical location.

5.11 ASBESTOS REMOVAL

Asbestos removal at RFAAP will be performed in strict compliance with current OSHA and USEPA regulations and the Operating Contractor's procedure, *Requirements for Removal of Asbestos Insulation.*

5.12 GENERAL DECONTAMINATION REQUIREMENTS

The appropriateness of decontamination protocols is critical to obtaining accurate analytical results for decision-making purposes. Sampling equipment will be decontaminated prior to use to ensure equipment cleanliness during usage at different locations to mitigate potential cross-contamination. Specific decontamination procedures will be dependent upon site contaminants, analyses performed, and sampling device composition. These procedures should be identified in WPA. General procedures for decontamination are outlined below and in SOP 80.1 (Appendix A).

5.12.1 Decontamination Pad

A decontamination pad will be constructed prior to the start of field investigations. The bottom and elevated sides of the decontamination pad will be constructed of plywood. The bottom of the decontamination pad will be sloped to allow for the containment of decontamination water. Polyethylene sheeting will cover the sides and bottom of the decontamination pad to form a watertight sump for the collection of washing and rinsing solutions. A centrifugal pump will be used to pump the accumulated decontamination water from the pad into a storage tank or other appropriate container (for IDM) located near the decontamination pad.

The decontamination pad will be used to contain the water from decontamination of the drill rigs, down hole equipment, and sampling equipment. The drill rigs will be backed into the decontamination pad and cleaned using the procedures outlined in Section 5.12.3. Down hole equipment decontamination will take place on metal sawhorses to prevent contact with the decontamination pad.

Decontamination of submersible pumps and sampling equipment requiring the use of polyethylene tubs to perform decontamination procedures will take place at a mobile decontamination station. Equipment, brushes, and polyethylene tubs needed for decontamination procedures will be underlain by polyethylene sheeting. Water used during the decontamination process will be transferred to the decontamination pad or appropriate container for IDM and managed according to the requirements described in Section 5.13.

5.12.2 Generation of Deionized, Organic-Free Water for Decontamination

Un-chlorinated water used for equipment decontamination will be obtained from the RFAAP potable water supply. A sample of the un-chlorinated water will be submitted to the contracted laboratory for analysis of investigation parameters of concern.

Deionized ultra-filtered (DIUF), HPLC-grade organic-free water used in decontamination will generally be purchased in lots from a supply company. The certificates of analysis will be reviewed prior to usage to ensure the water is free of contamination.

5.12.3 Drill Rig and Down Hole Equipment

Prior to beginning drilling operations, and between boring locations, the drill rig and other down hole equipment will be steam-cleaned with USACE-approved water. This activity will be performed in the leak-proof decontamination pad, which will be constructed prior to commencement of the field investigation. Sampling equipment associated with the drill rig such as split spoons, augers, and geo-punch stems will be decontaminated as specified in SOP 80.1. Equipment decontaminated within the pad will be placed on metal sawhorses to prevent contact with the decontamination pad. Water generated during this process will be periodically pumped from the decontamination pad into a holding tank and appropriately managed as IDM (see Section 5.13). Residual solids (including plastic sheeting) generated from the decontamination process will also be appropriately managed as IDM.

5.12.4 Well Casing and Screen

Prior to use, well casing and screen materials will be decontaminated. This activity will be performed in the leak proof, decontamination pad, which will be constructed prior to commencement of the field investigation. The decontamination process will follow procedures specified within SOP 80.1.

5.12.5 Non-Dedicated Sampling Pumps

Submersible pumps and associated equipment used to purge and sample groundwater from wells will be decontaminated as outlined within SOP 80.1.

5.12.6 Sampling Equipment

Sampling equipment for soil, sediment, water level measurement, etc., will be decontaminated as outlined within SOP 80.1.

5.12.7 Other Sampling and Measurement Probes

Temperature, pH, conductivity, oxidation/reduction potential, and dissolved oxygen, turbidity probes will be decontaminated according to manufacturer's specifications. If no such specifications exist, remove gross contaminant and triple-rinse probe with DIUF water.

5.13 INVESTIGATION-DERIVED MATERIAL

General guidelines and procedures for managing IDM generation during site investigations at RFAAP are included in SOP 70.1 in Appendix A.

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6.0 HUMAN HEALTH RISK ASSESSMENT

6.1 OBJECTIVES AND GENERAL APPROACH

The purpose of a human health risk assessment (HHRA) is to evaluate the probability and magnitude of potential adverse effects on human health associated with actual or potential exposure to site-related chemicals. The HHRA may provide a basis for determining whether or not remedial action is necessary at a site and justification for performing remedial action that may be required. The HHRA is performed in compliance with Comprehensive Environmental Response, Compensation, and Liability Act/Superfund Amendments and Reauthorization Act (CERCLA/SARA) and pursuant to the RCRA Corrective Action Requirements. In conducting the assessments, the procedures outlined in USEPA's *Interim Final Risk Assessment Guidance for Superfund (RAGS)--Human Health Evaluation Manual (Part A)* (USEPA 1989) are followed. Other resources used when performing an HHRA include: the *Exposure Factors Handbook* (USEPA 1997b); the *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (USEPA 1991a); the Integrated Risk Information System (IRIS); the Health Effects Assessment Summary Tables (HEAST); the *Role of Baseline Risk Assessment in Superfund Remedy Selection Decision* (USEPA 1991b); and USEPA Region III's *Risk Based Concentration Table* (USEPA, April 2002 Update).

An HHRA is prepared following the four main steps listed below. The remainder of this section describes each of these steps in more detail. The uncertainty analysis, which presents the uncertainties associated with the HHRA, is also described.

Step 1: Data Summary and Selection of Chemicals of Potential Concern. The chemicals detected in environmental media are identified and discussed. The data are summarized by presenting the frequency of detection and the range of detected concentrations in site-related samples and the range of concentrations in background samples. In addition, chemicals of potential concern (COPCs) are selected for quantitative evaluation in the HHRA based on a review of the data, a comparison to USEPA Region III's risk-based screening concentrations (or health-based screening criteria for RCRA sites), and a comparison to relevant background concentrations for inorganic chemicals.

Step 2: Human Health Exposure Assessment. The potential pathways by which individuals may be exposed to COPCs are discussed and exposure pathways are selected for further evaluation. The chemical concentrations at the points of potential exposure are presented for each complete exposure pathway. Standard exposure factors and health-protective assumptions are used to assess the magnitude, frequency, and duration of exposure for each pathway and potential exposures (intakes) are then estimated.

Step 3: Human Health Toxicity Assessment. The potential toxicity of chemicals to humans and the chemical-specific health effects criteria to be used in the quantitative assessment are presented.

Step 4: Human Health Risk Characterization. Quantitative risk estimates are calculated for each complete exposure pathway by combining the toxicity criteria with estimated intakes of potentially exposed individuals.

6.2 DATA SUMMARY AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN

6.2.1 Methodology for Data Summary

This section discusses the methodologies used to summarize the data and select COPCs for detailed evaluation in the HHRA.

The first step of the HHRA process is to summarize the analytical data collected. Detailed discussions of sampling approaches and results will be presented in the data evaluation section of the RFI Report. The quality assurance and control activities implemented during the collection of the data as described will be evaluated prior to the selection of COPCs.

The following steps, which are in accordance with USEPA (1989) guidance, are used to summarize the validated analytical data for the HHRA:

- The data are summarized by environmental medium (e.g., groundwater, soil, sediment, and surface water). In addition, the samples are divided into groups that describe conditions relevant to potential exposure by receptors or pertinent to site environmental factors (e.g., contamination patterns, hydrology).

- The data are qualified by the analytical laboratory and independently validated using the USEPA Region III guidance *Innovative Approaches to Data Validation* (USEPA 1995). Validation for organic data will be performed at Manual Level M3 and the verification for inorganic data will be performed at Manual Level IM2. The qualification and validation of the analytical data includes a comparison of the site data to corresponding blank (laboratory and field) concentration data. If the detected concentration in a site sample is less than ten times (for common laboratory contaminants) or five times (for other compounds) the concentration in the corresponding blank sample, the data are considered for exclusion from the Risk Assessment (RA) calculations. Other qualifiers and validation codes are identified in the analytical data. Data that are rejected by the validation process (R-qualified) are not used in the RA. Data that are considered estimated values (e.g., J-qualified) are used in the RA without modification.

- One-half the sample quantitation limit is used for non-detects if the chemical was detected in at least one other sample for the same medium. One-half the sample quantitation limit is typically used in assessments (USEPA 1989) when averaging non-detect concentrations, because the actual value can be between zero and a value just below the sample quantitation limit.

- Data from duplicate samples are averaged together and treated as one result. If a chemical is detected in a maximum of one of two duplicate samples, the detected value is averaged with one-half the sample quantitation limit of the non-detect sample, and the result is counted as one "detect" sample.

- Frequency of detection is calculated as the number of samples in which the chemical was detected over the total number of samples analyzed. The frequency of detection is calculated after the exclusion of R-qualified values (data) and elimination of data for blank contamination reasons, and after the treatment of duplicate sample data. The frequency of detection also reflects multiple rounds of data collected at a single sample location. The analytical results from each sampling event are typically considered individually, rather than averaging the results for the sample location.

6.2.2 Selection of COPCs for the HHRA

Once the sampling data are grouped and summarized, COPCs for the HHRA are selected. The purpose of selecting COPCs is to identify those chemicals to be carried through the RA process. Chemicals that qualify for evaluation, as COPCs, are chemicals detected at least once in environmental samples. The essential nutrients calcium, sodium, potassium, and magnesium, chemicals disqualified in the validation process and tentatively identified compounds (TICs) not positively identified will be eliminated as COPCs.

COPCs will be identified by comparing maximum detected concentrations (MDCs) in a specific medium with chemical-specific risk-based screening criteria, unless the data display the statistical properties required to calculate a valid 95% upper confidence limit (UCL). If this is the case, then the 95% UCL will be employed. Chemicals with MDCs exceeding risk-based criteria will be identified as COPCs and will be carried through to the cumulative risk-screening step of the assessment.

Soil and Sediment. COPCs in surface and subsurface soil and sediment will be identified by comparing MDCs (or 95% UCLs, if appropriate) in these media to Risk-Based Concentrations (RBCs) in the most recent version of the USEPA Region III RBC Table for soil ingestion using the Residential and Industrial scenarios (USEPA 2002).

For soils and sediments that are exposed a significant portion of the year (i.e., greater than six months/year), screening levels shall correspond, or be adjusted to correspond, to an increased cancer risk of 1 x 10^{-6} and a noncancer Hazard Quotient (HQ) of 0.1. COPCs can be identified if the MDCs (or 95% UCLs, if appropriate) are greater than the screening values for the ingestion and/or inhalation pathways. For sediments that are not exposed, comparisons to adjusted soil screening levels may be used to decide on the need for further evaluation (e.g., quantitative RA), further investigation or response action.

In recognition of the special nature of sediment, a ten-fold exposure factor will be applied to the screening values for both cancer and non-cancer compounds as identified in the Region III RBC Tables. The result is still screening sediment at approximately a HQ = 0.1 and an increased cancer risk = 1 x 10^{-6} using this ten-fold multiplier. For example, the screening concentration of aluminum and arsenic in residential soil would be 7,800 milligrams per kilogram (mg/kg) and 0.43 mg/kg, respectively. The screening concentration in sediment for aluminum and arsenic would be 78,000 mg/kg and 4.3 mg/kg, respectively.

If lead concentrations in soil are greater than 400 mg/kg (USEPA 1994a), then potential risk associated with lead will be evaluated using the Integrated Exposure Uptake Biokinetic model (USEPA 1994b). As a screening value point of reference, USEPA Region III recommends an industrial soil lead screening value of 1,000 mg/kg. The model will be run using site-specific input parameters based on Site Screening Process (SSP) findings and consultation with USEPA Region III. If the percentage of children expected to have blood lead levels of 10 micrograms per deciliter (µg/dL) or greater exceeds 5%, then lead will be retained as a COPC to be evaluated in the next steps of the HHRA (Exposure Assessment and Risk Characterization).

If iron concentrations in soil result in a HQ of 0.5 or greater, then a "margin of exposure" evaluation will be performed. Risks from exposure to iron will be characterized by comparing estimated iron intake to the recommended dietary allowance (RDA) and concentrations known to cause adverse effects in children (NCEA 1996).

Groundwater and Surface Water. COPCs in groundwater and surface water will be identified by comparing MDCs (or a 95% UCL if appropriate) of chemicals in these media to RBCs in the most recent version of the USEPA Region III RBC Table for tap water (USEPA 2002), and to federal and state Maximum Contaminant Levels (MCLs) for groundwater and surface water used as a source of drinking water.

For ground water, as well as surface water that may be a source of drinking water, RBC screening levels shall correspond, or be adjusted to correspond, to an increased cancer risk of 1 x 10^{-6} and a noncancer HQ of 0.1. For other surface water, comparisons to adjusted ground water screening levels may be used to decide on the need for further evaluation (e.g., quantitative RA), further investigation, or response action. Note that for screening of COPCs, ground water will be considered a source of drinking water unless deemed non-potable (i.e., Class III).

In recognition of the special nature of surface water, a ten-fold exposure factor will be applied to the screening values for both cancer and non-cancer compounds as identified in the Region III RBC Tables. The result is still screening surface water at approximately a HQ = 0.1 and an increased cancer risk = 1 x 10^{-6} using this ten-fold multiplier. For example, the screening concentration of aluminum and arsenic in groundwater would be 3,700 micrograms per liter (μg/L) and 0.045 μg/L, respectively. The screening concentration in surface water for aluminum and arsenic would be 37,000 μg/L and 0.45 μg/L, respectively.

If lead concentrations in groundwater or surface water are greater than 15 micrograms per liter (µg/L) (USEPA 1996b), then potential risk associated with lead will be evaluated using the Integrated Exposure Uptake Biokinetic (IEUBK) model (USEPA 1994b). The model will be run using site-specific input parameters based on SSP findings and consultation with USEPA Region III. If the percentage of children expected to have blood lead levels of 10 µg/dL or greater exceeds 5%, then lead will be retained as a COPC to be evaluated in the next steps of the HHRA (Exposure Assessment and Risk Characterization).

If iron concentrations in water result in a HQ of 0.5 or greater, then a "margin of exposure" evaluation will be performed. Risks from exposure to iron will be characterized by comparing estimated iron intake to the RDA and concentrations known to cause adverse effects in children (NCEA 1996).

Fish. COPCs in fish will be identified by comparing MDCs (or 95% UCLs, if appropriate) of chemicals in fish tissue samples to screening level RBCs for fish in the USEPA Region III RBC Table (USEPA 2002). Screening levels shall correspond, or be adjusted to correspond, to an increased cancer risk of 1 x 10^{-6} and a noncancer HQ of 0.1.

Chemicals Lacking RBCs. For chemicals lacking USEPA Region III published RBCs, but having available associated toxicity data that are considered reliable, risk assessors will obtain information from the following sources, which are listed in order of preference: USEPA's IRIS, HEAST, and provisional values from the National Center for Environmental Assessment (NCEA). From these sources, risk assessors will make a good faith effort to propose alternative-screening values for those constituents lacking published RBC values.

Summary. In summary, a detected chemical will be retained as a COPC for a specific medium if the MDC (or a 95% UCL if appropriate) is greater than the corresponding screening criteria described above.

6.3 HUMAN HEALTH EXPOSURE ASSESSMENT

The next step of the HHRA is the exposure assessment, where the route, frequency, duration, and magnitude of exposure to COPCs at the site are characterized. Two overall exposure conditions are evaluated: current land-use condition and future land-use condition. The current land-use condition evaluates the potential for exposures associated with the site, as it currently exists. The future land-use condition evaluates the potential for exposures under future land-use conditions, assuming no remedial action is taken (i.e., the no-action alternative) at the site. The exposure assessment is conducted in a series of three steps: (1) receptor characterization; (2) exposure pathway identification; and (3) exposure quantification.

6.3.1 Receptor Characterization

As the first step of the exposure assessment, potentially exposed populations (receptors) are identified and described with respect to those characteristics that influence exposure. Factors such as activity patterns in the area, as well as source characteristics and routes of transport for the COPCs, are considered when identifying potentially exposed populations.

6.3.2 Exposure Pathway Identification

The exposure pathways associated with receptors at the site are identified based on consideration of the sources, releases, types and locations of chemicals, and the location and activities of receptor populations. Each exposure pathway includes:

1. A source and mechanism of release;

2. An environmental transport medium;

3. A point of potential exposure with the contaminated medium; and

4. A route of exposure (e.g., incidental ingestion of surface soil) at the exposure point.

Those pathways that contain each of these elements are complete and are considered for quantitative evaluation.

6.3.3 Exposure Quantification

For each exposure pathway selected for quantitative evaluation, concentrations at the exposure points are calculated using collected data. In accordance with USEPA's *Supplemental Guidance to RAGS: Calculating the Concentration Term* (USEPA 1992c), the reasonable maximum exposure (RME) point concentration is based on a lognormal distribution and is the 95% UCL on the arithmetic mean, or the MDC in a given medium/data grouping if the calculated 95% UCL is less than 80% of the maximum reported value. This deviation to RAGS is proposed by USEPA Region III to ensure that potential "hot spots" are considered in the RA. Next, chemical exposures are quantified for each receptor population by calculating lifetime average daily doses (LADDs) for exposure to chemical carcinogens and average daily doses (ADDs) for exposure to noncarcinogenic chemicals, following USEPA (1989) guidance. LADDs and ADDs are based on the exposure point concentrations and assumptions regarding the frequency and duration of exposures, and the rate of intake (e.g., amount of soil ingested). In accordance with USEPA (1989) guidance, exposures are quantified assuming a RME scenario. Dermal absorption of chemicals is quantitatively evaluated following USEPA (1992c) guidance for dermal exposure assessment.

6.4 TOXICITY ASSESSMENT

The COPCs are characterized with respect to their toxic effects in humans, and relevant critical toxicity criteria are identified for each chemical. Two types of dose-response toxicity criteria are used for the human health assessment: USEPA-derived cancer slope factors (CSFs) for potentially carcinogenic chemicals; and risk reference doses (RfDs) for chemicals exhibiting noncarcinogenic effects. For carcinogens, the chemicals' weight-of-evidence classifications for human carcinogenicity are provided and discussed. For non-carcinogens, uncertainty factors used in deriving the RfDs are provided, along with toxicity information such as target organs and effects endpoints. The primary source of the toxicity criteria will be USEPA's IRIS and HEAST. If necessary, USEPA Region III and the Environmental Criteria and Assessment Office (ECAO) will also be contacted for toxicological information, as well as for guidance on the evaluation of chemicals that do not have USEPA-published toxicity values.

6.5 RISK CHARACTERIZATION

Potential human health effects are characterized by combining estimated exposures (LADDs and ADDs) with appropriate and available USEPA dose-response criteria. The results of the risk characterization include estimates of the upper-bound individual cancer risk estimates for potential carcinogens and a hazard index for non-carcinogens. The individual lifetime excess cancer risk for a chemical exhibiting carcinogenic effects is calculated by multiplying the upper-bound CSF by the estimated LADD averaged over 70 years. For non-carcinogens, potential adverse effects are calculated by means of a hazard index technique, where the ADD is divided by the RfD, as recommended by USEPA (1989). A hazard index greater than a threshold level of 1.0 triggers a detailed evaluation, in which hazard indices for groups of chemicals affecting similar target organs are calculated. If a target organ-specific hazard index exceeds 1.0, there may be concern for potential health effects (USEPA 1989).

The comparisons of lead levels detected in environmental media at the site to the 400 mg/kg goal (unless directed otherwise) for soil and sediment and the 15 µg/L action level for groundwater and surface water are also presented in the risk characterization section. If either of these levels is exceeded, then a potential for lead hazards is noted.

6.5.1 Uncertainty Analysis

The uncertainties associated with the HHRA are presented with emphasis on the major sources of uncertainty affecting the outcome, including:

- Selection of COPCs;
- Exposure assessments;
- Chemical monitoring data;
- Toxicity estimates;
- Sampling design;
- Explosive assessment; and
- Risk characterization.

7.0 ECOLOGICAL RISK ASSESSMENT

This Section describes the methodologies to be used for conducting an Ecological Risk Assessment (ERA) at SWMUs identified for the RFAAP. The ERA will be conducted in accordance with *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments* (USEPA 1997a). Supporting documents may also include *Proposed Guidelines for Ecological Risk Assessment* (USEPA 1998), and relevant Army guidance.

As described in USEPA (1997a), the overall objective of the ERA is to identify and characterize the current and potential threats to the environment from a hazardous substance release. The ERA process combines a conservative screening-level investigation, which examines and estimates potential ecological threats with, a detailed baseline ERA (if necessary), which focuses on and thoroughly evaluates current and relevant ecological risks. Ultimately, this information can then be used to identify risk management decisions (e.g. cleanup values) that would be protective of natural resources from risk (USEPA 1997a).

The ERA investigation at SWMUs identified for the RFAAP will follow an eight-step process (USEPA 1997a):

Step 1:	Screening-Level Problem Formulation and Ecological Effects Evaluation;
Step 2:	Screening-Level Preliminary Exposure Estimate and Risk Calculation;
Step 3:	Baseline Risk Assessment Problem Formulation;
Step 4:	Study Design and Data Quality Objectives;
Step 5:	Field Verification of Sampling Design;
Step 6:	Site Investigation and Analysis of Exposure and Effects;
Step 7:	Risk Characterization; and
Step 8:	Risk Management.

Steps 1 and 2 in the 8-Step risk assessment process and the refinement step for preliminary COPCs, Step 3a will be completed as part of the screening level ERA. Steps 1 and 2, involve characterizing the environmental setting, identifying known or suspected contaminants, evaluating the transport pathways to ecological receptors, selecting assessment endpoints, and selecting and comparing site data to conservative screening values and/or food-web modeling. Step 3a refines the contaminants of ecological concern (COPCs) identified in Steps 1 and 2. Collectively, these results will assess whether additional ecological risk evaluation is necessary.

The remainder of Step 3 and Steps 4 through 7 include a baseline assessment and evaluation of SWMUs identified during the screening-level assessment which need a detailed risk investigation. Step 3 develops a focused problem formulation by using a refined list of contaminants of ecological concern (COPCs) to refine exposure pathways, the Ecological Conceptual Site Model (ECSM), assessment endpoints, and measurement endpoints. Step 4 involves establishing a study design and data quality objectives (DQO) based on the problem formulation. Step 5 verifies that the sampling plan designed in Step 4 is appropriate and implementable at the site. Step 6 is the implementation of the sampling plan and analysis of the data. Step 7, the Risk Characterization, is conducted following the completion of site investigations and integrates data on exposure and effects with the assessment endpoints established during the problem formulation.

Risk management decisions, in the form of Scientific/Management Decision Points (SMDP), are made throughout the investigation process. SMDPs reflect concurrent discussions with USEPA Region III Biological Technical Assistance Group (BTAG) about the status of the investigation and appropriate next steps. The culmination of the ERA also provides for management decisions and recommendations (made in Step 8) based on the results of the risk characterization.

These eight steps are addressed in more detail throughout this Section.

7.1 SCREENING-LEVEL PROBLEM FORMULATION AND ECOLOGICAL EFFECTS EVALUATION

The screening level problem formulation development is the planning and scoping phase of the ERA process that results in the identification of the ERA objectives and scope, and the characterization of specific ecological resources on or adjacent to the site. In addition to collecting and evaluating historical data, the screening-level problem formulation includes general descriptions of areas of investigation, characterization of site contaminants, contaminant sources, migration routes, and an evaluation of potential routes of contaminant exposure to relevant ecological receptors. Assessment and measurement endpoints are selected during this process.

The following sections provide a description of the major components of the screening-level problem formulation process.

7.1.1 Site Characterization

The objectives of the site characterization are twofold: (1) to identify and characterize the habitats and ecological resources occurring on and around SWMUs at the RFAAP; and (2) to preliminarily describe the nature and extent of chemical contamination at the SWMU being investigated.

A site reconnaissance will be conducted by an ecologist to qualitatively identify and characterize the habitat types at and adjacent to a SWMU. The site characterization may include descriptions of the site setting and adjacent land use, nature and extent of the terrestrial and aquatic habitats, identification of wildlife species occurring, or likely to occur (based on habitat composition) at the SWMU, and examination of pathways between sources of contamination and potential wildlife groups. Information about local terrestrial and aquatic resources will be obtained from maps of the study area, available reports describing the area, state agencies with responsibility for natural resources, and available scientific literature. A search will be conducted of the Natural Heritage database to identify threatened or endangered species and/or critical or protected habitats occurring on or around RFAAP.

7.1.2 Identification of Ecological Chemicals of Potential Concern

The purpose of selecting COPCs is to identify site-related chemicals that have the potential to adversely affect ecological resources. COPCs will be identified by comparison of maximum site concentrations to Region III BTAG screening values and/or by simple food-web modeling for bioaccumulative compounds. It should be noted that BTAG screening values (USEPA, 1995) are for direct contact only. Bioaccumulative compounds (including, but not limited to those as identified in *Bioaccumulative Testing and Interpretation for the Purpose of Sediment Quality Assessment, Status and Needs,* EPA-823-R-00-001, February 2000) found at the site will be considered in the food chain evaluation. Initial screening of analytical data will be conducted using media specific screening values considered protective of wildlife. Chemicals will be selected as COPCs if one of the following conditions are met: if maximum detected concentrations exceed screening values for ecological receptors, if the chemical is non-detect and the detection limit exceeds the screening value, and/or if screening value is not identified. COPCs identified in this step will be carried through to the risk characterization step of the screening level RA, however non-detect COPCs will only be discussed in the Uncertainty Analysis section of the screening level ERA.

As directed by EPA Region III BTAG, Region III Draft BTAG Screening Values will be used to identify COPCs in the screening level ERA despite the following limitations:

- Region III BTAG Screening Values are draft and have not been finalized,
- Derivations/calculations of some of the values are not clearly provided in the document, and
- Updates have not been issued to reflect the increased knowledge base in ecological risk assessment since their compilation in 1995. Consequently, these values do not reflect current advances in risk assessment.

In order to account for these limitations and to ensure that the screening process is adequately conservative but realistic, the Master Work Plan will incorporate values from sources identified in the following paragraph in subsequent steps of the risk assessment and COPC refinement.

Media specific values will be used to better characterize exposure and risk in subsequent steps of the risk assessment. Values will be derived from various Federal and State sources as well as relevant and current scientific literature. Screening values may include sources such as Region III BTAG Screening Values (1995), Federal Standards for Ambient Water Quality Criteria (AWQC), Virginia Criteria for Surface Water (2002), Canadian Environmental Quality Guidelines (Canadian Council of Ministers of the Environment, 2002), , Great Lakes Research Threshold Effect Levels (TEL) (Smith et. al. 1996) for freshwater habitats, USEPA surface soil screening levels (USEPA 2000b), USEPA Region V Ecological Data Quality Levels (EDQL) (USEPA, 1999), and ORNL screening levels for surface water, sediment, and soil (Efroymson et al., 1977, Jones and Suter, 1997, Suter and Tsao, 1996, and Efroymson, Will, and Suter, 1997).

Site-specific metal concentrations will be compared to background concentrations at the end of the risk characterization step, as part of the risk management step. This evaluation will result in the elimination of metals from the risk management process that are not attributable to site-related activities.

It is likely that some of the COPCs retained during the initial screening pose minimal risk to wildlife due to the highly conservative nature of the initial screening process. Therefore, a review of the assumptions used in the initial screening will identify the need for refinement comparisons to more realistic screening values. Chemicals, for which the exceedances of the refined screening values are negligible, may be dropped from the list of COPCs.

7.1.3 Identification of Exposure Pathways and Potential Receptors for Analysis

The potential pathways by which ecological resources may be exposed to the COPCs at a given SWMU will be identified and evaluated along with the ecological receptors that could be affected by these chemicals. Exposure pathways will be identified based on:

1. The source and mechanism of chemical release;
2. The medium (or media) of chemical transport;

3. The area of potential contact by the receptor organism; and

4. The route of exposure at the contact point.

Potential receptors will be identified based on consideration of the available habitat and the type, extent, magnitude, and location of potential chemical contamination.

The development of a preliminary ECSM is important in the identification of exposure pathways, site-specific objectives, and the scope of the screening-level RA. The preliminary ECSM is designed to diagrammatically identify potentially exposed receptor populations and applicable exposure pathways, based on the physical nature of the SWMU and the potential contaminant source areas. A separate ECSM will be developed for each area of investigation because the contaminant source, migration pathways, assessment and measurement endpoint, and exposure pathways are site-specific. However, in appropriate cases, more than one area of investigation can be included in a single ECSM if, for example, there are common exposure and/or migration pathways.

The ECSM may include a number of potential exposure pathways by which terrestrial ecological resources may be exposed to chemicals. For example, terrestrial animals may be exposed by direct contact through ingestion of soil or contaminated food items, and by incidental ingestion from activities such as grooming, foraging, digging, or feeding on items to which soil has adhered. Terrestrial wildlife may also come into contact with contaminants in surface water by drinking or bathing, although these exposure routes represents a negligible portion of total exposure for most receptors. Terrestrial ecological resources may include the following receptor groups:

- Terrestrial plants;
- Terrestrial invertebrates;
- Reptiles and amphibians;
- Invertivorous birds;
- Carnivorous mammals and birds; and
- Herbivorous, invertivorous, and omnivorous mammals.

Aquatic wildlife may be exposed to COPCs through a variety of potential exposure pathways including the ingestion of surface water, the ingestion of food items (e.g. aquatic invertebrates or fish) that have accumulated chemicals, direct contact with media, and the incidental ingestion of sediment while foraging or grooming. Aquatic ecological resources may include the following receptor groups:

- Aquatic plants;
- Benthic invertebrates;
- Fish, reptiles, and amphibians;
- Piscivorous birds; and
- Semi-aquatic mammals.

Relevant and ecologically appropriate receptors will be evaluated in detail based on contaminants fate and transport and receptor life history. For example, owing to the invasive and successive nature of plant communities, plants as site receptors are not always included in a detailed examination of effects. Vegetation communities will be considered as a potential receptor where appropriate.

Toxicity values will be used to evaluate potential constituent effects to birds and mammals. Chemical-specific criteria will be developed in order to estimate the dose of a chemical at which no adverse effects are likely to occur in the selected indicator species based on simple food-web modeling. Where available, dietary No Observed Adverse Effect Levels (NOAELs) will be used to evaluate the potential for adverse effects to wildlife. In the absence of these values, the toxicity values from the scientific literature will be reviewed. If a NOAEL is not available for a chemical, a Lowest Observed Adverse Effect Level (LOAEL) or LC_{50} will be used and uncertainty factors will be applied to estimate a NOAEL as described in the *Standard Practice for Wildlife Toxicity Reference Values,* USACHPPM TG 254 (2000). For interspecies extrapolations, the more refined approach in Wentsel et al. 1996 (Figure 12) will be used.

7.1.4 Identification of Assessment Endpoints and Measurement Endpoints

Assessment endpoints are defined as the ecological effects that drive the decision making process regarding the need for further investigation and/or remediation (Suter 1993). Specific assessment endpoints focus the ERA on protecting parts of the ecosystem that could be negatively affected by COPCs (USEPA 1997a). Measurement endpoints are the methods or means by which the assessment endpoints are approximated or represented (Suter 1993). Measurement endpoints serve as tools for ranking and evaluating environmental values that are to be protected. While declines in populations and shifts in community structure can be quantified, studies of this nature are generally time-consuming and difficult to interpret. However, measurement endpoints indicative of observed effects on individuals are relatively easy to measure in laboratory toxicity studies and can be related to the site-specific assessment endpoint. Assessment endpoints will be discussed with BTAG, and agreed upon, in accordance with the USEPA guidance (USEPA 1997a).

7.1.5 Screening-level Exposure Estimate and Risk Characterization

The concentration and/or dose of the COPCs to which a receptor species could be exposed is identified in the exposure estimate and evaluated in the risk characterization. For each exposure pathway, receptor-specific exposure will be quantified. Exposure point concentrations will be estimated using environmental sampling data either alone or in conjunction with environmental fate and transport models.

The food chain modeling will be performed in accordance with current guidance and use conservative exposure parameter values (maximum ingestion rate, minimum body weight (bw), 100% bioavailability) (USEPA 1997a). The ecological exposure assessment will consist of two phases. The first, most conservative, phase will be based on conservative exposure assumptions such as:

1. Maximum analytical results for each medium of concern used as EPCs; and

2. Site use factor equals one.

The second phase will be based on conservative yet more realistic exposure assumptions such as:

1. The 95% UCL of the mean analytical results for each medium of concern used as EPCs; and

2. Determining a site use factor based on the size of the site, proximity to operational areas and/or sensitive habitats, the quality of habitat present, and behavior of important ecological receptors.

Exposures may be quantified by estimating the total daily dose (in mg/kg bw) for the selected receptors. The specific model used to quantify potential exposures will depend on the specific receptor species and exposure pathways being evaluated. The following exposure model, provides an example of the type of model that would be used to estimate the total daily dose of a chemical that a terrestrial predator would receive from the ingestion of a potential prey item:

$$D_{Food} = C_{Food} * FI$$

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where:

D_{Food} = daily dose from food (mg/kg bw-day),

C_{Food} = chemical concentration in food (mg/kg food), and

FI = ingestion rate (kg food/kg bw-day).

Chemical concentration in a particular food item will be estimated by multiplying bioconcentration factors (BCFs) or bioaccumulation factors (BAFs) (whichever is applicable) obtained from the scientific literature with the chemical concentrations measured in the abiotic media to which the food item is exposed. Factors such as habitat, food preference, and home range as described in the available literature will be used to estimate exposure.

Estimated exposure concentrations for the COPCs will be compared to toxicity reference values (TRVs) by creating a ratio of the estimated exposure concentration to the TRV, which is termed the environmental effects quotient (EEQ). If the EEQ ratio is less than 1.0 (indicating the exposure concentration is less than the TRV) then adverse effects are considered unlikely. If the EEQ ratio is equal to or greater than 1.0, adverse effects may occur. The confidence level of the conclusion increases as the magnitude of the ratio departs from 1.0. For example, there is greater confidence in a risk estimate where the EEQ ratio is 0.1 or 10, than in an EEQ ratio that is closer to 1.0. The potential magnitude of the toxic effect also increases as the EEQ ratio increases above 1.0. Exposures that exceed a selected toxicity value suggest that adverse effects to ecological resources are possible. The potential implications of these exceedances will be discussed in detail.

7.1.6 Screening-Level Results and Conclusions

Steps 1 and 2 in the 8-Step risk assessment process and the refinement step for preliminary COPCs, Step 3a, will be completed as part of the screening-level Risk Assessment. The screening-level ERA will provide exposure estimates based on conservative assumptions and assessments of contaminants and exposure pathways that may pose a risk to ecological receptors. The screening-level ERA will also provide conclusions and recommendations regarding ecological risk at the site. The Risk Assessment group and BTAG will use these data to make ecological risk management decisions concerning each SWMU. The SMDPs reached from the screening-level ERA will include one of the following:

1. There is adequate information to conclude that ecological risks are negligible and therefore there is no need for further action at the SWMU based on ecological risk;
2. The information is not adequate to make a decision at this point and further collection/refinement of data is needed to augment the screening-level ERA; and
3. The information collected and presented indicates that a more thorough assessment is warranted and the risk process will continue into a baseline ERA.

8.0 ENTRY TO RADFORD ARMY AMMUNITION PLANT

The following rules and guidelines are to be used by USACE contractors and the Installation Operating Contractor's subcontractors when performing work on the RFAAP property. As used in this section, "Contractor" refers to USACE contractors and subcontractors, the Installation Operating Contractor's contractors, and lower-tier subcontractors performing work at RFAAP.

8.1 PRE-WORK MEETING

The Pre-work Meeting is conducted by the Safety Department, with a member of Purchasing, the Assigned Engineer or Supervisor, and Contractor's Supervision in attendance. The Pre-work Meeting is held to discuss, in detail, the security and safety requirements expected of the contractor while on RFAAP property. The Pre-work Meeting must be conducted prior to the contractor entering the plant to start work.

A Pre-work Meeting shall include the following elements:

- Review work conditions with the contractor's supervision and ensure contractor employees are also informed by a qualified supervisor of the contractor;
- Ensure that contractor personnel receive a copy of the *Safety, Security and Environmental Rules for Contractors and Subcontractors Handbook* (ATK 2000); ensure that contractor personnel sign the Contractors and Subcontractors Safety Rules form; and forward the forms to the Safety Department; and
- Notify contractor personnel of plant safety, security, fire protection, and engineering standards.

8.2 CONTRACTOR AND SUBCONTRACTOR SAFETY

The purpose of this procedure is to provide basic guidelines governing the safety of contractor personnel while on plant property. Compliance with the Virginia Occupational Safety and Health Administration (VOSHA) criteria is required as a minimum.

The safety of the contractor and his employees rests solely with the contractor who is expected to take steps necessary to establish, administer, and enforce safety rules. The Subcontractor will train personnel to be on site in the requirements of this section. The Subcontractor will adhere strictly to the following safety precautions. In addition, the Subcontractor will assure compliance by lower-tier subcontractors and visitors on the job site. Safety inspectors and engineering personnel will aid in the accident prevention effort by making reviews of area conditions and employee actions on a day-to-day basis.

Contractors and employees of contractors will:

- Enter and leave the plant through the assigned gate;
- Maintain proper identification while on plant property;
- Drive job-related vehicles into the plant's limited area;
- Park personal vehicles in assigned areas;

- Confine themselves to their work site;

  NOTE: If facilities are not available, the contractor must provide office, sanitary, and change house facilities. The location of these facilities, as well as storage locations, must be approved by the Safety Department.

- Smoke in specified areas; and

- Request hot work permits through the Assigned Engineer or Supervisor.

  NOTE: The contractor supervision, once oriented, can provide orientation to their working personnel. A replacement for an existing contractor's supervisor cannot give orientation to his working personnel until he has been given the orientation by the plant's designated Installation's Operating Contractor personnel. This orientation must be done as outlined in this procedure and is applicable to the job supervisor and higher.

8.2.1 Assembly Location

Prior to start of work on plant, an assembly location will be established. In the event of an incident, subcontractor personnel will immediately proceed to the assigned assembly location. Subcontractor's supervision will account for personnel. Problems or questions will be presented to the Installation Operating Contractor engineer. If the incident does not involve the general area of the work site, and there are no problems, work may resume. If the incident does involve the general area of the work site, the subcontractor will report to Security and the Installation Operating Contractor engineer, and then leave the plant.

8.2.2 Explosives

These facilities have been used in the manufacture of various propellants. Propellants are sensitive to heat, spark, and open flame. Residual material may present a fire hazard when exposed to heat, spark, or open flame. The Installation Operating Contractor does not warrant that the areas or buildings are entirely free of propellant contamination and no representation is made that hazardous materials have been removed, nor will the Installation Operating Contractor be liable for damage to persons or property should damage occur as a result of hazardous materials that may not have been removed. The Subcontractor will be held responsible for making these facts known to personnel on site during the performance of this work. In the event suspect material is found, stop work in that area immediately and notify the Installation Operating Contractor's engineer assigned.

8.2.3 Ammonia

Located in the Acid Area of the plant are large quantities of anhydrous ammonia. Ammonia is a colorless gas, which in large quantities is extremely toxic and can be lethal. In case of an ammonia spill, a warning of repeated three short blasts will be sounded on the Powerhouse whistle. If this alert is sounded, take note of your location in relation to the Acid Area and the wind direction. (Wind direction can be ascertained by observing the windsock atop the tower in the Acid Area.) Staying upwind of the Acid Area, proceed to your designated assembly location and account for employees and visitors. Remaining up wind and away from the Acid Area, proceed to the nearest exit from the plant. Prior to exiting the plant, inform Security and the assigned Installation Operating Contractor engineer of your situation. This is necessary for an accounting of personnel on plant. The material safety data sheet (MSDS) for ammonia will be discussed at the Pre-work Meeting and included in the safety information presented to the subcontractor.

8.2.4 Nitric Oxides, Nitrogen Oxides (NO, NO_2)

The Acid Area produces and stores large quantities of nitric acid. In abnormal circumstances these operations can discharge nitric and nitrogen oxides, which are hazardous materials. In the event a yellowish or orange discharge of fumes is observed emanating from the Acid Area and traveling in the direction of your work site, take note of the wind direction. Wind direction can be ascertained by observing the windsock atop the tower in the Acid Area. Staying upwind of the Acid Area and fume cloud, proceed to your designated assembly location or designated alternate assembly location and account for employees and visitors. Remaining upwind and away from the Acid Area and fume cloud, proceed to the nearest exit from the plant. Some effects of over-exposure can be delayed; therefore, exposure will be reported. Prior to exiting plant property, inform Security and the Assigned Engineer of your personnel situation and location. This is necessary for safety and an accounting of personnel on plant. The MSDS for nitric and nitrogen oxides will be discussed at the Pre-work Meeting and will be included in the safety information presented to the subcontractor.

8.3 REPORTING REQUIREMENTS

The subcontractor will report injuries incurred on plant within 24 hours of their occurrence. The subcontractor will provide monthly a copy of the OSHA 200 Log that includes injuries requiring such reporting.

8.3.1 Deficiency Reporting – Installation Operating Contractor's Contractors

A person observing a deficiency has the responsibility to do the following:

- Stop conditions or employee actions that are judged immediately dangerous to life or health;
- Notify the responsible engineer or supervisor immediately; and
- If not available, notify the next highest supervisor.

The responsible Engineer or Supervisor has the responsibility to do the following:

- Together with the person who observed the deficiency, discuss the observed condition or action with contractor supervision, pointing out the violated standard or rule;
- Prepare a memorandum documenting the details of the event and forward it to the contractor no later than the beginning of the next workday; and
- Send copies of the memorandum to the person who observed the deficiency, the Safety Department, and Purchasing.

The Safety Department, Responsible Engineer or Supervisor, and person observing the deficiency have the responsibility to do the following:

- Follow up to ensure corrective action is taken and compliance with the violated standard or rule is maintained.

8.3.2 Deficiency Reporting – USACE Contractors

A person observing a deficiency has the responsibility to do the following:

- Stop conditions or employee actions that are judged immediately dangerous to life or health;
- Immediately contact the Installation Operating Contractor's Safety Manager or Safety Supervisor and relay the facts concerning the observed deficiency; and
- Forward a handwritten memorandum to the Installation Operating Contractor's Safety Department prior to leaving the plant the day of the observation.

The Safety Manager or Supervisor has the responsibility to do the following:

- Inform the USACE Project Manager requests them to ensure corrective action; and
- Follow up to confirm compliance with the violated regulation.

8.4 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

PPE will be worn while on RFAAP property inside the fenced area, unless otherwise specified. At a minimum, personnel are to wear steel-toed boots or conductive shoes, hardhat, and safety glasses. During the Pre-work Meeting or prior to entering the plant, other PPE may be specified and must be worn by personnel.

8.5 UTILITIES

Unless otherwise specified in the Pre-work Meeting, no utilities will be provided to the USACE contractor or the Installation Operating Contractor's subcontractor. It is highly recommended, and in some cases required, that radios or cellular telephones be used to maintain communications.

8.6 HEAVY EQUIPMENT TRANSPORT ON THE NEW RIVER BRIDGE

The following limitations (Table 8-1) have been established to prevent the overloading of the New River Bridge. These limits apply to vehicles or mobile equipment having a gross weight of over 40,000 pounds, but not exceeding 80,000 pounds, or which are over ten feet wide (vehicle or load).

Table 8-2 gives the maximum allowable gross weight for the respective distances between the first and last axle of the vehicle or vehicle combination, measured longitudinally to the nearest foot. Under no conditions will the gross weight of a vehicle exceed 80,000 pounds when carrying cargo that can reasonably be reduced to the allowable weight. Vehicles exceeding the maximum load for the respective axle spacing as set forth in Table 8-2 and carrying cargo that cannot be reduced to the allowable weight shall be authorized by Facilities Engineering to cross the bridge after analysis shows that stresses in the components of the bridge will be within acceptable limits.

If the gross weight of a vehicle is suspected to be over 40,000 pounds, it must be weighed at Building 534, if the vehicle is on the south side of the New River Bridge. If the vehicle is on the Horseshoe side, the weight must be estimated. Generally, vehicles having or requiring a Virginia Department of Transportation Hauling and Moving Permit will require review and approval by Facilities Engineering. Should new maintenance equipment that exceeds the maximum limits be brought on site, the pertinent data (axle weight and spacing) will be submitted to Facilities Engineering and the stresses defined prior to using the New River Bridge.

Table 8-1

Maximum Allowable Loads
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Axle Loads	Pounds
Any one axle	20,000
Tandem axles (at least 40-inch but not more than 96-inch space between axle centers)	34,000
Single Unit (2 axles)	40,000
Single Unit (3 axles)	54,000
Single Unit (4 axles)	*See Table 8-2*
Tractor-Semi-Trailer (3 axles)	60,000
Tractor-Semi-Trailer (4 axles)	74,000
Tractor-Semi-Trailer (5 axles)	80,000
Tractor-Semi-Trailer (6 axles)	80,000
Tractor-Twin Trailers (5 or more axles)	80,000
Other Combinations (5 or more axles)	80,000

Table 8-2
Maximum Allowable Gross Weight
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Distance in Feet Between the First and Last Axles	Maximum Weight in Pounds between the Extremes of Any Two or More Consecutive Axles				
	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles
4	34,000				
5	34,000				
6	34,000				
7	34,000				
8	34,500	34,000			
9	39,000	42,500			
10	40,000	43,500			
11		44,000			
12		45,000	50,000	50,000	
13		45,500	50,500	50,500	
14		46,500	51,500	51,500	
15		47,000	52,000	52,000	
16		48,000	52,500	58,000	
17		48,500	53,500	58,500	
18		49,500	54,000	59,000	
19		50,000	54,500	60,000	
20		51,000	55,500	60,500	66,000
21		51,500	56,000	61,000	66,500
22		52,500	56,500	61,500	67,000
23		53,000	57,500	62,500	68,000
24		54,000	58,000	63,000	68,500
25		54,500	58,500	63,500	69,000
26		55,500	59,500	64,000	69,500
27		56,000	60,000	65,000	70,000
28		57,000	60,500	65,500	71,000
29		57,500	61,500	66,000	71,500
30		58,500	62,000	66,500	72,000
31		59,000	62,500	67,500	72,500
32		60,000	63,500	68,000	73,000
33			64,000	68,500	74,000
34			64,500	69,000	74,500
35			65,500	70,000	75,000
36			66,000	70,500	75,500
37			66,500	71,000	76,000
38			67,500	72,000	77,000
39			68,000	72,500	77,500
40			68,500	73,000	78,000
41			69,500	73,500	78,500

Table 8-2 (continued)
Maximum Allowable Gross Weight
RCRA Facility Investigation Master Work Plan
Radford Army Ammunition Plant, Radford, Virginia

Distance in Feet Between the First and Last Axles	Maximum Weight in Pounds between the Extremes of Any Two or More Consecutive Axles				
	2 Axles	3 Axles	4 Axles	5 Axles	6 Axles
42			70,000	74,000	79,000
43			70,500	75,000	80,000
44			71,500	75,500	
45			72,000	76,000	
46			72,500	76,500	
47			73,500	77,500	
48			74,000	78,000	
49			74,500	78,500	
50			75,500	79,000	
51			76,000	80,000	

8.7 LABORATORIES

Laboratories activities will be conducted in accordance with the established guidelines in the USEPA Directive, *RCRA Corrective Action Plan* (USEPA 1994a). Data will be validated in accordance with current USEPA guidance including *Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganics Analysis* (USEPA 1993b) and *Region III Modifications to National Functional Guidelines for Organic Data Review Multi-media, Multi-concentration (OLM01.0-OLM01.9)* (USEPA 1994c), or the appropriate guidance in effect at the time of investigation. Preliminary specifications for sampling and analysis will be included in the site-specific WP/QAP/HSP, to be submitted prior to the performance of fieldwork. Specifications will include, as a minimum, proposed SW-846 methods or Standard Methods to be employed, detection limits, practical quantitation limits (PQLs), and the identification of the laboratory. Methods and detections will be, as a minimum, those established by guidance from USEPA Region III or as established by Virginia Department of Environmental Quality (VDEQ) approved plans, if applicable.

8.8 INSPECTIONS

The Installation Operating Contractor reserves the right to have representatives on the job site. It is clearly understood and agreed by the contractor and/or subcontractor that the presence of the Installation Operating Contractor's representative will in no way relieve the contractor and/or subcontractor of their responsibility to perform the work. Work performed will be subject to inspection by Installation Operating Contractor's personnel.

8.9 SECURITY

If work must be performed outside the limited area of RFAAP, it is the contractor and/or subcontractor's responsibility to arrange with the Installation Operating Contractor's representative for access to the site. Unless otherwise agreed to in advance, the Installation Operating Contractor's representative will open the gate for access in the morning, twice for lunch, and once in the evening. It is recommended that mobile communication devices be used to contact plant security in the event of an emergency.

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APPENDIX A

STANDARD OPERATING PROCEDURES

Standard Operating Procedures

SOP SERIES	TITLE
10.0	DOCUMENTATION
10.1	Field Logbook
10.2	Surface Water, Groundwater, and Soil/Sediment Field Logbooks
10.3	Boring Logs
10.4	Chain-of-Custody Forms
20.0	SUBSURFACE INVESTIGATION
20.1	Monitoring Well Installation
20.2	Monitoring Well Development
20.3	Well and Boring Abandonment
20.4	Test Pits
20.5	Active Soil Gas Survey
20.6	Ground-Penetrating Radar Surveys
20.7	Resistivity and Electromagnetic Induction Surveys
20.8	Magnetic and Metal Detection Surveys
20.9	Piezometer Installation
20.10	Placement of Dye Detector Holders
20.11	Drilling Methods and Procedures
20.12	Direct Push Groundwater Sampling
30.0	SAMPLING
30.1	Soil Sampling
30.2	Groundwater Sampling
30.3	Surface Water Sampling
30.4	Sediment Sampling with Scoop or Tube Sampler
30.5	Sediment and Benthic Macroinvertebrate Sampling with Eckman Sampler or Ponar Sampler
30.6	Containerized Material
30.7	Sampling Strategies
30.8	VOC Sample Collection Using Sodium Bisulfate Preservation (Low Level) and Methanol Preservation (High Level)
30.9	Collection of Soil Samples By USEPA SW 846 Method 5035 Using Disposable Samplers
30.10	Collection of Wipe Samples
30.11	Lead Check Soil Screening Kit
30.12	Vibracore Deep Sediment Sampling
40.0	FIELD EVALUATION
40.1	Multiparameter Water Quality Monitoring Instrument
40.2	Water Level and Well-Depth Measurements
40.3	Slug Tests
40.4	Water Flow Measurements Using Water Flow Probe
50.0	SAMPLE MANAGEMENT
50.1	Sample Labels
50.2	Sample Packaging
60.0	DATA MANAGEMENT
70.0	INVESTIGATION-DERIVED MATERIAL
70.1	Investigation-Derived Material
80.0	DECONTAMINATION
80.1	Decontamination
90.0	AIR MONITORING EQUIPMENT
90.1	Photoionization Detector (HNu Model PI-101 and HW-101)
90.2	Photoionization Detector (Microtip HL-200)
90.3	Personal Air Sampling Pump (GilAir)

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STANDARD OPERATING PROCEDURE 10.1
FIELD LOGBOOK

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording daily site investigation activities.

Records should contain sufficient information so that anyone can reconstruct the sampling activity without relying on the collector's memory.

2.0 MATERIALS

- Field Logbook;
- Indelible ink pen; and
- Clear tape.

3.0 PROCEDURE

Information pertinent to site investigations will be recorded in a bound logbook. Each page/form will be consecutively numbered, dated, and signed. All entries will be made in indelible ink, and all corrections will consist of line out deletions that are initialed and dated. If only part of a page is used, the remainder of the page should have an "X" drawn across it. At a minimum, entries in the logbook will include but not be limited to the following:

- Project name (cover);
- Name and affiliation of personnel on site;
- Weather conditions;
- General description of the field activity;
- Sample location;
- Sample identification number;
- Time and date of sample collection;
- Specific sample attributes (e.g., sample collection depth flow conditions or matrix);
- Sampling methodology (grab or composite sample);
- Sample preservation, as applicable;
- Analytical request/methods;
- Associated quality assurance/quality control (QA/QC) samples;

- Field measurements/observations, as applicable; and
- Signature and date of personnel responsible for documentation.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program.* EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, DC.

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STANDARD OPERATING PROCEDURE 10.2
SURFACE WATER, GROUNDWATER, AND SOIL/SEDIMENT FIELD LOGBOOKS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording surface water, groundwater, and soil/sediment sampling information, as well as instrument calibration data in field logbooks.

2.0 MATERIAL

- Applicable field logbook (see attached forms); and
- Indelible ink pen.

3.0 PROCEDURE

All information pertinent to surface water, groundwater, or soil/sediment sampling will be recorded in the appropriate logbook. Each page/form of the logbook will be consecutively numbered. All entries will be made with an indelible ink pen. All corrections will consist of line out deletions that are initialed and dated.

3.1 SOIL/SEDIMENT

3.1.1 Field Parameters/Logbook (Form 10.2-a)

1. HIGH CONCENTRATION EXPECTED?: Answer “Yes” or “No.”;
2. HIGH HAZARD?: Answer “Yes” or “No.”;
3. INSTALLATION/SITE: Record the complete name of the installation or site;
4. AREA: Record the area designation of the sample site;
5. INST. NAME: Record the two-letter installation name for Radford Army Ammunition Plant – “RD”;
6. SAMPLE MATRIX CODE: Record the appropriate sample matrix code. Common codes are “SD” for solid - sediment, “SI” for soil - gas, “SL for solid sludge, “SO” for surface other, “SS” for solid – soil, “SW” for surface wipe, “WD” for water – potable, “WG” for water – ground, “WS” water – surface, “WT” – water treated and “WW” water -waste;
7. SITE ID: Record a code up to 20 characters or numbers that is unique to the site;
8. ENV. FIELD SAMPLE IDENTIFIER: Record a code up to 20 characters specific for the sample;
9. DATE: Enter the date the sample was taken;
10. TIME: Enter the time (12-hour or 24-hour clock acceptable as long as internally consistent) the sample was taken;

11. AM PM: Circle "AM" or "PM" to designate morning or afternoon (12-hour clock);
12. SAMPLE PROG: Record "RFI" (RCRA Facility Investigation) or other appropriate sample program;
13. DEPTH (TOP): Record the total depth sampled;
14. DEPTH INTERVAL: Record the intervals at which the plug will be sampled;
15. UNITS: Record the units of depth (feet, meters);
16. SAMPLE MEASUREMENTS: Check the appropriate sampling method;
17. CHK: Check off each container released to a laboratory;
18. ANALYSIS: Record the type of analysis to be performed on each sample container;
19. SAMPLE CONTAINER: Record the sample container type and size;
20. NO.: Record the number of containers;
21. REMARKS: Record any remarks about the sample;
22. TOTAL NUMBER OF CONTAINERS FOR SAMPLE: Record the total number of containers;
23. SITE DESCRIPTION: Describe the location where the sample was collected;
24. SAMPLE FORM: Record the form of the sample (i.e., clay, loam, etc.) using The Unified Soil Classification System (USCS);
25. COLOR: Record the color of the sample as determined from standard Munsell Color Charts;
26. ODOR: Record the odor of the sample or "none";
27. PID: Record the measured PID values or other similar measurement instrument value;
28. UNUSUAL FEATURES: Record anything unusual about the site or sample;
29. WEATHER/TEMPERATURE: Record the weather and temperature; and
30. SAMPLER: Record your name.

3.1.2 Map File Form (refer to form 10.2-c)

1. SITE ID: Record the Site ID from the field parameter form;
2. POINTER: Record the field sample number for the sample being pointed to;
3. DESCRIPTION/MEASUREMENTS: Describe the location where the sample was taken, along with distances to landmarks;
4. SKETCH/DIMENSIONS: Diagram the surroundings and record the distances to landmarks;
5. MAP REFERENCE: Record which U.S.G.S. Quad Map references the site;
6. COORDINATE DEFINITION: Write the compass directions and the X- and Y-coordinates of the map run;
7. COORDINATE SYSTEM: Write "UTM" (Universal Transverse Mercator);
8. SOURCE: Record the 1-digit code representing the Map Reference;
9. ACCURACY: Give units (e.g., write "1-M" for 1 meter);
10. X-COORDINATE: Record the X-coordinate of the sample site location;
11. Y-COORDINATE: Record the Y-coordinate of the sample site location;

12. UNITS: Record the units used to measure the map sections;
13. ELEVATION REFERENCE: Record whether topography was determined from a map or a topographical survey;
14. ELEVATION SOURCE: Record the 1-digit code representing the elevation reference;
15. ACCURACY: Record the accuracy of the map or survey providing the topographical information;
16. ELEVATION: Record the elevation of the sampling site;
17. UNITS: Write the units in which the elevation is recorded; and
18. SAMPLER: Write your name.

3.2 SURFACE WATER

3.2.1 Field Parameter Logbook (Forms 10.2-b and 10.2-c)

1. CAL REF: Record the calibration reference for the pH meter;
2. pH: Record the pH of the sample;
3. TEMP: Record the temperature of the sample in degrees Celsius;
4. COND: Record the conductivity of the water;
5. Description of site and sample conditions (refer to 10.2-b);
6. Map File Form (refer to Section 3.1.2).

3.3 GROUNDWATER (FORMS 10.2- D)

3.3.1 Field Parameter Logbook (Form 10.2.b)

Refer to Section 3.2.1.

3.3.2 Map File and Purging Forms

1. WELL NO. OR ID: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on pages 18-21 of the IRDMIS User's Guide for chemical data entry;
2. SAMPLE NO.: Record the reference number of the sample;
3. WELL/SITE DESCRIPTION: Describe the location where the sample was taken, along with distances to landmarks;
4. X-COORD AND Y-COORD: Record the survey coordinates for the sampling site;
5. ELEV: Record the elevation where the sample was taken;
6. UNITS: Record the units the elevation was recorded in;
7. DATE: Record the date in the form MM/DD/YY;
8. TIME: Record the time, including a designation of AM or PM;
9. AIR TEMP.: Record the air temperature, including a designation of C or F (Celsius or Fahrenheit);
10. WELL DEPTH: Record the depth of the well in feet and inches;
11. CASING HEIGHT: Record the height of the casing in feet and inches;
12. WATER DEPTH: Record the depth (underground) of the water in feet and inches;

13. WELL DIAMETER: Record the diameter of the well in inches;
14. WATER COLUMN HEIGHT: Record the height of the water column in feet and inches;
15. SANDPACK DIAM.: Record the diameter of the sandpack. Generally, this will be the same as the bore diameter;
16. EQUIVALENT VOLUME OF STANDING WATER: Use one of the following equations to determine one equivalent volume (EV);

    1 EV = volume in casing + volume in saturated sandpack. Or:

    $1\ EV = [\pi R_w^2 h_w + 0.30p(R_s^2 - R_w^2)h_s] * (0.0043)$

Where:

R_s = radius of sandpack in inches
R_w = radius of well casing in inches
h_s = height of sandpack in inches
h_w = water depth in inches

$0.0043 = gal/in^3$
and filter pack porosity is assumed as 30%, or

Volume in casing =
$(0.0043\ gal/in^3)(p)(12\ in/ft)(R_c^2)(W_h)$

Where:

R_c = radius of casing in inches, and
W_h = water column height in feet

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Wh)(0.30)

(if Wh is less than the length of the sandpack), or

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Sh)(0.30)

(if Wh is greater than the length of the sandpack).

where:

Rb = radius of the borehole, and
Sh = length of the sandpack.

Show this calculation in the comments section.

1. PUMP RATE: Record pump rate;
2. TOTAL PUMP TIME: Record total purge time and volume;

3. WELL WENT DRY? Write "YES" or "NO";
4. PUMP TIME: Record pump time that made the well go dry;
5. VOLUME REMOVED: Record the volume of water (gal) removed before the well went dry;
6. RECOVERY TIME: Record the time required for the well to refill;
7. PURGE AGAIN?: Answer "YES" or "NO";
8. TOTAL VOL. REMOVED: Record the total volume of water (in gallons) removed from the well;
9. CAL REF.: Record the calibration reference for the pH meter;
10. TIME: Record time started (INITIAL T(0)), 2 times DURING the sampling and the time sampling ended (FINAL);
11. pH: Record the pH at start of sampling (INITIAL), twice DURING the sampling, and at the end of sampling (FINAL);
12. TEMP: Record the water temperature (Celsius) at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
13. COND: Record the conductivity of the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
14. D.O.: Record the dissolved oxygen level in the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
15. TURBIDITY: Record the readings from the turbidity meter (nephelometer) and units at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
16. ORD: Record the oxidation/reduction (RedOx) potential of the water sample at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
17. HEAD SPACE: Record any positive readings from organic vapor meter reading taken in well headspace before sampling;
18. NAPL: Record the presence and thickness of any non-aqueous phase liquids (LNAPL and DNAPL)
19. COMMENTS: Record any pertinent information not already covered in the form; and
20. SIGNATURE: Sign the form.

3.4 FIELD CALIBRATION FORMS (REFER TO FORM 10.2-E)

1. Record time and date of calibration;
2. Record calibration standard reference number;
3. Record meter ID number;
4. Record initial instrument reading, recalibration reading (if necessary), and final calibration reading on appropriate line;
5. Record value of reference standard (as required);
6. COMMENTS: Record any pertinent information not already covered on form; and
7. SIGNATURE: Sign form.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCE

USEPA. 1991. *User's Guide to the Contract Laboratory Program.* EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response, January.

FIELD PARAMETER/LOGBOOK FORM 10.2-a
SOIL AND SEDIMENT SAMPLES

HIGH CONCENTRATION EXPECTED? __________________ HIGH HAZARD?

INSTALLATION/SITE ____ AREA __________________

INST NAME __________ FILE NAME ____

SAMPLE MATRIX CODE ____________ SITE ID ______________
ENV. FIELD SAMPLE IDENTIFIER __________________

DATE (MM/DD/YY) __/__/__ TIME __________ AM PM SAMPLE PROGRAM

DEPTH (TOP) ______ DEPTH INTERVAL _____________ UNIT ____________

SAMPLING METHOD:

SPLIT SPOON __ AUGER __ SHELBY TUBE __ SCOOP __ OTHER

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE______

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION:____

SAMPLE FORM ____________________ COLOR ______________ ODOR ____________
PID (HNu)___________________ UNUSUAL FEATURES_____________________

WEATHER/TEMPERATURE

SAMPLER __________________

FIELD PARAMETER/LOGBOOK FORM 10.2-b
GROUNDWATER AND SURFACE WATER SAMPLES

HIGH CONCENTRATION EXPECTED? ________________ HIGH HAZARD?

INSTALLATION/SITE _____________________ AREA

INST CODE __________ FILE NAME ____________________ SITE TYPE

SITE ID __________________ FIELD SAMPLE NUMBER

DATE (MM/DD/YY) __/__/__ TIME __________ AM PM SAMPLE PROG.

DEPTH (TOP) _________ DEPTH INTERVAL ___________ UNITS

SAMPLING MEASUREMENTS

CAL REF. ____ pH _____ TEMPERATURE °C _____ CONDUCTIVITY _____ REDOX _____

DISSOLVED OXYGEN ____ TURBIDITY _____ OTHER

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE______

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION____

SAMPLING METHOD____________________________________

SAMPLE FORM _________________ COLOR ________ ODOR ________

PID (HNu)_______________________________________

UNUSUAL FEATURES____________________________

WEATHER/TEMPERATURE____ SAMPLER _______________

EXAMPLE MAP FILE LOGBOOK FORM 10.2-c
SURFACE WATER, SOIL, AND SEDIMENT SAMPLES

SITE ID________________________ POINTER__________________

DESCRIPTION/MEASUREMENTS____

SKETCH/DIMENSIONS :

MAP REFERENCE______________________________________

COORDINATE DEFINITION (X is ______________ Y is ___________)

COORDINATE SYSTEM ______________ SOURCE _______________ ACCURACY_________________

X-COORDINATE ___________ Y-COORDINATE ___________ UNITS_________

ELEVATION REFERENCE_______________________________

ELEVATION SOURCE _______________ ACCURACY ______________ELEVATION_________________

UNITS______________

SAMPLER_________

EXAMPLE MAP FILE AND PURGING LOGBOOK FORM 10.2-d
GROUNDWATER SAMPLES

WELL COORD. OR ID ______________________ SAMPLE NO.______________

WELL/SITE DESCRIPTION____

____

X-COORD. _______ Y-COORD. ______________ ELEV. _________ UNITS

DATE ____/____/____ TIME _________________ AIR TEMP.

WELL DEPTH _____________ FT. ______ IN. CASING HT. _____ FT. _____ IN.

WATER DEPTH _______ FT. ______ IN. WELL DIAMETER _________ IN.

WATER COLUMN HEIGHT ________ FT. ______ IN. SANDPACK DIAM. _____ IN.

EQUIVALENT VOLUME OF STANDING WATER _______________ (GAL) (L)

VOLUME OF BAILER _______ (GAL) (L) or PUMP RATE _________ (GPM) (LPM)

TOTAL NO. OF BAILERS (5 EV) _________ or PUMP TIME ________ MIN.

WELL WENT DRY? [Yes] [No] NUM. OF BAILERS ________ or PUMP TIME

VOL. REMOVED ______________ (GAL) (L) RECOVERY TIME

PURGE AGAIN? [Yes] [No] TOTAL VOL. REMOVED ___________ (GAL) (L)

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color / clarity / odor / partic.)
(before)									
(during)									
(during)									
(during									
(after)									

COMMENTS____

SIGNATURE_________________________________

EXAMPLE FIELD CALIBRATION FORM 10.2-e
FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY, ORD, AND DISSOLVED OXYGEN METERS

INITIAL CALIBRATION	FINAL CALIBRATION
DATE:	DATE:
TIME:	TIME:

pH METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

pH STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
7.0			
10.0			
4.0			

CONDUCTIVITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

COND. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

TEMPERATURE METER CALIBRATION

METER ID__________________

TEMP. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
ICE WATER			
BOILING WATER			
OTHER ________			

EXAMPLE FIELD CALIBRATION FORM 10.2-e
FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY, ORD, AND DISSOLVED OXYGEN METERS

TURBIDITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID___________________

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

ORD METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID___________________

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

DISSOLVED OXYGEN METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID___________________

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

COMMENTS____

SIGNATURE___________________________________

STANDARD OPERATING PROCEDURE 10.3
BORING LOGS

1.0 INTRODUCTION

The purpose of this standard operating procedure (SOP) is to describe the methods to be followed for classifying soil and rock, as well as preparing borehole logs and other types of soil reports.

2.0 MATERIALS

The following equipment is required for borehole logging:

- HTRW ENG Form 5056-R and 5056A-R boring log forms;
- Daily inspection report forms;
- Chain-of-custody forms;
- Request for analysis forms;
- ASTM D 2488 classification flow chart;
- Soil and/or Rock color chart (i.e., Munsell®);
- Grain size and roundness chart;
- Graph paper;
- Engineer's scale;
- Previous reports and boring logs;
- Pocketknife or putty knife;
- Hand lens;
- Dilute hydrochloric acid (10% volume);
- Gloves;
- Personal protective clothing and equipment, as described in work plan addenda health and safety plan;
- Photoionization detector or other appropriate monitoring equipment per site-specific health and safety plan; and
- Decontamination supplies (SOP 80.1).

3.0 PROCEDURE

Each boring log should fully describe the subsurface environment and the procedures used to obtain this description.

Boring logs should be prepared in the field on USACE Engineer Form 5056-R and 5056-R. Logs should be recorded in the field directly on the boring log form and not transcribed from a field book.

A "site geologist" should conduct borehole logging and soil/rock identification and description or other professional trained in the identification and description of soil/rock.

3.1 BORING LOG INFORMATION

As appropriate, the following information should be recorded on the boring log during the course of drilling and sampling activities:

- Project information including name, location, and project number;
- Each boring and well should be uniquely numbered and located on a sketch map as part of the log;
- Type of exploration;
- Weather conditions including events that could affect subsurface conditions;
- Dates and times for the start and completion of borings, with notations by depth for crew shifts and individual days;
- Depths/heights in feet and in decimal fractions of feet;
- Descriptions of the drilling equipment including rod size, bit type, pump type, rig manufacturer and model, and drilling personnel;
- Drilling sequence and descriptions of casing and method of installation;
- Description and identification of soils in accordance with ASTM Standard D 2488;
- Descriptions of each intact soil sample for the parameters identified in Section 3.2;
- Descriptions and classification of each non-intact sample (e.g., wash samples, cuttings, auger flight samples) to the extent practicable;
- Description and identification of rock;
- Description of rock (core(s)) for the parameters identified in Section 3.7;
- Scaled graphic sketch of the rock core (included or attached to log) according to the requirements identified in Section 3.7;
- Lithologic boundaries, with notations for estimated boundaries;
- Depth of water first encountered in drilling, with the method of first determination (any distinct water level(s) below the first zone will also be noted);
- Interval by depth for each sample taken, classified, and/or retained, with length of sample recovery and sample type and size (diameter and length);
- Blow counts, hammer weight, and length of fall for driven samplers;

- Rate of rock coring and associated rock quality designation (RQD) for intervals cored;
- Drilling fluid pressures, with driller's comments;
- Total depth of drilling and sampling;
- Drilling fluid losses and gains should be recorded;
- Significant color changes in the drilling fluid returned;
- Soil gas or vapor readings with the interval sampled, with information on instrument used and calibration;
- Depth and description of any in-situ test performed; and
- Description of other field tests conducted on soil and rock samples.

3.2 SOIL PARAMETERS FOR LOGGING

In general, the following soil parameters should be included on the boring log when appropriate:

- Identification per ASTM D 2488 with group symbol;
- Secondary components with estimated percentages per ASTM D 2488;
- Color;
- Plasticity per ASTM D 2488;
- Density of non-cohesive soil or consistency of cohesive soil;
- Moisture condition per ASTM D 2488 (dry, moist, or wet);
- Presence of organic material;
- Cementation and HCL reaction testing per ASTM D 2488;
- Coarse-grained particle description per ASTM D 2488 including angularity, shapes, and color;
- Structure per ASTM D 2488 and orientation;
- Odor; and
- Depositional environment and formation, if known.

ASTM D 2488 categorizes soils into 13 basic groups with distinct geologic and engineering properties based on visual-manual identification procedures. The following steps are required to classify a soil sample:

1. Observe basic properties and characteristics of the soil. These include grain size grading and distribution, and influence of moisture on fine-grained soil.
2. Assign the soil an ASTM D 2488 classification and denote it by the standard group name and symbol.
3. Provide a written description to differentiate between soils in the same group if necessary.

Many soils have characteristics that are not clearly associated with a specific soil group. These soils might be near the borderline between groups, based on particle distribution or plasticity characteristics. In such a case, assigning dual group names and symbols (e.g., GW/GC or ML/CL) might be an appropriate method of describing the soil. The two general types of soils, for which classification is performed, coarse- and fine-grained soils, are discussed in the following sections.

3.3 COURSE-GRAINED SOIL IDENTIFICATION

For soils in the coarse-grained soils group, more than half of the material in the soil matrix will be retained by a No. 200 sieve (75-μm).

1. Coarse-grained soils are identified on the basis of the following:
    a) Grain size and distribution;
    b) Quantity of fine-grained material (i.e., silt and clay as a percentage); and
    c) Character of fine-grained material.
2. The following symbols are used for classification:

Basic Symbols	Modifying Symbols
G = gravel	W = well graded
S = sand	P = poorly graded
	M = with silty fines
	C = with clayey fines

3. The following basic facts apply to coarse-grained soil classification.

- The basic symbol G is used if the estimated percentage of gravel is greater than that for sand. In contrast, the symbol S is used when the estimated percentage of sand is greater than the percentage of gravel.
- Gravel ranges in size from 3-inch to 1/4-inch (No. 4 sieve) diameter. Sand ranges in size from the No. 4 sieve to No. 200 sieve. The Grain Size Scale used by Engineers (ASTM Standards D 422-63 and D 643-78) is the appropriate method to further classify grain size as specified by ASTM D 2488.
- Modifying symbol W indicates good representation of all particle sizes.
- Modifying symbol P indicates that there is an excess or absence of particular sizes.
- The symbol W or P is used only when there are less than 15% fines in a sample.
- Modifying symbol M is used if fines have little or no plasticity (silty).
- Modifying symbol C is used if fines have low to high plasticity (clayey).

Figure 10.03a is a flowchart for identifying coarse-grained soils by ASTM D 2488.

3.4 FINED-GRAINED SOIL IDENTIFICATON

If one-half or more of the material will pass a No. 200 sieve (75 μm), the soil is identified as fine-grained.

1. Fine-grained soils are classified based on dry strength, dilatancy, toughness, and plasticity.
2. Classification of fine-grained soils uses the following symbols:

Basic Symbols

M = silt (non plastic)
C = clay (plastic)
O = organic
Pt = peat

Modifying Symbols

L = low liquid limit (lean)
H = high liquid limit (fat)

3. The following basic facts apply to fine-grained soil classification:
   - The basic symbol M is used if the soil is mostly silt, while the symbol C applies if it consists mostly of clay.
4. Use of symbol O (group name OL/OH) indicates that organic matter is present in an amount sufficient to influence soil properties. The symbol Pt indicates soil that consists mostly of organic material.

- Modifying symbols (L and H) are based on the following hand tests conducted on a soil sample:
  - — Dry strength (crushing resistance).
  - — Dilatancy (reaction to shaking).
  - — Toughness (consistency near plastic limit).
- Soil designated ML has little or no plasticity and can be recognized by slight dry strength, quick dilatency, and slight toughness.
- CL indicates soil with slight to medium plasticity, which can be recognized by medium to high dry strength, very slow dilatancy, and medium toughness.

Criteria for describing dry strength per ASTM D 2488 are as follows:

Description	Criteria
None	Dry sample crumbles into powder with pressure of handling
Low	Dry specimen crumbles into powder with some finger pressure
Medium	Dry specimen breaks into pieces or crumbles with considerable finger pressure
High	Dry specimen cannot be broken with finger pressure but will break into pieces between thumb and a hard surface
Very high	Dry specimen cannot be broken between the thumb and a hard surface stiffness

Criteria for describing dilatancy per ASTM D 2488 are as follows:

None	No visible change in the sample
Slow	Water appears slow on the surface of the sample during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the sample during shaking and disappears quickly upon squeezing

Criteria for describing toughness per ASTM D 2488 are as follows:

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit and the thread and lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit and the thread and lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit and the thread and lump have very high stiffness

Figure 10.03b is a flowchart for identifying fine-grained soils by ASTM D 2488.

3.5 DENSITY AND CONSISTENCY

Relative density for coarse-grained soils and consistency for fine-grained soils can be estimated using standard penetration test blow count data (ASTM D 1586). The number of blows required for each 6 inches of penetration or fraction thereof is recorded. If the sampler is driven less than 18 inches, the number of blows per each complete 6-inch interval and per partial interval is recorded.

For partial increments, the depth of penetration should be recorded to the nearest 1 inch. If the sampler advances below the bottom of the boring under the weight of rods (static) and/or hammer, then this information should be recorded on the log.

The following are some "rule-of-thumb" guidelines for describing the relative density of coarse-grained soils:

Blow Count	Relative Density for Sand
0–4	Very loose
4–10	Loose
10–30	Medium dense
30–50	Dense
>50	Very Dense

The following are some "rule-of-thumb" guidelines for describing the consistency of fine-grained soils:

Blow Count	Consistency for Clays	Description
0–2	Very Soft	Sample sags or slumps under its own weight
2–4	Soft	Sample can be pinched in two between the thumb and forefinger
4–8	Medium Stiff	Sample can be easily imprinted with fingers
8–16	Stiff	Sample can be imprinted only with considerable pressure of fingers
16–32	Very Stiff	Sample can be imprinted very slightly with fingers
>32	Hard	Sample cannot be imprinted with fingers; can be pierced with pencil

3.6 OTHER DESCRIPTIVE INFORMATION

The approximate percentage of gravel, sand, and fines (use a percentage estimation chart) should be recorded per ASTM D 2488 as follows:

Modifiers	Descriptions
Trace	Less than 5%
Few	5%–10%
Little	15%–25%
Some	30%–45%
Mostly	50%–100%

Color/discoloration should be recorded and described using a soil color chart, such as the Munsell® Soil Color Charts. A narrative and numerical description should be given from the color chart, such as Brown 10 YR, 5/3 (Munsell®). Odor should be described if organic or unusual.

Plasticity should be described as follows:

Description	Criteria
Non-plastic	A 1/8-inch thread cannot be rolled at any water content
Low	Thread can barely be rolled and lump cannot be formed when drier than plastic limit.
Medium	Thread is easy to roll; plastic limit can be reached with little effort and lump crumbles when drier than plastic limit.
High	Considerable time is required to reach the plastic limit and lump can be formed without crumbling when drier than plastic limit

Moisture condition should be recorded as dry (absence of moisture), moist (damp but no visible water) or wet (visible free water).

Cementation should be recorded (carbonates or silicates) along with the results of HCL reaction testing. The reaction with HCL should be described as none (no visible reaction), weak (some reaction with slowly forming bubbles) or strong (violent reaction with bubbles forming immediately).

Particle description information for coarse-grained soil should be recorded where appropriate per ASTM D 2488 including maximum particle size, angularity (angular, subangular, subrounded, or rounded), shape (flat, elongated or flat and elongated), and color.

Structure (along with orientation) should be reported using the following ASTM D 2488 descriptions:

Description	Criteria
Stratified	Alternating layers of varying material or color with layers greater than 6 millimeters thick
Laminated	Alternating layers of varying material or color with layers less than 6 millimeters thick
Fissured	Breaks along definite planes of fracture with little resistance
Slickensided	Fracture planes that appear polished or glossy, can be striated
Blocky	Inclusion of small pockets of different soils
Homogeneous	Same color and appearance throughout

3.7 ROCK CORE PARAMETERS FOR LOGGING

In general, the following parameters should be included on the boring log when rock coring is conducted:

- Rock type;
- Formation;
- Modifier denoting variety;
- Bedding/banding characteristics;
- Color;
- Hardness;
- Degree of cementation;
- Texture;
- Structure and orientation;
- Degree of weathering;
- Solution or void conditions;
- Primary and secondary permeability including estimates and rationale; and
- Lost core interval and reason for loss.

A scaled graphic sketch of the core should provided on or attached to the log, denoting by depth, location, orientation, and nature (natural, coring-induced, or for fitting into core box) of all core breaks. Where fractures are too numerous to be shown individually, their location may be drawn as a zone.

The RQD values for each core interval (run) should be calculated and included on the boring log. The method of calculating the RQD is as follows per ASTM D 6032:

RQD = [Σ length of intact core pieces > 100 mm (4-inches)] x 100%/total core length.

3.8 PROCEDURES FOR ROCK CLASSIFICATION

For rock classification record mineralogy, texture, and structural features (e.g., biotite and quartz fine grains, foliated parallel to relict bedding oriented 15 to 20 degrees to core axis, joints coated with iron oxide). Describe the physical characteristics of the rock that are important for engineering considerations such as fracturing (including minimum, maximum, and most common and degree of spacing), hardness, and weathering.

1. The following is to be used as a guide for assessing fracturing:

AEG Fracturing	Spacing
Crushed	up to 0.1 foot
Intense	0.1–0.5 foot
Moderate	0.5 foot–10 feet
Slight	1.0 foot–3.0 feet
Massive	>3.0 feet

2. Record hardness using the following guidelines:

Hardness	Criteria
Soft	Reserved for plastic material
Friable	Easily crumbled by finger pressure
Low	Deeply gouged or carved with pocketknife
Moderate	Readily scratched with knife; scratch leaves heavy trace of dust
Hard	Difficult to scratch with knife; scratch produces little powder and is often faintly visible
Very Hard	Cannot be scratched with knife

3. Describe weathering using the following guidelines:

Weathering	**Decomposition**	**Discoloration**	**Fracture Condition**
Deep	Moderate to complete alteration of minerals feldspars altered to clay, etc.	Deep and thorough	All fractures extensively coated with oxides, carbonates, or clay
Moderate	Slight alteration of minerals, cleavage surface lusterless and stained	Moderate or localized and intense	Thin coatings or stains
Weak	No megascopic alteration of minerals	Slight and intermittent and localized	Few strains on fracture surfaces
Fresh	Unaltered, cleavage, surface glistening		

3.9 PROCEDURE FOR LOGGING REFUSE

The following procedure applies to the logging of subsurface samples composed of various materials in addition to soil as may be collected from a landfill or other waste disposal site.

1. Observe refuse as it is brought up by the hollow stem auger, bucket auger, or backhoe.

2. If necessary, place the refuse in a plastic bag to examine the sample.

3. Record observations according to the following criteria:

   - Composition (by relative volume), e.g., paper, wood, plastic, cloth, cement, or construction debris. Use such terms as "mostly" or "at least half." Do not use percentages;
   - Moisture condition: dry, moist, or wet;
   - State of decomposition: highly decomposed, moderately decomposed, slightly decomposed, etc.;
   - Color: obvious mottling and/or degree of mottling;
   - Texture: spongy, plastic (cohesive), friable;
   - Odor;

- Combustible gas readings (measure down hole and at surface); and
- Miscellaneous: dates of periodicals and newspapers, ability to read printed materials, degree of drilling effort (easy, difficult, and very difficult).

3.10 SUBMITTAL REQUIREMENTS

Each original boring log should be submitted to the Contracting Officer Representative (CRO) after completion of the boring. When a monitoring well will be installed in a boring, the boring log and well installation diagram should be submitted together.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Not applicable.

6.0 REFERENCES

ASTM Standard D 1586–84 (1992). 1992. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 2488-93. 1993. *Standard Practice for Description and Identification of Soils Visual-Manual Procedure).*

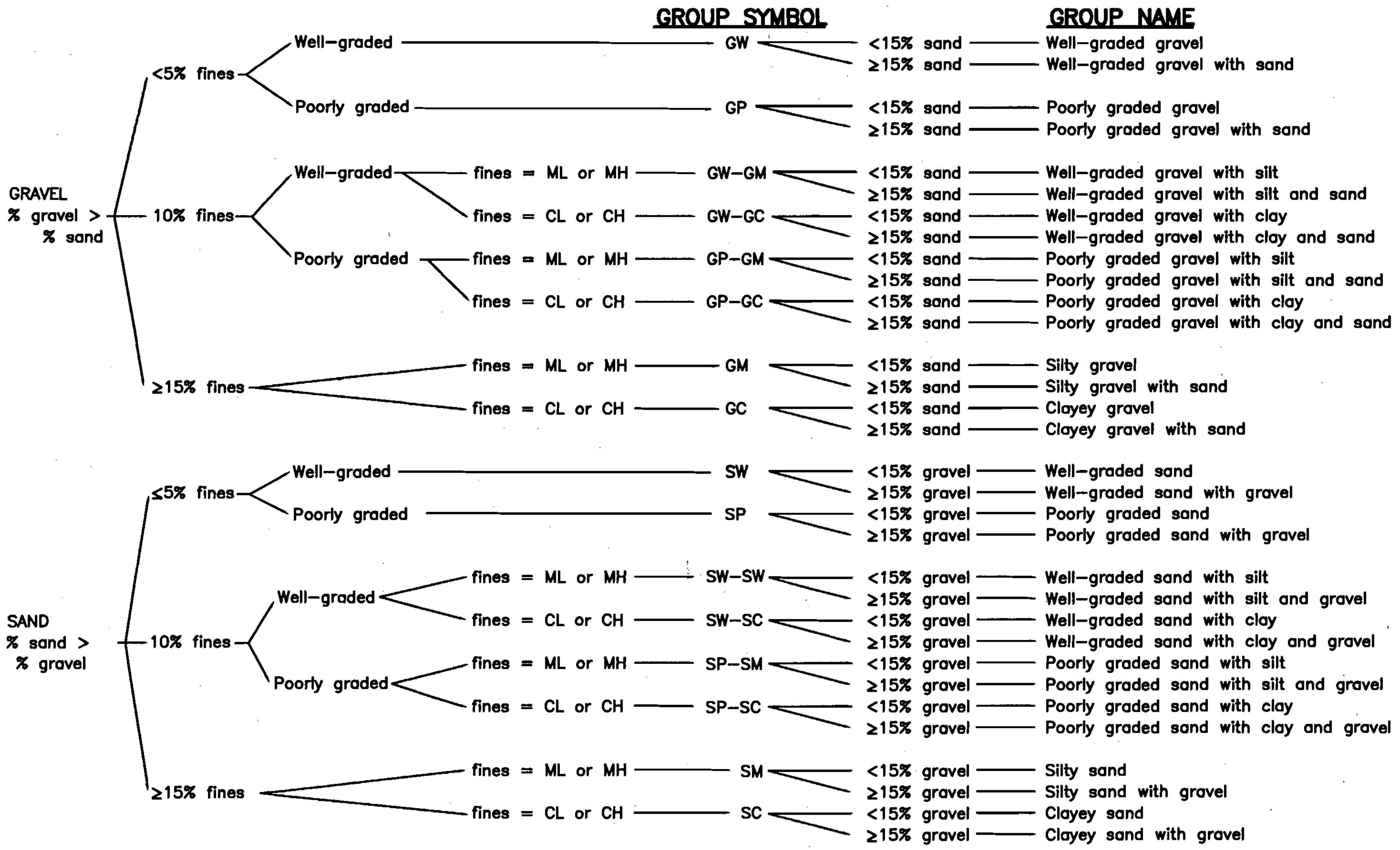
ASTM Standard D 5434-93. 1993. *Guide for Field Logging of Subsurface Explorations of Soil and Rock.*

ASTM Standard D 6032-96. 1996. *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core.*

Compton, R. R. 1962. *Manual of Field Geology.* John Wiley & Sons, Inc., New York.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1, November.

U.S. Department of the Interior. 1989. *Earth Manual.* Water and Power Resources Service, Washington, DC.



NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

SOURCE: ASTM D 2488

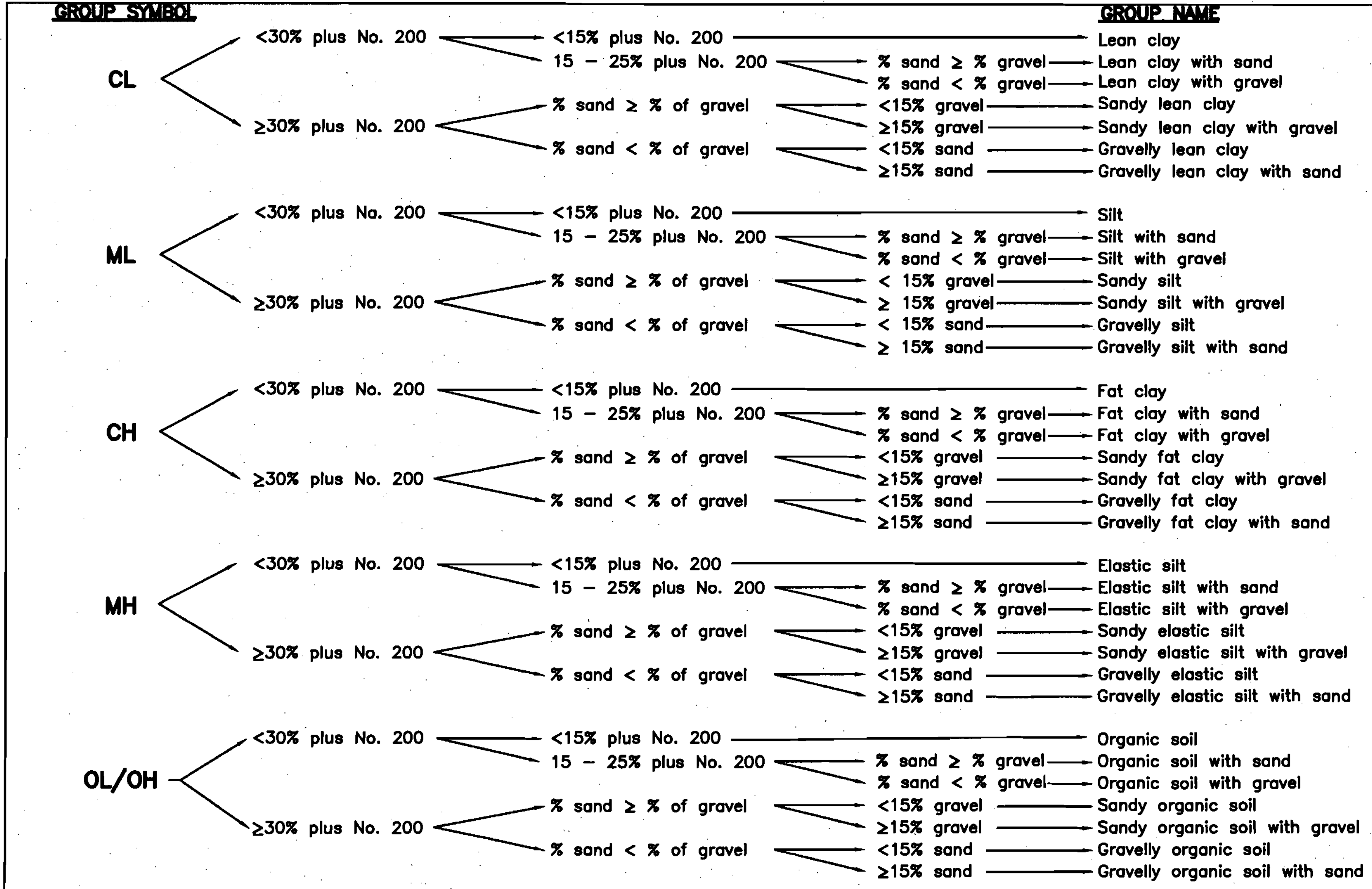
RFAAP

MASTER WORK PLAN

Date: *06/13/01*	**Prepared By:** *URS Corp./DRT*
Scale: *NO SCALE*	**File Name:** *P:\...\Figure XXX.x..*

FIGURE 10.03a

FLOW CHART FOR IDENTIFYING COARSE-GRAINED SOILS



NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

RFAAP
MASTER WORK PLAN

Date: 06/13/01

Prepared By: URS Corp./DRT

Scale: NO SCALE

File Name: P:\...\Figure XXX.x..

FIGURE 10.03b

FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS

SOURCE: ASTM D 2488

STANDARD OPERATING PROCEDURE 10.4
CHAIN-OF-CUSTODY FORM

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for use of the chain-of-custody form. An example is provided as part of this SOP. Other formats with similar levels of detail are acceptable.

2.0 MATERIALS

- Chain-of-custody form; and
- Indelible ink pen.

3.0 PROCEDURE

1. Record the project name and number.
2. Record the project contact's name and phone number.
3. Print sampler's names in "Samplers" block.
4. Enter the Field Sample No.
5. Record the sampling dates for all samples.
6. List the sampling times (military format) for all samples.
7. Indicate, "grab" or "composite" sample with an "X."
8. Record matrix (e.g., aqueous, soil).
9. List the analyses/container volume across top.
10. Enter the total number of containers per Field Sample No. in the "Subtotal" column.
11. Enter total number of containers submitted per analysis requested.
12. State the carrier service and airbill number, analytical laboratory, and custody seal numbers.
13. List any comments or special requests in the "Remarks" section.
14. Sign, date, and time the "Relinquished By" section when the cooler is relinquished to the next party.
15. Upon completion of the form, retain the shipper copy and place the forms and the other copies in a zip seal bag to protect from moisture. Affix the zip seal bag to the inside lid of the sample cooler to be sent to the designated laboratory.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program.* EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, DC, December 1990.

USEPA. 1991. *User's Guide to the Contract Laboratory Program..* EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response, January 1991.

USEPA. 1998. *EPA Requirements for Quality Assurance Project Plans.* EPA/600/R-98/018, QA/R5, Final, Office of Research and Development, Washington, D.C.

FIGURE 10.4-a
EXAMPLE CHAIN-OF-CUSTODY FORM

Project Number	Project Name				Matrix	A	N	A	L	Y	S	E	S		LAB :
Project Contact (Name and Phone Number)															AIRBILL No:
Samplers:															Courier:
Field Sample No.	Date (MM-DD-YY)	Time	Comp	Grab										Subtotal	REMARKS
				TOTAL											

Relinquished by:	Date/time	Received by:	Relinquished by:	Date/Time	Received by:
Relinquished by:	Date/time	Received by: (for lab)	Date/Time	Remarks	

STANDARD OPERATING PROCEDURE 20.1
MONITORING WELL INSTALLATION

1.0 SCOPE AND APPLICATION

The installation of monitoring wells is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to delineate the quality control measures required to ensure the accurate installation of monitoring wells. For a particular site investigation, the associated work plan addenda should be consulted for specific installation instructions. The term “monitoring wells”, as used herein is defined to denote any environmental sampling well.

2.0 MATERIALS

2.1 DRILLING EQUIPMENT

- Appropriately sized drill rig adequately equipped with augers, bits, drill stem, etc;
- Steam cleaner and approved source water for decontamination of drilling equipment, etc.;
- Source of approved water;
- Photoionization detector or other appropriate monitoring instrument per the site-specific Health and Safety plan;
- Water level indicator (electrical);
- Weighted steel tape measure;
- Steel drums and other appropriate containers for investigation-derived materials (drill cuttings, contaminated PPE, decontamination solutions, etc.);
- Absorbent pads and/or logs;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination supplies, pad with heavy plastic sheeting (SOP 80.1).

2.2 WELL INSTALLATION MATERIALS

Technical information on all installed materials (screens, riser pipe, filter pack, bentonite, cement, etc.) and representative samples of the proposed filter pack will be supplied to the Contracting Officer's Representative (COR) before initiating well installation.

Well screen slot size and filter pack gradation will be determined based on existing site geology before initiating site-specific investigations.

- Well screen :

  Polyvinyl Chloride (PVC): JOHNSON (or equivalent); PVC commercially slotted continuous slot, wire wrapped screen; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage or ASTM

Standard Specification F 480 and bear the appropriate rating logo. PVC should be free of ink markings, cleaned, and prepackaged by manufacturer;

Stainless Steel: JOHNSON (or equivalent); stainless steel Vee-Wire continuous slot, wire wrapped screen; 304 stainless steel (unless the sum concentration of Cl^-, F^-, and Br^- is <1000 ppm, case type 316 should be used); ASTM F 480 flush threads; cleaned, wrapped, and heat-sealed by manufacturer;

- Riser pipe:
  - PVC: JOHNSON (or equivalent); STD. PVC; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to NSF Standard 14 or F 480; free of ink markings; cleaned and prepackaged by manufacturer;
  - Stainless Steel: JOHNSON (or equivalent); SCH 5; 304 stainless steel; ASTM type A312 material; 4-in. diameter.; cleaned, wrapped and heat-sealed by manufacturer;
- Plugs/Caps: JOHNSON (or equivalent); standard PVC or stainless steel;
- Filter pack: MORIE, clean sorted gravel (or equivalent);
- Bentonite seal: BAROID, bentonite pellets (3/8-in. diameter.);
- Cement: Type II Portland Cement; if sulfate concentrations are higher than 1500 ppm, Type IV Portland Cement will be used;
- Bentonite powder: BAROID, Aquagel Gold Seal;
- Steel Protective Casing: BRAINARD-KILMAN (or equivalent) zinc-plated steel, lockable, painted;
- Containers for purged water, as required;
- Submersible pump or bailer of appropriate capacity, and surge block sized to fit well;
- Hach DREL 2000 portable laboratory (or equivalent);
- Multiprobe Electronic Water Quality Recorder (Hydrolab);
- Electric well sounder and measuring tape;
- Portland Type II cement (see footnote); and
- Steel Posts (pickets), painted (see footnote).

2.3 DOCUMENTATION

- Copy of work plans and health and safety plan;
- Copy of USACE EM 110-1-4000 Monitoring Well Requirements.;
- Copies of permits (area entry, hot work, well, and utility clearance);
- Boring log forms;
- Well completion diagram form; and
- Field logbook.

2.4 GEOLOGIST'S PERSONAL EQUIPMENT

- Boring log materials per SOP 10.3; and
- Personal protective equipment and clothing (PPE) as required by the site-specific health and safety plan.

3.0 PROCEDURE

3.1 MATERIALS APPROVAL

3.1.1 Source Water

Water sources for drilling, grouting, sealing, filter pack placement, well installation, and equipment decontamination must be approved by the COR before arrival of the drilling equipment. Information required for the water source includes:

- Water source;
- Manufacturer/owner and their address and telephone number;
- Type of treatment and filtration prior to tap;
- Time of access;
- Cost per gallon (if applicable); and
- Dates and results associated with all available chemical analyses over the past 2 years, and the name and address of the analytical laboratory (if applicable).

3.1.2 Bentonite

Pure sodium bentonite with no additives (bentonite) will be the only drilling fluid additive allowed, and its use must be approved by the COR before the arrival of the drilling equipment. The information required for evaluation includes brand name, manufacturer, manufacturer's address and telephone number, product description, and intended use for the product, and potential effects on chemical analysis of water samples.

3.1.3 Granular Filter Pack

Granular filter pack material must be approved by the COR before drilling. A one-pint representative sample must be supplied to the COR. Information required includes lithology, grain size distribution, brand name, source, processing method, and size of intended screen.

3.1.4 Cement

Portland Type II cement will be used for grout (or Type IV, as noted in Section 2.2).

3.2 DRILLING

The objective of the selected drilling technique used at given site is to ensure that the drilling method provides representative data while minimizing subsurface contamination, cross contamination, and drilling costs.

Drilling methods that are appropriate for boring or monitoring well installation will depend on the subsurface geology most likely to be encountered in the boring. The geology for each site should be determined by reviewing previous investigation data (boring data, geophysics, etc.) from the site or nearby areas. Specific drilling methods that will be used to support site activities will be incorporated into work plan addenda.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of monitoring wells at the Radford Army Ammunition Plant (RFAAP) based on the different types of conditions encountered. The different drilling methods discussed in this section of the Master Work Plan including:

- Hollow Stem Auger (for soil);
- Air Rotary (soil and rock);
- Water Rotary and wire-line casing advancement (soil and rock);
- Drill-Through-Casing Driver (soil and rock); and
- Sonic (soil and rock).

3.2.1 Responsibilities of the Site Geologist

A Site Geologist will be present during all well drilling and installation activities and will fully characterize all tasks performed in support of these activities in the monitoring well logbook. The Site Geologist will be responsible for the logging samples, monitoring drilling operations, recording water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures for one operating rig. The Site Geologist will have sufficient equipment in operable condition on-site to perform efficiently his/her duties.

3.2.2 Additives

No lubricants will be used on down hole drilling equipment. Additives containing either lead or copper will not be allowed. In addition, polychlorinated biphenyls will not be permitted in hydraulic fluids or other fluids used in the drilling rig, pumps, or other field equipment and vehicles.

Surface runoff or other fluids will not be allowed to enter any boring or well during or after drilling/construction.

Antifreeze used to keep equipment from freezing will not contain rust inhibitors and sealants. Antifreeze is prohibited in any areas in contact with drilling fluid. Absorbent pillows will be placed to catch any obvious leaks from the drill rig.

3.2.3 Boring Logs and Field Notes

Borings for monitoring wells will be logged by a geologist as described in SOP 10.3. Logs will be recorded on USACE HTRW ENG Form 5056-R and 5056A-R boring log forms.

Daily investigation activities at the site related to drilling should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

3.3 WELL CONSTRUCTION AND INSTALLATION

Specifications for monitoring well construction and installation for a given site being investigated are to be included in work plan addenda. In case the previously defined criteria have not been met before the depth range for a given hole is reached, the geologist will stop the drilling and confer with the supervisor. The current boring conditions (depth, nature of the stratigraphic unit, and water-table depth) will be compared to those of other wells nearby to decide whether to continue drilling or to terminate and complete the well.

3.3.1 Overburden Wells

Overburden wells at the RFAAP are typically designed as a 4-inch diameter, single cased well (see Figure 20-1a) installed into a surficial aquifer, which is present above bedrock. For this type of well, the well boring would be terminated before penetrating any underlying confining unit and/or bedrock.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of overburden wells.

If dense, non-aqueous liquid (DNAPL) is encountered during drilling, the well boring will be terminated and completed at the base of the overburden aquifer being monitored.

3.3.2 Bedrock Wells

Multi-cased wells or wells with an outer casing installed into competent bedrock should be specified for wells that are designed to monitor groundwater within bedrock (see Figure 20-1c). The installation of a multi-cased well or outer casing will isolate the zone(s) monitored from overburden and will minimize the potential for cross-contamination during and after drilling.

The general procedure to be followed for installation of a multi-cased well is as follows. This procedure assumes the installation of a 4-inch diameter monitoring well. Specific procedures, drilling techniques and design of monitoring wells will be presented in work plan addenda for site-specific investigations.

1. If soil sampling is required within overburden, use appropriate drilling techniques to advance the boring and collect the soil samples.

2. A minimum 10-inch drill bit should be advanced from the surface into competent bedrock a distance not less than 2 feet. A drilling technique appropriate for penetrating overburden and bedrock should be used such as air rotary.

3. After the borehole has been advanced to the target depth within competent bedrock, a 6-inch diameter steel or Schedule 80 PVC outer casing should be lowered to the bottom of the boring.

4. Once the outer casing has been lowered to the bottom of the boring, the casing should be grouted in-place using a decontaminated tremie pipe equipped with a side discharge. The annulus between the outer casing and borehole wall will be injected with grout until undiluted grout reaches the surface.

5. The grouting mixture, specification, and placement should be consistent with the requirements identified in Section 3.3.8.

6. The grout should be allowed to cure a minimum of 24 hours before further drilling.

7. After adequate curing time for outer casing, drilling with a 5-5/8-inch bit until the desired total depth is reached should complete the well boring.

8. Once the well boring is completed, an appropriate bedrock well will be constructed based on site-specific conditions. The types of wells that may be installed may include a constructed well with screen, casing, filter pack, seal, and grout; an open-bedrock well; or a lined open bedrock well (see Section 3.3.3).

3.3.3 Well Screen Usage

Well screen usage for a given site should be specified in work plan addenda based on expected site conditions.

In general, wells installed within overburden will be installed with a screen as per Figure 20.01-a or 20.01-b. Bedrock wells may be installed with or without a screen depending on site specific conditions such as the depth of water bearing zones, stability of bedrock, occurrence of karst zones, and construction of existing wells at the site being investigated.

In general, bedrock wells installed within karst zones will be completed as open-hole construction (see Figure 20.01c). If evidence of potential or severe borehole collapse (unstable bedrock) is indicated during drilling, casing and screen will be installed in the borehole as a removable lining. If desired, multiple flow zones may be monitored in an open bedrock well by installing a multiport well, which has monitoring/sampling intervals sealed off from the rest of the boring and from each other by packers.

3.3.4 Beginning Well Installation

Schedule

Monitoring well installation should begin within 12 hours of boring completion for holes that are uncased or partially cased with temporary drill casing. In the case where a partially cased hole into bedrock is to be partially developed prior to well insertion, the well installation should begin within 12 hours of this initial development. For holes that are fully cased, installation should begin within 48 hours. Once begun, well installation should not be interrupted.

Placement of Materials

Temporary casing and hollow stem augers may be removed from the boring prior to well installation if the potential for cross contamination is low and if the borehole will remain stable during the time required for installation.

Where borehole conditions are unstable, some or all of the well materials may need to be installed prior to removal of the temporary casing or hollow stem augers. The casing or hollow stem augers should have an inside diameter sufficient to allow the installation of the screen and casing plus annular space for a pipe through which to place filter pack and grout.

Any materials blocking the bottom of the drill casing or hollow stem auger should be dislodged and removed from the casing prior to well insertion.

3.3.5 Screens, Casing, and Fittings

Borehole Specifications

The borehole for each well should be of sufficient diameter to provide for at least 2 inches of annular space between the borehole wall and all sides of the casing.

Well Screens

Material specifications for well screens, casings, and fittings are discussed in Section 2.2.
Screen bottoms should be securely fitted with a threaded cap or plug of the same composition as the screen. The cap/plug should be within 0.5 feet of the open portion of the screen. A sediment trap/sump will not be used.

Screen slot size will be appropriately sized to retain 90%–100% of the filter pack material, the size of which will be determined by sieve analysis of formation material.

Well screen lengths should be specified in work plan addenda and will be based on various site-specific factors such as environmental setting, subsurface conditions, analytes of concern, regulatory considerations, etc.

Assembly and Placement of Well Screen and Casing

Personnel should take precautions to assure that grease, oil, or other contaminants do not contact any portion of the well screen and casing assembly. Clean latex or nitrile gloves should be worn when handling the screen and casing assembly. Flush, threaded joints usually can be tightened by hand. If necessary, steam cleaned wrenches may be used to tighten joints.

In general, each section of the well assembly is lowered into the borehole, one section at a time, screwing each section securely into the section below it. No grease, lubricant, polytetrafluoroethylene (PTFE) tape, or glue may be used in joining the sections of screen and casing.

The assembly should be lowered to its predetermined level and held in position for placement of the filter pack. It is essential that the assembly be installed straight (with centralizers as appropriate) to allow for appropriate sampling. Buoyant forces associated with fluids in the borehole may require that the assembly be installed with the aid of hydraulic rams of the drill rig. When the well assembly is placed to predetermined level, a temporary cap should be place on the well to prevent foreign material from entering the well.

The bottoms of well screens should be placed no more than 3 feet above the bottom of the drilled borehole. If significant overdrilling is required, a pilot boring should be used. Sufficient filter pack should be placed at the bottom of the borehole

The well casing should be pre-cut (square) to extend 2 to 2.5 feet above the ground surface. Before placement of the last piece of well casing, a notch or other permanent reference point will be cut, filed, or scribed into the top edge of the casing.

The tops of all well casing will be capped with covers composed of materials compatible with the products used in the well installation. Caps will be loose fitting, constructed to preclude binding to the well casing caused by tightness of fit, unclean surfaces, or weather conditions. In either case, it should be secure enough to preclude the introduction of foreign material into the well, yet allow pressure equalization between the well and the atmosphere.

The top of each well casing should be level so that the maximum difference in elevation between the highest and lowest points of the casing is less than or equal to 0.02 ft.

3.3.6 Filter Pack

The volume of filter pack that is required to fill the annular between the well screen/casing and borehole should be computed, measured, and recorded.

Granular filter packs will be chemically and texturally clean, inert, and siliceous. The gradation of filter packs will be selected based on the screen size used and will be specified in the work plan addenda for the site being investigated.

Primary Filter Pack

Filter pack material should be placed in the borehole using a decontaminated tremie pipe. An appropriate amount of primary filter pack should be placed in the borehole prior to final positioning of the well screen to provide an appropriate barrier between the bottom of the borehole and the bottom of the screen. Once the initial filter pack has been placed and the well assembly is appropriately positioned and centered in the borehole, the remaining primary filter pack should be placed in increments (and tamped) as the tremie pipe is gradually raised.

As the primary filter pack is placed, approved source water may need to be added to help move the filter pack. A weighted tape should be used to measure the top of the filter pack as it is being placed. If bridging of the filter pack occurs, then this bridging should be broken mechanically prior to adding additional filter pack.

When temporary casing or hollow stem augers are used, the casing or augers should be removed in increments such that lifting of the well assembly is minimal. After removal of each increment, it should be confirmed by direct measurement that the primary filter pack has not been displaced during the removal.
The primary filter pack should extend from the bottom of the borehole to 3 to 5 ft above the top of the screen.

Secondary Filter Pack

The primary filter pack may be capped with 1 to 2 feet of feet of secondary filter pack to prevent the intrusion of the bentonite seal into the primary filter pack. The need for this filter pack (and specifications) should be addressed in work plan addenda for the site being investigated. Such factors as the gradation of the primary filter pack, the potential for grout extrusion, and site hydrogeology should be considered when evaluating the need for this filter pack.

3.3.7 Bentonite Seal

A bentonite seal, consisting of hydrated 3/8-inch diameter. bentonite pellets, will be installed immediately above the filter pack. The seal may be installed with a tremie pipe, which is lowered to the top of the filter pack and slowly raised as the pellets fill the annular space. In deep wells, the pellets may bridge and block the tremie pipe; in this case, pellets may be placed by free fall into the borehole. A weighted tape should be used to measure the top of seal as it is installed.

When cement grout is to be used above the bentonite seal, a minimum of 3 to 4 hours should be allowed for hydration of the pellets.

When installing a seal above the water table, water should be added to the bentonite for proper hydration. In this case, the seal should be placed in lifts of 0.5 to 1 foot with each lift hydrated for a period of 30 minutes.
If the bentonite seal is to be installed far below the water table, a bentonite slurry seal will be installed. Cement-bentonite grout will not be used below the water table. The slurry will be mechanically blended aboveground to ensure a lump-free mixture. The slurry will consist of bentonite powder and approved water mixed to a minimum 20 percent solids by weight of pumpable slurry with a density of 9.4 pounds per gallon or greater. The slurry will be pumped into place through a tremie pipe and measured as installed.
Bentonite seals should be 3 to 5 ft thick as measured immediately after placement. The final depth to the top of the bentonite seal will be measured and recorded before grouting.

3.3.8 Grout

Cement grout used in construction will be composed of the following:

- Type II Portland Cement (or Type IV as noted in Section 2.2);
- Bentonite (2 to 5% dry bentonite per 94-lb sack of dry cement); and
- A maximum of 6 to 7-gallons of approved water per 94-lb sack of cement

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump before placement. Grout placement should be performed as follows:

1. Grout should be placed from a rigid tremie pipe located just over the top of the bentonite seal. The tremie pipe should be decontaminated prior to use.
2. The tremie pipe should be kept full of grout from start to finish with the discharge end of the pipe completely submerged as it is slowly and continuously lifted.
3. The annulus between the drill casing and well casing should be filled with sufficient grout to allow for the planned drill casing removal. Grout should not penetrate the well screen or filter pack.

- For incremental removal of drill casing, grout should be pumped to maintain at least 10 ft of grout in the drill casing remaining in the borehole after removing the selected length of casing. After each section of casing is removed, the tremie pipe may be reinserted to the base of the casing not yet removed.
- In the case where drill casing will be removed all at once, grout should be pumped from the tremie pipe until undiluted grout flows from the annulus at the ground surface.

4. If the un-grouted portion of a borehole is less than 15 feet and without fluids after drill casing removal, then the un-grouted portion may be filled by pouring grout from the surface.
5. If drill casing was not used for well installation, grouting should proceed to the surface in one continuous operation.
6. For grout placement in a dry and open hole less than 15 ft deep, grout may be manually mixed and poured in from the surface providing that integrity of the bentonite seal is maintained.
7. Protective casing should be installed immediately after completion of grouting.
8. Grout settlement should be checked within 24 hours of the initial grout placement. Additional grout should be added grout should be added to fill any observed depressions.

The following will be noted in the boring logs: (1) exact amounts of cement, bentonite, and water used in mixing grout and (2) actual volume of grout placed in the hole.

3.3.9 Well Protection

The major elements of well protection will include:

- A protective casing;

- Protective concrete pad around the well; and
- Protective steel posts set around the well outside of the concrete pad.

Well Protective Casing

Well protective casings will be installed around all monitoring wells immediately after grouting. The protective casing should consist of a minimum 5-ft long, steel pipe (protective casing) installed over the well casing and into the grout. The protective casing should be installed to a depth of approximately 2.5-feet below ground surface (extending approximately 2.5 feet above ground surface). The internal well casing (riser) and protective casing will not be separated by more than 0.2 feet of height.

An internal mortar collar will be placed within the protective steel casing and outside the well casing to a height of 0.5 above ground surface.

After placement and curing of the mortar collar, an internal drainage hole will be drilled through the protective casing, which is centered no more 1/8 inch above the grout filled annulus between the well riser and the protective casing.

Any annulus formed between the outside of the protective casing and the borehole will be filled to ground surface with cement.

Concrete Pad

After the grout has thoroughly set and the well protective casing has been installed, a protective concrete pad will be installed around the well. This pad will be at least 4 inches thick and 4 feet square and sloped away from the well to provide for adequate drainage.

Protective Posts

Additional protection will be provided at each well location by the installation of four steel posts outside of each corner of the concrete pad. The installation of protective posts should occur before the well is sampled.

The posts should have a minimum diameter of 3 inches, be placed 2 to 3 feet below ground surface, and extend at least 3 feet above ground surface. Posts should be painted orange using a brush.

Posts should be set in post holes, which are backfilled with concrete. For additional protection, the posts can be filled with concrete.

3.3.10 Well Construction Diagram and Field Notes

The construction of each well will be depicted as built in a well construction diagram (see Figure 20.1a). The diagram will be attached to the boring log and the following will be graphically denoted:

- Bottom of boring;
- Screen location, length, and size;
- Coupling locations;
- Granular filter pack;
- Seal;
- Grout;

- Cave-in;
- Centralizers;
- Height of riser;
- Protective casing detail;
- Water level 24 hours after completion with date and time of measurement;
- Quantity and composition of materials used; and
- Material between bottom of boring and bottom of screen.

Daily activities at the site related to monitoring well installation should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.4 GENERAL SEQUENCE OF MONITORING WELL COMPLETION

The following is a general sequence of monitoring well completion with reference to the specific details included in Section 3.3.

1. Completion of borehole;
2. Assembly and placement of well assembly as described in Section 3.3.5;
3. Placement of the appropriate filter pack(s) as discussed in Section 3.3.6;
4. Installation of an appropriate bentonite seal as discussed in Section 3.3.7;
5. Grouting the remaining annular space of the borehole as discussed in Section 3.3.8;
6. Set the protective casing for the well as discussed in Section 3.3.9;
7. Complete the protective concrete pad as discussed in Section 3.3.9; and
8. Install the protective posts as discussed in Section 3.3.9.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

ASTM Standard D 5092-90. 1990. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

ASTM Standard D 5717-95. 1995. *Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured Rock Aquifers.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1, November.

EXAMPLE WELL DEVELOPMENT FORM

WELL DESIGNATION:__________________ DATE(S) OF INSTALLATION:____/____/____

SITE GEOLOGIST:______________________ DEVELOPMENT DATE(S):____/____/____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT *:

BEFORE _____________ DATE ___________ 24 HR. AFTER ___________ DATE___________

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT *:

BEFORE _____________ DATE ___________ 24 HR. AFTER ___________ DATE___________

DEPTH TO WELL BOTTOM *: _________________ SCREEN LENGTH ______________

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: ___________________

QUANTITY OF MUD/WATER:

LOST DURING DRILLING (+)____________________gallons

REMOVED PRIOR TO WELL INSERTION (-)____________________gallons

LOST DURING THICK FLUID DISPLACEMENT (+)____________________gallons

ADDED DURING FILTER PACK PLACEMENT (+)____________________gallons

TOTAL LOSSES ____________________gallons

(a) Water column ht. (ft.) _____________ (b) Well radius (in.)____________

(c) Screen length (ft.) _____________ (d) Borehole radius (in.)____________

(e) QUANTITY OF FLUID STANDING IN WELL
Install Equation Editor and double-click here to view equation. 1 _________ gallons
(Show Calculation)

(f) QUANTITY OF FLUID IN ANNULUS Install Equation Editor and double-click here to view equation. 1_________gallons
(Show Calculation)

DEVELOPMENT VOLUME = (5 * TOTAL LOSSES) + [5 * (e + f)] = _____________ gallons
(Show Calculation)

*** ALL DEPTHS MEASURED FROM TOP OF WELL CASING**

EXAMPLE WELL DEVELOPMENT RECORD

WELL DESIGNATION ______________ DATE(S) OF DEVELOPMENT: _____/_____/_____

TYPE AND SIZE OF PUMP: ______________________________

TYPE AND SIZE OF BAILER: ______________________________

DESCRIPTION OF SURGE TECHNIQUE: ______________________________

____

____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/ odor/partic.)
(before)									
(during)									
(during)									
(during									
(after)									

TYPICAL PUMPING RATE________ GAL./HR. EST. RECHARGE RATE______________

TOTAL QUANTITY OF WATER REMOVED_________ TIME REQUIRED______________

REMARKS______________________________

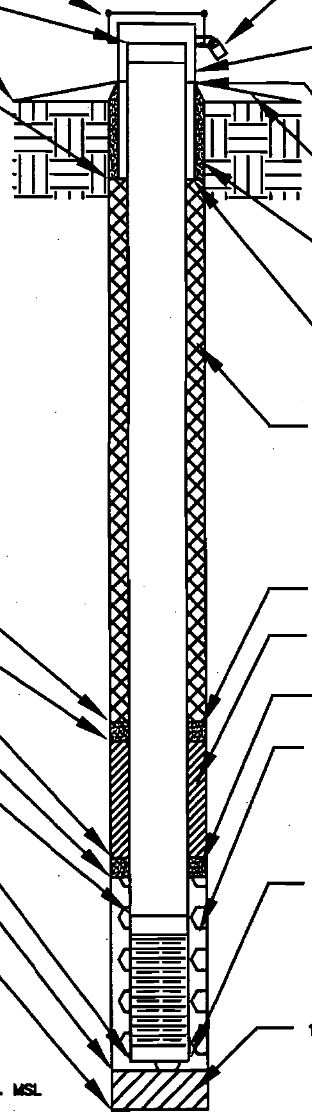
____

____

SIGNATURE OF SITE GEOLOGIST______________________________

Facility/Project Name	Local Grid Location of Well ______m. ☐N. ☐S. ______m. ☐E. ☐W.	Well Number
Facility License, Permit or Monitoring Number	Grid Origin Location Lat.___ ___ ___ Long ___ ___ ___ or St. Plane ________m. N.________m. E.	Date Well Installed (Start)
Type of Protective Cover: Above—Ground ☐ Flush—To—Ground ☐	Section Location of Waste/Source ____1/4 of____1/4 of Sec.____T.____N.R____ ☐E. ☐W.	Date Well Installed (Completed)
Well Distance From Waste/Source Boundary	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	Well Installed By: (Person's Name & Firm) ________________ ________________
Maximum Depth of Frost Penetration (estimated)		

Note: Use top of casing (TOC) for all depth measurments.



A. Protective casing, top elevation ________m. MSL

B. Well casing, Top elevation ________m. MSL

C. Land surface elevation ________m. MSL

D. Surface seal, bottom______m. TOC or______m. MSL

16. USCS classification of soil near screen:
GP ☐ GM☐ GC ☐ GW☐ SW☐ SP☐
SM ☐ SC☐ ML ☐ MH☐ CL ☐ CH☐
Bedrock ☐

17. Sieve analysis attached? ☐ Yes ☐ No

18. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
________________ Other ☐

19. Drilling fluid used Water ☐ Air ☐
Drilling mud ☐ None ☐

20. Drilling additives used? ☐ Yes ☐ No
Describe ________________

21. Source of water (attach analysis):
____

E. Secondary filter, top______m. TOC or______m. MSL

F. Bentonite seal, top ______m. TOC or______m. MSL

G. Secondary filter, top______m. TOC or______m. MSL

H. Primary filter, top ______m. TOC or______m. MSL

I. Screen joint ______m. TOC or______m. MSL

J. Well bottom ______m. TOC or______m. MSL

K. Filter pack, bottom______m. TOC______m. MSL

L. Borehole, bottom______m. TOC or______m. MSL

M. Borehole, diameter________mm.

N. O.D. well casing ________mm.

O. I.D. well casing ________mm.

P. 24—hr water level after completion______m. TOC or______m. MSL

1. Cap and Lock? ☐ Yes ☐ No

2. Protective posts? ☐ Yes ☐ No

3. Protective casing:
a. Inside diameter: ________mm.
b. Length: ________m.

4. Drainage port(s) ☐ Yes ☐ No

5. Surface seal: Gravel blanket ☐
a. Cap Bentonite ☐
Concrete ☐
________________ Other ☐

b. Annular space seal: Bentonite ☐
Cement ☐
________________ Other ☐

6. Material between well casing and protective casing: Bentonite ☐
Cement ☐
________________ Other ☐

7. Annular space seal: A. Granular Bentonite ☐
b. ______Lbs/gal mud weight........Bentonite—sand slurry ☐
c. ______Lbs/gal mud weight..................Bentonite slurry ☐
d. ______x Bentonite..................Bentonite—cement grout ☐
e. ____________m^3 volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☐
Gravity ☐

8. Centralizers ☐ Yes ☐ No

9. Secondary Filter ☐ Yes ☐ No
a. Volume added ________m^3 ____________ Bags/Size

10. Bentonite seal: a. Bentonite granules ☐
b. 1/4in. 3/8in. 1/2in. Bentonite pellets ☐
c. ________________ Other ☐

11 Secondary Filter ☐ Yes ☐ No
a. Volume added________ m^3 ____________ Bags/Size

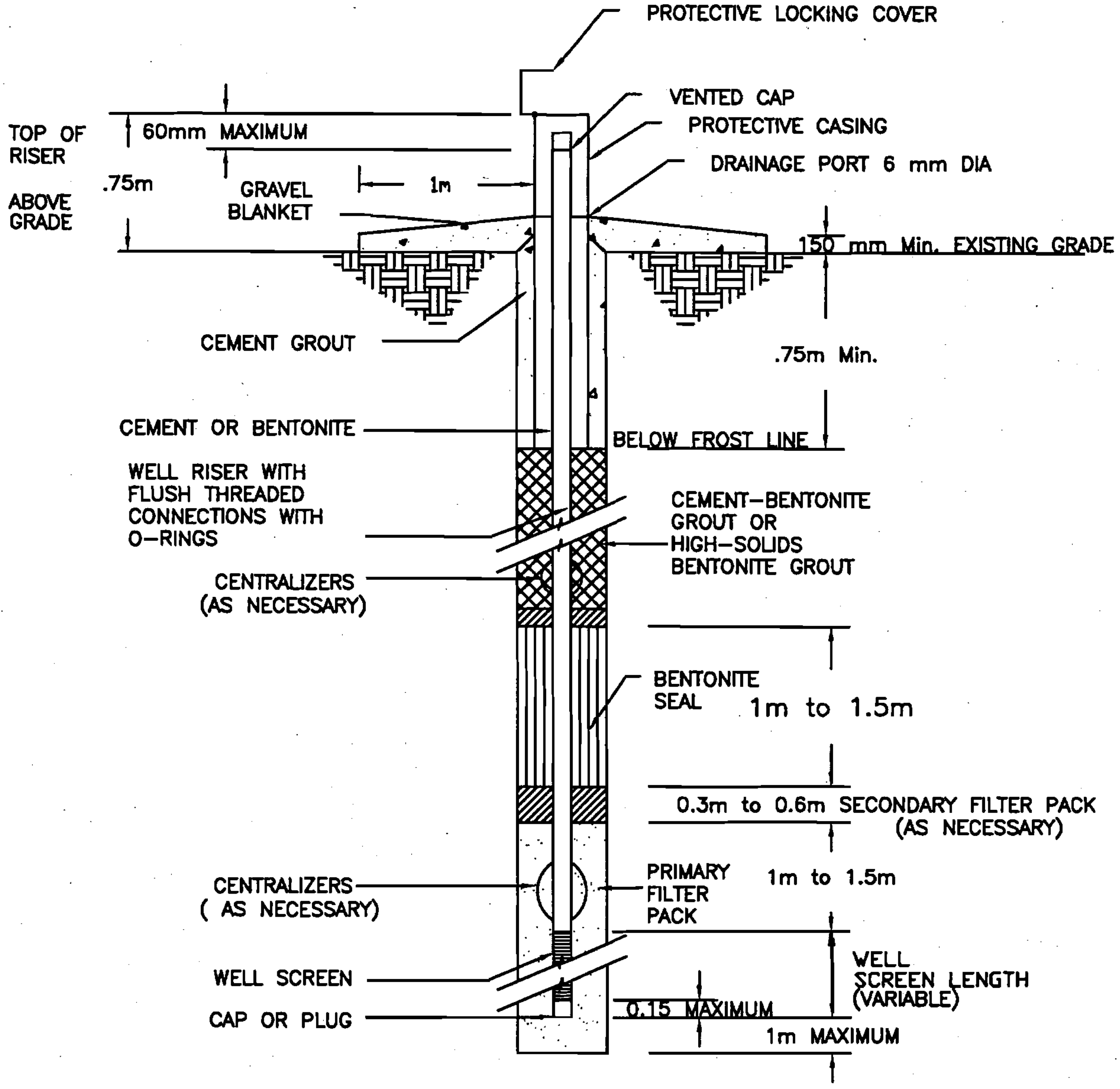
12. Filter pack material: Manufacturer, product name & mesh size
a.
b. Volume added________m^3 ____________ Bags/Size

13. Well casing: Flush threaded PVC schedule 40 ☐
Flush threaded PVC schedule 80 ☐
________________ Other ☐

14. Screen material:
a. Screen type: Factory cut ☐
Continous slot ☐
________________ Other ☐
b. Manufacturer
c. Slot size: 0.________in.
d. Slotted length: ________in.

15. Backfill material (below filter pack): None ☐
________________ Other ☐

RFAAP **MASTER WORK PLAN**		**FIGURE 20-1a**
Date: *06/27/01*	**Prepared By:** *URS Corp./TAC*	**SCHEMATIC CONSTRUCTION DIAGRAM OF MONITORING WELL**
Scale: *NO SCALE*	**File Name:** *P:\...\Figure XXX.x..*	



RFAAP

MASTER WORK PLAN

Date: 06/29/01

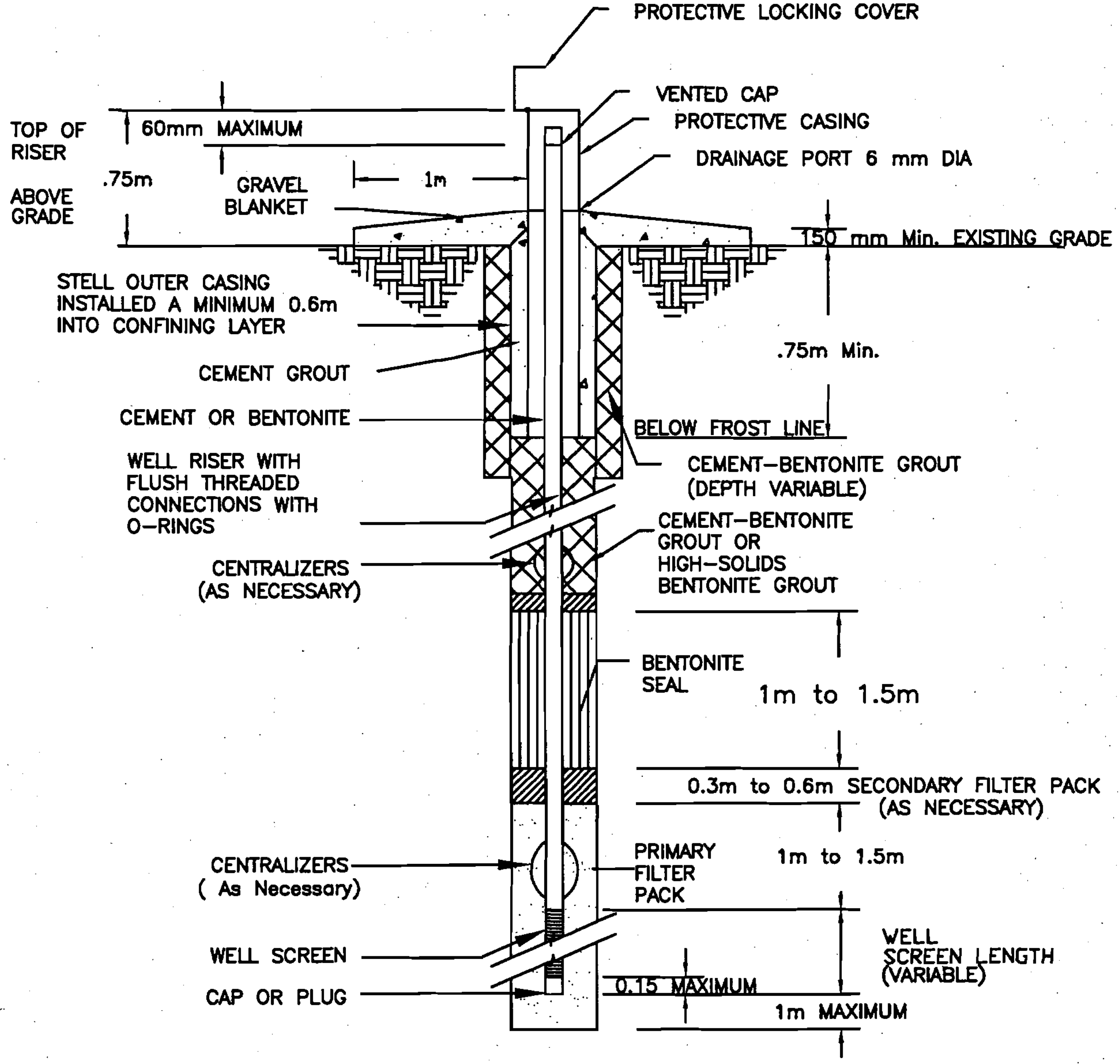
Prepared By: URS Corp./TAC

Scale: NO SCALE

File Name: P:\...\Figure 20-1b

FIGURE 20-1b

SCHEMATIC CONSTRUCTION OF SINGLE-CASED WELL WITH GRAVEL BLANKET



RFAAP **MASTER WORK PLAN**		**FIGURE 20-1c**
Date: *06/29/01*	**Prepared By:** *URS Corp./TAC*	**SCHEMATIC CONSTRUCTION OF MULTI-CASED WELL WITH CONCRETE PAD**
Scale: *NO SCALE*	**File Name:** *P:\...\Figure XXX.x..*	

STANDARD OPERATING PROCEDURE 20.2
MONITORING WELL DEVELOPMENT

1.0 SCOPE AND APPLICATION

Well development is the process by which drilling fluids, solids, and other mobile particulates within the vicinity of the newly installed monitoring well are removed, while ensuring proper hydraulic connection to the aquifer. Development stabilizes the formation and filter pack sands around the well screen to ensure aquifer water moves freely to the well.

Well development will be initiated not less than 48 consecutive hours but no longer than 7 calendar days following grouting and/or placement of surface protection.

2.0 MATERIALS

- Work Plans;
- Well Development Form;
- Field Logbook;
- Boring Log and Well Completion Diagram for the well;
- Submersible pump, control box, associated equipment, etc;
- Photoionization detector or other appropriate monitoring instrument as specified in site-specific health and safety plan;
- Personal protective equipment and clothing (PPE) as specified in site-specific health and safety plan;
- Flow-through-cell and probes measuring specific conductance, pH, temperature, oxidation/reduction potential, dissolved oxygen, and turbidity;
- Decontamination supplies (SOP 80.1);
- Electric well level indicator and measuring tape;
- Appropriate containers for purged water and other investigation-derived material, as required; and
- Drilling tools for reverse-air circulation development, as appropriate.

3.0 PROCEDURE

3.1 SELECTING METHOD OF DEVELOPMENT

The type of subsurface conditions encountered should determine the method of well development used at a particular site at the Radford Army Ammunition Plant (RFAAP).

When monitoring wells are installed within overburden material, fractured bedrock or karst aquifers producing little sediment, a combination of mechanical surging and pumping (over pumping) or bailing is generally appropriate for well development. In general, over-pumping is the method of pumping the well at a rate higher than recharge occurs. Moving a tight-fitting surge block along the inside of the well screen to create a vacuum completes surging.

When monitoring wells are installed with solution features containing excessive amounts of sediment, reverse-circulation airlifting should be used as the initial step of development. Because reverse-circulation tools airlift methods avoid forcibly exposing the annular space to air, reverse-circulation tools can be run throughout the entire water column in the wells being developed.

After the excessive sediment has been removed by reverse-circulation airlifting, conventional pumping techniques may be used as appropriate to complete the well development.

3.2 DEVELOPMENT AND SAMPLING TIMING

Final development of monitoring wells should not be initiated any sooner than 48 hours after or more than 7 days beyond the final grouting of the well. Pre-development or preliminary development may be initiated before this 48-hour minimum period. Preliminary development may be conducted for open wells or for screened wells after installation of the well screen, casing, and filter pack but before installation of the annular seal. Pre-development is recommended when the natural formation will be used as a filter pack. Well development should be completed at least 14 days prior to sampling.

3.3 SUMMARY OF PROCEDURES

In general, the following procedure should be followed when developing a well using the pump and surge technique:

1. Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
2. Calibrate water quality meters (refer to SOP 40.1).
3. Determine the depth to water and total depth of well (refer to SOP 40.2).
4. Calculate the equivalent volume (EV) of water in well to be developed (refer to SOP 30.2).
5. Pump or bail the well to ensure that water flows into it and to remove some of the fine materials from the well. Removal of a minimum of one EV is recommended at this point. The rate of removal should be high enough to stress the well by lowering the water level to approximately one-half its original level.
6. Remove pump or bailer, slowly lower a close-fitting surge block into the well until it rests below the static water level but above the screened interval. (NOTE: The latter is not required in the case of an LNAPL well.)
7. Begin a gentle surging motion along top on-third length of the screen, which will allow any material blocking the screen to break up, go into suspension, and move into the well. Note that development should always begin above or at the top of the screen and move progressively downward to prevent the surge block from becoming sand locked in the well casing. Continue surging for 5-10 minutes, remove surge block, and pump or bail the well, rapidly removing at least one EV.
8. Repeat previous step at successively lower levels within the well screen, until the bottom of the well is reached. As development progresses, successive surging can be more vigorous and of longer duration as long as the amount of sediment in the screen is kept to a minimum.
9. Development should continue until the well development criteria listed in Section 3.1.3 have been achieved.

10. All water removed must be managed as directed by the site investigation plan.

3.3.1 Well Development Criteria

In general, well development should proceed until the following criteria are met:

1. At a minimum, removal of three EV of water from the well.
2. Removal of three times of the amount of fluid (mud and/or water) lost during drilling.
3. Removal of three times the fluid used for well installation.
4. The following indicator parameters should be stabilized as indicated by three successive readings within:
   - ± 0.2 for pH;
   - ±3% for specific conductance;
   - ±10 mV for oxidation/reduction potential;
   - ± 1 degree Celsius for temperature; and
   - ±10% for turbidity and dissolved oxygen (except for wells installed in karst aquifers).
5. Well water is clear to the unaided eye (except for wells installed in karst aquifers).
6. The sediment thickness remaining within the well is less than one percent of the screen length or less than 0.1 ft for screens equal to or less than 10 feet.
7. Site specific factors should be evaluated to determine appropriate well development criteria have been if:
   - Well recharge is so slow that the required volume of water cannot be removed during 48 consecutive hours of development;
   - Water discoloration persists after the required volumetric development; and
   - Excessive sediment remains after the required volumetric development.

3.4 WELL DEVELOPMENT RECORD

Record all data as required on a Well Development Record Form (see example), which becomes a part of the complete Well Record. These data include the following:

- Project name, location;
- Well designation, location;
- Date(s) and time(s) of well installation;
- Static water level from top of well casing before and 24 hours after development;
- Depths and dimensions of the well, the casing, and the screen, obtained from the Well Diagram;
- Water losses and uses during drilling, obtained from the boring log for the well;
- Water contained in the well, obtained from calculations using the depth of the water column and the well radius, plus the radius and height of the filter pack and an assumed 30% porosity;
- Measurements of the following indicator parameters: pH, conductivity, oxidation/reduction potential, temperature, and turbidity before and after development and once during each EV;

- Notes on characteristics of the development water;
- Data on the equipment and technique used for development; and
- Estimated recharge rate and rate/quantity of water removal during development.

Well development records shall be submitted to the COR after the development has been completed.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addendum for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

Aller, Linda, et al. 1989. *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.* National Water Well Association.

EPA Groundwater Handbook. 1989.

Nielsen, David M. 1993. *Correct Well Design Improves Monitoring,* in "Environmental Protection," Vol. 4, No.7, July, 1993.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1 November.

ASTM Standard D 5092-90. 1990. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

ASTM Standard D 5717-95. 1995. *Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured Rock Aquifers.*

EXAMPLE WELL DEVELOPMENT FORM

WELL DESIGNATION:________________ DATE(S) OF INSTALLATION:____/____/____

SITE GEOLOGIST:____________________ DEVELOPMENT DATE(S):____/____/____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT :

BEFORE ____________ DATE __________ 24 HR. AFTER __________ DATE__________

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT * :

BEFORE ____________ DATE __________ 24 HR. AFTER __________ DATE__________

DEPTH TO WELL BOTTOM *: ______________ SCREEN LENGTH _____________

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: ________________

QUANTITY OF MUD/WATER:

LOST DURING DRILLING	(+)________________	gallons
REMOVED PRIOR TO WELL INSERTION	(-)________________	gallons
LOST DURING THICK FLUID DISPLACEMENT	(+)________________	gallons
ADDED DURING FILTER PACK PLACEMENT	(+)________________	gallons
TOTAL LOSSES	________________	gallons

(a) Water column ht. (ft.) ____________ (b) Well radius (in.)__________

(c) Screen length (ft.) ____________ (d) Borehole radius (in.)__________

(e) QUANTITY OF FLUID STANDING IN WELL

Install Equation Editor and double-click here to view equation. 1 ________ gallons
(Show Calculation)

(f) QUANTITY OF FLUID IN ANNULUS Install Equation Editor and double-click here to view equation. 1________gallons
(Show Calculation)

DEVELOPMENT VOLUME = (3 * TOTAL LOSSES) + [5 * (e + f)] = ____________ gallons
(Show Calculation)

* ALL DEPTHS MEASURED FROM TOP OF WELL CASING

EXAMPLE WELL DEVELOPMENT RECORD

WELL DESIGNATION ______________ DATE(S) OF DEVELOPMENT: ____/____/____

TYPE AND SIZE OF PUMP:________________________________

TYPE AND SIZE OF BAILER:________________________________

DESCRIPTION OF SURGE TECHNIQUE:________________________________

____

____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/ odor/partic.)
(before)									
(during)									
(during)									
(during									
(after)									

TYPICAL PUMPING RATE________ GAL./HR. EST. RECHARGE RATE________________

TOTAL QUANTITY OF WATER REMOVED_________ TIME REQUIRED_______________

REMARKS________________________________

____

____

SIGNATURE OF SITE GEOLOGIST________________________________

STANDARD OPERATING PROCEDURE 20.3
WELL AND BORING ABANDONMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to establish the protocols by which all borings and wells will be abandoned. The primary objective of boring or well abandonment activities is to permanently abandon the boring or well so that the natural migration of groundwater or soil vapor is not significantly influenced.

2.0 MATERIALS

- Well abandonment equipment including appropriate grout mixing/placement equipment, and heavy equipment as appropriate (drill rig, crane, backhoe, etc.);
- Pure sodium bentonite powder with no additives (bentonite);
- Bentonite pellets (seal);
- Cement (Portland Type II); and
- Approved source water.

3.0 PROCEDURE

The volume of grout required for borehole or well abandonment should be calculated prior to proceeding with abandonment. These calculations should consider loss of material to the formation, changes in borehole diameter, potential zones of washout, and shrinkage of material. Calculations should be recorded on an abandonment record (see Section 3.1.4).

In general, cement grout should be used for boring and well abandonment per the specifications in Section 3.1 and procedures identified in the following sections. Specialized narrow diameter soil borings (3-inches or less) associated with direct push methods or hand augers may be abandoned using bentonite pellets or chips (see Section 3.5).

Any replacement borings or wells associated with the abandonment should be offset at least 20 feet from any abandoned site in a presumed up- or cross-gradient direction.

3.1 GROUT

Grout used in construction will be composed by weight of the following:

- Type II Portland cement (Type IV Portland Cement if sulfate concentrations are greater than 1,500 ppm);
- Bentonite (2 to 5% dry bentonite per 94-lb sack of dry cement); and
- A maximum of 6 to 7 gallons of approved water per 94-lb sack of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump before placement.

Grout placement will be performed using a commercially available grout pump and a rigid tremie pipe. Removal and grouting will be accomplished in stages, aquifer by aquifer, sealing the boring from the bottom to ground surface. This will be accomplished by placing a grout pipe to the bottom and pumping grout through the pipe until undiluted grout reaches the bottom of the next higher section of casing or, for the top-most section, until grout flows from the boring at ground surface.

After 24 hours, the abandoned drilling site will be checked for grout settlement. Any settlement will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at the ground surface.

3.2 BORINGS

The term "borings" as used in this SOP applies to any drilled hole made that is not completed as a well. This includes soil test borings, soil sampling borings, and deep stratigraphic borings. Whether completed to the planned depth or aborted for any reason before reaching that depth, borings will be grouted and will be normally closed within 12 hours.

To achieve an effective seal, the borehole to be abandoned should be free of debris and foreign matter that may restrict the adhesion of the grout to the borehole wall. Borehole flushing with a tremie pipe may be required to remove such materials prior to grouting.

Each boring to be abandoned should be sealed by grouting from the bottom of the boring to the ground surface. This will be accomplished by placing a tremie pipe to the bottom of the borehole and pumping grout through the pipe at a steady rate. The grouting should be completed slowly and continuously to prevent channeling of material. The tremie pipe should be raised when pumping pressure increases significantly or when undiluted grout reaches the surface.

After 24 hours of completing the abandonment, the abandoned boring or well should be checked for any grout settlement. The settlement depression should be filled with grout and rechecked 24 hours later. Grout should be placed with a tremie pipe if the open hole is 15 feet or deeper or if the hole is not dry. Otherwise, the grout may be poured from the surface.

3.3 NARROW BORINGS

Narrow borings, those with diameter less than 3 inches, advanced by hand auger or direct push methods, may be sealed using bentonite pellets or chips rather than a grout mixture. Often times a grout pump is not available to mix the grout when these methods have been used. Bentonite pellets or chips will be poured into the boring from the ground surface. Then bentonite will hydrate by absorbing moisture from the ground; unapproved water should not be added to the boring. After 24 hours, the abandoned boring will be checked, and any grout settlement will be topped off with more bentonite. The process will be repeated until bentonite remains at ground surface unless site condition indicates otherwise.

3.4 WELLS

The following procedure applies to wells aborted before completion and existing wells determined to be ineffective or otherwise in need of closure.

General Considerations

A number of techniques are available for abandoning monitoring wells and other monitoring devices including:

- Abandonment in place by grouting the well screen and casing in place;
- Removal of the well by pulling; and
- Overdrilling.

The particular method used for abandonment should be specified in the work plan addenda developed for a site-specific investigation. Several factors must be considered when selecting the appropriate abandonment technique including well construction, well condition, and subsurface conditions.
In general the preferred method for abandonment of wells is to remove all existing well materials to:

- Reduce the potential for the formation of a vertical conduit to occur at the contact between the casing and annular seal;
- Reduce the potential for well materials interfering with the abandonment procedures; and
- Decrease the potential for reaction between the well materials and grout used for abandonment.

In general, all well materials will be removed during abandonment (including screen and casing) by either pulling out the casing, screen, and associated materials or by overdrilling using a rotary or hollow stem auger drilling procedure.

Abandonment with Well Materials In Place

In the event that it is not possible to remove the casing and screen, the casing and screen will be perforated using a suitable tool. A minimum of four rows of perforations several inches long and a minimum of five perforations per linear foot of casing or screen is recommended.

After the screen and casing have been appropriately perforated, the well should be abandoned by grouting from the bottom of the well to the ground surface using a tremie pipe as described in Section 3.2. The tremie pipe should be raised when pumping pressure increases significantly or when undiluted grout reaches the surface.

After 24 hours of completing the abandonment, the abandoned well should be checked for any grout settlement. The settlement depression should be filled with grout and rechecked 24 hours later. Grout should be placed with a tremie pipe if the open hole is 15 feet or deeper or if the hole is not dry. Otherwise, the grout may be poured from the surface.

Abandonment by Removal

Site conditions permitting, relatively shallow monitoring wells may be successfully abandoned by removal providing that the well is generally good condition and sections of casing (including screen) can be successfully removed with materials intact.

This method of abandonment is generally accomplished by removing (pulling) sections of casing and screen out of the subsurface using a drill rig, backhoe, crane, etc. of sufficient capacity. Materials with lower tensile strength such as polyvinyl chloride (PVC) generally cannot be removed by pulling if they have been appropriately cemented in place.

Once the well materials have been removed from the borehole, the borehole should be abandoned by grouting in the same manner discussed for borings in Section 3.2. If the borehole collapses after removal of well materials, then the borehole should be over drilled to remove all material and then grouted to the surface.

Overdrilling

With this method of abandonment, the well materials are removed by overdrilling (overreaming) the well location. Overdrilling using rotary techniques may be accomplished using an overreaming tool. This tool consists of a pilot bit that is approximately the same size as the inner diameter of well casing and a reaming bit that is slightly larger than the diameter of the borehole. As drilling proceeds, all well materials are destroyed and returned to the surface. After completion of the overdrilling, the borehole should be immediately grouted with a tremie pipe as described in Section 3.2.

In the case of overburden wells, a hollow stem auger may be used for overdrilling providing that this method of drilling appropriate for the subsurface conditions. The hollow stem auger should be equipped with outward facing carbide-cutting teeth with a diameter 2 to 4 inches larger than the well casing. With this method, the casing guides the cutting head and remains inside the auger. When the auger reaches the bottom of the well boring and the well materials have been removed, the borehole may be grouted with a tremie pipe (Section 3.2) through the augers as the augers are gradually withdrawn.

Considerations for Fractured Bedrock and Karst Wells

Multi-cased wells completed into bedrock as screened wells, open wells, or open-lined wells may be abandoned with the outer casing left in place providing that the integrity of this casing and associated annular seal is good. A cement bond log (acoustic amplitude boring geophysical log) may be used to evaluate the integrity of the casing and annular seal, if the outer casing is to be left in place.

Borings or wells completed in karst zones may be difficult to abandon because of the potential presence of large conduits, which may make it difficult to grout. Where large conduits exist or difficulties are encountered when abandoning a boring or well, fill the portion of the borehole penetrating the solution cavity with inert gravel (quartz, claystone, etc.). Packers can be used to isolate critical intervals for filling with grout above and below these zones.

3.5 RESTORATION

All work areas around the borings or wells abandoned should be restored to a condition essentially equivalent to that before the borings and wells were installed.

3.6 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material should be managed in accordance with the requirements of SOP 70.1 and the work plan addenda associated with the site investigation

3.7 DOCUMENTATION

For each abandoned boring or well, a record should be prepared to include the following as appropriate:

- Project and boring/well designation;
- Location with respect to replacement boring well (if any);

- Open depth of well/annulus/boring prior to grouting;
- Casing or items left in hole by depth, description, composition, and size;
- Copy of the boring log;
- Copy of construction diagram for abandoned well;
- Reason for abandonment;
- Description and total quantity of grout used initially;
- Description and daily quantities of grout used to compensate for settlement;
- Disposition of investigation-derived material;
- Water or mud level prior to grouting and date measured; and
- Remaining casing above ground surface, height above ground surface, size, and disposition of each.

Daily investigation activities at the site related to boring and well abandonment should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

4.0 PRECAUTIONS

Refer to the health and safety plan associated with the Work Plan Addenda and the Master Health and Safety Plan.

5.0 REFERENCES

ASTM Standard D 5299-92. 1992. *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1 November.

STANDARD OPERATING PROCEDURE 20.4
TEST PITS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the excavation of test pits and provide general guidelines for sample collection from the test pits.

Test pit excavations are conducted to investigate and identify possible areas of contamination. Thus, samples taken from the excavation will be positively biased according to visual inspection (i.e., soil discoloration, soil staining) and field screening. Areas showing evidence of possible contamination will be sampled directly. If no evidence of contamination is present during excavation, then samples will be collected in two equally spaced intervals or at intervals specified in work plan addenda for site-specific investigations. In either case, no less than two representative samples per excavation site should be collected. Excavation (and sampling) shall terminate if the water table is encountered before terminal depth.

2.0 MATERIALS

- Master Work Plan;
- Work Plan Addenda;
- Field log books;
- Appropriate health and safety equipment for monitoring conditions in the work zone and excavation area including a photoionization detector (PID) or other types of monitoring equipment;
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan;
- Backhoe and associated equipment;
- Appropriate soil sampling equipment such as stainless steel scoops, trowels, spoons, and bowls/trays SOP 30.1);
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Tarps or plastic sheeting;
- Measuring tape;
- Camera and film; and
- Decontamination equipment and supplies.

3.0 PROCEDURE

3.1 DOCUMENTATION

Field activities and sampling information should be recorded in the field logbooks as outlined in SOPs 10.1 and 10.2.

Cross-sections and sketches of the layout will be prepared upon completion of the excavation. The sketches will indicate soil horizons and geologic observations. Soil horizons will be differentiated based upon variations in soil color (i.e., Munsell Chart), texture, coarse fragment content, structure, and consistence. Refer to SOP 10.3 for boring log completion procedures. In addition, depth and thickness of horizontal depth to bedrock (if encountered) and indicators of seasonal high water table (presence of redoximorphic features) will be recorded. Sketches will also indicate the location of any samples collected. Photographs of the excavation will be taken and locations noted on the field map.

3.2 DECONTAMINATION

Decontamination of the backhoe, trowels or spoons, bowls, field tape measure, and other associated equipment will be carried out before use and between each test pit as outlined in work plan addenda and SOP 80.1.

3.3 SITE PREPARATION

Mark out dimensions of excavation and possible hazards (e.g., utilities, former structures). The backhoe must be equipped with a protective shield and the operator properly trained in the use of level B respiratory and dermal protection. The backhoe bucket and arm must be thoroughly decontaminated by steam cleaning before use and between each test pit location as described in work plan addenda and SOP 80.1. Discuss all hazards with equipment operator before any intrusive activities.

Set up exclusion zone with caution tape and position backhoe upwind of excavation site. All activities must be conducted in accordance with the health and safety plan developed for work plan addenda.

3.4 EXCAVATION AND SAMPLING

The backhoe operator shall be directed to excavate until the sampler indicates the desired depth has been reached. If the pit is less than 3 ft deep, the sampler can enter the pit and collect the samples using a decontaminated stainless steel trowel or spoon as described in SOP 30.1. As the pit becomes deeper, the sampler will collect the soil samples directly from the center of the bucket of the backhoe in an area not in contact with the sides of the bucket. The samples will then be transferred from the bucket into the appropriate sample container following sampling techniques outlined in SOP 30.1. Screening processes and analytical parameters for field screening soil samples will vary from site to site as specified per scope of work.

Begin excavating in increments of 6 to12 inches per pass. Deeper passes may be necessary if the soil is rocky. Total excavation width will be of adequate dimensions to visually characterize the soil profile as observed on the excavation walls, typically not exceeding the width of the backhoe bucket. However, total width of the excavation will be dependent on the depth of the excavation, thus wider dimensions may be necessary for characterization of deeper pits. Excavation will be continuously monitored with health and safety monitoring equipment. Safety measures must be exercised when working near and around the backhoe arm and excavation pit. Health and safety procedures and any installation safety procedures must be strictly followed.

All soil removed during excavation shall be placed on a tarp or plastic sheeting. Soil exhibiting signs of contamination based on visual or olfactory observations, as well as monitoring results, will be separated from uncontaminated soil and containerized for site removal.

Samples will be collected at desired intervals as specified in work plan addenda. Sampling procedures will follow the requirement of work plan addenda and SOP 30.1.

3.5 BACK FILL

Once the terminal depth of the excavation is reached or the water table is encountered and all samples are collected, the trench will be backfilled with certified clean fill. Soils removed during excavation shall be containerized and disposed of at an approved landfill or moved to an approved storage area for subsequent disposal. All backfilled material will be tamped to a proper compacted level to ensure no major settling will occur. After all backfilling and compacting procedures are complete, the area will be raked and seeded or resurfaced with asphalt, as appropriate. When the area is properly secured, decontamination procedures shall begin.

4.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

5.0 REFERENCE

USEPA. 1987. *A Compendium of Superfund Field Operations Methods*. December.

STANDARD OPERATING PROCEDURE 20.5
ACTIVE SOIL GAS SURVEY

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) is applicable when conducting soil gas sampling. A soil gas survey is an effective screening tool for locating and delineating areas contaminated with volatile organic compounds (VOCs).

2.0 MATERIALS

- Work plans and site maps;
- Field logbooks;
- Soil gas sampling equipment and tools, driving mechanism, vacuum pump and box, and power source, as applicable;
- Sample tubing and tubing for vacuum box;
- Appropriate sample containers to collect soil gas samples;
- Appropriate air monitoring equipment such as a photoionization detector (PID) or flame ionization detector (FID);
- Tape measure;
- Decontamination equipment and supplies (SOP 80.1).;
- Materials to abandon probe holes (bentonite pellets or chips, and appropriate source water);
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan.

3.0 PROCEDURE

3.1 DOCUMENTATION

All information pertaining to soil gas investigations and sampling should be recorded in the field log books according to the requirements of SOPs 10.1 and 10.2. This information should include all site setup and sample collection, preparation and handling, and all field analysis results.

3.2 GENERAL PROCEDURE

Because of the variety of sampling containers that may be used to sample soil gas, a general description of the sampling procedure for active sampling is provided below. The selection of the particular device system and method of measurement of soil gas should be specified in work plan addenda based on site-specific conditions and data quality objectives.

1. Assemble decontaminated probe device to the desired sampling depth. This device may consist of a drive point, point holder, a hollow extension pipe, or other equipment.

2. Advance the sample probe by applying static pressure, impacts, or vibration or combination of these techniques to the aboveground portion of the sampler extensions until the sampler has been advanced its full length to the desired depth or strata.
3. Attach flexible polyethylene tubing with an appropriate sampling port or sorbent media cartridge, followed by additional tubing to a vacuum pump.
4. Extract gas through the probe using the vacuum pump. Five probe volumes should be extracted prior to sample collection. Vacuum rates and flow rates should be monitored as a check for leaks or short circuits. A drop in vacuum or too low of a vacuum may indicate problems with the sampling system.
5. Begin sampling with appropriate containers through a sampling port set between the probe and the pump. Various containers may be used such as gas-tight syringes, tedlar bags, summa canisters or real time monitoring instruments such as a photoionization detector or flame-ionization detector may be used for a whole air sample.
6. To complete the sampling, close off appropriate valves for sample containers. Soil gas samples should be protected from heat or light.
7. Appropriately label and handle the sample. Samples not analyzed immediately should be appropriately handled and shipped to the laboratory.
8. After completion the sampling, the probe device should be removed and the associated hole abandoned according to SOP 20.3.

3.3 DECONTAMINATION

All sampling equipment should be appropriately decontaminated before and after use according to the requirements of work plan addenda and SOP 80.1.

4.0 MAINTENANCE

None.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

ASTM Standard D 5314-93. 1993. *Standard for Soil Gas Monitoring in the Vadose Zone.*

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 20.6
GROUND-PENETRATING RADAR SURVEYS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide a general description and technical management guidance concerning the use of Ground-Penetrating Radar (GPR) Surveys.

2.0 MATERIALS

- Work plans;
- Field logbook;
- Site maps;
- GPR and associated equipment;
- Data Sheets;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan.

3.0 PROCEDURE

3.1 DESCRIPTION OF METHODS

3.1.1 Theory and Principles of Operation

Commercially available Ground-Penetrating Radar (GPR) equipment operates on the principle of time-domain reflectometry, in which the differences in strength and the time delay between a transmitted electromagnetic pulse and its reflection from an object are measured. The time delay (t) is directly related to the propagation velocity of the electromagnetic waves (v) and to the distance between the transmitter and the object (D) as follows:

$$t = \frac{2D}{v}$$

Because surface GPR is normally used at or near the surface of the ground, the distance (D) corresponds directly to the depth of the buried targets that reflect the radar signals.

The strength of a radar signal is a complex function of the distance traveled through the medium, the dielectric constant, the magnetic permeability, and the electrical conductivity. Radar signals are attenuated rapidly in materials with a high dielectric constant. The attenuation of radar signals in subsurface media is a strong function of the mineralogy and the water content. Thus, materials such as dry sands and gravels are least absorptive of radar signals, whereas wet clays are highly absorptive. The absorptive properties of the medium limit the penetration depth, i.e., and the depth at which targets can be detected.

In operation, the GPR repetitively transmits short-duration (typically 5-10 nanosecond) pulses of high-frequency (typically 50 GHz) electromagnetic energy through a transmitting antenna that is moved along the ground surface at a constant speed. Reflected pulses are detected by a receiving antenna at a location corresponding to the distance traveled by the antenna during the transmission and reflection of the pulse, at which point another pulse is transmitted. At a typical antenna speed of 2 miles per hour (3 ft per second), a complete transmit/receive cycle occurs about every 2 inches along the path of the antenna.

Radar antennas are available that operate at frequencies centered on 50, 80, 120, 300, 500, and 900 MHz and 1 GHz. Whereas the higher frequencies are able to detect smaller targets, the penetration depth is roughly inversely proportional to frequency. Thus, each GPR survey requires an analysis of the trade-off between resolution and depth of penetration so that the optimal frequency can be selected.

The strength of a radar reflection is a function of the composition, size, shape, and depth of the target. Reflections are strong from objects exhibiting large differences in dielectric constant from the surrounding medium and that are large in size compared with the radar signal wavelength.

3.1.2 General Applicability

GPR signals are reflected from any interface that corresponds to an abrupt change in dielectric constant. Therefore, both metallic and nonmetallic objects (including voids), as well as changes in geologic structure, can be detected by this method. Because of the higher frequencies used, target resolution is considerably improved over seismic or resistivity sounding methods. However, the high frequencies also result in strong attenuation of the signals, particularly in clay materials with high moisture content. At 100 MHz, the useful penetration depth in clay soil with 20% moisture content is about 3 feet, whereas in dry clay or sand with 20% moisture the penetration depth extends to about 30 feet. By changing the frequency of the antenna, greater or lesser depths of penetration can be accomplished.

GPR can be a powerful method for locating and mapping buried drums, wooden objects, foundations, non-containerized wastes, underground utilities, and any other artifacts (including historical artifacts) at a site. Depending on whether sufficient penetration can be achieved, the method can also be used to map saturated zones and bedrock contours and locate sinkholes or fracture systems. GPR has also been used to map contaminants indirectly, both polar and non-polar.

3.1.3 Instrumentation

The standard array of GPR instrumentation consists of transmitting and receiving antennas, which are pulled along the ground; a control unit, containing power supply and signal processing circuitry, which is connected to the antenna by a cable; and an oscillograph or analog tape recorder. The system can be vehicle-mounted, and the transmitter can be connected via radio link to the signal processing and recording equipment. Systems have been modified to include digitizing, onsite computer processing, and digital, graphic display equipment.

3.2 DATA ACQUISITION

3.2.1 Field Procedures

Establishing a grid of parallel survey lines across the site and moving the radar antenna along each of these lines perform GPR surveys. A suitable means must be provided for determining the location of the radar unit along each of the lines and for documenting this information on the recording medium. Typical systems measure the time and velocity of antenna motion, or determine the position of the antenna by synchronization signals from the wheels or tracks of the vehicle used to tow the antenna or by means of an electronic marking device.

Depending on the data quality objectives and site conditions, different frequency antennas are needed. The GRP contractor will beta-test all methods in one small representative area to verify that the selected antennas produce reasonable, defensible data. In the event selected antennas or the GPR method does not meet the project's data quality objectives, the antennas and method will be eliminated from the survey.

To assess the depth of anomalies noted on radar traces, it is necessary to convert the travel time data that are actually recorded. The velocity of electromagnetic waves in the subsurface medium at the site is determined at a particular site by excavation to observed targets or known test targets and measuring their depths. The velocity should be determined at several points in the area of interest. Another method to determine the depth to a target is by assessing the velocity of the medium. This can be accomplished by performing wide-angle, reflection/refraction measurements, known as WARR. Separating the transmitter and receiver portions of the antenna at a constant rate over a known distance and recording the refraction pattern accomplish this. By determining the slope of the refraction pattern, a velocity can be obtained.

Electronic data generated during GPR surveys shall backed up at the end of every data for both field and processed data. A backup of all hard copy data shall also be maintained.

3.2.2 Data Format

Reflected radar signals are electronically processed and displayed as an intensity-modulated time spectrum, where the time corresponds to target depth as described above. The series of signals corresponding to the reflected pulses as the antenna moves along a path forms a three-dimensional data set containing distance of traverse, depth, and intensity information.

Typically, the data are recorded on magnetic tape and/or displayed on an X-Y oscillograph, with distance displayed along the X-axis, time (depth) displayed along the Y-axis, and the intensity given by the degree of darkness of the trace. In a typical survey, a series of parallel tracks are traversed by the GPR, and the series of resulting oscillograph traces thus provide XYZ location information on, as well the intensity of reflection from targets of interest.

Although much of the data obtained in a GPR survey are automatically recorded by the instrumentation, additional information to unambiguously identify and interpret each trace should be recorded on standard data sheets. As a minimum, the data sheet should contain the following information:

- Project name, number and location;
- Company or organization;
- Date and time of day;
- Operator's name;
- Line and trace designation (also recorded directly on the signal recording medium);
- Receiving levels and filter settings;
- Antenna frequency(s);
- Direction and speed of antenna movement;
- Weather and temperature;
- Relative soil moisture content and soil type;

- Site map coordinates at the beginning and end of the trace. At least one point in the survey must be tied into the state plane coordinate system for follow-on work;
- Notes, remarks, or comments; and
- Electromagnetic velocity in the subsurface medium at the nearest calibration point.

3.3 DATA INTERPRETATION

Except for those systems that provide extensive data processing, interpretation of anomalies in GPR traces requires considerable subjective evaluation by a qualified geophysicist. Extensive experience is essential to distinguish target reflections from inherent system noise and interferences. In many cases, the anomalies from targets of interest are small compared with varying reflections from the antenna system, the ground surface, geologic perturbations, and other interferences. Similarly, an acceptable interpretation of target depth from travel time data requires knowledge of geophysical and geological characteristics across the site. A radar antenna transmits a "cone" rather than a thin beam of electromagnetic energy. Therefore, reflections are obtained from objects not directly below the antenna. As the antenna moves across the plane of an object, reflections are obtained for a considerable distance along the antenna path. The signal travel times vary during this process, corresponding to the distance between the antenna and the object. A discrete spherical target, therefore, will exhibit a hyperbolic reflection pattern on the radar trace, with the apex of the hyperbola corresponding to the location and depth of the object. Multiple or odd-shaped targets or targets of considerable size (compared with the radar wavelength) will exhibit complex reflection patterns consisting of overlapping hyperbolas. Thus, a true "picture" of subsurface objects is not obtained, and experience is necessary to translate the complex tracings into information on target depths size or shape.

Radar signals can be digitized which permits digital recording, computer processing and enhanced display of the location and intensity data. Typical computer processing includes removing extraneous signal interferences, changing hyperbolic reflection patterns to signals more representative of the size or shape of targets, color-coding of intensity data, blocking of data sets to correspond to the site map, and map-view displays of targets at a given depth.

3.4 APPLICATIONS MANAGEMENT

3.4.1 Prerequisites

Appropriate planning of GPR surveys requires an understanding of the geohydrological and geophysical characteristics of the site. The type and structure of soils and geologic formations should be indicated. The description of the site should include the depth, size, and shape and type of potential targets to be detected, as well as obstructive site features such as terrain and underground structures. Additionally, existence of and depth to known buried objects should be listed and mapped, and electromagnetic sources of interference to the survey should be considered.

3.4.2 Work Planning and Scheduling

If possible, GPR surveys should be performed concurrently (if warranted) with other geophysical surveys and in advance of excavation or drilling at a site. Radar data complements information from other geophysical methods such as, electromagnetic induction, seismic refraction, magnetometry, terrain conductivity, and resistivity, in arriving at an interpretation of subsurface geohydrologic features and buried waste materials.

The time and effort required to perform GPR surveys varies greatly depending on the sophistication of the available equipment and the complexity of the site. Assuming a two-person team, simple hand-operated radar systems can cover from ¼ to ½ acre per day for the survey, proper documentation, and simple interpretation. Vehicle-mounted systems with automatic data recording and processing can cover from 2 to 5 acres per day. Sophisticated data processing, detailed interpretations, and high-quality displays require considerable computer usage and approximately twice the time required for the actual field survey.

The specific objectives of the GPR survey should be defined in work plan addenda and should include the following elements:

- Type of survey (level of detail) to be accomplished, and area to be covered;
- Type, depth, size, and composition of targets of interest;
- Locational accuracy required;
- Schedule limitations;
- Degree of sophistication required for data presentation and interpretation;
- Specific deliverables required; and
- Logistics.

3.4.3 Quality Control (QC)

3.4.4 General

Because of the specialized nature of the method and the highly subjective interpretations needed to process the data, GPR surveys are subject to misapplication, erroneous interpretation, and collection of inadequate or incomplete data. This susceptibility to misuse requires that an adequate quality control program be established. Quality control aspects common to most geophysical field programs include the following:

- Program management personnel (i.e., the project geologist or geophysicist, RI leader, or site manager) with technical expertise in the subject for preparation of statements of work, proposal reviews, work plans, and reports.
- Defined scope of work, specifications, and data validation procedures.
- Defined field quality control procedures.
- No data should be rejected from a data set without appropriate justification; field data sheets should contain all observed data and the conditions that could affect data validation.
- All field data parameters should be recorded in permanent ink in a bound logbook with each page signed and dated by the operator. Original unaltered logbooks should be retained in the RI/FS contractor's files.
- Properly calibrated instruments provide an added measure of data validity and permit correlation and comparison of the associated data with site features and geohydrologic characteristics not evident at the time of the field effort. Some geophysical survey objectives can be met by relative measurements across an area or with depth.
- An evaluation should be made of noise, interferences, and obstructions at a site and should be recorded in the field. These real-time quality control procedures aid field personnel in correction of noise sources, validating suspected external sources, and early detection of problems that may jeopardize the survey objectives.

3.4.5 Calibration

The determination of target depth from travel time measurements requires calibration of the instrumentation for these two parameters. Travel time is calibrated periodically in the field by using a secondary-standard, previously calibrated pulse generator to produce timing marks directly on the radar trace. The travel time to a target is determined by the position of the target reflection along the timing marks. This calibration should be performed several times daily, and each radar trace should be referenced to the most recent calibration. Calibration of the radar traces for depth determination may be performed as follows:

- For reconnaissance surveys or for surveys where lateral resolution is more important than depth, the traces can be roughly calibrated by estimating the velocity of electromagnetic materials in the media at the site. The crudeness of the calibration is evidenced by considering that the velocity can vary by more than an order of magnitude, depending on the soil/rock properties and the moisture content.
- For surveys requiring reasonable resolution of target depth, the travel time to targets of known depths must be determined at each site. A radar trace is made over the known targets, and the reflection patterns then provide direct depth-calibration points on the trace. Sites with uniform lithology may require only a few depth calibrations, but generally, it is necessary to perform these calibrations at several locations and at several depths throughout the area of interest because dielectric constants may vary across the site. Each radar trace should be referenced to the calibration most representative of the trace coordinates at the site. The preferred method is to use buried objects of known depth as calibration targets or to excavate to detected objects and measure the depth. A less desirable (but often necessary) procedure is to bury standard targets at various depths within the area of interest.
- WARR measurements should be made on a daily basis at various positions at the site, especially in areas where subsurface conditions may vary greatly.

3.4.6 Daily Quality Control

All radar traces and interpreted data sets should be accompanied by quality control data that indicate the level of quality of the data. Periodic replicate measurements should be made so that measurement precision can be established. Time and/or depth calibrations should be performed on a daily basis.

A calibration that yields significant changes in instrument parameters or travel time may indicate the need for repetition of data or increased density of travel time calibrations in the area of interest. Graphical data should be reviewed during the field activities to determine data quality, and whether the survey results appear to be consistent with geophysical knowledge of the site.

3.5 HEALTH AND SAFETY CONSIDERATIONS

All procedures for hazardous waste site entrance, traverse, and egress that apply to general field operations also apply to GPR surveys. The GPR survey consists of traversing the site on foot or in vehicles, and the extent of the activities results in considerable periods of time during which personnel are exposed to any adverse conditions that may exist. An appropriate level of protection against these risks must be planned and provided.

Hand-towed GPR systems involve physical activity (particularly on sloping or rough terrain) that is much more strenuous than when vehicle-mounted systems are used. Precautions must be taken against exposure to heat or cold in accordance with the type of activity that is planned. Extreme weather conditions will have an adverse effect on the time required to complete a survey, thereby increasing the duration of personal exposure to the elements and to hazardous site conditions.

3.6 POTENTIAL PROBLEMS AND LIMITATIONS

A wide-variety of problems may be encountered during GPR surveys. Problems can be expected to arise in the following areas:

3.6.1 Limitations Inherent to Geophysical Methods

A basic limitation of geophysical methods is that a given set of data cannot always be associated with a particular set of subsurface conditions. In general, surface geophysical measurements alone cannot provide a complete assessment of subsurface conditions. When appropriately integrated with other information from subsurface borings, borehole geophysics, etc., GPR can be an effective, accurate, and cost effective method of obtaining subsurface information.

Geophysics at Radford Army Ammunition Plant will, where coverage permits, integrate surface and down hole methods to develop more accurate and refined interpretations of subsurface conditions that possible with either type of method alone.

3.6.2 Planning and Execution

Rarely is a survey accomplished exactly according to the original plan. Site features not previously specified and other variations can occur that force changes in the details of the approach. However, the objectives of the survey, the general methodology, the amount and quality of data required, and the degree of data interpretation requested should remain unchanged. Project work scopes should be written with some degree of latitude to allow a change in plans whenever justified.

3.6.3 Material Properties Contrast

It may be difficult to identify a particular subsurface boundary or feature if the subsurface materials have an insufficient velocity contrast or gradual boundary.

3.6.4 Noise and Interferences

Measurements can be severely affected by both natural and man-made sources of interference. Sources of system noise that degrade the quality of radar traces include improper spacing of antennas above ground, improper cable placement, location of antennas too close to other system components, and facility instrument operation. Because reflections are obtained from any object with a dielectric constant differing from the surroundings, large masses of buried or surface rocks, metal, debris, wet soil, or aboveground structures can mask targets of interest. Some antennas are not shielded on top, and similar interfering reflections will be obtained from overhead objects such as trees, power lines, and buildings. The site personnel must recognize the limitations posed by these obstructions and take steps to minimize the interferences.

Topographic and geologic features can also interfere with acquisition of high-quality target detection data. Small depressions in the ground surface, the presence of boulders, clay lenses, and moist soil zones affect both the detectability of a target and determination of its depth from the travel time.

Sources of electromagnetic energy in the vicinity, such as radio or television transmitters or navigational radar antennas, can result in spurious signals in the radar traces. In some cases, these problems can be minimized by judicious selection of radar and/or data communications frequency and by scheduling the surveys during periods of transmission inactivity.

3.6.5 Weather Conditions

Because water is a good absorber of radar signals, wet weather has a very serious effect on the ability to perform GPR surveys. Physical difficulties in executing a survey over wet terrain also may be expected. The field activities should be planned, if possible, during periods when dry weather can be expected. Schedules for surveys should account for the probability that moist soil conditions will exist.

3.6.6 Technical Difficulties

Preventable difficulties include equipment malfunction or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the geophysical characteristics of the site are not as initially conceptualized. Early recognition and response by technical management can minimize the effect of any problems. Interim, real-time scrutiny of the data by the site geophysicists is essential. The geophysicist must be responsive regarding equipment replacement, repair, or changes in personnel. The site manager and the site geologist should be cognizant of technical difficulties beyond the control of the field personnel and should recognize the need to change plans, change performers, or cancel a survey, as appropriate.

4.0 REFERENCES

Good discussions of various geophysical survey techniques and applications are found in the following references:

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ASTM Standard D 6432-99. 1999. *Standard Guide for Using the Surface Ground Penetrating Radar Method for Subsurface Investigation.*

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Olhoeft, Gary R. 1989. *Geophysics Advisor Expert System: Version 1.0*, Interagency Agreement DW 14932497, USEPA EMSL, Las Vegas, NV.

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STANDARD OPERATING PROCEDURE 20.7
RESISTIVITY AND ELECTROMAGNETIC INDUCTION SURVEYS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide a general description and technical management guidance on the use of Resistivity and Electromagnetic Induction (Terrain Conductivity) Surveys.

2.0 MATERIALS

- Work Plans;
- Field Logbook;
- Site maps;
- Electromagnetic induction unit; and
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan.

3.0 PROCEDURE

3.1 DESCRIPTION OF METHODS

3.1.1 Theory and Principles of Operations

Resistivity. A resistivity survey measures the electrical resistivity of a geohydrologic section indirectly. A DC or low-frequency AC electrical current is injected into the ground through electrodes embedded in the ground surface. The flow of current within the subsurface produces an electric field with lines of equal potential perpendicular to the current flow. This potential field (voltage) is measured between a second pair of electrodes also embedded in the ground surface.

The actual resistivity is a complex function of the applied current, observed voltage, and the characteristics of the subsurface section that provide multiple current flow paths. The apparent subsurface resistivity can be calculated as a function of the applied current, the measured voltage, the separation of the electrodes, and the geometry of the current and potential electrode pairs. For the simplest electrode configuration in which all four electrodes are equally spaced in the order current-potential-current (i.e., the Wenner array) the apparent resistivity is given by the following equation:

$$a = \frac{2\pi A V}{I}$$

Where:
a = apparent resistivity in ohm-meters or ohm-feet,
V = the measured potential difference in volts, and
I = the applied current in amperes.

The calculations are similar for other electrode configurations except geometric factors other than 2 are used. Equipment operating manuals provide nomographs for determination of apparent resistivity from field measurements for all standard electrode configurations. These calculations are simple and can be performed on a hand-held calculator.

Of the many possible geometric configurations of current and potential electrodes, some of the most commonly used arrays are as follows:

- Linear array with electrodes in the order current-potential-potential-current. A Wenner array results if the spacing between each successive pair of electrodes is equal. For a Schlumberger array, the distance between the two potential electrodes is a small fraction of the distance between the two current electrodes.
- Linear array with electrodes in the order current-current-potential-potential. In this dipole-dipole configuration, the separation of the two current and the two potential electrodes is equal, with an equal or greater separation of the two dipole pairs.

Resistivity surveys may be conducted to determine either vertical or horizontal electrical anomalies. *Vertical electrical soundings* (VES) are made by symmetrically expanding a Wenner or Schlumberger array in line about a point, i.e., the electrode spacing is increased for successive readings. Measurements of potential and input current are made for each set of electrode spacings, and the apparent resistivity is calculated as described below. The resultant plot of spacing versus apparent resistivity is interpreted to yield the resistivity distribution with depth beneath the midpoint between the potential electrodes. However, the resistivity being measured is that of the materials beneath the entire array.

For *horizontal profiling,* apparent resistivity from a series of measurements is plotted as a function of the X+Y coordinates of the site. One or more of the following procedures accomplishes horizontal profiling:

- A series of VES profiles at several locations are compared;
- Measurements are made with fixed-electrode spacing along a line or over an area; and/or
- Dipole-dipole measurements are made with the current or potential dipole at a fixed location and the other dipole located at increasing distances along a line. This process provides a resistivity "cross-section" beneath the line.

The Wenner and Schlumberger configurations are most often used for vertical investigation, whereas the dipole-dipole configuration is most often used for lateral surveys.

Electromagnetic Induction (EM). In the Electromagnetic Induction (EM) method, the electrical conductivity of a geohydrologic section is measured by transmitting a high-frequency electromagnetic field into the earth, producing eddy currents that generate secondary electromagnetic fields that can be detected by a receiver. The eddy currents are induced in the earth by an aboveground transmitter coil, and the resulting secondary electromagnetic fields are coupled to an aboveground receiver coil. Thus, EM measurements do not require direct ground contact, as is the case for resistivity measurements, and surveys across a line or area may be performed quite rapidly.

EM instruments are calibrated to read subsurface conductivity directly in units of millimhos per meter, Where:

$$1{,}000 \text{ milliohm per meter} = \frac{1}{\text{ohm-meter}}$$

This relation indicates that the conductivity obtained from EM measurements varies inversely with the resistivity measured using a resistivity survey. However, because the subsurface sections associated with the two methods are generally of different depth or cross-sectional area, there is not an exactly inverse relationship between conductivity and resistivity surveys.

The conductivity value obtained by an EM instrument depends on the combined effects of the number of soil and rock layers, their thicknesses and depths, and the inherent conductivities of the materials. The quantity actually measured is an apparent conductivity of the earth volume between the ground surface and an effective penetration depth, which is defined as the depth at which variations in conductivity no longer have a significant effect on the measurement. The sampling depth is related to the spacing between the transmitter and receiver coils of the instrument, approximately as follows:

Sampling depth = 1.5 (coil spacing) (Vertical Dipole)
= 0.75 (coil spacing) (Horizontal Dipole)

Vertical profiling can be accomplished by multiple measurements about a point, with varying coil spacings. Horizontal profiling is performed by making measurements along traverses with a fixed coil spacing.

3.1.2 Application

The measurement of a subsurface resistivity or conductivity at a hazardous waste site provides a valuable contribution to site characterization for the following reasons:

1. Conductivity (resistivity) is a function of the geohydrologic section and is overwhelmingly influenced by the presence of water. Therefore, conductivity (resistivity) can provide indirect evidence on the porosity and permeability of subsurface materials and the degree of saturation. These parameters, in turn, are directly related to subsurface lithology, and to the potential for infiltration/migration of contaminants from a source area.

2. Conductivity (resistivity) is influenced by the presence of dissolved electrolytes in soil or rock pore fluids. Contaminant plumes in the vadose (unsaturated) and saturated zones can be mapped if there is sufficient change in conductivity to be detected by EM or resistivity measurements.

   In general, contaminant plumes of inorganic wastes are most easily detected because conductivity may be increased by 1 to 3 orders of magnitude above background values. The limit of detection is a change from a background of 10%–20%. Plumes of non-polar organic constituents from spills or leaking containers may be detected if sufficient soil moisture has been displaced to affect the ground conductivity to a measurable degree.

3. Conductivity (resistivity) can be used to detect the presence of buried wastes if the degree of saturation, containerization, or inherent electrical properties of the wastes produce sufficient variation from the soil matrix. The degree of detail provided by typical surveys cannot distinguish the size, shape, or mass of sources except in a qualitative manner.

For these reasons, resistivity and conductivity surveys should be investigated as potentially appropriate site characterization tools when any of the following information is desirable:

- Detection and mapping of contaminant plumes; the rate of plume movement may also be deduced from measurements made over time;
- Estimates of depth, thickness, and resistivity of subsurface layers, depth to the water table, or probable geologic composition of a layer;
- Detection, mapping, and depths of burial pits, landfills, clay caps or lenses, or deposits of buried waste;
- Determination of locations for drilling to intercept contamination or to investigate aquifer properties; and
- Corroboration of limited chemical and geohydrologic data at a site.

In general, surface geophysical measurements alone cannot provide a complete assessment of subsurface conditions, When appropriately integrated with other investigative information from subsurface borings, borehole geophysics, etc., surface geophysical surveys can be an effective, accurate, and cost effective method of obtaining subsurface information. Geophysics at Radford Army Ammunition Plant will, where coverage permits, integrate surface and down hole methods to develop more accurate and refined interpretations of subsurface conditions that possible with either type of method alone.

3.1.3 Instrumentation

Resistivity. The basic components of a field resistivity system are two current and two potential electrodes, electrical cables, centralized power unit (current source), and resistivity meter. Automated instrumentation is commonly used to conduct two or three-dimensional surveys. One such system is the Advanced Geosciences, Inc. (AGI) Sting/Swift system, which includes a central power unit, resistivity meter (Sting), control unit (Swift), and switched electrode cables for use with up to 254 electrodes. This AGI allows for automated measurements, complete control of the measurement array, programmable measurement cycles, large capacity storage of data with linkup to a personal computer. The Sting/Swift system allows for rapid collection of resistivity data and testing of arrays. Measurement ranges for the Sting/Swift system are 0.1 milliohm to 400kohms (resistance) and 0 to 500 volts full-scale auto ranging (volts).

Electromagnetic Induction (EM). Generally EM instruments are available in two forms:

1. Single-piece models operable by one person, with a fixed coil spacing 12 feet; these provide sampling depths on the order of 10 and 20 feet. The Geonics EM31DL is one example of this type of instrument.
2. Dual-coil models, operable by two persons, with variable coil spacing up to about 40 feet (sampling depth up to about 60 feet). The Geonics EM 34-3XL is an example of this type of instrument.

The 12-foot fixed coil and the dual coil apparatus are most commonly used in hazardous waste site investigations. In either case, an additional person to record data and identify measurement locations is highly desirable and more time efficient. The instruments are calibrated to read directly in conductivity units, and values are typically read and recorded on a data sheet. Some units have been modified to provide direct digital recording on magnetic tape.

3.2 DATA ACQUISITION

3.2.1 Field Procedures

Initial Operations. As with most geophysical surveys, conductivity or resistivity surveys involve the following initial steps:

- **Planning.** Known or assumed geohydrologic features of the site, potential source locations and migration characteristics of hazardous constituents, are used to select specific techniques and equipment to establish appropriate locations and depths for geophysical measurements (see Section 5.1.2). The level of detail necessary (data quality objectives) determines the amount of effort and, in simple terms, the required number and density of data points. As a minimum, the data quality will depend on the method and specific equipment selected and the supporting hardware and software capabilities.

An "expert" system known as the Geophysics Advisor Expert System, developed by the Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas, may be used as a planning tool to assist in selecting an appropriate geophysical method. This system prompts the user through a series of site-specific questions that will eventually rank various geophysical methods as to their feasibility at a specific site.

Most of the details can be planned before site activities; however, some leeway must be accorded to the field procedures to account for variable site conditions and weather.

- **Site Layout.** One of the most labor-intensive and time-consuming aspects of the fieldwork involves layout of grids and surveying or careful measurement of locations to allow geophysical surveys to be accomplished in a systematic, documentable manner. Location coordinates of sufficient resolution to accomplish the objectives of the survey must uniquely identify every data point.
- **Array and Spacing Tests.** Select one area or line that typifies the site. Test different array types and spacing. Analyze the data to see if the results match induction or normal resistivity and drilling logs from nearby wells. Select the optimal array type and spacing configuration, and proceed with the survey. If induction or normal resistivity logs are not available for wells at or near the site, log these wells before executing the surface surveys.

Resistivity Measurements. Resistivity electrodes must be installed in the proper array and spacing at a particular site grid location (according to specific manufacturers directions). The cables connecting the electrodes to the current source and potentiometer are then attached, and the current flow is initiated. Voltage is measured directly on the potentiometer. The process is repeated at the next site grid location (for horizontal profiling) or with the next electrode spacing (for vertical electric soundings) as necessary for QC purposes.

General rules for electrode spacings are difficult to specify because of site-specific variation; depending on the site geohydrology and source characteristics. As a general rule of thumb, the maximum electrode spacing should be at least three to five times that of the maximum target depth.

Electromagnetic Induction Measurements. At a given site grid location, the specified orientation of the apparatus is established, i.e., with the axis of the coils either parallel or perpendicular to the direction of the survey line. The meter reading is recorded and the apparatus is moved to the next site grid location.

For the dual-coil method, both the intercoil spacing and coplanarity of the coils must be established before recording the data. Surveys are normally conducted with the coil axes horizontal and at right angles to the survey direction.

EM profiles can be accomplished in a continuous manner using vehicle-mounted equipment in conjunction with strip charts, magnetic tape recorders, or digital recorders. Location information must be appended by tic marks or voice-over and some means provided to reference written field logs in a consistent manner.

3.2.2 Data Format

General. Information obtained during a resistivity or EM survey should be presented according to a standard data format, using standardized data sheets with original field entries. As a minimum, the heading for each data sheet should contain the following information:

- Project, task, site, and location identification;
- Company or organization;
- Date (and time, if applicable);
- Operator's name and signature;
- Method/technique identification;
- Instrument make, model, serial number, and calibration date/frequency (if applicable);
- Test location (according to the survey plan);
- Electrode or coil type and configuration;
- Line or site grid location(s);
- Weather and site conditions and temperatures;
- Identity of relevant calibration and QC data; and
- Records of data for each sounding or profile on a single sheet, if possible;

Resistivity. Survey data should include, in a tabular format, the following information:

- Electrode location, per the survey plan;
- Electrode spacing, in feet or meters;
- Input current applied, in amperes; and
- Measured potential, in volts.

Electromagnetic Induction. Survey data should include, in a tabular format, the following information:

- Coil location, per the survey plan;
- Coil spacing;
- Coil configuration (unless specified in the heading); and
- Meter reading, in millimhos per meter.

Special precautions to systematize and preserve data will be required for data that are recorded continuously on strip charts, magnetic tape recorders, or digital recorders. Strip charts should be permanently affixed to the field logbook. The first original hard copy of output from magnetic tape should be treated similarly. Identifying header information must be recorded directly on the tape.

3.3 DATA INTERPRETATION

3.3.1 Resistivity Data

For each data point, the apparent resistivity is calculated according to the formula appropriate for the type of electrode array employed. For horizontal profiling, curves of apparent resistivity versus distance along a line defined by the site grid locations are plotted. These curves of lateral changes in resistivity at a given electrode spacing (therefore, at a given survey depth) provide a cross-section for interpretation of the anomalous subsurface features. Multiple parallel profile lines can be combined to produce an area map of apparent resistivity at a particular depth.

For vertical electrical soundings, the series of apparent resistivities are plotted versus corresponding electrode spacings on log-log graph paper. The curves can be compared qualitatively with known or suspected subsurface conditions or with idealized layer-models to determine layer thicknesses and depths. Computer processing is typically applied for analysis of complex data sets and inverse layer modeling.

3.3.2 Electromagnetic Induction Data

Corrections may be applied to EM data for accuracy and drift, variation in location from pre-established coordinates, topography, changes in scale, and non-linearities associated with high conductivity values. In all cases, such corrections must be fully supported by data originally recorded or annotated in the field. Profile data along traverses are obtained as plots of conductivity versus distance. As with resistivity profiling, parallel traverse data may be combined to provide conductivity contour maps of a site. Two or more profiles at different sampling depths, as well as sounding data at a given location, provide information on the relative conductivities of shallow and deeper layers. Contour plots may provide valuable information on the extent and direction of groundwater flow and contaminant transport.

Detailed comparison of EM sounding measurements with layer models of the site can be made. This type of interpretation has been used at sites with relatively simple, uniform geohydrology to determine overburden and bedrock spatial and depth relationships. In some cases, very detailed interpretations, including aquifer flow properties, location of permeable zones, and interaquifer transfer, are possible.

3.4 POTENTIAL PROBLEMS

Resistivity and EM surveys are geophysical methods that, although standardized and frequently applied, are subject to a wide variety of problems. Problems can be expected to arise in the following areas:

- **Planning and Execution.** Rarely is a survey accomplished exactly according to the original plan. Site features not previously specified and myriad other variations can occur that force changes in the details of the approach. However, the data quality objectives of the survey, the general methodology, the amount of data required, and the degree of data interpretation requested should remain unchanged. Project work scopes should be written with some degree of latitude to allow a change in plans whenever justified.
- **Noise and Interferences.** Measurements can be affected severely both by natural and man-made sources of electrical and electromagnetic noise. Nearby power lines, stray ground currents, and atmospheric discharges adversely affect both types of surveys. Large masses of buried metal, fences, railroad tracks and underground pipes or cables can strongly distort measurements and reduce instrument sensitivity to features of interest. These problems generally can be accounted for or overcome but must be recognized early in the survey so that appropriate avoidance measures can be implemented. Known or suspected sources of interference should be included in the initial planning for a project.
- **Weather Conditions.** It is possible to conduct the surveys under almost any conditions that permit traverse of the site. However, snow cover, standing water, heavy rainfall, or thoroughly saturated surface soils may severely restrict the ability to meet project objectives and schedules. Scheduling contingencies should be included whenever possible, especially during periods when inclement weather is expected.
- **Technical Difficulties.** Preventable difficulties include equipment malfunction or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the geophysical response of the site is not as initially conceptualized. Early recognition and response by technical management can minimize the effect and severity of any problems. Interim, real-time scrutiny

of the data by the site geophysicist is essential. The geophysicist must be responsive regarding equipment replacement, repair, or changes in personnel. The site manager and the site geologist should be cognizant of technical difficulties beyond the control of the field personnel and should recognize the need to change plans, field personnel, or cancel a survey, as appropriate.

- **Topographic Changes.** Significant changes in topography should be addressed when planning and making measurements.

3.5 QUALITY CONTROL

3.5.1 General

Geophysical surveys, including resistivity and conductivity surveys, are subject to misapplication, erroneous interpretations, and use of incomplete or inadequate data. All of these avoidable errors can severely affect both the cost of subsequent site investigations and the validity of the site characterization. This susceptibility to misuse and potential for negative effect demands an assurance that appropriate quality control measures have been implemented. Quality control aspects common to most types of geophysical field programs are as follows:

- Integrating surface-based results (indirect measurements) with well sampling results, drilling logs, and down hole (direct measurement) geophysical logs.
- Program management personnel with technical expertise in preparing statements of work; reviewing proposals, work plans, and reports; and supervising technical subcontracts and field-related programs.
- Insistence on a defined scope of work, clear specifications, and data validation procedures.
- Appropriate justification before rejection of data points from a data set. Field data sheets should contain all observed data and the conditions that could affect data validity.
- Field data should be recorded in permanent ink in a bound logbook with each page signed and dated by the operator. Original unaltered logbooks should be retained in the site file.
- Complete and clear understanding of manufacturer's operation manual for the particular apparatus being used.
- Properly calibrated instrument provides an added measure of data validity and permits correlation and comparison of the associated data with site features and geohydrologic characteristics not evident at the time of the field effort. Some geophysical survey objectives can be met by relative measurements across an area or with depth.
- An evaluation should be made of noise, interferences, and obstructions at a site. Such measurements, inferences, and explanations should be recorded in the field. These real-time quality control procedures aid field personnel in correction of noise sources over which they have control, in validating suspected external sources, and in early detection of problems that may jeopardize the survey objectives.

3.5.2 Resistivity Surveys

The resistivity apparatus consists of a current source and potentiometer, both of which must be calibrated at least twice a day, e.g., once at the beginning of the day and once at the end of the day.
The current source (source of the energy driving the system) is calibrated by placing an ammeter in series with the electrode cables. The reading obtained on the reference ammeter is then compared with the value read from the ammeter on the current source. The current source ammeter is then adjusted to the reading on the reference ammeter.

The potentiometer is the other apparatus that must be calibrated. This is normally accomplished by placing a precision resistor in series with the current load. A precision resistor is an electronic device that has a predetermined (as specified by the manufacturer) resistance to the electric current passing through the device, i.e., reduction in amperage. The potentiometer is then placed across the resistor. The potential measured should be equal to the product of the known resistance and the indicated current. Precision resistors can be purchased at most electronics supply stores.

All data sets should be accompanied by quality control data that indicate the level of quality of each individual data point. Periodically taking replicate measurements or re-running with the spacing and array configuration accomplishes this. These measurements should be averaged or statistically compared so that measurement precision can be estimated. Each data set should also be referenced to the most recent calibration. Data obtained before a calibration requiring significant changes in instrument controls is suspect. (NOTE: A significant change in instrument readings as a result of recalibration is interpreted as successive calibration values that vary by more than 10%).

Resistivities should be calculated and plotted during data acquisition to determine the overall quality of the data and whether the survey results are consistent with the site conceptualization. Data points representing discontinuities in the curves should be validated by repetition and, if necessary, a fine grid of measurements made to determine whether the anomaly represents a site feature of interest, a spurious reading, or an obstructive interference.

3.5.3 Electromagnetic Induction Surveys

Calibration. The manufacturer calibrates EM instruments over massive rock outcrops of known characteristic that are used as a geologic standard to measure the absolute conductivity over a uniform section of earth. The user should maintain the EM apparatus in calibration by noting drift in the readings at a stable "secondary standard" site. A secondary standard site is a location established in the field that is used to check the accuracy (calibration of the instrument and the drift precision of the instrument). A secondary standard site is a location used daily on large projects to check instrument accuracy, much the same way the manufacturer uses massive rock outcrops for precision and accuracy determination.

Unacceptable drift or erratic operation shall be corrected by replacement with an instrument in proper working order. Values that are obtained from measurements over the stable secondary standard site that vary by more than 10%–15% are considered to be unacceptable drift, if environmental conditions remain somewhat constant (i.e., heavy precipitation can make measurements radically different).

All aspects of the daily quality control measures discussed for resistivity measurements apply also to EM measurements. Repeated periodic measurements (at least twice a day) should be made at one or more locations and orientations at the site to determine the precision of measurements and to detect instrument drift.

4.0 HEALTH AND SAFETY CONSIDERATIONS

All procedures for hazardous waste site entrance, traverse, and egress that apply to general field operations also apply to conduct of geophysical surveys. Resistivity and conductivity surveys depend on traverse of the site on foot or in vehicles, and there are extended periods during which personnel are subject to adverse environments at the site. In addition, resistivity measurements require implanting electrodes beneath the surface, which increases the risk of contact with toxic or hazardous agents. An appropriate level of protection against these risks must be provided during the surveys.

The geophysical methods discussed herein do not require extremely strenuous activity, and exposure to heat or cold is similar to that during other field activities. Extreme weather conditions will have adverse effects on the time required to obtain validated data, thereby increasing the duration of personal exposure to the elements and to hazardous site influences.

In resistivity surveys, substantial levels of electrical charges and voltage may be present across the current electrodes, and field procedures must be designed to ensure that no personnel are in contact with the electrodes when the current source is energized. The site-specific Health and Safety Plan must address emergency procedures in the event of electrical shock and possible loss of consciousness.

5.0 REFERENCES

Good discussions of various survey techniques and applications are found in the following references:

ASTM Standard D 6429-99. 1999. *Standard Guide for Selecting Surface Geophysical Methods.*

ASTM Standard D 6431-99. 1999. *Standard Guide for Using the Direct Current Resistivity Method for Subsurface Investigation.*

Benson, Richard C., Robert A. Glaccum and Michael R. Noel. 1982. *Geophysical Techniques for Sensing Buried Wastes and Waste Migration.* Technos, Inc., Miami, FL., Contract No. 68-03-3050, USEPA Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Costello, Robert L. 1980. *Identification and Description of Geophysical Techniques.* Report No. DRXTH-TE-CR-80084, US Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD; Defense Technical Information System No. ADA 123939.

Keiswetter, D., Won, I. J., Bell, T., Barrow, B., and Khadr, N. 1998. Electromagnetic Induction Spectroscopy. Geophex, Ltd., Raleigh, N.C. and AETC Inc., Arlington, VA.

Loke, M.H. 2000. *Electrical Imaging Surveys for Environmental and Engineering Studies.*

McKown, G.L., G.A. Sandness and G.W. Dawson, 1980. *Detection and Identification of Buried Waste and Munitions.* Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, VA.

Olhoeft, Gary R. 1989. *Geophysics Advisor Expert System: Version 1.0.* Interagency Agreement DW 14932497, USEPA EMSL, Las Vegas, NV.

USACE. 1995. *Geophysical Exploration for Environmental and Engineering Investigations.* EM 1100-1-19802. 31 August.

STANDARD OPERATING PROCEDURE 20.8
MAGNETIC AND METAL DETECTION SURVEYS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide a general description of and technical management guidance on the use of Magnetic and Metal Detection Surveys.

2.0 MATERIALS

- Work Plans;
- Site maps;
- Field logbook;
- Metal detectors;
- Magnetometers;
- Pin flags;
- Surveys tape; and
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan.

3.0 PROCEDURE

3.1 DESCRIPTION OF METHODS

3.1.1 Theory and Principles of Operation

Magnetometry: All materials subjected to a magnetic field (including the magnetic field of the earth) will develop an induced magnetization, the intensity of which is proportional to the applied magnetic field and the magnetic susceptibility of the material. Ferromagnetic materials, such as iron or steel, have very high magnetic susceptibilities.

Induced magnetization in an object produces a local magnetic field that either reinforces (positive magnetic susceptibility) or reduces (negative susceptibility) the external applied field. The variations in an otherwise homogenous field caused by the presence of the object are called a magnetic anomaly, and observations of such anomalies can be used to infer the presence of nearby objects.

Magnetometry consists of measuring local variations in the earth's magnetic field along a traverse or across an area on the surface. Because the intensity of the earth's magnetic field depends in part on the magnetic susceptibility of subsurface material, a knowledge of variations in field intensity provides an indication of variations in the distribution of materials with different magnetic susceptibilities. In particular, the anomalies produced by buried ferromagnetic objects can be detected by magnetometers, which are instruments designed to measure the earth's magnetic field at a given location. In addition, many natural subsurface features, some of which are of interest in geohydrologic site investigations, may produce magnetic anomalies.

The intensity and inclination, or dip, of the earth's magnetic field varies smoothly (except for anomalies) with latitude. From the south to north across the United States, the intensity and inclination vary from about 49,000 to 60,000 gammas and from about 580 to 760, respectively. Nominal values for the Middle Atlantic Region (Washington, DC) are about 56,500 gammas and 690 for intensity and inclination, respectively. The intensity can vary ("drift") daily due to changes in the ionosphere, sunspots, and other phenomena. Therefore, the latitude, time, and regional magnetic trends are important considerations during the magnetic surveys.

The myriad features of both natural and artificial origin that influence magnetic field measurements means that there is no unique interpretation of a set of magnetometry data. Conversely, there is no unique magnetic anomaly produced by a particular kind of buried object. Factors that influence the response of a magnetometer include the size, shape, depth, orientation, magnetic susceptibility, and permanent magnetism of a buried object. The sensitivity of magnetometers is such that many objects of interest at hazardous waste sites (particularly buried ferromagnetic materials such as drums, tanks, pipes, and iron scrap) are detectable. However, it is often difficult to interpret and identify the source of magnetic anomalies.

Metal Detection: When a radio frequency electromagnetic field generated by a transmitter coil encounters a highly conductive object such as a metal (not necessarily ferromagnetic), alternating currents are induced in the object that, in turn, generate alternating secondary magnetic fields which can be detected as alternating voltages by a receiver coil. The presence of the metal object effectively "couples" the transmitter and receiver coils, which otherwise are oriented so that little or no coupling exists. The principles of metal detector operation are very similar to those associated with electromagnetic induction instruments.

A number of factors influence the response of a metal detector. The receiver response increases with the size and surface area and decreases with the depth of a buried object. Factors such as soil properties and shape complicate detectability and interpretation of responses. Certain shapes, such as elongated metal rods, are difficult to detect. Iron minerals and conductive fluids will affect the detector response in much the same manner as a target of interest. Generally, metal detectors show greater response to smaller nearby targets than to larger targets at greater depth, and the presence of widespread metallic debris at a site can interfere with attempts to detect buried drums and other objects.

3.2 GENERAL APPLICABILITY

Magnetic Surveys (Magnetometry): Applications of magnetic surveys at hazardous waste sites center on confirming the presence (or absence) and location of buried ferromagnetic objects. Location of buried waste containers such as drums or tanks and surveying of proposed drill sites to detect interfering pipes, cables, or tanks are two important applications. Typically, a single 55-gallon drum can be detected at depths of up to 6 meters and large drum deposits or large tanks can be detected at depths of 20 meters or more.

Magnetic surveys can more readily detect metallic masses than identify or characterize targets. Calculations of the mass or size of detected objects generally yields only approximate results.

Magnetic surveys may be impractical in areas where metal pipes, fences, railroad tracks, buildings, and other ferrous metal artifacts are abundant. However, proper selection of equipment and survey techniques can often alleviate some of these problems.

Metal Detection: Metal detectors (MDs) can be used for locating buried metallic containers of various sizes; defining the boundaries of trenches containing metallic containers; locating buried metallic storage tanks; locating buried metallic pipes; avoiding buried utilities when drilling or trenching; or locating utility trenches that may provide a permeable pathway for contaminants.

The detection range of a MD is relatively short. Its sensitive areas are focused directly above and below the coil, providing good definition of object location. Quart-sized metal objects can be detected at a distance of about 1 meter; objects the size of a 55-gallon drum can be detected at depth up to 3 meters; and massive piles of metals can be detected at depths of 3 to 6 meters. Deeper objects are difficult to detect with a MD. Although most MDs are operated on foot, some can be vehicle-mounted if desired.

3.2.1 Instrumentation

Magnetometers: Two types of magnetometers, the fluxgate and proton procession magnetometers, are commonly used at hazardous waste sites. The fluxgate magnetometer uses an iron core sensor of high magnetic susceptibility. The amount of coiled electrical current necessary to induce magnetic saturation of the rod is directly dependent upon, and thus measures, the strength of the ambient magnetic field. In a proton magnetometer, a strong magnetic field is applied to a bottle of proton-rich fluid (e.g., kerosene), which realigns the protons. The field is then turned off and the frequency of the signal generated by the protons as they realign themselves ("process") to the earth's magnetic field is dependent upon, and thus measures, the strength of the field at that point. Some magnetometers, such as the fluxgate, are extremely sensitive to orientation during measurement. To alleviate this problem, two sensors are connected by a rigid pole to form a "gradiometer" that measures only a certain directional component of the earth's magnetic field. These gradiometers are commonly used at hazardous waste sites.

The type of magnetometer best suited for a particular site investigation depends upon characteristics of that site and should be chosen by a person familiar with the different instruments available. Proton magnetometers, for example, while very useful in some situations, will cease to function in an area with high magnetic gradients such as a junkyard or near a steel bridge.

Different instruments have different levels of sensitivity. In some cases, high sensitivity may be desired to detect deeply buried objects; in other instances, a low sensitivity instrument may be desired to reduce the effects of "noise" from nearby fences or cars. Furthermore, the size of the survey area and the resolution required will determine whether the magnetometer used is hand-held for stationary measurements or a vehicle-mounted continuous sensor model.

Metal Detectors (MDs): Three general classes of metal detectors are commonly used in hazardous waste site studies: pipeline/cable locators, conventional "treasure hunter" detectors, and specialized detectors. EPA field investigation teams commonly use the pipeline/cable detectors; they do not respond to small objects like soda cans. Although most of the "treasure hunter" type detectors are used for locating coin-sized objects, some can be fitted with larger sensor coils suitable for detection of larger objects at greater depths. Some of these models also can operate with adverse soil conditions such as high iron content. Specialized detectors are also available to operate to greater depths, operate over a wide sweep area, operate continuously, cope with special field problems, or operate while vehicle-mounted. These special MDs require an experienced operator and are not commonly available.

3.3 DATA ACQUISITION

3.3.1 Field Procedures

Magnetics: Magnetic measurements are generally made in a cross-grid pattern or if a continuous sensor is used, in a series of parallel lines across the survey area. The desired resolution (reconnaissance or high density) and the size and depth of the objects sought determine the spacing of measurement stations or surveys lines. Because of the phenomenon of temporal magnetic drift, a magnetic survey must include a base station at which magnetic measurements are made at regular intervals. These base stations are later used to correct all survey data for temporal differences due to drift. If the survey area permits, surveys are often conducted in a loop, the base station forming the end and starting points.

Magnetometers require special care during use. An experienced technician is recommended. The operator must not take measurements with the sensor near ferromagnetic objects such as belt buckles or steel-toed boots. The orientation of the magnetometer and its height from the ground must also be carefully controlled during operation. Recorded data must be annotated with station locations to allow construction of a site magnetic map.

Metal Detector: Planning surveys with metal detectors are similar to surveys with magnetometers. A grid pattern of evenly spaced parallel lines is used. Desired resolution and the size of objects determine the grid spacing. In some cases, elevating the MD a few feet off the ground may help to eliminate noise from small surface objects. An experienced operator is recommended. Recorded data must be annotated with station locations to allow construction of a site metal detection map.

3.3.2 Data Format

Magnetics: The output of a magnetometer is a numerical value (in gausses) of the intensity of the earth's magnetic field at a location. It may be displayed electronically or printed on tape depending on the instrument used. Because the object of a magnetic survey is often to complete a map of the survey area, each magnetic reading must be coupled with a record of its precise location.

The time of each reading must also be recorded to allow temporal drift connection. Some recent proton magnetometers include microprocessors for recording information on readings, locations, and times in one memory for playback at the survey's completion.

Metal Detection: The data provided by a metal detector is less quantitative than that of a magnetometer. The MD signal strength may vary (depending on the instrument) with object depth, size and shape, but this signal does not translate into a quantity such as field strength. It merely indicates the presence of a metal object. This on/off type of signal is useful because it can indicate the boundaries of a metal-bearing zone more clearly than some quantitative data such as magnetometer recordings.

3.4 DATA INTERPRETATION

3.4.1 Magnetics

Before interpreting magnetic data, it must first be corrected for regional trends and temporal drift. Regional trends, as determined from magnetic maps, are subtracted from the observed values to resolve magnetic anomalies due to objects at the site. Temporal drift is corrected by calculating the base station field strength changes over time and subtracting the appropriate time-dependent value from each observation. Other corrections for terrain or for compliance with other magnetic data are also sometimes employed.

The calculations can be done by hand or via computer processing. Once these mathematical corrections have been performed, the result is a set of profiles on a magnetic contour map. Interpretation then involves matching the observed anomalies with inferred underground shapes of given magnetic properties. This "modeling" of the subsurface (or data conversion) can involve mathematical techniques such as upward and downward continuations that reduce topographic and other interfering effects. The interpretation of magnetic anomalies must be based upon auxiliary evidence of what is at the site because there is no unique geometric solution for any magnetic anomaly. Furthermore, because of magnetic inclination, magnetic anomalies do not appear directly above their source. An experienced geophysicist must perform interpretation of magnetic maps.

3.4.2 Metal Detection

Very little interpretation is necessary for metal detection surveys performed to provide qualitative data on the presence of metallic objects in the survey area as a precursor to more detailed subsequent geophysical surveys. For these cases, the positive audible response or meter deflections are recorded on site grid maps, and no further processing or interpretation is made. More detailed metal detection surveys using strip chart or magnetic tape recording are possible. Typically, data is plotted on site grid maps following computer processing. Corrections are made for nonlinearities and to eliminate small-target responses.

3.5 POTENTIAL PROBLEMS

Magnetic and metal detection surveys are geophysical methods that, although frequently applied, are subject to a wide variety of problems. Problems can be expected to arise in the following areas:

Planning and Execution: Rarely is a survey accomplished exactly according to the original plan. Site features not previously specified and other variations can occur that force changes in the details of the approach. However, the objectives of the survey, the general methodology, the amount of data required, and the degree of data interpretation requested should remain unchanged. Project work scopes should be written with some degree of latitude to allow a change in plans whenever justified.

Noise and Interferences: Measurements can be affected severely by both natural and man-made sources of metal and electrical currents. Iron-bearing minerals, metallic structures, and the presence of metal on the operator can adversely affect both types of surveys. Large masses of buried metal, fences, railroad tracks, and underground pipes or cables can strongly distort measurements and reduce instrument sensitivity to features of interest. These problems generally can be overcome but must be recognized early in the survey so that appropriate avoidance measures can be implemented. Known or suspected sources of interference should be included in the initial planning for a project.

Weather Conditions: It is possible to conduct the surveys under almost any conditions that permit traverse of the site. However, snow covers, standing water, heavy rainfall, or thoroughly saturated surface soils adversely affect metal detection surveys.

Technical Difficulties: Preventable difficulties include equipment malfunction or misapplication, poor operator training, and lack of applications experience. Other difficulties may arise because the magnetic character of the site is not as initially conceptualized. Early recognition and response by trained geophysicists can minimize the effect of any problems. Interim, real-time scrutiny of the data by the site geophysicists is essential. The geophysicist must be responsive regarding equipment replacement and/or repair or changes in personnel.

3.6 QUALITY CONTROL

Geophysical surveys, including magnetic and metal detection surveys, are subject to misapplication, erroneous interpretations, and use of incomplete or inadequate data, all of which can severely affect both the cost of subsequent site investigations and the validity of the survey. This susceptibility to misuse and the potential for negative effects demands that appropriate quality control measures have been implemented. Quality control aspects common to most types of geophysical field programs include the following:

- Program management personnel (i.e., the field operations leaders, RI leader and site manager) with adequate technical expertise in the subject for preparing statements of work; reviewing proposals, work plans, and reports; and supervising technical subcontracts.

- Insistence on a defined scope of work, specifications, and data validation procedures.
- Requirement of a field quality control program.
- No data point should be rejected from a data set without appropriate justification; field data sheets should contain all observed data and the conditions that could affect data validation.
- All field data should be recorded in permanent ink in a bound logbook with each page signed and dated by the operator. Original unaltered logbooks should remain in the project files of the RI/FS contractor.
- In general, the objectives of geophysical surveys can be met by relative measurements across an area or with depth. Absolute calibration is therefore of lesser importance than precision of measurements. However, a properly calibrated instrument provides an added measure of data validity and permits correlation and comparison of the associated data with site features and geohydrologic characteristics not evident at the time of the field effort.
- An evaluation should be made of noise, interferences, and obstructions at a site and such measurements, inferences, and explanations should be recorded in the field. These real-time quality control procedures aid field personnel in correcting noise sources over which they have control and validating suspected external sources and in early detection of problems that might jeopardize the survey objectives.

3.6.1 Magnetic Surveys

Calibration: Magnetometer readings should regularly be compared with readings of a reference base station magnetometer; this procedure is necessary if corrections are to be made for changes in the earth's magnetic field over time. Absolute calibration should be performed periodically by use of a reference magnet or a standard laboratory electromagnet. Calibration should be recorded on an instrument calibration sheet, a copy of which accompanies the instrument to the field. Fluxgate magnetometers are inherently calibrated except for the crystal-controlled frequency counter, which requires periodic laboratory calibration.

Daily Quality Control: All data sets should be accompanied by quality control data that indicate the level of quality of each individual data point. Periodically, replicate measurements should be made so that measurement precision can be established. This procedure also requires corrections for variations in the earth's magnetic field with time. Each data set should be referenced to the most recent calibrations. All data obtained before a calibration requiring significant changes in instrument controls is suspect and the measurements should be repeated or otherwise validated. Data should be preliminarily reduced and plotted during the field program to determine the overall quality of the data and whether the survey results are consistent with the site conceptualization. Data points representing discontinuities in the curves should be validated by repetition and, if necessary, a fine grid of measurements made to determine whether the anomaly represents a site feature of interest, a spurious reading, or an obstructive interference.

3.6.2 Metal Detection

Calibration: Metal detectors normally are not calibrated, and only relative response is of interest. Periodically, nulling the instrument at a fixed location known to be free of metal and adjusting the gain to provide a proper response over a known target should check the sensitivity.

Daily Quality Control: Metal detector data should be accompanied by sufficient quality control data to verify that the instrument was operating properly. Occasional repetitive measurements and a log of the sensitivity adjustments usually suffice for this purpose.

4.0 HEALTH AND SAFETY CONSIDERATIONS

All procedures for hazardous waste site entrance, traverse, and egress that apply to general field operations also apply to the conduct of geophysical surveys. Magnetic and metal detection surveys depend on traverse of the site on foot or in vehicles, and there are extended periods during which personnel are subject to adverse environments at the site. A site health and safety survey must be performed before the geophysical survey, and an appropriate level of protection must be provided during the geophysical surveys.

The geophysical methods discussed here do not require sub-surface penetration and do not require extremely strenuous activity. Exposure to heat or cold is similar to that experienced during other field activities. Extreme weather conditions will have adverse effects on the time required to obtain validated data, thereby increasing the duration of personnel exposure to the elements and to hazardous site influences.

Although the instruments themselves are held above the ground (unless sled mounted), the probes should be covered with non-metallic (i.e., plastic) covers at highly contaminated sites to avoid the possibility of accidental contamination.

5.0 REFERENCES

Good discussions of various geophysical survey techniques and applications are found in the following references:

ASTM Standard D 6429-99. 1999. *Standard Guide for Selecting Surface Geophysical Methods.*

Benson, R.C., R.A. Glaccum and M.R. Noel. 1982. *Geophysical Techniques for Sensing Buried Wastes and Waste Migration.* Technos, Inc., Miami, FL, Contract No. 68-03-3050, US EPA Environmental Monitoring Systems Laboratory, Las Vegas, NV.

Costello, R.L. 1980. *Identification and Description of Geophysical Techniques.* Report No. DRXTH-TE-CR-80084, US Army Toxic and Hazardous Materials Agency, Aberdeen Proving Ground, MD; Defense Technical Information System Number ADA 123939.

McKown, G.L., G. A. Sandness and G.W. Dawson. 1980. *Detection and Identification of Buried Waste and Munitions.* Proceedings of the 11th American Defense Preparedness Association Environmental Systems Symposium, Arlington, VA, 1980.

Olhoeft, Gary R. 1989. *Geophysics Advisor Expert System: Version 1.0.* Interagency Agreement DW 14932497, USEPA EMSL, Las Vegas, NV.

USACE. 1995. *Geophysical Exploration for Environmental and Engineering Investigations.* EM 1100-1-19802. 31 August.

STANDARD OPERATING PROCEDURE 20.9
PIEZOMETER INSTALLATION

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to define acceptable piezometer types and installation techniques. For the purposes of this SOP, a piezometer is defined as a well installation designed to determine and/or monitor groundwater level rather than to acquire environmental samples. The objective of the selected installation technique is to ensure that the piezometer provides representative data while minimizing subsurface contamination, cross-contamination, and installation costs.

A piezometer may typically consist of a 2-inch diameter casing with attached screen. This installation may differ from a typical monitoring well installation in one of several ways. The screen may be stainless steel, a stainless steel drive-point, slotted polyvinyl chloride (PVC), or continuously wire-wrapped PVC. The piezometer screen may either be driven into place or set in a drilled, open hole. If the screen is driven into place, an engineered filter pack is omitted.

Regardless of the screen and casing material or the method in which the piezometer is installed, proper care will be taken to avoid providing a vertical conduit for contaminants between aquifers. This will be accomplished by the use of bentonite and/or grout seals, as appropriate.

Piezometers may be installed singly or in clusters to monitor one or more piezometric surface(s). Piezometers may not be located within 15 ft of an existing monitoring well. Piezometers should not be installed upgradient of monitoring wells. It is recommended that multiple (nested or clustered) piezometers be located 10 to 15 ft apart.

2.0 MATERIALS

General Materials

- Work Plans;
- Field logbook;
- Electronic water level meter and steel tape;
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan; and
- Photoionization detector or other monitoring instruments per the site-specific health and safety plan.

General Materials for Installation

- Stainless steel piezometer drive-points or stainless steel or PVC well screens;
- Casing;
- Personal protective equipment;
- Large stand-mounted hammer with attached leveling device;
- Large wooden mallet;

- Hand-held level;
- Steel measuring tape;

or

- Drill rig and associated equipment;
- Bentonite pellets (SOP 20.1); and
- Cement (SOP 20.1).

3.0 INSTALLATION

Three options for the installation of piezometers are discussed below.

Driven screens/sampling points are, by their design, point source samplers, and a qualified geologist or geotechnical engineer on site must determine their placement. Estimated depths of placement should be included in the work plans for piezometer installation. The maximum depth to which a given point can be driven is a function of a number of parameters, such as the degree of induration and friction coefficient of the material(s) through which it is being advanced, the rigidity of the rod(s), and the driving force available.

3.1 WELL SCREEN IN OPEN HOLE

If the piezometer is to be installed in a drilled, open hole, refer to SOP 20.1 for appropriate drilling and installation protocol. In this case, the piezometer will differ from a monitoring well only in the diameter of the casing and possibly the construction of the screen (e.g., slotted rather than wire-wrapped). All other provisions for preventing vertical migration of contaminants will be observed.

3.2 DRIVEN POINT BELOW OPEN HOLE

If the piezometer employs a drive-point screen driven through a hole that is pre-drilled to the top of the target aquifer, follow the drilling procedures detailed in SOP 20.1, set the drive point according to the procedures below, and grout the hole according to SOP 20.1.

3.3 DRIVEN POINT FROM SURFACE

If the piezometer is to be driven from the surface, the installation should be considered as temporary. Work plan addenda must include a timetable for and details of the abandonment plan for these piezometers. Follow the installation steps below:

1. Drill or hand-auger a small diameter hole to a maximum depth of 2 ft to serve as a guide for the drive point.
2. Assemble and set the drive point, screen (typically a 2-ft length), and an appropriate number of threaded stainless steel casing extensions into this pilot hole.
3. If a drill rig is used, the hydraulic system may be used to press the drive point downward or the drop hammer may be used to drive the point downward. If the piezometer site is inaccessible by drill rig, a tripod-mounted drop hammer may be used to drive the point. Threaded stainless steel casing (typically 2-ft lengths) extensions may be added as needed until the piezometers are driven to the desired depth.
4. At sites where the soil or sediment is relatively soft and the desired screen depth is not greater than 2 ft, a large mallet may be used to pound the piezometer to the desired depth directly from the surface.

5. Add additional threaded casing onto top of piezometer if needed so that piezometer extends 2 to 3 ft above land surface. Place protective cap on top of piezometer.
6. Measure height of the piezometer casing above land surface. Record site number, screen depth, and height above ground surface.
7. If a shallow pilot hole was used, fill the hole to ground surface with bentonite pellets.
8. Decontaminate soil augers before moving onto another site.

3.4 COMPLETION

Complete drilled holes according to procedures detailed in SOP 20.1.

3.5 DEVELOPMENT

Develop piezometers according to procedures in SOP 20.2.

3.6 RELATED SOPS

Refer to SOPs 10.1 (Field Logbook), 80.1 (Decontamination), 40.2 (Water Level and Well-Depth Measurements), and applicable parts of 20.1 (Monitoring Well Installation).

4.0 MAINTENANCE

Not Applicable.

5.0 PRECAUTIONS

5.1 CONTAMINATION

Water, soil, and vapors at the sites may be contaminated with solvents, petroleum, chemical agents, explosives and heavy metals or their respective byproducts. Therefore, extreme care will be taken to avoid skin contact with potentially contaminated material.

Refer to the site-specific Health and Safety Plan (in work plan addenda) for discussion of hazards, preventive measures and PPE to be used during piezometer installation and development activities.

5.2 WATER SAFETY

If piezometers are being installed from boats or piers over bodies of open water, personal flotation devices (life jackets) will be required as part of the PPE.

6.0 REFERENCES

Aller, Linda, et al. 1989. *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.* National Water Well Association.

ASTM Standard D 5092-90 1990. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

COMAR 26.04.04 Well Construction.

EPA Groundwater Handbook. 1989.

Nielsen, David M. 1993. *Correct Well Design Improves Monitoring,* in "Environmental Protection," Vol. 4, No. 7, July 1993.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1 November.

STANDARD OPERATING PROCEDURE 20.10
PLACEMENT OF DYE DETECTOR HOLDERS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to define guidelines to be followed by field personnel in placement and retrieval of dye detectors.

2.0 MATERIALS

- Work plans;
- Field logbook;
- Dye-detector monitoring sheet;
- Photoionization detector (PID) or other appropriate monitoring equipment per site-specific health and safety plan;
- Weighted "gum drop" or brick sampler for detector placement in streams and springs;
- Disposable bailer for detector placement in monitoring wells or piezometers;
- Nylon cord;
- Activated carbon detectors (coconut charcoal type);
- Rubber boots/waders;
- Plastic sheeting;
- Clear or white plastic cable tie;
- Nylon or polypropylene line;
- Boat; personal flotation devices (PFDs), as applicable;
- Personal protective equipment;
- Cooler with blue ice;
- Hose;
- Gallon jug/ bucket; and
- Zip-lock bags.

3.0 PROCEDURE

The placement of dye-detectors (activated carbon samplers) is critical to the overall objectives of a dye trace study. The preferred method for sampler placement is dependent on the sampling point (i.e., spring, monitoring well, or domestic water supply well.

Careful and consistent placement of the activated carbon detectors (sampler) in the proper locations is required throughout the tracer study. The sampler will be collected and replaced on a regular schedule depending on the objectives on the project and site conditions. Frequent changing (less than once per week) is appropriate if the travel time is an important consideration (Aley 1999). An accelerated schedule may be used in this case, such as daily for the first week and weekly thereafter.

Sampling periods should be of equal length if dye concentrations will be compared for the different periods. The sampling interval should not be of such length that most of the detectable dye might discharge during a single sampling period (Aley 1999).

At highly contaminated sites, Eosine and Rhodamine WT dyes are more sensitive to decreased absorption rates with increased exposure time of the samplers than is the case for Fluorescein dye. Thus, more frequent sampling intervals, such as more than once per week, may be appropriate in these situations (Aley 1999).

All detectors placed in streams and springs should be securely anchored in areas of maximum flow. Detectors placed in piezometers or monitoring wells should be weighted so as to maintain contact with water column.

3.1 PREPARATION

3.1.1 Office

Before field activities can begin, equipment and supplies must be acquired and permission for property access secured, where applicable. Notification should be given to the laboratory concerning the sample types, the number of samples, and the approximate arrival time of the collected samples.

3.1.2 Documentation

Equipment necessary for accurate documentation includes a field logbook (SOP 10.1) and dye-detector "Bug Sheets" (Attachment A). The dye-detector "Bug Sheets" will be used to record site monitoring stations, date of placement and collection, and time of day and sample media.

3.1.3 Field Procedures

3.1.3.1 Sample Placement and Collection at Springs and Streams

Samplers in streams and springs should be placed where there is a reasonable current. Avoid placing the sampler at locations where it will likely be battered by swift current or where it will likely accumulate debris. Stream velocities between 0.1 and 1 foot per second are the most desirable (Aley 1999).

If the stream or spring has a soft bottom, place the samplers where they are at least a few inches above the soft materials (Aley 1999). When placing a detector in springs and streams, "gum drops" or bricks will be used as detector holders. They will be tied with a nylon cord to an adjacent tree, root, or rock to prevent accidental loss of detectors due to storms. The cord will be of natural colors (brown, gold, olive, or black) to discourage tampering. If the sampler detector is not completely submerged, modifications can be made to the "gum drop" by bending the strand. An aluminum identification tag will be placed on each detector holder including the sample site name and site number.

Replace the detector by removing the "gum drop" from the spring or stream and replacing it with a fresh one. Each detector will be placed in its own pre-labeled (on outside) zip-top bag from which a fresh detector has been removed. Information will be recorded regarding the integrity of the detectors and any other visual characteristics. Any signs of unusually colored water will require that a sample be collected for spectrofluorometric analysis. Place the new detector and its holder back into the spring or stream.

3.1.3.2 Detector Placement and Collection at Monitoring Wells, Piezometers, and Non-Pumped Domestic Wells

Activated carbon samplers will be prepared before insertion into the well or piezometer to prevent the release of activated carbon powder to the well. The following procedure can be used:

1. Add samplers (up to 25) to a bucket containing one gallon of distilled or de-ionized water, slosh them around, and let stand for 10 minutes.
2. Discard the used water from the bucket and add a second gallon of clean distilled or de-ionized water, slosh, and let stand for 10 minutes.
3. Repeat the procedure with a third gallon of water.
4. Store the samplers wet and in a plastic bag under refrigeration and use within one week (Aley 1999).

Monitoring wells will be sampled by attaching an activated carbon sampler to the top of a disposable bailer with a clear or white plastic cable tie (Aley 1999). After nylon or polypropylene line has been appropriately attached to the bailer, the sampler is lowered with the bailer to the center of the screened interval or to the middle of the saturated zone of the well. The line holding the bailer is then secured by tying to a fixed point on the well casing.

When it is time for a detector to be collected, place plastic sheeting around the monitoring well. Unlock the well and perform organic vapor check using a PID or similar instrument following the procedures outlined in SOP 40.2 of the MWP. Pull the bailer line up, thereby raising the bailer and attached sampler to the surface. Place the rope on the plastic sheeting as it is being raised. Remove one end of the cap, and then remove and replace the detector packet. Secure well cap and lock well.

3.1.3.3 Detector Placement and Collection at Domestic Pumped Wells

Detectors for domestic pumped wells will be received in canisters from the laboratory.

The canisters will be replaced, and the laboratory analyst will remove the detectors. Remove the pumped-well dye-detector (PWDD) canister from its pre-labeled plastic zip-top bag and replace it with a fresh one. The PWDD is attached to a garden hose with the opposite end connected to a faucet. In some instances, a special connection may be needed to allow homeowner use of outside faucet. This can be accomplished by attaching a Y-connector that has a cutoff valve on each outlet connection. The valve will allow constant flow for the PWDD while allowing homeowner full use of the faucet if needed.

The valve or faucet is turned on to allow water flow of approximately 1 gal/min through the PWDD canister. Use a gallon jug or bucket and a stop watch or watch with a second hand to measure and adjust the flow rate. The discharge end of the hose is allowed to discharge to the ground away from the house at a location that is acceptable to the homeowner.

3.1.3.4 Maintaining Sample Integrity

In addition to appropriate sampling and chain-of-custody protocols, the following steps should be followed to maintain the integrity of activated carbon samplers:

1. Limit labeling of sample bags to the outside and do not use any colored pen or marker as these contain some of the tracer dyes in the ink.
2. Keep the collected samplers under refrigeration until analysis.

3. Use cold packs and cooler chests to keep samples cool during field and sample shipping. Avoid using real ice since it can cross-contaminate samples during melting.
4. Do not wash samplers in chlorinated tap water.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

Alexander, Calvin E., Jr. and James F. Quinlan. 1992 (2nd Edition). *Practical Tracing of Groundwater, with Emphasis on Karst Terrains.* Short Course presented on the occasion of the Annual Meeting of the Geological Society of America. October 24, 1992, Cincinnati, OH.

Aley, Thomas. 1999. *The Ozark Underground Laboratory's Groundwater Tracing Handbook.*

ATTACHMENT A

BUG SHEET - Sites Monitored for Dyes

TEST ____________________ RUN BY ________________________ DATE _______

JAR #	Fl	Eos	RWT	SRB	Site Code	Location	Pull Gum Drop	Pull All Bugs	Hang Charcoal	Rig Gum Drop
	Charcoal Sampler									

STANDARD OPERATING PROCEDURE 20.11
DRILLING METHODS AND PROCEDURES

1.0 SCOPE AND APPLICATION

The use of an appropriate drilling procedure is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to outline procedures for the various methods of soil and rock drilling identified in the Master Work Plan. In addition it provides procedures for using sampling devices commonly used during soil and rock drilling such as split-barrel sampling, thin walled tube sampling, direct push samplers, and rock coring. For a particular site investigation, the associated work plan addendum will identify the appropriate drilling method and method of sampling, along with proposed sampling depths and intervals and any special procedures or methods.

2.0 MATERIALS

The following types of materials are generally appropriate for drilling:

2.1 SPLIT-BARREL SAMPLING

- Split barrel sampler;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.2 THIN WALLED TUBE SAMPLING

- Thin walled tubes;
- Sealing materials for sample such as sealing wax, metal disks, wood disks, tape, cheesecloth, caps, etc;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.3 DIRECT PUSH SAMPLING

- Direct push unit with hydraulic ram, hammer, etc;
- Sample collection devices, associated equipment and expendable supplies such as sample liners, sample retainers, appropriate lubricants, etc;
- Hollow extension rods;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;

- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.4 HOLLOW-STEM AUGER DRILLING

- Drill rig and associated equipment;
- Hollow stem auger assemblies for drilling to appropriate depth including auger heads, drive assembly, pilot assembly, and hollow-stem auger sections;
- Auxiliary devices such as wrenches, auger forks, hoisting hooks, swivels, and adaptors;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.5 DIRECT AIR ROTARY DRILLING

- Drill rig with rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Sampling devices and equipment, as appropriate;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.6 DRILL-THROUGH CASING DRIVER

- Drill rig equipped with a mast-mounted, percussion driver;
- Casing, drill rods, and drill bits or hammers;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Sampling devices and equipment, as appropriate;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Welding equipment and materials for installation of casing;

- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.7 DIRECT WATER-BASED ROTARY DRILLING

- Drill rig with derrick, rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, cyclone de-sander(s), drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1.
- Decontamination supplies and equipment per SOP 80.1.

2.8 DIRECT ROTARY WIRELINE-CASING ADVANCEMENT DRILLING

- Drill rig with either hollow spindle or top-head drive;
- Drill rods, coring or casing bits, overshot assembly, pilot bit, and core barrel;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.9 DIAMOND CORE DRILLING

- Direct rotary drill rig and associated equipment (see Sections 2.4, 2.5 or 2.6);
- Core barrels and core bits;
- Core lifters;
- Core boxes, engineers scale, permanent marking pen, and camera for photographing cores;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;

- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

3.0 PROCEDURES

3.1 PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

The following general procedure may be followed as outlined in ASTM Standard Test Method D 1586-84.

1. Advance the boring to the desired sampling depth using an appropriate drilling method (see sections below) and remove excessive cuttings from the borehole.
2. Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.
3. Position the hammer above and attach the anvil to the top of the drilling rods.
4. Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the borehole, remove the sampler and rods from borehole and remove the cuttings.
5. Mark the drill rods in three successive 6-inch increments so that the advance of the sampler can be observed.
6. Drive the sampler with blow from the 140 pound hammer and count the number of blows applied in each 6-inch increment until:
    a. Fifty (50) blows have been applied during one of the three 6-inch increments.
    b. A total of 100 blows have been applied.
    c. There is no observed advance of the sampler during the application of 10 successive blows of the hammer.
7. The sampler is advanced the complete 18-inches without the limiting blow counts occurring as described above.
8. Record the number of blows that is required to achieve each 6-inch increment of penetration or fraction of this increment on the boring.
    a. The first 6 inches is considered the seating driver.
    b. The sum of the second and third 6-inch penetration intervals is termed the "standard penetration resistance" or "N-value."
    c. If the sampler is driven less than 18 inches as discussed in No. 6, then the number of blow for each partial increment will be recorded.
    d. For partial increments, the depth of penetration should be recorded to the nearest 1-inch on the boring log.
    e. If the sampler advances below the bottom of the boring under the weight of rods (static) and/or hammer, then this information will be recorded on the boring log.
9. The raising and dropping of the 140 pound hammer may be accomplished by:
    a. Using a trip, automatic, or semi-automatic hammer drop system that lifts the hammer and allows it to drop 30± 1 inches.

   b. Using a cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 inches. The cathead should be operated at a minimum speed of rotation of 100 revolutions per minute. No more than 2-1/4 rope turns on the cathead may be used when conducting the penetration test.

10. For each hammer blow, a 30-inch lift and drop shall be used.
11. After completing the penetration test, retrieve the sampler and open. Record the percent recovery or the length of sample recovered. Following the procedures outlined in SOP 30.1 when collecting environmental soil samples.
12. Borehole logging should be completed per SOP 10.3.
13. Split-barrel samples must be decontaminated before and after each use per the requirements of SOP 80.1.

3.2 THIN WALLED TUBE SAMPLING

The following general procedure may be followed for collection of relatively undisturbed, thin walled tube samples (e.g., Shelby tube) as outlined in ASTM Standard Practice D 1587-94.

1. Clean out the borehole to targeted sampling depth using most appropriate method, which avoids disturbing the material to be sampled. If groundwater is encountered, maintain the liquid level in the borehole at or above the groundwater level during sampling.
2. Place the sample tub so that its bottom rests on the bottom of the borehole.
3. Advance the sampler without rotation by a continuous relatively rapid motion.
4. Determine the length of the advance by the resistance and condition of the formation, the length of the advance should never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clay.
5. When the formation is too hard for push type of sampling, the tube may be driven or the practice used for ring-lined barrel sampling may be used per ASTM Standard D 3550-84 (1995). When a sample is driven, the weight and fall of the hammer must be recorded along with the penetration achieved.
6. The maximum length of sample advance will be no longer than the sample-tube length minus an allowance for the sample head and a minimum of 3-inches for sludge-end cuttings.
7. Upon removal of the tube, measure the length of the sample in the tube. Remove the disturbed material in the upper end of the tube and re-measure the sample length.
8. Remove at least one-inch of material from the lower end of the tube for soil description and identification per SOP 10.3. Measure the overall sample length. Seal the lower end of the tube. If directed, the material from the end of the tube will not be removed for soil identification and description; in this case the tube will be sealed promptly.
9. Prepare sample labels and affix (or markings) on the tube.

3.3 DIRECT PUSH SOIL BORING

The following general procedures outlined in this section may be followed as described in ASTM Standard Test Method D 6282-98.

General considerations for this method include the following:

- A variety of direct push drive systems may be used to advance soil borings based on the intended sampling depths and subsurface conditions and include the following:

  Shallower Depths and Less Difficult Conditions

  - Percussive driving systems – use hydraulically operated hammers and mechanically operated hammers.
  - Static push drive systems – use hydraulic rams to apply pressure and exert static pull (e.g., cone penetrometer systems).
  - Vibratory/sonic systems – use a vibratory device, which is attached to the top of the sampler extension rods.

  Greater Depths and More Difficult Conditions

  - Sonic or resonance drilling systems – use a high power vibratory system to advance larger diameter single or dual tube systems.
  - Rotary drilling equipment – use hydraulic system of drill rig for direct push.

- The equipment used for direct push must be capable of apply sufficient static force, or dynamic force, or both, to advance the sampler to the required depth of collection. Additionally, this equipment must have adequate retraction force to remove the sampler and extension/drive rods once the sample has been collected.
- Avoid using excessive down pressure when advancing the drilling tools/sampler. Excessive pressure may cause the direct push unit to offset from the boring location and may damage drilling tools and samplers.
- Sample liners should be compatible with the material being sampled and the type of analysis to be conducted on the sample. Sealing of liners for submittal to the laboratory for physical testing should be accomplished according to ASTM Standard D 4220-95 (Standard Practice for Preserving and Transporting Soil Samples).
- The general procedure for completing direct push soil borings is the following:

1. Stabilize direct push unit and raise mast at desired location.
2. Attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit the position over the borehole, and ready the tools for insertion.
3. Inspect the direct push tools before and after use. Decontaminate all down hole tools before and after use per SOP 80.1.
4. Inspect drive shoes for damaged cutting edges, dents or thread failures and these conditions could cause loss of sample recovery and slow the rate of advancement.
5. Assemble samplers and install where required, install sample retainers where needed, and install and secure sampler pistons to ensure proper operation where needed (see Steps 14 through 20 for the various sampler assembly procedures, etc.).
6. After sampler has been appropriately installed (see Steps 14 through 20 for installation procedures, etc.) advance the boring to the target sampling depth using an appropriate direct push technique, as identified above under general considerations.
7. Collect the soil sample from the target sampling depth using one of the methods identified in Steps 14 through 20.

8. Retrieve the sampler and appropriately process the soil sample as identified in Steps 14 through 20 below and in SOP 30.1.
9. Log the borehole per the requirements of SOP 10.3.
10. If collecting another soil sample, decontaminate the sampler for reuse per the requirements of SOP 80.1 or use another decontaminated sampler.
11. Appropriately manage investigation-derived material (discarded samples, decontamination fluids, etc.) per SOP 70.1.
12. Upon completion of the boring and collection of the desired soil samples, abandon the boring per the requirements of SOP 20.2.
13. The following single tube sampling systems (generally piston rod) may be used to collect soil samples (see Steps 14 through 16 below):
    a. Open Solid Barrel Sampler;
    b. Closed Solid Barrel Sampler (e.g. Geoprobe Macro-Core® Piston Rod Sampler); and
    c. Standard Split Barrel Sampler (see Section 3.1).
14. The following two tube sampling systems may be used to collect soil samples (see Steps 17 through 20 below):
    a. Split Barrel Sampler;
    b. Thin Wall Tubes;
    c. Thin Wall Tube Piston Sampler; and
    d. Open Solid Barrel Samplers.
15. Sampling with the single tube, open solid barrel sampler:
    a. Attach the required liner to the cutting shoe by insertion into the machined receptacle are or by sliding over the machined tube.
    b. Insert the liner and shoe into the solid barrel and attach the shoe.
    c. Attach the sampler head to the sampler barrel.
    d. Attach the sampler assembly to the drive rod and the drive head to the drive rod.
    e. Position the sampler assembly under the hammer anvil and advance the sampler assembly into the soil at a steady rate slow enough to allow the soil to be cut by the shoe and move up into the sample barrel.
    f. At the completion of the sampling interval, removal the sampler from the borehole. Remove the filled sampler liner from the barrel by unscrewing the shoe. Cap the liner for laboratory testing or split open for field processing (see SOP 30.1).
    g. Log the borehole per the requirements of SOP 10.3.
16. Sampling with the closed, solid barrel sampler (e.g., Macro-Core® sampler).
    a. Insert or attach the sample liner to the shoe and insert the assembly into the solid barrel sampler. Install the sample, retaining basket, if desired.
    b. Attach the latch coupling or sampler head to the sampler barrel, and attach the piston assembly with point and "O" rings if free water is present, to the latching mechanism.
    c. Insert the piston or packer into the liner to its proper position so that the point leads the sampler shoe. Set latch, charge packer, or install locking pin, and attach assembled sampler to drive rod.
    d. Add drive head and position under the hammer anvil. Apply down pressure, and hammer if needed, to penetrate the soil strata above the targeted sampling interval.

- e. When the sampling interval is reached, insert the piston latch release and recovery tool, removing the piston, or insert the locking pin removal/extension rods through the drive rods, turn counter clockwise, and remove the piston locking pin so the piston can float on top of the sample, or release any other piston holding device.
- f. Direct push or activate the hammer to advance the sampler the desired interval.
- g. Retrieve the sampler from the borehole by removing the extension/drive rods. Remove the shoe, and withdraw the sample line with sample for processing (see SOP 30.1).
- h. Clean and decontaminate the sampler, reload as described above and repeat the same procedure for collection of addition samples.
- i. Log the borehole per the requirements of SOP 10.3.

17. Sampling with standard split barrel (split spoon) sampler generally consists of the following:
    - a. Attach the split barrel sampler to an extension rod or drill rod.
    - b. Using a mechanical or hydraulic hammer drive the ampler into the soil the desired interval. The maximum interval that should be driven is equal to the sample chamber length of the split barrel sampler, which is either 18-inches or 24-inches.
    - c. Retrieve the sampler from the borehole by removing the extension/drive rods.
    - d. Split the sampler open for field processing (see SOP 30.1).
    - e. Clean and decontaminate the sampler (SOP 80.1), re-attach and repeat the same procedure for collection of additional samples.
    - f. Log the borehole per the requirements of SOP 10.3.
18. Sampling with a two tube, split barrel sampler generally consists of the following:
    - a. Assemble the outer casing with the drive shoe on the bottom, attach the drive head to the top of the outer casing, and attach the sampler to the extension rods.
    - b. Connect the drive head to the top of the sampler extension rods, and insert the sampler assembly into the outer casing.
    - c. The cutting shoe of the sampler should contact the soil ahead of the outer casing to minimize sample disturbance.
    - d. The sample barrel should extend a minimum of 0.25 inches ahead of the outer casing.
    - e. Mark the outer casing to identify the required drive length, position the outer casing and sampler assembly under the drill head.
    - f. Move the drill head downward to apply pressure on the tool string. Advance the casing assembly into the soil at a steady rate, which is slow enough to allow the soil to be cut by the shoe and move up inside the sample barrel.
    - g. Occasional hammer action during the push may assist recovery.
    - h. If smooth push advancement is not possible because of subsurface conditions, use the hammer to advance the sampler.
    - i. Stop the application of pressure or hammering when target interval has been sampled. Move the drill head off the drive head. Attach a pulling device to the extension rods or position the hammer bail and retrieve the sampler from the borehole.
    - j. At the surface, remove the sampler from the extension rods and process the sample per Section 3.01 and SOP 30.1.
    - k. Log the borehole per the requirements of SOP 10.3.

19. Sampling with a two tube, thin wall tube sampler generally consists of the following:
    a. Attach the tube to the tube head using removable screws.
    b. Attach the tube assembly to the extension rods and position at the base of the outer casing shoe protruding a minimum of 0.25 inches to contact the soil ahead of the outer casing.
    c. Advance the tube with or without the outer casing at a steady rate.
    d. After completing the sampling interval, let the tube remain stationary for one minute. Rotate the tube slowly two revolutions to shear off the sample.
    e. Remove the tube from the borehole and measure the recovery, and log the borehole per the requirements of SOP 10.3.
    f. For field processing, extrude the sample from the tube sampler and process per SOP 30.1. Alternatively, the tube may be sealed and shipped to the laboratory.
20. Sampling with two tube, thin wall tube, piston sampler generally consists of the following:
    a. Check the fixed piston sampling equipment for proper operation of the cone clamping assembly and the condition of the "O" rings.
    b. Slide the thin wall tube over the piston, and attach it to the tube head. Position the piston at the sharpened end of the thin wall tube just above the sample relief bend.
    c. Attach the tube assembly to the extension rods and lower the sampler into position through the outer casing. Install the actuator rods through the extension rod, and attach to the actuator rod in the sampler assembly.
    d. Attach a holding ring to the to top of the actuator rod string and hook the winch cable or other hook to the holding ring to hold the actuator rods in a fixed position.
    e. Attach the pushing fork to the drill head/probe hammer and slowly apply downward pressure to the extension rods advancing the thin wall tube over the fixed piston into the soil for the length of the sampling interval.
    f. After completing the sampling interval, let the tube remain stationary for one minute. Rotate the tube slowly one revolution to shear off the sample.
    g. Remove the tube sampler from the borehole and measure the recovery, and log the borehole per the requirements of SOP 10.3.
    h. For field processing, extrude the sample from the tube sampler and process per SOP 30.1.
21. Sampling with an two tube, open solid barrel sampler generally consists of the following:
    a. This sampling technique may be used when soil conditions prevent advancement of a split barrel sampler or advancement of an outer casing.
    b. The solid, single, or segmented barrel sampler requires the use of a liner.
    c. Use sampler in advance of outer casing when this casing cannot be advanced.
    d. Follow the procedures outlined for two tube, split barrel sampling.

3.4 HOLLOW-STEM AUGER DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5784.

1. Stabilize drill rig and raise mast at desired location.
2. Attach an initial assembly of hollow-stem auger components (hollow stem auger, hollow auger head, center rod and pilot assembly, as appropriate) to the rotary drive of the drill rig.
3. Push the auger assembly below the ground surface and initiate rotation at a low velocity.

4. Decontamination of auger head may be necessary after this initial penetration if this surface soil is contaminated.
5. Continue drilling from the surface, usually at a rotary velocity of 50 to 100 rotations per minute to the depth where sampling or in-situ testing is required or until the drive assembly is within approximately 6- to 18 inches of the ground surface.
6. As appropriate, collect a soil sample from the required depth interval. The sample may be conducted by
   a. Removing the pilot assembly, if used, and inserting and driving a sampler through the hollow stem auger of the auger column; or
   b. Using a continuous sampling device within the lead auger section, where the sampler barrel fills with material as the auger is advanced.
7. Additional sections of hollow stems augers may be added to drill to a greater depth. After these auger sections are added, rotation of the hollow-stem auger assembly may be resumed.
8. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.

   Monitoring wells or piezometers may be installed using hollow-stem augers by:
   a. Drilling with or without sampling to the target depth.
   b. Removal of the pilot assembly, if used, and insertion of the monitoring well (or piezometer) assembly.
   c. The hollow stem auger column should be removed incrementally as the monitoring well (or piezometer) completion materials are placed (see SOP 20.1 for grouting).
9. If materials enter the bottom of the auger hollow stem during the removal of the pilot assembly, it should be removed with a drive sampler or other appropriate device.
10. If sampling or *in-situ* testing is not required during completion of the boring, the boring may be advanced with an expendable knock out plate or plug of an appropriate material instead of a pilot assembly.
11. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1. It may be necessary to drill through a hole of sheet of plywood or similar material to prevent cuttings from contacting the ground surface.
12. The hollow-auger assembly and sampling devices must be decontaminated before and after each use per the methods specified in SOP 80.1.
13. Borehole logging should be completed per SOP 10.3.
14. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.5 DIRECT AIR ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5784-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit, down hole hammer, or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed below the top of the dust collector.
4. Activate the air compressor to circulate air through system.

5. Initiate rotation of bit.
6. Continue with air circulation and rotation of the drill-rod column to the depth where sampling or in-situ testing is required or until the length of the drill rod section limits further penetration.
7. Monitor air pressure during drilling operations. Maintain low air pressure at bit to prevent fracturing of surrounding material.
8. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.
9. Open reaching a desired depth of sampling, stop the air circulation and rest bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
10. When sampling, remove the drill rod column from the borehole or leave the drill rod assembly in place if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 12 should be conducted for each sampling or testing interval.
14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
15. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
16. Monitoring wells or piezometers may be installed by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the drill rod assembly and insertion of the monitoring well (or piezometer) assembly.
    c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
17. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
18. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
19. Borehole logging should be completed per SOP 10.3.
20. Borehole abandonment, when required, should be conducted according to SOP 20.3

3.6 DRILL-THROUGH CASING DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5872-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit or down hole hammer with a single section of drill rod and casing to the top-head drive unit.

4. Activate the air compressor to circulate air through system.
5. Drilling may be accomplished by
    a. Method 1- the casing will fall, or can be pushed downward behind the bit.
    b. To drill using Drive the casing first followed by drilling out the plug inside the casing.
    c. Method 2 - Advancing the casing and bit as a unit, with the drill bit or hammer, extending up to 12-inches below the casing.
6. Method 3 - Under reaming method where bit or hammer pens a hole slightly larger than the casing so that Method 1, drive the casing first and drill out the plug in the casing by moving the bit or hammer beyond the casing and then withdrawing it into the casing. Air exiting the bit will remove the cuttings up the hole. Separate cuttings from the return air with a cyclone separator or similar device.
7. To drill using Method 2, advance casing and bit as unit with the bit or hammer extending up to 12-inches beyond the casing depending on the conditions. While drilling, occasionally stop the casing advancement, retract the bit or hammer inside the casing to clear and maintain air circulation to clear cuttings.
8. To drill using Method 3, use a special down hole bit or hammer to open a hole slightly larger than the outside diameter of the casing so that the casing will fall or can be pushed downward immediately behind the bit. After advancing the casing, retract the radial dimension of the drill bit to facilitate removal of the down hole bit or hammer and drill tools inside the casing. Cuttings are removed from the borehole with the air that operates the bit or hammer and can be separated from the air with a cyclone separator or similar device.
9. Monitor air pressure during drilling operations. Maintain low air pressure at bit or hammer to prevent fracturing of surrounding material.
10. Continue air circulation and rotation of the drill rod column until drilling is completed to the target depth (for sampling, in-situ sampling, etc.) or until the length of the drill-rod section limits further penetration.
11. Stop rotation and lift bit or hammer slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.
12. After reaching a desired depth of sampling, stop the air circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
13. When sampling, remove the drill rod column from the borehole. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
14. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
15. The procedure described in Steps 11 through 14 should be conducted for each sampling or testing interval.
16. Drilling to a greater depth may be accomplished by attaching an additional drill rod section and casing section to the top of the previously advanced drill-rod column/casing and resuming drilling operations as described above.
17. Monitoring wells or piezometers may be installed by:
    a. Casing advancement in increments, with or without sampling to the target depth.
    b. Removal of the drill rods and the attached drill bit while the casing is temporarily left in place to support the borehole wall.

   c. Insertion of the monitoring well (or piezometer) assembly.
   d. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
18. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
19. The drill rod assembly, casing, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
20. Borehole logging should be completed per SOP 10.3.
21. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.7 DIRECT WATER-BASED ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5783-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the mud tub and install surface casing and seal at the ground surface.
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed with the top of the surface casing.
4. Activate the drilling-fluid circulation pump to circulate drill fluid through the system.
5. Initiate rotation of bit and apply axial force to bit.
6. Document drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, etc.) as described in SOP 10.3.
7. Continue with drill fluid circulation as rotation and axial force are applied to the bit until drilling to the depth
   a) Where sampling or in-situ testing is required;
   b) Until the length of the drill rod section limits further penetration; or
   c) Until core specimen has completely entered the core barrel (when coring) or blockage has occurred.
8. Stop rotation and the lift bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue fluid circulation until the drill cuttings are removed from the borehole annulus.
9. After reaching a desired depth of sampling, stop the fluid circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
10. When sampling, drill rod removal is not necessary if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 11 should be conducted for each sampling or testing interval.
14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.

15. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
16. Monitoring wells or piezometers may be installed using hollow-stem augers by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the drill rod assembly and insertion of the monitoring well (or piezometer) assembly.
    c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
17. Drill cuttings and fluids should be appropriately controlled and contained as IDM per SOP 70.1.
18. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
19. Borehole logging should be completed per SOP 10.3.
20. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.8 DIRECT ROTARY WIRELINE CASING ADVANCEMENT DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5876-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the mud tub (for water based rotary) and install surface casing and seal at the ground surface.
2. Record the hole depth by knowing the length of the rod-bit assemblies and comparing its position relative to the established surface datum.
3. Attach an initial assembly of a lead drill rod and a bit or core barrel below the top-head drive unit, with the bit placed with the top of the surface casing.
4. Activate the drilling-fluid circulation pump to circulate drill fluid through the system.
5. Initiate rotation of bit and apply axial force to bit.
6. Document drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, down feed pressures etc.) as described in SOP 10.3.
7. In general, the pilot bit or core barrel can be inserted or removed at any time during the drilling process and the large inside diameter rods can act as a temporary casing for testing or installation of monitoring devices.
8. Continue with drill fluid circulation as rotation and axial force are applied to the bit until drilling to the depth
    a) Where sampling or in-situ testing is required;
    b) Until the length of the drill rod section limits further penetration; or
    c) Until core specimen has completely entered the core barrel (when coring) or blockage has occurred.
9. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue fluid circulation until the drill cuttings are removed from the borehole annulus.
10. After reaching a desired depth of sampling, stop the fluid circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.

11. When sampling, drill rod removal is not necessary if the sampling can be performed through the hollow axis of the drill rods and bit.
12. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
13. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it may be necessary to further clean the hole by rotary recirculation.
14. Continuous sampling may be conducted with a soil core barrel or rock core barrel (see Section 1.7).
15. The pilot bit or core barrel may need to be removed during drilling such as when core barrels are full or there is evidence of core blocking. Before the drill string is reinserted, the depth of the boring should be rechecked to evaluate hole quality and determine whether casing may be required.
16. Water testing may be performed in consolidated deposits by pulling back on the drill rods and passing inflatable packer(s) with pressure fitting to test the open borehole wall (see ASTM Standards D 4630 and D 4631).
17. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
18. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings might be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
19. Monitoring wells or piezometers may be installed by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the pilot bit or core barrel and insertion of the monitoring well (or piezometer) assembly.
    c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
20. Drill cuttings and fluids should be appropriately controlled and contained as IDM per SOP 70.1.
21. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
22. Borehole logging should be completed per SOP 10.3.
23. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.9 DIAMOND CORE DRILLING

The following general procedure may be followed as outlined in ASTM Standard Practice D 2113-83 (1993).

1. Use core-drilling procedures, such as the water-rotary drilling method outlined in Section 3.6.
2. Seat the casing on bedrock or firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the formation that the casing will be seated on as needed.
3. Begin core drilling using an N-size double-tube, swivel-type core barrel or other approved size or type. Continue core drilling until core blockage occurs or until the net length of the core has been drilled.
4. Remove the core barrel from the borehole, and dis-assemble the core barrel as necessary to remove the core.
5. Reassemble the core barrel and return it to hole.
6. Continue core drilling.

7. Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box. Wrap soft or friable cores, etc. as needed or required. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core that might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.
8. The core within each completed box should be photographed after core surface has been cleaned or peeled, as appropriate, and wetted. Each photo should be in sharp focus and contain a legible scale in feet and tenths of feet (or metric if appropriate). The core should be oriented so that the top of the core is at the top of the photograph. A color chart should be included in the photograph frame as a check on photographic accuracy. The inside lid of the box should also be shown.
9. The inside of the box lid should be labeled at a minimum with the facility name, project name, boring number, box number, and core interval.
10. A preliminary field log of the core must be completed before the core box has been packed for transport (see SOP 10.3). Detailed logging may be conducted at a later time providing the core is appropriately handled and transported.
11. Four levels of sample protection may be used depending on character of the rock and the intended use of the rock core including:
    a. *Routine care* – for rock cored in 5 to 10 foot runs. Consists of placing in structurally sound boxes. Lay flat tubing may be used prior to placing the core.
    b. *Special care* – for rock samples to be tested that are potentially moisture sensitive, such as shale. This care consists of sealing with a tight fitting wrapping of plastic film and application of wax at the ends of the sample.
    c. *Critical care* – for rock samples that may be sensitive to shock and vibration and/or temperature. Protect by encasing each sample in cushioning material, such as sawdust, rubber, polystyrene, foam, etc. A minimum one-inch thick layer of cushioning material should be used. Thermally insulate samples that are potentially sensitive to changes in temperature.
    d. *Soil-Like care* – handle per ASTM Standard D 4220-95.
12. Drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, down feed pressures, core blockage etc.) should be documented on the boring log as described in SOP 10.3.
13. Drill cuttings and fluids should be appropriately controlled and contained as investigation-derived material per SOP 70.1.
14. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
15. Borehole logging should be completed per SOP 10.3.
16. Borehole abandonment, when required, should be conducted according to SOP 20.3.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to site-specific health and safety plan included in work plan addenda.

6.0 REFERENCES

ASTM Standard D 2113-83 (1993). 1993. *Standard Practice for Diamond Core Drilling for Site Investigation.*

ASTM Standard D 1586-84 (1992). 1992. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 1587-94. 1994. *Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils.*

ASTM Standard D 4220-95. 1995. *Standard Practices for Preserving and Transporting Soil Samples.*

ASTM Standard D 5079-90. 1995. *Standard Practices for Preserving and Transporting Rock Core Samples.*

ASTM Standard D 5782-95. 1995. *Standard Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5783-95. 1995. *Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5784-95. 1995. *Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5872-95. 1995. *Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5876-95. 1995. *Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 6282-98. 1998. *Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000. 1, November.

STANDARD OPERATING PROCEDURE 20.12
DIRECT PUSH GROUNDWATER SAMPLING

1.0 SCOPE AND APPLICATION

The use of direct push groundwater sampling is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to outline procedures for the collecting groundwater samples using direct push sampling. For a particular site investigation, the associated work plan addendum will identify the appropriate drilling method and method of groundwater sampling, along with proposed sampling depths and intervals and any special procedures or methods.

2.0 MATERIALS

The following types of materials are generally appropriate for direct push groundwater sampling with a protected screen sampler:

- Direct push unit with hydraulic ram, hammer, etc;
- Groundwater sampling system consisting of expendable sampling tips, well screen with protective sleeve, connector assembly, probe rods (riser pipe), drive cap, grab sampling devices (bailers, if used), sample tubing and check valve assembly (if used), and sampling pump (if used);
- As needed, soil sampling devices and associated equipment and expendable supplies such as sample liners, sample retainers, appropriate lubricants, etc;
- Auxiliary tools for handling, assembling, and disassembling tools and probe rods;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

3.0 PROCEDURES

Static probing systems, penetrometer systems, or rotary drilling equipment can be used for inserting direct-push groundwater sampling devices.

The following general procedures outlined in this SOP may be followed as described in ASTM Standard Test Method D 6001-96.

General considerations for this method include the following:

- A variety of direct push drive systems may be used to advance borings based on the intended sampling depths and subsurface conditions and include the following:

Shallower Depths and Less Difficult Conditions

- *Percussive driving systems* – use hydraulically operated hammers and mechanically operated hammers;
- *Static push drive systems* – use hydraulic rams to apply pressure and exert static pull (e.g., cone penetrometer systems); and
- *Vibratory/sonic systems* – use a vibratory device, which is attached to the top of the sampler extension rods.

Greater Depths and More Difficult Conditions

- *Sonic or resonance drilling systems* – use a high power vibratory system to advance larger diameter single or dual tube systems; and
- *Rotary drilling equipment* – use hydraulic system of drill rig for direct push.

- The equipment used for direct push must be capable of apply sufficient static force, or dynamic force, or both, to advance the sampler to the required depth of collection. Additionally, this equipment must have adequate retraction force to remove the sampler and extension/drive rods once the sample has been collected.
- Avoid using excessive down pressure when advancing the drilling tools/sampler. Excessive pressure may cause the direct push unit to offset from the boring location and may damage drilling tools and samplers.
- Direct push sampling materials should be compatible with the material being sampled and the type of analysis to be conducted on the sample. A variety of materials are available including stainless steel, rigid polyvinyl chloride (PVC) and polytetrafluorethylene (PTFE).

The following general procedure involves the advancement of a direct push boring and collection of a groundwater sample using a protected screen sampler:

1. Stabilize direct push unit and raise mast at desired location.
2. Attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit the position over the borehole, and ready the tools for insertion.
3. Inspect the direct push tools before and after use. Decontaminate all down hole tools before and after use per SOP 80.1.
4. If soil samples will be collected to characterize soil stratigraphy and/or identify zones of groundwater for sampling, the drilling and soil sampling procedures outlined in SOP 20.11 (Section 3.3) should be followed.
5. Connect the sampler assembly (well screen enclosed in sheath), with drive point to probe rods along with any subassemblies such as friction reducers.
6. Prior to driving, measure the length of the sampling assembly and probe rod(s) to determine the depth of sampling.
7. After the sampling assembly has been appropriately installed to the probe rod, advance the assembled sampler using the drill rigs hydraulic rams (smooth quasi static push) or the drill rig hammer (percussive driving), or both.
8. Add additional probe rods as the sampling assembly is advanced and greater depths are reached. As the sampling assembly is advanced, the number of rod sections (riser) added should be recorded to ensure that groundwater sampling occurs at the targeted depth.

9. Once the sampling assembly is advanced to the desired depth check the system for leakage before exposing the screen for sampling. The leakage test does not have to be performed if the sampling system allows for direct connection to the screened sampling area (using a sealed chamber or tubing).
10. If appropriate, the leakage test will be conducted by checking for the presence of water inside the riser with an electronic water level meter. If no leakage is observed, then sampling may proceed. If water is present in the riser pipe from an unknown source, it should be purged before sampling; otherwise the sampling effort should be abandoned.
11. Extension rods are used to hold the screen in position as the casing puller assembly is used to retract the probe rods. The extension rods pass through the sampler to the bottom of the screen.
12. Groundwater sampling may be completed once the well screen is fully exposed. The extension rods are then removed and polyethylene or Teflon tubing with a check valve is then inserted inside the probe rods to the bottom of the screen.
13. The sampling tube assembly may then be oscillated up and down to bring water to the surface for sample collection.
14. Alternatively, if permitted by the sampling plan, a sampling pump (e.g., peristaltic) may be connected to the tubing to draw in the sample.
15. In lieu of using sampling tubing, a small diameter bailer may be lowered inside the probe rods to the interval of the screen to collect a grab sample of groundwater.
16. Collect groundwater samples directly from the end of tubing into clean laboratory-prepared (preserved) containers, as specified in work plan addenda prepared for site-specific investigations. Allowing the discharge from the tubing or bailer to flow gently down the inside of the container with minimal turbulence should fill all samples. Volatile organic compounds (VOCs) and gas sensitive parameter samples should be collected first followed by other parameters.
17. In general, samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is VOCs, extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any well location are site-specific and are specified in work plan addenda.
18. Depending on the screen used and site conditions; samples may contain sediment and may require filtration before placement into containers. Refer to the site-specific sampling and analysis plan for requirements for filtration.
19. After sampling, the boring may be abandoned by incrementally removing the screen assembly and probe rods and pumping grout into the probe through the tubing used for sample collection. Other abandonment methods for direct push borings are described in SOP 20.3.
20. Samples should be handled and shipped as specified in SOPs 50.1 and 50.2 and the work plan addenda prepared for site-specific investigations.
21. Log the borehole per the requirements of SOP 10.3.
22. Appropriately manage investigation-derived material (discarded samples, decontamination fluids, etc.) per SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to site-specific health and safety plan included in work plan addenda.

6.0 REFERENCES

ASTM Standard D 6001. 1996. *Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations.*

ASTM Standard D 6282-98. 1998. Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization.

STANDARD OPERATING PROCEDURE 30.1
SOIL SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for sampling surface and subsurface soils.

2.0 MATERIALS

- Stainless steel scoop, spoon, trowel, knife, spatula, (as needed);
- Split-spoon, Shelby tube, or core barrel sampler;
- Hand auger or push tube sampler;
- Drill rig and associated equipment (subsurface soil);
- Stainless steel bowls;
- Photoionization detector or other appropriate instrument as specified in site-specific health and safety plan;
- Sampling equipment for collection of volatile organic samples;
- Appropriate sample containers;
- Appropriate sample labels and packaging material.;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination equipment and supplies (SOP 80.1).

3.0 PROCEDURE

3.1 DOCUMENTATION

Soil sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.2 SURFICIAL SOIL SAMPLES

The targeted depths for surficial soil samples (surface and near surface) will be specified in the work plan addenda developed for site-specific investigations.

1. All monitoring equipment should be appropriately calibrated before beginning sampling according to the requirements of the work plan addenda and SOP 90.1 or 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Use a spade, shovel, or trowel or other equipment (manufactured from material, which is compatible with the soil to be sampled) to remove any overburden material present (including vegetative mat) to the level specified for sampling.
4. Measure and record the depth at which the sample will be collected with an engineers scale or tape.

5. Remove the thin layer that was in contact with the overburden removal equipment using a clean stainless steel scoop or equivalent and discard it.
6. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
7. When a sample will not be collected with a core type of sampler (push tube, split spoon, etc.), the sample for VOC analysis will be collected from freshly exposed soil. The method of collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
8. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
9. Collect a suitable volume of sample from the targeted depth with a clean stainless steel scoop (or similar equipment), push tube sampler, or bucket auger
10. For core type of samplers, rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife. Samples collected with a bucket auger or core type of sampler should be logged per the requirements of SOP 10.3.
11. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
12. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
13. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
14. Return any remaining unused soil to the original sample location. If necessary, add clean sand to bring the subsampling areas back to original grade. Replace the vegetative mat over the disturbed areas.

3.3 SUBSURFACE SAMPLES

All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.

1. All monitoring equipment should be appropriately calibrated before sampling according to the requirement of the work plan addendum and SOP 90.1 or SOP 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Collect split-spoon; core barrel, Shelby tube, sonic core or other similar samples during drilling.
4. Upon opening sampler or extruding sample, immediately screen soil for VOCs using a PID or appropriate instrument. If sampling for VOCs, determine the area of highest concentration; use a

stainless steel knife, trowel, or lab spatula to cut the sample; and screen for VOCs with monitoring instrument(s).

5. Log the sample on the boring log before extracting from the sampler per the requirements of SOP 10.3.
6. Any required VOC samples will be collected first followed by the other parameters. VOC samples will not be composited or homogenized and will be collected from the area exhibiting the highest screening level. The method of VOC sample collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
8. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
9. If homogenization or compositing of the sampling location is not appropriate for other parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
10. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
15. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
16. Discard any remaining sample into the drums used for collection of cuttings.
17. Abandon borings according to procedures outlined in SOP 20.2.

3.4 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

NOTES: If sample recoveries are poor, it may be necessary to composite samples before placing them in jars. In this case, the procedure will be the same except that two split-spoon samples (or other types of samples) will be mixed together. The boring log should clearly state that the samples have been composited, which samples were composited, and why the compositing was done. In addition, VOC fraction should be collected from the first sampling device.

When specified, samples taken for geotechnical analysis (e.g., percent moisture, density, porosity, and grain size) will be undisturbed samples, such as those collected using a thin-walled (Shelby tube) sampler, sonic core sampler, etc.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

Soil samples will not include vegetative matter, rocks, or pebbles unless the latter are part of the overall soil matrix.

6.0 REFERENCES

ASTM Standard D 1586-84. 1984. *Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 1587-83. 1983. *Thin Walled Sampling of Soils.*

ASTM Standard D 5633-94. 1994. *Standard Practice for Sampling with a Scoop.*

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 30.2
GROUNDWATER SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the collection of groundwater samples from monitoring wells.

2.0 MATERIALS

- Work Plans;
- Field logbooks and field parameter forms;
- Plastic sheeting;
- Decontamination equipment and supplies (SOP 80.1);
- Variable-speed, low-flow submersible pump with safety drop cable;
- Nylon stay-ties;
- Generator;
- Dedicated Teflon tubing or Teflon lined polyethylene tubing;
- Flow-through-cell and probes for measuring pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity (SOP 40.1);
- Electronic water-level indicator;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Cooler with ice;
- Silicone tubing;
- 0.45-micron disposable filters (as appropriate).
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan;
- Photoionization detector (PID) or other appropriate monitoring instrument per the site-specific health and safety plan; and
- Appropriate containers for investigation-derived material.

3.0 PROCEDURE

3.1 DOCUMENTATION

Groundwater sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

The following are general rules for the field parameter logbook for groundwater, as described in SOP 10.2:

- Only information for one site or installation per logbook. The same book maybe used for more than one sampling event.
- The first five pages will be reserved for index, general notes, etc. Sign and date each entry.
- Fill in the forms.
- Duplicate copies, index pages, and calibration sheets remain intact.

3.2 OVERVIEW OF SAMPLING TECHNIQUES

In general, two different techniques may be used to sample groundwater from monitoring wells at Radford Army Ammunition Plant (RFAAP):

- Low flow purging and sampling (Type I); and
- Conventional purging and low-flow sampling (Type II).

These two sampling techniques are intended to address the different groundwater conditions that may be encountered at RFAAP.

The Type I sampling technique will be used in the following situations:

- In wells where only one discrete water-producing zone is encountered;
- In wells with no discrete water bearing zone and a low yield (generally < 0.5 liters per minute); and
- In wells sampled during seasonal low groundwater conditions with greatly reduced yield.

The Type II sampling technique will be used in the following situations:

- In a well with potential or documented multiple flow zones and where individual flow zones will not be evaluated;
- In moderately producing wells (> 0.5 liters per minute) where no discrete flow zones were documented during drilling; and
- In wells sampled during seasonal high groundwater conditions with enhanced yield (and potentially additional flow zones).

Groundwater samples should be collected no sooner than 14 days after well development. Information from the boring logs, well completion records, and well development records should be reviewed before sampling a well to determine the most appropriate sampling technique. Pertinent information for each well to be sampled includes:

- Well construction;
- Depth and nature of water producing zones;
- Sustainable pumping rate of the well to be sampled;
- Well recharge characteristics; and
- Baseline turbidity.

Because of the heterogeneous nature of the fracture and solution-enhanced fractured bedrock at RFAAP, monitoring well purging and sampling techniques will need to be flexible. This flexibility is necessary to obtain representative samples that meet the data quality objectives (DQOs) specified in site-specific work plan addenda.

In general, when using the pumps specified in the following sections, situate any gasoline-powered generator on level ground approximately 15 ft downwind from the well. All generator maintenance (oil and fueling) is to be performed off site. If the hose(s) and/or power cord of the pump is not on a reel, place the pump with its hose and power cord on the plastic sheeting downhill from the well.

3.3 TYPE I SAMPLING PROCEDURES

Type I low flow purging and sampling procedures include the following:

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.
- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.
- Well depth at the time of purging will be obtained from well construction and existing data.
- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the desired depth. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- For wells with very low sustainable pumping rates (≤ 0.5 liters per minute), the pump should be set in the middle of the saturated screen section of the well or middle of the water column for open wells. The pump should be set 12 hours prior to purging so that the depth to water equilibrates and sediments disturbed during pump placement have time to settle.
- For wells with sustainable pumping rates (> 0.5 liters per minute), the pumps will be set at a desired depth prior to purging, allowing for the depth to water to equilibrate before sampling. The desired depth will be specified in work plan addenda based on site-specific conditions and DQOs.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into a appropriate container(s) to collect purge water.
- Immediately prior to purging, the depth to water will be measured and record. Start pumping the water at a rate of 100 to 400 milliliters per minute. Avoid surging. The pumping rate should cause minimal drawdown (less than 0.2 ft). Water level measurements should be collected continuously to document stabilization of the water level. Pumping rates should, if needed, be reduced to the minimal capabilities of the pump to avoid dewatering the screen interval and ensure stabilization of indicator parameters.

- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.
- Continue purging until stabilization of indicator parameters is achieved. Stabilization is defined as three consecutive readings that are within the following criteria:
  - ± 0.1 for pH;
  - ±3% for specific conductance;
  - ±10 mV for oxidation/reduction potential (Eh); and
  - ±10% for turbidity and dissolved oxygen.
- If the parameters have stabilized, but the turbidity is not in the range of 5 to 10 NTU, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-though cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- In general, samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is VOCs, extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any well location are site-specific and are specified in work plan addenda.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well be replacing and locking the lid.

3.4 TYPE II SAMPLING PROCEDURES

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.

- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.
- Well depth at the time of purging will be obtained from well construction and existing data.
- Calculate the standing water column in the well by subtracting the depth to water from the total depth of the well as recorded during completion of the well.
- From the water depth, well diameter, sand pack length, etc., calculate the equivalent volume (1 EV) of water in the well.

  1 EV = volume in casing + volume in saturated sand pack. Therefore; if the water table lies below the top of the sand pack, use the following equation:

  $1\ EV = (pR_w^2h_w) + (0.30p(R_s^2\text{-}R_w^2)h_w) * (0.0043)$

  If the water table lies above the top of the sand pack use this equation:

  $1\ EV = [(pR_w^2h_w) + (0.30p(R_s^2\text{-}R_w^2)h_s)] * (0.0043)$

  Where: R_s = radius of sand pack in inches
  R_w = radius of well casing in inches
  h_s = height of sand pack in inches
  h_w = water depth in inches

  $0.0043\ gal/in^3$
  Assumed filter pack porosity = 30%

Tables and graphs showing equivalent volumes for typical well constructions are available.

- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the middle of the saturated screen interval or water column in an open borehole. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into an appropriate container to collect purge water.
- Start purging the well at the minimally achievable pumping rate. Gradually increase the pumping rate to achieve the maximum flow rate of the pump or the maximum sustainable flow rate that does not draw down the static water level to a point below the top of the first water bearing zone, whichever is achieved first.
- During purging, water level measurements should be collected periodically to verify water levels in the well.
- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.
- Note when each indicator parameter stabilizes. Stabilization is defined as three consecutive readings that are within the following criteria:
  - ± 0.1 for pH;
  - ±3% for specific conductance;

  - ±10 mV for oxidation/reduction potential (Eh); and
  - ±10% for turbidity and dissolved oxygen.
- Three calculated eVs of water in the will be purged prior to sampling. It will be documented if stabilization of the indicator parameters has not occurred after three calculated well volumes have been removed and sampling procedures begin.
- If the turbidity is not in the range of 5 to 10 NTU when purging has been completed, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-though cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well be replacing and locking the lid.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addendum for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Refer to manufacturer's requirements for maintenance of pumps and generators.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3, 1 February.

USEPA. 1997. *Recommended Procedure for Low-flow Purging and Sampling of Groundwater Monitoring Wells.* Bulletin No. QAD023, October.

STANDARD OPERATING PROCEDURE 30.3
SURFACE WATER SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for collecting grab samples of surface water. This procedure can be applied to the collection of surface water samples from streams, rivers, ditches, lakes, ponds, and lagoons.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Photoionization detector (PID) or other appropriate monitoring instrument as specified site-specific health and safety plan;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Long-handled dip sampler (polytetrafluoroethylene (PTFE) or stainless steel), as applicable;
- Short-handled dip sampler (PTFE or stainless steel), as applicable;
- Pond sampler (PTFE or stainless steel), as applicable;
- Boat, other stable working platform, personal flotation device, as applicable;
- Sample filtration apparatus, as applicable;
- Peristaltic pump with 0.45-µm filters and disposable PTFE tubing, as applicable;
- Personal protective equipment and clothing (PPE) per site specific health and safety plan; and
- Appropriate containers for investigation-derived material.

3.0 PROCEDURE

3.1 CONSIDERATIONS

Factors that will need to be considered for selection of a surface water sampler include the width, depth, and flow of the surface water body, and whether the sample will be collected from the shore or a vessel. The most appropriate method(s) of sample collection and the appropriate depths of sampling (sampling strategies) will be specified in work plan addenda based on site-specific conditions and data quality objectives (DQOs).

3.2 DOCUMENTATION

Surface water sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2. This information should include a description of the water body characteristics (size, depth, flow, etc.).

Sampling locations should be marked on a site map. Describe each location and place a numbered stake above the visible high water mark on the bank closest to the sampling location and/or mark adjacent trees with surveyor's flagging. The descriptions must be adequate to allow the sampling station to be relocated at some future date by someone other than the original sampling crew.

3.3 SAMPLE LOCATION AND TIMING

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected upstream. In addition, if sediment samples are to be collected at the same locations as the surface water samples, the water samples must be collected first. Sampling should be performed quickly and in a manner that minimizes disturbance of bottom sediments to ensure a representative sample.

In general, surface water samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is volatile organic compounds (VOCs), extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any location are site-specific and are specified in work plan addenda.

3.4 SAMPLING METHODS

Various methods may be used to collect samples of surface water and the method used will depend on the considerations discussed in Section 3.1. Some of the more common methods used to collect surface water samples from shallow depths include:

- Submergence of sampling containers;
- Dipper and pond sampler; and
- Peristaltic pump (for non-volatile parameters).

Submergence of Sampling Container

Direct filling the sample containers by submergence is advantageous when the sample might be significantly altered during transfer from a collection device into another container. This method would not be appropriate for sampling at depth.

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Samples should be collected in order specified in the work plan addenda prepared for the site-specific investigation (also see Section 3.3).
4. Submerge an appropriate sample container with the cap in place with minimal surface disturbance so that the open end is pointing upstream. Sample container requirements are specified in work plan addenda.
5. Allow the container to fill slowly and continuously using the cap to regulate the inflow of water.
6. Retrieve the sample from the surface water with minimal disturbance.
7. Preserve the sample as specified in work plan addenda. Secure the cap on the sample container tightly.

8. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).

Sampling with Dip and Pond Sampler

Dipper and pond samplers prevent unnecessary contamination of the outer surface of the sample container that would occur with the direct submergence method of sampling.

A long handled dipper sampler or a pond sampler can be used to remotely obtain samples where access is poor or non-contact with water is suggested in the health and safety plan.
Sampling with the PTFE or stainless steel dipper or pond sampler (long-handled or measuring cup type):

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Assemble the sampler.
4. Samples should be collected in order specified in the work plan addenda prepared for the site-specific investigation (also see Section 3.3).
5. Collect samples by slowly submerging the pre-cleaned dipper or pond sampler with minimal surface disturbance. Make sure the open end is pointing upstream.
6. Remove the cap from the sample container and slightly tilt the mouth of the bottle below the edge of the sampler. Sample container requirements are specified in work plan addenda.
7. Empty the sampler slowly. Allow the sample stream to flow gently down the side of the bottle with entry turbulence. Avoid aerating the sample.
8. Continue filling the sample container until the container is filled.
9. Preserve the sample as specified in work plan addenda. Secure the cap on the sample container tightly.
10. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).

Sampling with a Peristaltic Pump

Sampling with a peristaltic pump will extend the lateral reach of the sampler and allow sampling from depths below the water surface. A disadvantage of this method is that it cannot be used to sample for volatile organic compounds because of potential degassing effects.

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Install clean medical grade silicone tubing in the pump head, as instructed by the manufacturer.
4. Select the length of appropriate suction tubing (PFTE or other) necessary to reach the required sample location/depth and attach to the pump intake or extended section of silicone tubing emanating from the intake side of the pump head.

5. Turn on pump and adjust flow to draw water through tubing. If possible, allow several liters of sample to pass through the system before actual sample collection.
6. Samples should be collected in order specified in the work plan addenda prepared for the site-specific investigation (also see Section 3.3).
7. VOC samples, if required, will be collected using another type of sampling device, as specified in the work plan addenda.
8. Collect surface water samples directly from the end of the tubing into clean laboratory-prepared (preserved) containers. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Sample container requirements are specified in work plan addenda.
9. Preserve the sample as specified in work plan addenda. Secure the cap on the sample container tightly.
10. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).

3.5 SAMPLE FILTRATION

If specified in work plan addenda, certain parameters such as metals may need to be collected for both total and dissolved fractions. In this case, filtration will be performed immediately after collecting sample. Set up filtration equipment before collecting sample. Filtration may be accomplished by gravity or, if necessary, due to slow filtering, a peristaltic pump can be used to pressure filter the sample. Vacuum filtration will not be used due to the possibility of analyte volatilization.

Gravity Filtration

1. Using decontaminated forceps, place a 0.45-μm membrane in a decontaminated filter funnel.
2. Slowly pour sample into the funnel and collect filtrate directly into appropriate sample container(s).
3. Preserve the sample as specified in work plan addenda. Secure the cap on the sample container tightly.
4. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
5. Appropriately dispose of filter membrane.

Filter with a Peristaltic Pump

1. Using previously assembled disposable tubing, 0.45-μm in-line filter, and peristaltic pump, filter sample from collection bucket into appropriate container.
2. Adjust pump rate to avoid aeration of sample.
3. Preserve the sample as specified in work plan addenda. Secure the cap on the sample container tightly.
4. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).

4.0 MAINTENANCE

Refer to manufacturer's specifications for maintenance procedures on generators and pumps.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

ASTM Standard D 5358-93. 1993. *Standard Practice for Sampling with a Dipper or Pond Sampler.*

Environmental Monitoring System Laboratory (EMSL), ORD, U.S. Environmental Protection Agency. *Characterization of Hazardous Waste Site-A Method Manual, Volume II-Available Sampling Methods.* 1983.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 30.4
SEDIMENT SAMPLING WITH SCOOP OR TUBE SAMPLER

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for obtaining representative sediments sampling using a scoop or hand corer.

Sediments include solid matter derived from rocks or biological materials that are suspended in, or settled from, water. This procedure can be applied to the collection of sediment samples from areas of deposition such as streams, rivers, ditches, lakes, ponds, and lagoons.

SOP 30.5 describes two methods of grab sampling (Ekman and Ponar) that are suitable for sampling surface or deep sediments. SOP 30.12 describes a method of sampling deep sediments by using a Vibracore sampler.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Photoionization detector (PID) or other appropriate monitoring instruments as specified in site-specific health and safety plan;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Stainless steel bowls;
- Stainless steel or polytetrafluoroethylene (PTFE) scoops, trowels, spoons, and knives;
- Hand core sediment sampler, liners (optional) and extensions;
- Hand auger with buckets, rods, and T-handles;
- Rubber boots/waders;
- Decontamination equipment and supplies (SOP 80.1);
- Plastic sheeting;
- Utility knife;
- Boat or other stable work platform, and personal flotation devices, as applicable; and
- Personal protective equipment and clothing (PPE) as specified in site-specific health and safety plan.

3.0 PROCEDURE

The water content of the sediment may vary greatly. Likewise, the sediments themselves may range from very soft to dense. It may be necessary to use a variety of equipment to obtain the required samples, even at a single site.

3.1 CONSIDERATIONS

Factors that determine the type of sediment water sampler used are primarily related to project objectives of surficial versus subsurface samples, site constraints of the water depth, sampling and sediment conditions, and cost-effectiveness of the sampler.

The most appropriate method(s) of sample collection and the appropriate depths of sampling (sampling strategies) will be specified in the work plan addendum based on site-specific conditions and data quality objectives (DQOs).

3.2 DOCUMENTATION

Sediment sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2. This information should include a description of the water body characteristics (size, depth, flow, etc.) and nature of sediments.

Sampling locations should be marked on a site map. Describe each location and place a numbered stake above the visible high water mark on the bank closest to the sampling location and/or mark adjacent trees with surveyor's flagging. The descriptions must be adequate to allow the sampling station to be relocated at some future date by someone other than the original sampling crew.

3.3 SAMPLE LOCATION AND TIMING

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected upstream. In addition, if surface water samples are to be collected at the same locations as the sediment samples, the surface water samples must be collected first. Sampling should be conducting using appropriate sampling devices that minimize disturbance and sample washing as the sample is retrieved through the liquid column.

In general, sediment samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is volatile organic compounds (VOCs), extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any location are site-specific and are specified in work plan addenda.

3.4 LOCATION

For all samples, mark the sampling location on a site map. Photograph (optional, recommended) and describe each location, and place a numbered stake above the visible high water mark on the bank closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at some future date.

3.5 GENERAL PROCEDURES

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of work plan addenda and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Document sample location and conditions appropriately in the field logbooks and on site maps.
4. Collect surface water sample as described in the work plan addenda and SOP 30.3, as necessary.
5. Collect sediment sample using the appropriate sampling device as described in the following sections.

3.6 SCOOP OR TROWEL METHOD

The scoop or trowel method is a very accurate procedure for collecting representative samples, but is limited to sampling exposed sediments or sediments in surface water less than 6-inches deep, with nominal flow.

1. Insert scoop or trowel into material and remove sample.
2. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
3. The method of collection for VOC samples will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda and sampling conditions.
4. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.
5. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
6. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers. Secure the cap of each container tightly. Sample container requirements are specified in work plan addenda.
7. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

3.7 TUBE SAMPLER

Tube samplers are a simple and direct method for obtaining sediment samples. The tube sampler is forced into the sediment and then withdrawn and the sample collected. Non-cohesive sediments may limit the effectiveness of this type of sampler.

1. Ensure that the corers and (optional) liners are properly cleaned.
2. Gradually force the corer into the sediment.
3. Carefully retrieve the tube sampler.
4. Remove the sediment core from the tube sampler and place core on a clean working surface.
5. Begin sampling with the acquisition of any discrete sample(s) for analysis of VOCs, with as little disturbance as possible. VOC samples will not be composited or homogenized.
6. The method of collection for VOC samples will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda and sampling conditions.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.

8. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
9. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers. Secure the cap of each container tightly. Sample container requirements are specified in work plan addenda.
10. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

3.8 HAND AUGER AND TUBE SAMPLER

In general, the use of a hand auger and tube sampler will allow for sampling deeper sediments than possible with the tube sampling method described in Section 3.7. A potential disadvantage of using this method is that it limited to use for water bodies of limited depth and hand augers may not be an effective method for penetrating soft sediments since the borehole may collapse prior to sampling.

1. Attach the auger bucket to a drill rod extension and attach the T-handle to the drill rod.
2. Begin drilling with the auger. Periodically remove accumulated sediment from the bucket.
3. After reaching the desired depth, slowly and carefully remove the auger from the boring.
4. Remove the auger bucket from the drill rod(s) and replace with a clean thin-wall tube sampler.
5. Remove the sediment core from the tube sampler and place core on a clean working surface.
6. Carefully lower the tube sampler down the borehole and gradually force it into the sediment, avoiding scraping the borehole sides.
7. Carefully retrieve the tube sampler and unscrew the drill rod(s).
8. Begin sampling with the acquisition of any discrete sample(s) for analysis of VOCs, with as little disturbance as possible. VOC samples will not be composited or homogenized.
9. The method of collection for VOC samples will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda and sampling conditions.
10. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.
11. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
12. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

3.9 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

ASTM Standard D 4700-91. 1991. *Standard Guide for Soil Sampling from the Vadose Zone.*

ASTM Standard D 5633-94. 1994. *Standard Practice for Sampling with a Scoop.*

USEPA. 1987. *A Compendium of Superfund Field Operations Methods.* EPA/540/P-87/001.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 30.5
SEDIMENT AND BENTHIC MACROINVERTEBRATE SAMPLING WITH ECKMAN SAMPLER OR PONOR SAMPLER

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) covers the protocol for obtaining qualitative or quantitative samples of soft sediments and macroinvertebrates inhabiting soft sediments in lakes, reservoirs, and other water bodies.

An Eckman grab sampler is well suited to collecting samples in deeper water bodies (up to 100 feet), but is unsuitable for sampling rock or hard bottom surfaces. For shallower applications, the sampler can be attached to a pole.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Camera, as applicable;
- Photoionization detector (PID) or another appropriate monitoring instrument as specified in health and safety plan;
- Eckman grab sampler, as applicable;
- Ponar grab sampler, as applicable;
- Boat or other stable platform, and personal flotation devices, as applicable;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Sieve, 500-μ (U.S. std. #30);
- Appropriate preservative for benthic sampling, as applicable;
- Stainless steel or polytetrafluoroethylene (PTFE) trays;
- Stainless steel or PTFE scoops, trowels, spoons, and knives;
- Decontamination equipment and supplies (SOP 80.1);
- Plastic sheeting; and
- Personal protective equipment and clothing (PPE) as specified in health and safety plan.

3.0 PROCEDURE

The water content of the sediment may vary greatly. Likewise, the sediments themselves may range from very soft to dense. It may be necessary to use a variety of equipment to obtain the required samples, even at a single site.

3.1 CONSIDERATIONS

Factors that determine the type of sediment water sampler used are primarily related to project objectives of surficial versus subsurface samples, site constraints of the water depth, sampling and sediment conditions, and cost-effectiveness of the sampler.

The most appropriate method(s) of sample collection and the appropriate depths of sampling (sampling strategies) will be specified in the work plan addendum based on site-specific conditions and data quality objectives (DQOs).

3.2 DOCUMENTATION

Sediment sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2. This information should include a description of the water body characteristics (size, depth, flow, etc.) and nature of sediments.

Sampling locations should be marked on a site map. Describe each location and place a numbered stake above the visible high water mark on the bank closest to the sampling location and/or mark adjacent trees with surveyor's flagging. The descriptions must be adequate to allow the sampling station to be relocated at some future date by someone other than the original sampling crew.

3.3 SAMPLE LOCATION AND TIMING

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect the samples collected upstream. In addition, if surface water samples are to be collected at the same locations as the sediment samples, the surface water samples must be collected first. Sampling should be conducting using appropriate sampling devices that minimize disturbance and sample washing as the sample is retrieved through the liquid column.

In general, sediment samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is volatile organic compounds (VOCs), extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any location are site-specific and are specified in work plan addenda.

3.4 LOCATION

For all samples, mark the sampling location on a site map. Photograph (optional, recommended) and describe each location, and place a numbered stake above the visible high water mark on the bank closest to the sampling location. The photographs and description must be adequate to allow the sampling station to be relocated at some future date.

3.5 SAMPLING WITH THE EKMAN SAMPLER

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Document sample location and conditions appropriately in the field logbooks and on site maps.
4. Collect surface water sample as described in the work plan addenda and SOP 30.3, as necessary.

5. Attach a decontaminated Ekman sampler to the necessary length of sample line or in shallow waters to the end of a pole.
6. Measure the depth to the top of the sediment with a weighted object. Record the depth to the top of sediment.
7. Mark the distance to the top of sediment on the sample line and add a proximity mark 3 feet above the first mark so that the person collecting the sampler will know when the Ekman sampler is approaching sediment.
8. Cock the sampler by raising each jaw upward into the cocked position using the attached cable and secure the cable to the catch pin located at the top of the sampler. From this point, support the sampler by its lift line or it will be tripped and close.
9. If using a sample line, tie the free end of the sample line to fixed support to prevent accidental loss of the sampler.
10. Lower the sampler slowly through the last 3 feet until contact is felt.
11. If using a sample line, place a weighted messenger on the sample line and release, allowing the messenger to slide down to the sample line and activate the spring. Record the depth penetration by the sampler.
12. Raise the Ekman sampler to clear surface at a slow but steady rate to prevent sample loss or washout.
13. Drain free liquids through the screen of the sample in such a way, as fine sediments are not lost.
14. Place the Ekman sampler into a stainless steel, PTFE, or PTFE-lined bowl or tray and open. Lift the sampler clear of the tray and set aside for decontamination.
15. If the sediment will be analyzed for VOCs, transfer the sample into the appropriate sample containers immediately.
16. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
17. The method of collection for VOC samples will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda and sampling conditions.
18. Samples should be taken from the center of the mass of sediment, avoiding material, which has contacted the walls of the sampler, and transferred into an appropriate sample container using a decontaminated stainless steel spoon or similar equipment. Secure the cap of each container tightly. Sample container requirements are specified in work plan addenda.
19. Repeat the above steps as necessary to collect sufficient volume for analysis.
20. If compositing of different locations is desired, transfer additional discrete samples to a stainless steel bowl for thorough mixing. Mix with stainless steel tools and transfer to appropriate sample containers. Secure the cap of each container tightly.
21. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
22. If benthic macroinvertebrates are to be collected, sieve sample and transfer macroinvertebrates into appropriate container. Appropriately, preserve the sample as directed in the work plan addenda.

3.6 SAMPLING WITH THE PONAR SAMPLER

In general, a Ponar sampler is applicable for a wide range of sediments. It can penetrate deeper and seal better than an Ekman sampler.

1. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
2. Spread new plastic sheeting on the ground at each sampling location to prevent cross-contamination. If sample access is restricted, use appropriate vessel or another stable working platform adjacent to the area to be sampled.
3. Document sample location and conditions appropriately in the field logbooks and on site maps.
4. Collect surface water sample as described in the work plan addenda and SOP 30.3, as necessary.
5. Attach a decontaminated Ponar sampler to the necessary length of sample line.
6. Measure the depth to the top of the sediment with a weighted object. Record the depth to the top of sediment.
7. Mark the distance to the top of sediment on the sample line and add a proximity mark 3 feet above the first mark so that the person collecting the sampler will know when the Ekman sampler is approaching sediment.
8. Open the sampler jaws until latched. From this point support the sampler by its lift line, or the sampler will be tripped and closed.
9. Tie the free end of the sample line to fixed support to prevent accidental loss of the sampler.
10. Begin lowering the sample until the proximity mark is reached and then lower the sampler at a slow rate for the last 3 feet until contact is felt.
11. Allow the sample line to slack slightly. More slack may be required in strong currents.
12. Raise the Ponar sampler to clear surface at a slow but steady rate to prevent sample loss or washout.
13. Drain free liquids through the screen of the sample in such a way, as fine sediments are not lost.
14. Place the Ponar sampler into a stainless steel, polytetrafluoroethylene (PTFE), or PTFE-lined bowl or tray and open. Lift the sampler clear of the tray and set aside for decontamination.
23. If the sediment will be analyzed for VOCs, transfer the sample into the appropriate sample containers immediately.
24. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
25. The method of collection for VOC samples will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda and sampling conditions.
26. Samples should be taken from the center of the mass of sediment, avoiding material, which has contacted the walls of the sampler, and transferred into an appropriate sample container using a decontaminated stainless steel spoon or similar equipment. Secure the cap of each container tightly.
27. Repeat the above steps as necessary to collect sufficient volume for analysis.

28. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
29. If benthic macroinvertebrates are to be collected, sieve sample and transfer macroinvertebrates into appropriate container. Appropriately, preserve the sample as directed in the work plan addenda.

4.0 MAINTENANCE

Maintain according to manufacturer's suggestions.

5.0 PRECAUTIONS

- Inspect the devices for mechanical deficiencies before use.
- These samplers may be inefficient for use during adverse weather conditions and may be ineffective where strong currents or wave actions exist.
- Exercise caution at all times once the grab is loaded or cocked because a safety lock is not part of the standard design.
- Operate the sampler from a boat with a winch and cable.
- While sampling from a boat or stable platform in water bodies with a depth of 5 ft or more, the sampling team will wear personal flotation devices (life jackets).

6.0 REFERENCES

ASTM Standard D 4387-84 (1989) 1989. *Guide for Selecting Grab Sampling Devices for Collecting Benthic Macroinvertebrates.*

USEPA. 1990. *Macroinvertebrate Field and Laboratory Methods for Evaluating the Biological Integrity of Surface Waters.* Office of Research and Development. EPA/600/4-90/030. November.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 30.6
CONTAINERIZED MATERIAL

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the opening and sampling of containerized liquids of potentially unknown substances.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Personal protective equipment and clothing per the site-specific health and safety plan;
- Monitoring instruments per the site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Tools;
- Historical data, if available;
- Sampling tube; and
- Remote samplers, as required.

3.0 PROCEDURE

Sealed containers with unknown contents represent potential severely hazardous situations for sampling teams. Even when the original identity of the contents is reasonably certain, contents may be under pressure or in a decomposed state and may readily react (sometimes violently) with air or water vapor in the atmosphere.

Only hazardous material specialists that have appropriate training and experience will inspect and sample unidentifiable drums or containers. Specialist team members will use extreme caution and care when opening sealed drums or cans of unknown content for purposes of inspection and sampling.

Efforts will be made to determine the identity of the contents, through markings, history of activities at the site, and similarity and proximity to containers of known contents. The range of possible hazards will dictate which specific procedure will be followed, and specific procedures will be identified in work plan addenda. All predetermined procedures will be strictly followed as designated by the site-specific conditions.

Using this SOP and appropriate health and safety protocols, field personnel will use extreme caution and care in opening sealed drums or cans of unknown contents for purposes of inspection and sampling. Specific activities include the following:

- Determine the identity of the contents through markings, history of activities at the site, and similarity and proximity to containers of known contents. The range of possible hazards will dictate which specific procedure should be followed.
- Handle containers as little as possible; however, if it is necessary to reorient a drum to allow access to a bung or cap, perform this activity using remote-handling forklift equipment with special drum-holding attachments.
- If contents are deemed to be under pressure, highly reactive, or highly toxic (or if these possibilities cannot be disproven), perform initial opening of the container remotely.
- Air monitoring stations will be established as necessary, using the following procedures:
    1. Affix a remote bung opener to the drum.
    2. Evacuate personnel to a safe distance or station them behind a barricade.
    3. Activate the non-sparking motor of the opener.
    4. After the bung is removed, monitor the drum for potential activity of the contents, such as vapor emission, smoking, or audible reaction.
    5. Approach cautiously while monitoring for toxic levels of airborne contaminants.
- If the contents of the drum pose acceptable hazards, accomplish opening (or inspection if previously opened remotely) and sampling with one of three approved devices. The preferred method is to use a clean glass tube, with or without bottom stopper, which can be placed in the drum (breaking it if necessary) after sampling is complete. Alternately (if a bung has been removed), a well sampler such as a Kemmererbailer can be used (but would require removal and cleaning or disposal according to the nature of the waste). By opening either of these devices at a desirable depth, stratified sampling can be performed. Also, the sampling tubes can be made with a plunger rod and O-ring seals at selected intervals, allowing simultaneous collection of multiple samples in a stratified medium.
- Following sampling, the drum will be resealed and/or overpacked to prevent any possibility of leakage while analysis determines the identity of the contents.
- Drums that do not have removable bungs may be opened remotely with a solenoid-activated punch (this requires that the drum be recontainerized or overpacked after sampling is complete).

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Not applicable.

6.0 REFERENCE

USEPA, 1989. A Compendium of Superfund Field Operation Methods. EPA/540/P-87/001. December.

STANDARD OPERATING PROCEDURE 30.7
SAMPLING STRATEGIES

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate sampling strategies for sampling various media.

2.0 MATERIALS

- Historical site data;
- Site topography;
- Soil types; and
- Sampled media.

3.0 PROCEDURE

The primary goal of any investigation is to collect samples representative of existing site conditions. Statistics are generally used to ensure samples are as representative as possible. Sampling plans may employ more than one approach to ensure project data quality objectives are adequately addressed. A comparison of sampling strategies is presented in Table 1.

3.1 CLASSICAL STATISTICAL SAMPLING

Classical statistical sampling strategies are appropriately applied to either sites where the source of contamination is known or small sites where the entire area is remediated as one unit. Primary limitations of this sampling approach include (1) inability to address media variability; (2) inadequate characterization of heterogenous sites; and (3) inadequate characterization of sites with unknown contamination characteristics.

3.1.1 Simple Random Sampling

Simple random sampling is generally more costly than other approaches because of the number of samples required for site characterization. This approach is generally used when minimal site information is available and visible signs of contamination are not evident and includes the following features:

- Sampling locations are chosen using random chance probabilities.
- This strategy is most effective when the number of sampling points is large.

3.1.2 Stratified Random Sampling

This sampling approach is a modification to simple random sampling. This approach is suited for large site investigations that encompass a variety of soil types, topographic features, and/or land uses. By dividing the site into homogenous sampling strata based on background and historical data, individual random sampling techniques are applied across the site. Data acquired from each stratum can be used to determine the mean or total contaminant levels and provide these advantages:

- Increased sampling precision results due to sample point grouping and application of random sampling approach.

- Control of variances associated with contamination, location, and topography.

3.1.3 Systematic Grid

The most common statistical sampling strategy is termed either systematic grid or systematic random sampling. This approach is used when a large site must be sampled to characterize the nature and extent of contamination.

Samples are collected at predetermined intervals within a grid pattern according to the following approach:

- Select the first sampling point randomly; remaining sampling points are positioned systematically from the first point.
- Determine the grid design: one or two-dimensional. One-dimensional sample grids may be used for sampling along simple man-made features. Two-dimensional grid systems are ideal for most soil applications.
- Determine the grid type: square or triangular. Sampling is usually performed at each grid-line intersection. Other strategies include sampling within a grid center or obtaining composite samples within a grid.
- Each stratum is sampled based on using the simple random sampling approach but determined using a systematic approach.

3.1.4 Hot-Spot Sampling

Hot spots are small, localized areas of media characterized by high contaminant concentrations. Hot-spot detection is generally performed using a statistical sampling grid. The following factors should be addressed:

- Grid spacing and geometry. The efficiency of hot-spot searches is improved by using a triangular grid. An inverse relationship exists between detection and grid point spacing, e.g., the probability of hot-spot detection is increased as the spacing between grid points is decreased.
- Hot-spot shape/size. The larger the hot spot, the higher the probability of detection. Narrow or semicircular patterns located between grid sampling locations may not be detected.
- False-negative probability. Estimate the false negative (β-error) associated with hot-spot analysis.

3.1.5 Geostatistical Approach

Geostatistics describe regional variability in sampling and analysis by identifying ranges of correlation or zones of influence. The general two-stage approach includes the following:

- Conducting a sampling survey to collect data defining representative sampling areas.
- Defining the shape, size, and orientation of the systematic grid used in the final sampling event.

3.2 NON-STATISTICAL SAMPLING

3.2.1 Biased Sampling

Specific, known sources of site contamination may be evaluated using biased sampling. Locations are chosen based on existing information.

3.2.2 Judgmental Sampling

This sampling approach entails the subjective selection of sampling locations that appear to be representative of average conditions. Because this method is highly biased, it is suggested that a measure of precision be included through the collection of multiple samples.

4.0 MAINTENANCE

Not applicable.

5.0 REFERENCES

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM200-1-3. 1 February.

TABLE 1
SAMPLING STRATEGIES

SAMPLING STRATEGY	DESCRIPTION	APPLICATION	LIMITATIONS
Classical Statistical Sampling Strategies			
Simple Random Sampling	Representative sampling locations are chosen using the theory of random chance probabilities.	Sites where background information is not available and no visible signs of contamination are present.	May not be cost-effective because samples may be located too close together. Does not take into account spatial variability of media.
Stratified Random Sampling	Site is divided into several sampling areas (strata) based on background or site survey information.	Large sites characterized by a number of soil types, topographic features, past/present uses, or manufacturing storage areas.	Often more cost-effective than random sampling. More difficult to implement in the field and analyze results. Does not take into account spatial variability of media.
Systematic Grid Sampling	Most common statistical strategy; involves collecting samples at predetermined, regular intervals within a grid pattern.	Best strategy for minimizing bias and providing complete site coverage. Can be used effectively at sites where no background information exists. Ensures that samples will not be taken too close together.	Does not take into account spatial variability of media.
Hot-Spot Sampling	Systematic grid sampling strategy tailored to search for hot spots.	Sites where background information or site survey data indicate that hot spots may exist.	Does not take into account spatial variability of media. Tradeoffs between number of samples, chance of missing a hot spot, and hot spot size/shape must be weighed carefully.
Geostatistical Approach	Representative sampling locations are chosen based on spatial variability of media. Resulting data are analyzed using kriging, which creates contour maps of the contaminant concentrations and the precision of concentration estimates.	More appropriate than other statistical sampling strategies because it takes into account spatial variability of media. Especially applicable to sites where presence of contamination is unknown.	Previous investigation data must be available and such data must be shown to have a spatial relationship.
Non-Statistical Sampling Strategies			
Biased Sampling	Sampling locations are chosen based on available information.	Sites with known contamination sources.	Contaminated areas can be overlooked if background information or visual signs of contamination do not indicate them. Best used if combined with a statistical approach, depending on the project objectives.
Judgmental Sampling	An individual subjectively selects sampling locations that appear to be representative of average conditions.	Homogenous, well-defined sites.	Not usually recommended due to bias imposed by individual, especially for final investigations.

STANDARD OPERATING PROCEDURE 30.8
VOC SAMPLE COLLECTION USING SODIUM BISULFATE PRESERVATION (LOW LEVEL) AND METHANOL PRESERVATION (HIGH LEVEL)

1.0 SCOPE AND APPLICATION

The purpose of this Standard Operating Procedure (SOP) is to describe the container preparation, collection, and methanol extraction/preservation to be used in conjunction with the analysis of soil samples for volatile organic compounds (VOCs). This SOP will ensure that soil samples collected for VOC analysis will be handled in a manner that will minimize the loss of contaminants due to volatilization and biodegradation.

2.0 MATERIALS

- Work Plans;
- Field Logbook;
- Photoionization detector (PID) or other similar monitoring instrument(s) per site-specific health and safety plan;
- Electronic scale;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan;
- Soil sampling equipment, as appropriate (SOP 30.1);
- Decontamination equipment and supplies (SOP 80.1);
- Sample containers, labels, etc;
- Sample coolers; and
- Small diameter coring device (e.g., modified 10-30 mL disposable syringe or small diameter tube/plunger sampler).

3.0 PROCEDURE

3.1 SAMPLE BOTTLE PREPARATION

The laboratory performing the analysis will complete sample bottle preparation. All sample bottles will be supplied by the laboratory performing the analysis and contain an appropriate volume and grade of chemical preservative.

The laboratory as part of sample container preparation will perform the following steps:

- Each sample container will be labeled with a unique sample identification number (i.e., sample label).

- *Low Level Analysis (0.5 to 200 µg/kg): t*he sample vial (40 mL) will be filled with an appropriate mass of sodium bisulfate and appropriate volume of organic free reagent water volume to form a solution capable of preserving the sample to a pH <2.
- *High Level Analysis (200 µg/kg and higher): t*he sample vial (40-mL) will be filled with an appropriate volume capable of preserving the sample to a pH <2.
- The sample container will be capped and weighed to the nearest 0.01 gram.
- The prepared sample container will be stored at 4±2°C before shipment. The sample bottle will be prepared no more than 14 days prior to shipment to the site.
- Once the sample container are prepared and shipped to the site, the contractor will have 4 days to collect the soil samples for VOC analysis and return the sample bottles to the laboratory for analysis.

3.2 SAMPLE COLLECTION

Soil samples for VOC analysis will be collected using a decontaminated small-diameter coring device, such as a modified 10–30-mL disposable syringe or a small-diameter tube/plunger sampler. The small-diameter coring device will be capable of collecting the required amount of sample from larger-diameter core samplers (e.g., split-spoons) or from freshly exposed soil. The small-diameter core sampler will also be capable of delivering the soil sample directly into the sample bottle. Therefore, the outer diameter of the core sampler must be smaller than the inner diameter of the sample bottle to avoid loss of sample and ease the transfer process.

Use an electronic scale to weigh the small-diameter coring device. The scale will be calibrated at the beginning of each day the soil samples are collected for VOC analysis.

Once the desired sampling depth is reached, field screen the soil with a properly calibrated PID or FID. The interval registering the highest PID or FID measurement will be sampled for VOC analysis.

For low-level analysis, sample material should be pre-tested for carbonate interference(s) before the samples are containerized. If carbonates are present, sodium bicarbonate may potentially react with the carbonates producing effervescence, which can promote VOC loss. If carbonate interference is observed an alternative VOC procedure should be used (EnCore® or methanol).

Collect approximately 5 grams of soil using the coring device.

Quickly weigh the soil sample. Reweigh after each addition until the target weight is obtained (i.e., 5 grams). The weight of soil collected can be determined using the following equation:

Soil weight (grams) = weight of soil and coring device - weight of coring device

Once the target weight is obtained, open the sample bottle and slowly extrude the soil core into the pre-weighed and pre-numbered sample container supplied by the laboratory. Avoid splashing preservative out of the sample container. Do not insert the small-diameter coring device into the mouth of the sample bottle or immerse the coring device into the methanol.

Use a paper towel to clean the threads of the sample container and cap to ensure a proper seal. If the sample bottle is not properly sealed, methanol may be lost, which will invalidate the sample.

After capping the sample container, gently tap the sample container to mix and break up the soil aggregate until the soil is covered with preservative. *Do not shake.* Sample bottle labeling and packaging will be conducted in accordance with SOPs 50.1 and 50.2.

At least two preserved aliquots should be collected at each sample location so that one aliquot can be used for laboratory screening.

3.3 MOISTURE DETERMINATION

A third aliquot (container) will be collected at each sample location to report the dry weight for moisture determination. Duplicate samples are defined as samples collected simultaneously from the same source under identical conditions. Ensure that the sample bottle is tightly sealed to prevent loss of soil moisture. Duplicate samples do not have to be weighed or preserved with sodium bisulfate or methanol.

3.4 TRIP BLANKS

A trip blank will accompany the sample bottles to the site and into the field before sampling, remain with the collected samples during the sampling sequence, accompany all VOC sample bottles shipped to the laboratory, and remain with the samples at the laboratory before analysis. The trip blank will remained sealed at all times until it is analyzed at the laboratory.

The trip blanks will be prepared by the laboratory at the same time and in the same manner as the sample containers, as described in Section 3.1

One trip blank will be shipped with each sample cooler that contains soil samples for VOC analysis.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Precautions must be taken to appropriately package and ship samples to the laboratory recognizing DOT regulations regarding definition of hazardous materials. Limited quantity exemptions exist for sodium bisulfate (aqueous solution) and methanol as preservatives; these quantities represent total volumes in sample containers packaged in a shipping container. Accounting for Dangerous Goods Regulations, packing group II materials (sodium bisulfate and methanol) are each limited to a net quantity of 500 mL preservative per shipping container. Other restrictions may be applied by shipping carriers and should be determined before packaging and shipping. General rules to be followed when packaging include:

- Sample containers must be stored upright and have the lid held securely in place and placed in such a way that the samples will not touch each other during shipment.
- Sample containers must be packed in a sorbent material capable of absorbing spills from leaks or breakage of the sample bottles.
- The maximum volume of preservative per sample cooler should be less than 500 mL.
- See SOP 50.2.

6.0 REFERENCES

ASTM Standard D 4547-91. 1991. *Standard Practice for Sampling Waste and Soils for Volatile Organics.*

Hewitt, A.D., Jenkins, T.F., Grant, C. *Collection, Handling, and Storage: Keys to Improved Data Quality for Volatile Organic Compounds in Soil.* American Environmental Laboratory, February 1995.

Hewitt, A.D., Lukash, Nicole J.E. *Sampling for In-Vial Analysis of Volatile Organic Compounds in Soil.* American Environmental Laboratory, August 1996, pp. 15-19.

Hewitt, A.D. *Chemical Preservation of Volatile Organic Compounds in Soil Subsamples.* SR 95-5, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, 1994.

Jackson, J., Thorney, N., Dietlein, L. *Degradation of Hydrocarbons in Soil Samples Analyzed within Accepted Analytical Holding Times.* 5th Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring, and Geophysical Methods. Las Vegas, NV. May 13-16, 1991. pp. 567-76.

NJDEP. *Methodology for the Field Extraction/Preservation of Soil Samples with Methanol for Volatile Organic Compounds.* February 1997.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3, 1 February.

USEPA. 1996. *Test Methods for Evaluating Solid Waste Physical/Chemical Methods.* Third Edition, Final, Method 5035.

STANDARD OPERATING PROCEDURE 30.9
COLLECTION OF SOIL SAMPLES BY USEPA SW 846 METHOD 5035 USING DISPOSABLE SAMPLERS

1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) outlines the recommended protocol and equipment for collection of representative soil samples to monitor potential volatile organic contamination in soil samples.

This method of sampling is appropriate for surface or subsurface soils contaminated with low to high levels of volatile organic compounds (VOCs). This sampling procedure may be used in conjunction with any appropriate determinative gas chromatographic procedure, including, but not necessarily limited to, SW-846 Method 8015, 8021, and 8260.

2.0 MATERIALS

- Work Plans;
- Field Logbook;
- Photoionization Detector (PID) or other monitoring instrument(s) per site-specific health and safety plan;
- Personal protective equipment and clothing per site-specific health and safety plan;
- Soil sampling equipment, as applicable (SOP 30.1);
- Disposable sampler;
- T-handle and/or Extrusion Tool; and
- Decontamination equipment and supplies (SOP 80.1).

3.0 PROCEDURE

3.1 METHOD SUMMARY

Disposable samplers are sent to the field to be used to collect soil samples. Three samplers must be filled for each soil sampling location, two for the low-level method (sodium bisulfate preservation) and one for the high level method (methanol preservation). After sample collection, disposable samplers are immediately shipped back to the laboratory for preservation (adding soil sample into methanol and sodium bisulfate solution). The ratio of volume of methanol to weight of soil is 1:1 as specified in SW-846 Method 5035 (Section 2.2.2). The amount of preservative in the solution corresponds to approximately 0.2 g of preservative for each 1 g of sample. Enough sodium bisulfate should be present to ensure a sample pH of ≤ 2.

If quality assurance/quality control (QA/QC) samples are needed, seven samplers will be needed for the original, matrix spike, and matrix spike duplicate analysis. Soil samples are collected in the field using the disposable samplers, sealed and returned to the laboratory. A separate aliquot of soil is collected in a 125-mL container for dry weight determination.

3.2 SAMPLE CONTAINERS, PRESERVATION, HANDLING AND STORAGE

After sample collection, the disposable samplers must be cooled to and maintained at 4°C. The contents of the samplers will be analyzed using EPA methods 8015, 8021, and/or 8260. The **disposable** sampler is a single use device. It cannot be cleaned and/or reused.

Disposable samplers have a 48 hour holding time from sample collection to sample preparation in the laboratory. Return the samplers to the laboratory immediately after sampling.

3.3 SAMPLE PROCEDURES

Before sampling, the disposable sampler should be prepared as follows:

1. Unpack the cooler/sampling kit received from the laboratory. Disposable samplers are packed in sealed aluminized bags. These should be over packed in plastic zip lock bags. A T-Handle will also be needed to collect samples with the disposable sampler.
2. Hold coring body and push plunger rod down until small 0-ring rests against tabs. This will assure that plunger moves freely.
3. Depress locking lever on the sampler T-Handle (or other extraction device). Place coring body, plungers end first, into the open end of the T-Handle, aligning the two slots on the coring body with the two locking pins in the T-Handle. Twist the coring body clockwise to lock the pins in the slots. Check to ensure the sampler is locked in place. Sampler is ready for use.

The following procedure should be followed when using a disposable sampler to sample for VOCs in soil:

1. After the soil-sampling device (split spoon, corer, etc.) is opened, the sampling process should be completed in a minimum amount of time with the least amount of disruption.
2. Visual inspection and soil screening should be conducted after the sampler is opened and a fresh surface is exposed to the atmosphere. Soil screening should be conducted with an appropriate instrument (PID or FID).
3. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
4. Orient the T-Handle with the T-up and the coring body down. This positions the plunger bottom flush with bottom of coring body (ensure that plunger bottom is in position). Using T-Handle, push sampler into soil until the coring body is completely full taking care not to trap air behind the sampler. When full, the small o-ring will be centered in the T-Handle viewing hole. Remove sampler from soil. Wipe excess soil from coring body exterior with a clean disposable paper towel.
5. Cap coring body while it is still on the T-Handle. ***<u>Push</u>*** cap over flat area of ridge ***<u>and twist</u>*** to lock cap in place. ***Cap must be seated to seal sampler.***
6. Remove the capped sampler by depressing locking lever on T-Handle while twisting and pulling sampler from T-Handle.
7. Lock plunger by rotating extended plunger rod fully counterclockwise until wings rest firmly against tabs.
8. Fill the 125-mL wide mouth jar for the non-preserved portion of the sample to be used for a moisture determination. These may be in a cardboard box. Retain all packaging to return the samples.

9. The disposable sampler should collect approximately 5 grams of soil (not necessary to weigh in the field). After a sample has been collected and capped, tear off the identification tag found at the bottom of the label on the aluminized bag. This tag is added to the sampler on the cap used to seal the sampler.
10. Place the sampler back in the aluminized bag and seal the top (a zip-lock seal). Make sure all the appropriate information is on the label. Record the sampler ID number on the chain-of-custody. Make sure each sampler and 125-mL container is labeled with the same location identification. The sampler should be placed inside the plastic zip-lock bags.
11. Place the 125-mL wide mouth jars in the cooler with the sampler on top. These should be sandwiched between bags of ice to maintain the correct temperature. If sent with the jars and samplers, a temperature bottle (used to evaluate the temperature on receipt) should be placed in the middle of the jars. The sample temperature should be 4°C during shipment.
12. Ship the samples so that they will be received within 24 hours of sampling. The laboratory must receive the sampler within 40 hours of the collection so that they can be correctly preserved.

3.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

1. All data must be documented on chain-of-custody forms, field data sheets and in the field logbook.
2. An equipment blank is a QA/QC sample that will determine potential contamination from sampling equipment used to collect and transfer samples from the point of collection to the sample container. An equipment blank is performed by pouring demonstrated analyte free water from one sample container, over a sampler, and into a separate set of identical sample containers. The equipment blank is optional when sampling with the methanol preservation technique. It may be required on a site-specific basis if elevated analytical results are suspected to be due to cross contamination from sampling equipment.
3. A trip blank is a QA/QC sample, which will determine additional sources of contamination that may potentially influence the samples. The sources of the contamination may be from the laboratory, sample containers, or during shipment. The laboratory prepares a trip blank at the same time and in the same manner as the sample containers. The trip blank must accompany the sample containers to the field and back to the laboratory along with the collected samples for analysis. It must remain sealed at all times until it is analyzed at the laboratory. The frequency of collection for the trip blank must be at a rate of one per sample shipment.

3.5 LIMITATIONS IN SAMPLING

This sampling protocol will not be applicable to all solid environmental matrices, such as those that cannot be cored including non-cohesive granular material, gravel, or hard dry clay. In this case, the procedure for collecting VOC samples using Methanol Preservation should be used (see SOP 30.8).

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

En Novative Technologies, Inc. 2000. Users Manual for En Core® Sampler. February 2001.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans*. EM 200-1-3, 1 February.

USEPA. 1997. *Test Methods for Evaluating Solid Waste, Volume IB: Laboratory Manual Physical/Chemical Methods,* Third Edition, (as updated through update IIIA). Office of Solid Waste and Emergency Response, Washington, DC.

STANDARD OPERATING PROCEDURE 30.10
COLLECTION OF WIPE SAMPLES

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to detail the general protocol of wipe samples to be analyzed for semi-volatiles, pesticides, polychlorinated biphenyls, and metals. Wipe samples are used to assess the existence and/or extent of contamination on various non-porous surfaces such as floors, walls, and ceilings.

2.0 MATERIALS

- Work Plans;
- Field Logbooks;
- 3×3-inch sterile gauze pads, individually wrapped;
- Appropriate collection medium (solvent);
- Gauze pad holder (so uniform pressure is applied;
- Aluminum foil;
- Forceps;
- Decontamination equipment and supplies;
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan; and
- Monitoring equipment per the site-specific health and safety plan.

3.0 PROCEDURE

3.1 DOCUMENTATION

Wipe sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.2 GENERALIZED PROCEDURE

Sample points should be specified in the work plan addenda based on site history, manufacturing processes, personnel practices, obvious contamination, and available surface area. A variety of surface wipe sampling methods vary may be used; the specific method to be used should be specified in the work plan addenda based on site conditions and data quality objectives (DQOs). A generalized procedure is presented below. Before sampling a specific matrix type, collect a field blank using the following general procedure:

1. Put on a new pair of disposable gloves.
2. Remove gauze pad from package using decontamination forceps (or filter paper) and fasten in holder.
3. Soak pad with 20 mL of appropriate collection medium (solvent).
4. Carefully fold the pad and place into a labeled sample collection bottle using the forceps.

To collect a wipe sample, use the following general procedures:

1. Mark the area to be sampled using an appropriately sized template cutout over the area to be sampled. Secure the template.
2. With a new pair of disposable gloves, remove the gauze pad from its package and position the pad on the holder and clip the edges. NOTE: Before positioning the pad on the holder for each sample, replace the aluminum foil liner of the pad holder.
3. Soak the pad with 20 mL of the collection medium.
4. First wipe - Starting in the upper left corner, apply pressure to the sample pad and move the holder horizontally left to right in the designated area in straight even strokes, attempting to slightly overlap each stroke.
5. Second wipe - After wiping left to right, repeat at a 90-degree angle to the first wipe by starting at the top left corner of the designated area and evenly drawing the pad vertically down to the bottom, progressing from left to right.
6. Wipe areas should be flat, even surfaces. If the surface is not flat, be sure to wipe in any crevices or depressions.
7. Without allowing the sample pad to contact any other surface, fold the pad with exposed side in, and then fold it again to form a 90-degree angle in the center of the pad.
8. Place the pad in an amber laboratory sample container, angle first, and replace the cap and secure tightly.
9. Appropriately label, handle, and ship the samples according to requirements specified in the work plan addenda prepared for site-specific investigations.
10. Clearly mark the boundaries of the sample area with masking tape and label it with the sample number. This marking of specific sample areas may be used for future reference. Photographs of the sampled area should also be taken to further document the location.
11. Further document the sample location by measuring the distance between two fixed points.

4.0 MAINTENANCE

None required

5.0 REFERENCE

NJDEP. 1992. *Field Sampling Procedures Manual.* May.

New Jersey "Technical Requirements for Site Remediation (N.J.A.C. 7:26E, May 1997).

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

USEPA. 1998. "Dust/Wipe Sampling." Region II CERCLA Quality Assurance Manual, Revision 0, March.

STANDARD OPERATING PROCEDURE 30.11
LEAD CHECK SOIL SCREENING KIT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations of the Lead Check soil screening kit. The screening kit is used for the detection of leachable lead in soil.

2.0 MATERIALS

- Work Plans;
- Field logbooks;
- Soil sampling equipment and supplies, as appropriate (SOP 30.1);
- Personal protective equipment and clothing (PPE) per the requirements of the site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1); and
- Lead Check soil screening kit.

3.0 PROCEDURE

3.1 SAMPLE PREPARATION

For maximum sensitivity, follow the drying procedures described below. For a rapid screen (sensitivity may vary with wet samples), skip the drying procedure and begin with step 3.

1. Spread the cup of soil out on a clean piece of paper or cardboard. Remove any stones or debris and allow the soil to air-dry until most of the moisture is removed.
2. After drying the soil, remove any remaining stones or debris.
3. Place the soil into the zip-top bag provided and break up large clumps. Mix well until the sample appears uniform in texture.

3.2 EXTRACTION PROCEDURE

1. With the tip of the extraction liquid dropper pointing down, crush and squeeze to release the entire contents of the dropper into the reaction bottle.
2. Using the plastic spoon provided, place *one level spoonful* of the soil into the reaction bottle containing the extraction solution and swirl a few times to mix. Clean out the spoon after use to avoid contamination of other samples.
3. Let stand for 30 min undisturbed. A layer of liquid will form on top of the soil sample.

3.3 TESTING PROCEDURE

1. After 30 min, remove a small amount of liquid from the top layer with the dropper provided in the kit. Use only a clean, unused dropper. *Try not to disturb the soil that has settled on the bottom of the bottle.*
2. Testing multiple sample drops from each extraction is recommended. This is done by placing two drops from the same sample bottle into two adjacent wells of the plastic reaction tray provided. Each Lead Check swab can be used to simultaneously develop the two samples as follows.
3. Activate a Lead Check swab by squeezing at points A and B. Shake once to mix the contents and squeeze to deliver two or three drops into each of the liquid samples. *Do not touch the tip of the swab to the sample drops in the reaction tray!* Observe the samples for color change. Any pink or red color due to the lead content of the soil will develop as the yellow "Lead Check" dye color fades. Placing the tray on white paper and tapping it gently may make it easier to see the developing pink color.

3.4 INTERPRETATION

Any pink or red color in the solution indicates that there is lead above 400 ppm in the sample. Red or pink precipitates may form and also indicate high lead content. For very low lead levels (at or near 400 ppm) the same sample may be tested again in 1 hr. Extra Lead Check swabs and reaction wells are provided in the kit for this purpose.

3.5 PRECAUTIONS

- Red or orange clay can make it difficult to read low levels of lead. Call manufacturer's toll free 800 number provided with each kit if testing red or orange soil.
- The extraction tubes contain ACID! Avoid contact with eyes, skin, or acid sensitive surfaces.
- Refer to the site-specific health and safety plan.

4.0 MAINTENANCE

None required.

5.0 REFERENCE

Lead Check for Soil manufacturers manual.

STANDARD OPERATING PROCEDURE 30.12
VIBRACORE DEEP SEDIMENT SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for obtaining representative deep sediments sampling using the Vibracore sediment sampling method. These procedures and guidelines were developed in conjunction with the procedures set forth in *Technical Practice for Vibracore Sediment Sampling* (Normandeau Associates). Sediments include solid matter derived from rocks or biological materials that settled from the water column. This procedure can be applied to the collection of sediment samples from areas of deposition such as streams, rivers, ditches, lakes, ponds, and lagoons.

2.0 MATERIALS

- Work Plans;
- Field logbook;
- Photoionization detector (PID) or other appropriate monitoring instrument per the site-specific health and safety plan;
- Stainless steel, polytetrafluoroethylene (PTFE), or PTFE-lined sampling tray or bowl;
- Stainless steel or PTFE dip sampler, scoops, trowels, spoons, and ladles;
- Portable Vibracore with marsh buggy, barge, boat, or truck (as needed based on site conditions);
- Aluminum core barrels and liners;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Rubber boots/waders;
- Plastic sheeting;
- Decontamination equipment and supplies (SOP 80.1);
- Personal flotation devices (PFDs), as applicable; and
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan.

3.0 OPERATING PROCEDURE

Portable vibratory coring uses a vibrating head assembly clamped onto a core barrel up to 30 ft in length to obtain a virtually undisturbed core sample in sand, silt, or clay. A plastic sample liner can be fitted into the core barrel to enable collection of continuous sediment samples up to 3 inches in diameter. The Vibracore sampling assembly can routinely collect 10–20-ft continuous core samples in loosely consolidated, wet, or submerged media.

For all samples, mark the sampling location on a site map. Photograph (optional, recommended) and describe each location. Place a numbered stake immediately adjacent to the sample location.

1. Don personal protective equipment in accordance with the site safety and health plan.
2. Assemble and test the Vibracore according to manufacturer's instructions and assemble the core liner, core cutter, and catcher.
3. Measure and record the length of the Vibracore unit from the bottom to the top of the core barrel.
4. Clamp the vibrating head assembly onto the core barrel and raise the unit off the deck until the coring assembly is vertical.
5. For submerged sediments the progress of the Vibracore will be measured at the surface of the water-air interface. To determine the sediment-water interface (0 ft of penetration), slowly lower the Vibracore and core barrel into the water until the bottom of the core barrel is at the sediment-water interface. Measure the depth of water. The water-air interface at 0 ft penetration is determined by subtracting the water depth from the measured length of the core barrel. Operate the Vibracore unit until the desired depth is obtained. Measure and record the length of core barrel extending above the water. The difference between these two measurements is the penetration depth.
6. For exposed sediments, 0 ft of penetration can be obtained visually when the core barrel contacts the surface.
7. Lower the assembly unit at a rate not to exceed 1 ft/sec.
8. Activate the Vibracore and begin lowering the unit to allow penetration into the sediment. A noticeable decrease in penetration will indicate that either a sediment clay layer has been reached or the unit has contacted an impervious object or material. With the latter, a second or third coring attempt may be necessary. Record the final penetration depth and time on Vibracore sampling log.
9. Slowly winch the Vibracore out of the sediment and up to the surface of the water. It may be necessary to activate the Vibracore for a short time to withdraw the core barrel from the sediment when collecting deep samples (i.e., 15 ft or deeper).
10. Place the core barrel on the deck of the barge or boat. Remove the cutter head and core catcher from the end of the core barrel. Cap and tape both ends of the core barrel and clearly label the core with the sample ID number and core orientation ("top" on one end and "bottom" on the other).
11. If possible, maintain the core sample in a vertical position until the core is delivered to the sample processing area.
12. Lay the sample tube horizontally on the sample-logging table, remove end caps, and drain excess water.
13. Cut the core barrel off on the end labeled "surface" just above sediment and replace the cap. Measure the length of the core sample recovered and record as core recovery in the sampling log. Cut the sample tube lengthwise with a clean stainless steel knife and separate the whole core into two lengthwise halves. Cut away the smeared edges of the core with a clean putty knife.
14. Log and photograph the core and record the data in the sample logbook

3.1 SAMPLING PROCEDURES

1. Make a sketch of the sample area, showing nearby features and permanent structures that could be used to locate the sample points on a map. Whenever possible, include measured distances from such identifying features. Include depth and width of waterway, rate of flow, type and consistency of sediment, and the point and depth of sample collection (e.g., along shoreline, mid-channel).
2. Start downstream and work upstream to prevent contamination of un-sampled areas.

3. Collect the sediment sample.
4. Ensure that all field observations are recorded in the sample logbook. The following data should be recorded:

   Sample location

   Sample depth

   Characteristics of the surficial sediment

   — Texture

   — Color

   — Biological structures (shells, macrophytes)

   — Presence of debris (wood chips, wood fibers)

   — Presence of oily sheen

   — Odor

   Changes in sediment characteristics

   Penetration depth

   Comments related to sample quality

   — Leakage

   — Winnowing

   — Disturbance
5. Screen the sediment sample with the PID following procedures outlined in the Master Health and Safety Plan.
6. Remove the sediment core from the tube sampler and place core on a clean working surface.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Based on the screening results collect the VOC fraction, as applicable.
8. Begin sampling with the acquisition of any discrete sample(s) for analysis of VOCs, with as little disturbance as possible. VOC samples will not be composited or homogenized.
9. The method of collection for VOC samples will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda and sampling conditions.
10. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent. Sample container requirements are specified in work plan addenda.
11. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers. Secure the cap of each container tightly.
12. Appropriately, label and package the samples according to the requirements specified in SOPs 50.1 and 50.2, respectively, and with any additional sample handling requirements specified in work plan addenda.

13. Decontaminate equipment according to SOP 80.1.

3.2 LABELING AND PACKAGING

Refer to SOPs 50.1 and 50.2.

3.3 INVESTIGATION-DERIVED MATERIAL

Manager investigation-derived material in accordance with SOP 70.1 and work plan addenda.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

- Both surface water and sediment samples are to be collected at the same location.
- Collect the surface water sample first (SOP 30.3). Sediment sampling usually results in disturbance of the sediments, which may influence the analytical results of the surface water samples.
- If sampling from a boat or near water bodies with a depth of 4 ft or more, the sampling team shall wear personal flotation devices (life jackets).
- Collect samples first from those areas that are suspected of being the least contaminated, thus minimizing the risk of cross contamination.

6.0 REFERENCES

USEPA. 1987. *A Compendium of Superfund Field Operations Methods.* EPA/540/P-87/001.

Normandeau Associates. *Technical Practice for Vibracore Sediment Sampling.*

STANDARD OPERATING PROCEDURE 40.1
MULTIPARAMETER WATER QUALITY MONITORING INSTRUMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operation with the multiparameter water quality logging system (data transmitter and visual display). This system can monitor up to eleven basic parameters, including dissolved oxygen, percent saturation, temperature, pH, specific conductance, resistivity, salinity, total dissolved solids, redox, level, and depth.

2.0 MATERIALS

- Visual display;
- Data transmitter;
- Underwater cables; and
- Field logbooks.

3.0 PROCEDURE

3.1 CALIBRATION

Calibration will be performed in the field daily before use according to manufacturer's specifications. The following parameters are calibrated to the following standards:

- Temperature—none required;
- Specific conductance—KCl or seawater standards;
- pH—pH 7 buffer plus a slope buffer;
- Dissolved oxygen—saturated air or saturated water;
- Redox—quinhydrone or transfer;
- Depth—set zero in air;
- Level—set zero in air; and
- Salinity—uses calibration for specific conductance.

3.2 OPERATION

1. Attach the cable to the transmitter.
2. Connect the other end of the cable to the display.
3. Press the On/Off key on the display panel. Allow a few seconds for the transmitter to start sending data to the display screen.
4. Calibrate the transmitter.
5. Deploy the sensor into a minimum of 4 in. of water.

6. Write data values from the display screen in the appropriate field logbook.
7. Retrieve sensor and clean the transmitter to prevent cross-contamination.
8. Move to the next sampling location. If travel time is great, turn off display by pressing On/Off key. Check condition of probes after each deployment.
9. Disconnect the transmitter when finished sampling for the day.

4.0 MAINTENANCE

Maintain according to specific manufacturer's specifications.

5.0 PRECAUTIONS

- Check condition of probes frequently between sampling; and
- Don't force pins into the connectors; note the keying sequence.

STANDARD OPERATING PROCEDURE 40.2
WATER LEVEL AND WELL-DEPTH MEASUREMENTS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for measuring water level and well depth. This procedure is applicable to the sampling of monitoring wells and must be performed before any activities that may disturb the water level, such as purging or aquifer testing.

2.0 MATERIALS

- Work Plans;
- Well construction diagrams;
- Field logbook;
- Photoionization detector (PID) or other monitoring instruments per site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Electric water level indicator (dipmeter) with cable measured at 0.01 ft increments;
- Oil-water interface probe (if non-aqueous phase liquid (NAPLs) are suspected to be present); and
- Plastic sheeting.

3.0 PROCEDURE

3.1 PRELIMINARY STEPS

1. Locate the well and verify its position on the site map. Record whether positive identification was obtained, including the well number and any identifying marks or codes contained on the well casing or protective casing. Gain access to the top of the well casing.
2. Locate the permanent reference mark at the top of the casing. This reference point will be scribed, notched, or otherwise noted on the top of the casing. If no such marks are present, measure to the top of the highest point of the well casing and so note this fact in field logbook. Determine from the records and record in the notebook the elevation of this point.
3. Record any observations and remarks regarding the completion characteristics and well condition, such as evidence of cracked casing or surface seals, security of the well (locked cap), and evidence of tampering.
4. Keep all equipment and supplies protected from gross contamination; use clean plastic sheeting. Keep the water level indicator probe in its protective case when not in use.

3.2 OPERATION

1. Sample the air in the well head for gross organic vapors by lifting the well cap only high enough for an organic vapor meter (PID or FID) probe to be entered into the well casing. This will indicate the presence of gross volatile contaminants as well as indicating potential sampler exposure.

2. Remove cap. Allow well to vent for 60–90 seconds. Resample headspace. Record both readings. If the second reading is lower than the first, use the second reading to determining whether respiratory protection will be required during subsequent water level and well depth determinations and sampling.
3. Note that all headspace sampling must be performed at arm's length and from the upwind side of the well if possible.
4. If NAPL contamination is suspected, use an interface probe to determine the existence and thickness of NAPLs.
   - Open the probe housing, turn the probe on, and test the alarm. Slowly lower the probe into the well until the alarm sounds. A continuous alarm indicates a NAPL, while an intermittent alarm indicates water. If a NAPL is detected, record the initial level (first alarm). Mark the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable sufficiently to record the depth.
   - Continue to slowly lower the probe until it passes into the water phase. Slowly retract the probe until the NAPL alarm sounds and record that level in the manner as described above.
   - Record the thickness of the LNAPL (see Section 3.3.1).
   - Continue to slowly lower the interface probe through the water column to check for the presence of DNAPL.
   - Measure and record the thickness of the DNAPL layer (if any) as described above.
   - Slowly raise the interface probe, recording the depth to each interface as the probe is withdrawn. If there is a discrepancy in depths, clean the probe sensors and re-check the depths.
   - NOTE: Air-liquid interface depth is more reliable if probe is lowered into liquid. NAPL-water depths are more accurate if probe is moved from water into NAPL.
   - Always lower and raise interface probe slowly to prevent undue mixing of media.
   - Always perform NAPL check in wells installed in areas with suspected NAPL contamination. Always perform NAPL check if headspace test reveals presence of volatiles. Always perform NAPL check the first time a well is sampled. If a well has been sampled previously and no NAPLs were present and none of the proceeding conditions are met, the NAPL check may be omitted.
5. If no NAPL is present, use an electronic water level detector as follows.
   - Remove the water level indicator probe from the case, turn on the sounder, and test check the battery and sensitivity scale by pushing the red button. Adjust the sensitivity scale until you can hear the buzzer.
   - Slowly lower the probe and cable into the well, allowing the cable reel to unwind. Continue lowering until the meter buzzes. Very slowly, raise and lower the probe until the point is reached where the meter just buzzes. Marking the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable and record the depth.

6. To measure the well depth, lower electric water level indicator probe or tape until slack is noted. Very slowly raise and lower the cable until the exact bottom of the well is "felt." Measure (cable) or read the length (tape) and record the depth.
7. Note that if the electric water level indicator is used to determine depth of well, the offset distance between the tip of the probe and the electrode must be added to the reading to determine actual depth.
8. Withdraw the probe or tape.
9. Decontaminate the probe(s) and cable(s), in accordance with SOP 80.1.

3.3 DATA RECORDING AND MANIPULATION

Record the following information in the field logbook and appropriate sampling forms:

- Date and time;
- Weather;
- Method of measurement;
- Casing elevation;
- NAPL surface elevation = casing elevation - depth to NAPL;
- Apparent measured LNAPL thickness = depth to bottom of NAPL - depth to top of NAPL;
- Water level elevation = casing elevation - depth to water; and
- Well bottom elevation = casing elevation - depth to bottom (or read directly from tape).

4.0 CALIBRATION

No calibration is required. Ensure operability of electric water level indicator by testing sounder before use.

5.0 PRECAUTIONS

- Depending upon the device used, correction factors may be required for some measurements;
- Check instrument batteries before each use; and
- Exercise care not to break the seals at the top of the electric water level indicator probe.

6.0 REFERENCES

ASTM Standard D 4750-87. 1987. *Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).*

M^{c}Alary, T. A., and Barker, J.F. 1987. "Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials" in *Ground Water Monitoring Review.* Fall 1987.

Thornhill, Jerry T. 1989. *Accuracy of Depth to Groundwater Measurements;* in "EPA Superfund Ground Water Issue" EPA/540/4-89/002.

STANDARD OPERATING PROCEDURE 40.3
SLUG TESTS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide information and technical guidance for performing falling- and rising-head *in situ* hydraulic conductivity tests and data analyses. The slug test method involves causing a sudden change in head in a control well and measuring the water level response within that control well. Head change may be induced by suddenly injecting into the well or removing from the well a known quantity of water, rapid removal of a mechanical "slug" from below the water level, increasing or decreasing the air pressure in the well casing, or emplacement of a mechanical slug into the water column.

The water level response in the well is a function of the mass of water in the well and the transmissivity and coefficient of storage of the aquifer. The results of the slug test may be used to determine an estimate of the hydraulic conductivity of the aquifer material near the well.

2.0 MATERIALS

- Work Plans;
- Field logbook;
- Well construction information and boring log;
- Photoionization detector (PID) or other monitoring instruments per site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Aquifer test data sheets;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Slug-inducing equipment (solid slug, line, etc.) large enough to displace groundwater beyond the well filter pack.

3.0 PROCEDURE

Initially, an appropriate test methodology should be chosen. The selection of the appropriate test method (rising or falling head) is dependent primarily on saturated screen length, the well diameter, and the estimated hydraulic conductivity. If the screen extends above the water table, a rising-head test (water removal) should be used. The performance of a falling-head test (water added) in this circumstance would overstate the hydraulic conductivity value, as the measured response would reflect the equilibration rate of previously unsaturated material; unsaturated materials would equilibrate faster than saturated materials. When the measured water level in a monitoring well is above the screened portion of the well, a falling-head test methodology should be employed. A rising-head test may also be performed, but only if the initial water level reading (after the slug is removed) is above the screened interval.

For larger diameter and deeper wells, as a general rule and particularly for high conductivity materials, it is not feasible to remove a large enough slug or water volume to cause a sufficient change in head. In these cases the falling-head test method should be used.

It is recommended that a pressure transducer be used whenever possible to record water levels and time. A pressure transducer is required to record useful data when the hydraulic conductivity is high (greater than 10^{-3} cm/sec). The standard stopwatch and water-level indicator method is adequate for lower conductivity units.

The procedures outlined below assume use of a pressure transducer. Readings should be collected at intervals set on the data logger if used. If manual readings are collected, the following intervals should be applied:

- 0 to 5 minutes, every 10 seconds;
- 5 to 10 minutes, every 30 seconds;
- 10 to 30 minutes, every 1 minute; and
- 30 to 60 minutes, every 2 minutes.

3.1 Falling-Head Tests

1. Install pressure transducer near the total well depth and permit transducer and water levels to equilibrate to ambient conditions. Secure transducer cable to prevent movement during the test. Begin transducer readings.
2. Manually measure the static water level.
3. Insert slug completely below static water level or add a water "slug."
4. Intermittently measure water level and note the time of measurement with reference to the data logger.
5. Continue monitoring until water level is within 90% of the static level.

If a solid slug was used, stop the falling-head test recording at this point and begin a rising-head test by removing the solid slug from the well. If a solid slug was not used, simply end recording by the data logger at the completion of the falling-head test.

3.2 Rising-Head Tests

1. Install pressure transducer near the total well depth and permit transducer and water levels to equilibrate to ambient conditions. Secure transducer cable to prevent movement during testing.
2. Manually measure the static water level.
3. Remove sufficient volume of water to lower the water level a minimum of 1 ft below static water level, or
4. Install the solid slug fully below water level; permit static conditions to return and then remove the solid slug.
5. Begin readings with data logger.
6. Intermittently measure water level and note time of measurement with reference to data logger.
7. Continue monitoring until the water level is within 90% of the static level.

As a check on equipment operation and in the event that test data for a particular well are not usable, the data should be printed out in the field. If there is equipment failure (e.g., a non-attainment of a 1-foot minimum head change, unexplained fluctuations in water levels, etc.), the test can be rerun with minimum time lost.

The well numbers, static and subsequent water levels, programmed test numbers, and general comments should be recorded in the field notebook.

4.0 PRECAUTIONS

Not applicable.

5.0 REFERENCES

ASTM Standard D 4043-91. *Standard Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties of Well Techniques.*

Hvorslev, M.J. 1951. *Time-Lag and Soil Permeability in Ground Water Observations.* U.S. Army Engineers, Bulletin 36 - This method can be applied to both unconfined and confined aquifers but provides only approximate conductivity values (Freezer R.A. and J.A. Cherry, 1979, Groundwater, Prentice-Hall, Inc.).

Cooper, H.H., J.D. Bredehoeft, I.S. Papadopulos. 1967. *Response of a Finite-Diameter Well to an Instantaneous Charge of Water.* Water Resources Division, U.S. Department of the Interior Geological Survey, Vol. 3, No. 1 - This method can be applied to aquifers under confined conditions and requires that the well completely penetrate the aquifer. This method is believed to produce most reliable data when applied to low-permeability materials.

Bouwer, H. 1989. *The Bouwer and Rice Slug Test -- An Update.* Ground Water, Vol. 27, No. 3; and Bouwer, H. and R.C. Rice. 1976. *A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells.* Water Resources Research, Vol. 12, No. 3 - This method takes into account additional well and aquifer configuration data points not considered by Hvorslev's more simplistic method. Computer analyses are available.

Nguyen, V., G.F. Pinder. 1984. *Direct Calculation of Aquifer Parameters in Slug Test Analyses, Groundwater Hydraulics.* American Geophysical Union Water Resources Monograph 9 - This method can be applied to partially penetrating wells in both confined and unconfined aquifers it produces better values for low- to moderate-permeability materials.

STANDARD OPERATING PROCEDURE 40.4
WATER FLOW MEASUREMENTS USING WATER FLOW PROBE

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with the hand-held flow meter. The flow probe uses a protected turbo-prop sensor and a positive displacement technique. Magnetic material on the propeller passes a pickup coil in the housing, producing electrical impulses. These electrical impulses are then carried by wire to a read-out display on the handle. This information is used to determine control measures such as protection and action levels.

2.0 MATERIALS

- PVC handle and propeller housing;
- Anodized aluminum shaft;
- Brass bearing on propeller shaft; and
- Two internal replaceable watch-type batteries.

3.0 PROCEDURE

3.1 SET UP

1. The set up sequence is entered automatically when the batteries are replaced. The sequence can also be entered at any time by holding down both buttons for 8 sec. At the start of sequence, all of the display segments are displayed, and then the "mi" appears for English units and "km" appears for metric units. The left button scrolls between English and metric.
2. For ft/sec stay in "mi." Push the right button to "cal." This is the probe calibration function. The probe is factory set at 33.31 ft/sec. If the batteries are changed this number will have to be reset. The left button increases the number when the arrow points up and decreases when the arrow points down.
3. Push the right button; be sure "CAD" is not displayed.

   Push the right button: Sleep will appear. If the probe is not used for longer than 1 month, leave it in sleep mode to reduce battery drainage.

   Push the right button, and then push the left button to toggle between the 12 and 24-hour clock.

   Push the right button, and then push the left button to set the hour.

   Push the right button, and then push the left button to set the minutes.

   Push the right button again to exit setup and get back to velocity ("V"). The unit is now ready to take readings.

3.2 GENERAL OPERATION

1. The clock may be set to use the time of day function.
2. The flow probe computer has a two-button operation. The right button changes between functions and the left button picks the options. Pushing both buttons for one second will zero the displayed value.
3. Push the right button to scroll through the functions. Velocity, "V," is the instantaneous velocity to the nearest 0.5 ft/sec. Push the left button to scroll between "AV" (average velocity) and "MX" (maximum velocity). Push both buttons to zero the displayed values.
4. Stop watch/clock function. The top number is the stopwatch. Push the left button to start and stop the function. The bottom number is the time of day.
5. Record flow in units of ft/sec in field logbook.

4.0 PRECAUTIONS

- Flow probe does not carry an intrinsic safety rating and must not be used in a hazardous location where flammable concentrations of gases or vapors are constantly present.
- Maintenance and servicing of this device, including battery changing, must be performed in a safe area away from hazardous locations.
- Do not open or mutilate battery cells.

STANDARD OPERATING PROCEDURE 50.1
SAMPLE LABELS

1.0 SCOPE AND APPLICATION

Every sample will have a sample label uniquely identifying the sampling point and analysis parameters. The purpose of this standard operating procedure (SOP) is to delineate protocols for the use of sample labels. An example label is included as Figure 50.1-A. Other formats with similar levels of detail are acceptable.

2.0 MATERIALS

- Sample label; and
- Indelible marker.

3.0 PROCEDURE

The use of preprinted sample labels is encouraged and should be requested from the analytical support laboratory during planning activities.

As each sample is collected, fill out a sample label ensuring the following information has been collected:

- Project name;
- Sample ID: enter the SWMU number and other pertinent information concerning where the sample was taken. This information should be included in site-specific work plan addenda;
- Date of sample collection;
- Time of sample collection;
- Initials of sampler(s);
- Analyses to be performed (NOTE: Due to number of analytes, details of analysis should be arranged with lab *a priori*); and
- Preservatives (water samples only).

Double-check the label information to make sure it is correct. Detach the label, remove the backing and apply the label to the sample container. Cover the label with clear tape, ensuring that the tape completely encircles the container.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

USEPA. 1998. *EPA Requirements for Quality Assurance Project Plans.* EPA/600/R-98/018, QA/R5, Final, Office of Research and Development, Washington, D.C.

FIGURE 50.1-A
SAMPLE LABEL

PROJECT NAME ________________________

SAMPLE ID ________________________

DATE: ___/___/___ TIME: ____:____

ANALYTES: VOC SVOC P/P METALS CN
PAH D/F HERBs ANIONS TPH
ALK TSS

PRESERVATIVE: [HCl] [HNO_3] [NaOH] [H_2SO_4]

SAMPLER: __________________

STANDARD OPERATING PROCEDURE 50.2
SAMPLE PACKAGING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the packing and shipping of samples to the laboratory for analysis.

2.0 MATERIALS

- Waterproof coolers (hard plastic or metal);
- Metal cans with friction-seal lids (e.g., paint cans);
- Chain-of-custody forms;
- Chain-of-custody seals (optional);
- Packing material;
- Sample documentation;
- Ice;
- Plastic garbage bags;
- Clear Tape;
- Zip-top plastic bags; and
- Temperature blanks provided by laboratory for each shipment.

3.0 PROCEDURE

1. Check cap tightness and verify that clear tape covers label and encircles container.
2. Wrap sample container in bubble wrap or closed cell foam sheets. Samples may be enclosed in a secondary container consisting of a clear zip-top plastic bag. Sample containers must be positioned upright and in such a manner that they will not touch during shipment.
3. Place several layers of bubble wrap, or at least 1 in. of vermiculite on the bottom of the cooler. Line cooler with open garbage bag, place all the samples upright inside the garbage bag and tie.
4. Double bag and seal loose ice to prevent melting ice from soaking the packing material. Place the ice outside the garbage bags containing the samples.
5. Pack shipping containers with packing material (closed-cell foam, vermiculite, or bubble wrap). Place this packing material around the sample bottles or metal cans to avoid breakage during shipment.
6. A temperature blank (provided by laboratory) will be included in each shipping container to monitor the internal temperature. Samples should be cooled to 4 degrees C on ice immediately after sampling.

7. Enclose all sample documentation (i.e., Field Parameter Forms, Chain-of-Custody forms) in a waterproof plastic bag and tape the bag to the underside of the cooler lid. If more than one cooler is being used, each cooler will have its own documentation. Add the total number of shipping containers included in each shipment on the chain-of-custody form.
8. Seal the coolers with signed and dated custody seals so that if the cooler were opened, the custody seal would be broken. Place clear tape over the custody seal to prevent damage to the seal.
9. Tape the cooler shut with packing tape over the hinges and place tape over the cooler drain.
10. Ship all samples via overnight delivery on the same day they are collected if possible.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

5.1 PERMISSIBLE PACKAGING MATERIALS

- Non-absorbent
  - Bubble wrap; and
  - Closed cell foam packing sheets.
- Absorbent
  - Vermiculite.

5.2 NON-PERMISSIBLE PACKAGING MATERIALS

- Paper;
- Wood shavings (excelsior); and
- Cornstarch "peanuts".

6.0 REFERENCES

USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program.* EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, D.C., December 1990.

USEPA. 1991. *User's Guide to the Contract Laboratory Program.* EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response. January 1991.

USEPA. 1998. *EPA Requirements for Quality Assurance Project Plans.* EPA/600/R-98/018, QA/R5, Final, Office of Research and Development, Washington, D.C

STANDARD OPERATING PROCEDURE 70.1
INVESTIGATION-DERIVED MATERIAL

1.0 SCOPE AND APPLICATION

Management of investigation-derived material (IDM) minimizes the potential for the spread of waste material onsite or offsite through investigation activities. The purpose of this standard operating procedure (SOP) is to provide general guidelines for appropriate management of potentially contaminated materials derived from the field investigations. Specific procedures related to the transportation and disposal of hazardous waste are beyond the scope of this SOP.

2.0 INTRODUCTION

Investigation derived material (IDM) consists of waste materials that are known or suspected to be contaminated with waste substances through the actions of sample collection or personnel and equipment decontamination. These materials include decontamination solutions, disposable equipment, drill cuttings and fluids, and water from groundwater monitoring well development and purging. To the extent possible, the site manager will attempt to minimize the generation of these materials through careful design of decontamination schemes and groundwater sampling programs. Testing conducted on soil and water investigation-derived material will show if they are also hazardous wastes as defined by RCRA. This will determine the proper handling and ultimate disposal requirements.

The criteria for designating a substance as hazardous waste according to RCRA is provided in 40 CFR 261.3. If IDM meet these criteria, RCRA requirements will be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR 262.34. Those materials that are judged potentially to meet the criteria for a regulated solid or hazardous waste will be placed in DOT-approved 55-gallon steel drums or another type of DOT approved container; based on waste characteristics and volume.
Investigation-derived material will be appropriately placed in containers, labeled, and tested to determine disposal options in accordance with RCRA regulations and Virginia Hazardous Waste Management Regulations.

3.0 INVESTIGATION-DERIVED MATERIAL MANAGEMENT

Procedures that minimize potential for the spread of waste material include minimizing the volume of material generated, material segregation, appropriate storage, and disposal according to RCRA requirements.

3.1 WASTE MINIMIZATION

In the development of work plan addenda, each aspect of the investigation will be reviewed to identify areas where excess waste generation can be eliminated. General procedures that will eliminate waste include avoidance of unnecessary exposure of materials to hazardous material and coordination of sampling schedules to avoid repetitious purging of wells and use of sampling equipment.

3.2 WASTE SEGREGATION

Waste accumulation and management procedures to be used depend upon the type of material generated. For this reason, IDM described below are segregated into separate 55-gallon storage drums or other appropriate DOT containers. Waste materials that are known to be free of potential hazardous waste contamination (such as broken sample bottles or equipment containers and wrappings) must be collected separately for disposal to municipal systems. Large plastic garbage or "lawn and leaf" bags are useful for collecting this trash. Even "clean" sample bottles or Tyvek should be disposed of with care. Although they are not legally a problem, if they are discovered by the public they may cause concern. Therefore, items that are known to be free from contamination but are also known to represent "hazardous or toxic waste" to the public must not be disposed of in any public trash receptacle, such as found at your hotel or park.

3.2.1 Decontamination Solutions

Solutions considered investigation-derived materials range from detergents, organic solvents, and acids used to decontaminate small hand samplers to steam-cleaning rinsate used to wash drill rigs and other large equipment. These solutions are to be placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT approved containers. Residual liquid IDM from decontamination pads will be removed and appropriately placed in container(s) at the end of each field day.

3.2.2 Soil Cuttings and Drilling Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities or drilling for the collection of subsurface soil samples or the installation of monitoring wells. Depending on the type of drilling, drilling fluids known as "muds" may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Drill cuttings, whether generated with or without drilling fluids, are to be removed with a flat-bottomed shovel and placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT containers, as conditions or volume of IDM dictate.

3.2.3 Well Development and Purge Water

Well development and purge water is removed from monitoring wells to repair damage to the aquifer following well installation, obtain characteristic aquifer groundwater samples, or measure aquifer hydraulic properties. The volume of groundwater to be generated will determine the appropriate container to be used for accumulation of IDM.

For well development and purging, 55-gallon drums are typically an efficient container for accumulation. When larger volumes of water are removed from wells, such as when pumping tests are conducted, the use of large-volume portable tanks such as "Baker Tanks" should be considered for IDM accumulation.

Analytical data for groundwater samples associated with the well development and purge water will be used to assist in characterizing IDM and evaluating disposal options.

3.2.4 Personal Protective Equipment and Disposable Sampling Equipment

Personal protective equipment and clothing (PPE) may include such items as Tyvek coveralls, gloves, booties, and APR cartridges. Disposable sampling equipment may include such items as plastic sheeting, bailers, disposable filters, disposable tubing and paper towels. PPE and disposable sampling equipment that have or may have contacted contaminated media (soil, water, etc.) will be segregated and placed in 55-gallon drums separate from soil and water IDM. Disposition of this type of IDM will be determined by the results of IDM testing of the media in which the PPE and sampling equipment contacted.

3.3 MATERIAL ACCUMULATION

The IDM in containers must be placed in an appropriate designated RCRA container accumulation area at RFAAP, where it is permissible to accumulate such waste. IDM placed into a designated 90-day accumulation area will be properly sealed, labeled and covered. All drums will be placed on pallets.

A secure and controlled waste staging area will be designated by the installation prior the commencement of field sampling activities. Per the facility's requirements as a RCRA large quantity generator, waste accumulation cannot exceed 90 days for materials presumed or shown to be RCRA-designated hazardous wastes; waste which is known not to be RCRA-designated waste should be promptly disposed to municipal waste systems or appropriate facility.

3.3.1 IDM Accumulation Containers

Containers will be DOT-approved (DOT 17H 18/16GA OH unlined) open-head steel drums or other DOT approved container, as appropriate.

Container lids should lift completely off be secured by a bolt ring (for drum). Order enough containers to accumulate all streams of expected IDM including soil, PPE and disposable sampling equipment, decontamination water, purge water, etc.

Solid and liquid waste streams will not be mixed in a container. PPE and expendable sampling equipment will be segregated from other IDM and placed in different containers than soil. Containers inside containers are not permitted. PPE must be placed directly in a drum not in a plastic bag.

Pallets are often required to allow transport of filled drums to the staging area with a forklift. Normal pallets are 3×4 ft and will hold two to three 55-gallon drums depending on the filled weight. If pallets are required for drum transport or storage, field personnel are responsible for ensuring that the empty drums are placed on pallets before they are filled and that the lids are sealed on with the bolt-tighten ring after the drums are filled. Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move the drums by hand.

3.3.2 Container Labeling

Each container that is used to accumulate IDM will be appropriately labeled at the time of accumulation and assigned a unique identification number for tracking purposes. The following information will be written in permanent marker on a drum label affixed on the exterior side at a location at least two-thirds of the way up from the bottom of the drum.

- Facility name.
- Accumulation start date and completion date.
- Site identifier information (SWMU, boring, well, etc.).
- Description of IDM.
- Drum ID No.

4.0 MATERIAL CHARACTERIZATION AND DISPOSAL

IDM will be characterized and tested to determine whether it is a hazardous waste as defined by 40 CFR Part 261 and to determine what disposal options exist in accordance with RCRA regulations and the Virginia Hazardous Waste Management Regulations (VHWMR).

In general, IDM will be considered a hazardous waste if it contains a listed hazardous waste or if the IDM exhibits a characteristic of hazardous waste.

Work plan addenda will identify the appropriate characterization and testing program for IDM based on the following:

- Site-specific conditions related to chemicals of concern, etc.
- The nature and quantity of expected IDM to be generated during site-specific investigations.
- Applicable Federal, State, and local regulations, such as RCRA, VHWMR regulations and policies and procedures, and Army Regulation 200-1.
- RFAAP specific requirements and policies for IDM characterization and disposal at the time of the investigation.

In general, appropriate USEPA SW 846 Test Methods for Evaluating Solid Waste will be used for testing IDM and will be specified in work plan addenda. Other appropriate test methods may be specified by RFAAP in addition to SW 846 Methods that are specific to installation operations, the site of interest (percent explosive content, reactivity, etc.), or requirements for disposal at RFAAP water treatment facilities or publicly owned treatment works.

Responsibility for the final disposal of IDM will be determined before field activities are begun and will be described in work plan addenda. Off-site disposal of IDM will be coordinated with RFAAP (generator) to ensure appropriate disposition. The contractor will coordinate IDM transportation and disposal activities for RFAAP (generator).

At the direction of RFAAP, appropriate waste manifests will be prepared by the USACE contractor or Alliant Techsystems subcontractor for transportation and disposal. Alliant Techsystems or other appropriate RFAAP entity will be listed as the generator and an appointed representative from RFAAP will review and sign the manifest for offsite disposal.

RFAAP will make the final decision on the selection of the transporter, storage, and disposal facility (TSDFs) or recycling facility. RFAAP will provide the contractor a listing of previously used TSDFs for priority consideration. Proposed facilities that are not included on the listing are required to provide a copy of the TSDFs most recent state or federal inspection to the installation. Waste characterization and testing results will be submitted to RFAAP (generator) for review and approval before final disposition of the material.

Hazardous waste: Prior to final disposition, a hazardous waste manifest will be furnished by the TSDF to accompany transport to the disposal facility. Following final disposition, a certificate of disposal will be furnished by the disposal facility. Copies of the manifests and certificates of disposal are to be provided to RFAAP and retained on file by the contractor or subcontractor.

4.0 PRECAUTIONS

- Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move drums by hand.
- Refer to the site-specific health and safety plan when managing IDM.

5.0 REFERENCES

Safety Rules for Contractors and Subcontractors, 1995. Alliant Techsystems, Incorporated, Radford Army Ammunition Plant.

STANDARD OPERATING PROCEDURE 80.1
DECONTAMINATION

1.0 SCOPE AND APPLICATION

Before leaving the site, all personnel or equipment involved in intrusive sampling or having entered a hazardous waste site during intrusive sampling must be thoroughly decontaminated to prevent adverse health effects and minimize the spread of contamination. Equipment must be decontaminated between sites to preclude cross-contamination. Decontamination water will be free of contaminants as evidenced through either chemical analyses or certificates of analysis. This standard operating procedure (SOP) describes general decontamination requirements for site personnel and sampling equipment. Decontamination procedures for contaminants requiring a more stringent procedure, e.g., dioxins/furans, will be included in site-specific addenda.

2.0 MATERIALS

- Plastic sheeting, buckets or tubs, pressure sprayer, rinse bottles, and brushes;
- U.S. Army Corps of Engineers or installation approved decontamination water source;
- Deionized ultra-filtered, HPLC-grade organic free water (DIUF);
- Non-phosphate laboratory detergent;
- Nitric Acid, 0.1 Normal (N) solution;
- Pesticide-grade solvent, Methanol;
- Aluminum foil;
- Paper towels;
- Plastic garbage bags; and
- Appropriate containers for management of investigation-derived material (IDM).

3.0 PROCEDURE

3.1 SAMPLE BOTTLES

At the completion of each sampling activity the exterior surfaces of the sample bottles must be decontaminated as follows:

- Be sure that the bottle lids are on tight.
- Wipe the outside of the bottle with a paper towel to remove gross contamination.

3.2 PERSONNEL DECONTAMINATION

Review the site-specific health and safety plan for the appropriate decontamination procedures.

3.3 EQUIPMENT DECONTAMINATION

3.3.1 Drilling Rigs

Drilling rigs and associated equipment, such as augers, drill casing, rods, samplers, tools, recirculation tank, and water tank (inside and out), will be decontaminated before site entry, after over-the-road mobilization and immediately upon departure from a site after drilling a hole. Supplementary cleaning will be performed before site entry. There is a likelihood that contamination has accumulated on tires and as spatter or dust en route from one site to the next.

1. Place contaminated equipment in an enclosure designed to contain all decontamination residues (water, sludge, etc.).
2. Steam-clean equipment until all dirt, mud, grease, asphaltic, bituminous, or other encrusting coating materials (with the exception of manufacturer-applied paint) has been removed.
3. Water used will be taken from an approved source.
4. When cross-contamination from metals is a concern, rinse sampling components such as split spoons, geo-punch stems, and augers with nitric acid, 0.1N.
5. Rinse with DIUF water.
6. When semi-volatile and non-volatile organics may be present, rinse the sampling components with pesticide-grade solvent methanol.
7. Double rinse the sampling components with DIUF water.
8. Decontamination residues and fluids will be appropriately managed as IDM per work plan addenda and SOP 80.1.

3.3.2 Well Casing and Screen

Prior to use, well casing and screen materials will be decontaminated. This activity will be performed in the leak proof, decontamination pad, which will be constructed prior to commencement of the field investigation. The decontamination process will include:

- Steam cleaning with approved source water.
- Rinse with DUIF water.
- Air-dry on plastic sheeting.
- Wrap in plastic sheeting to prevent contamination during storage/transit.

3.3.3 Non Dedicated Submersible Pumps Used for Purging and Sampling

1. Scrub the exterior of the pump to remove gross (visible) contamination using appropriate brushes, approved water, and non-phosphate detergent (steam cleaning may be substituted for detergent scrub).
2. Pump an appropriate amount of laboratory detergent solution (minimum 10 gallons) to purge and clean the interior of the pump.
3. Rinse by pumping no less than 10 gallons of approved water to rinse.
4. Rinse the pump exterior with approved decontamination water.
5. When cross-contamination from metals is a concern, rinse the pump exterior with approved nitric acid 0.1N solution.
6. Rinse the pump exterior with DIUF water.

7. When semi-volatile and non-volatile organics may be present, rinse the pump exterior with pesticide-grade solvent methanol.
8. Double rinse the pump exterior with DIUF water.
9. Air-dry on aluminum foil or clean plastic sheeting.
10. Wrap pump in aluminum foil or clean plastic sheeting, or store in a clean, dedicated PVC or PTFE storage container.
11. Solutions and residuals generated from decontamination activities will be managed appropriately as IDM per work plan addenda and SOP 80.1.

3.3.4 Sample Equipment and Measuring Water Level Devices

1. Scrub the equipment to remove gross (visible) contamination using appropriate brush (es), approved water, and non-phosphate detergent.
2. Rinse with approved source water.
3. When cross-contamination from metals is a concern, rinse the sampling equipment with approved nitric acid 0.1N solution.
4. Rinse equipment with DIUF water.
5. When semi-volatile and non-volatile organics may be present, rinse the sampling equipment with pesticide-grade solvent methanol.
6. Double rinse the sampling equipment with DIUF water.
7. Air-dry on aluminum foil or clean plastic sheeting.
8. Wrap in aluminum foil, clean plastic sheeting, or zip top bag or store in a clean, dedicated PVC or PTFE storage container.
9. Solutions and residuals generated from decontamination activities will be managed appropriately as IDM per work plan addenda and SOP 80.1.

3.3.5 Other Sampling and Measurement Probes

Temperature, pH, conductivity, Redox, and dissolved oxygen probes will be decontaminated according to manufacturer's specifications. If no such specifications exist, remove gross contamination and triple-rinse probe with DIUF water.

4.0 PRECAUTIONS

- Manage IDM appropriately according to the requirements specified in work plan addenda.
- Follow appropriate procedures as specified in the site-specific health and safety plan.

5.0 REFERENCES

USACE. 2001. Requirements for the Preparation of Sampling and Analysis Plans. EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 90.1
PHOTOIONIZATION DETECTOR (HNu Model PI–101 and HW–101)

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with a photoionization detector (HNu Systems Model PI-101 or HW–101). The photoionization detector (PID) detects total ionizables; hence it is used to monitor both organic and inorganic vapors and gases to determine relative concentrations of air contaminants. This information is used to establish level of protection and other control measures such as action levels. The PID cannot effectively detect compounds having ionization potentials above the photon energy level of the lamp used; therefore, methane, which has an ionization potential of 12.98 eV, is undetectable by PIDs because the lamps produce 9.5, 10.2, or 11.7 eV.

Use of brand names in this SOP is in not intended as an endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc., are acceptable. If alternate equipment is to be used, the contractor shall provide applicable and comparable SOPs for its maintenance and calibration.

2.0 MATERIALS

- HNu Systems Model PI–101 or HW–101 survey probe with 9.5, 10.2, or 11.7 eV lamp;
- Lead-acid gel-cell battery;
- Calibration gas (e.g., isobutylene, 101 ppm) with regulator;
- Tygon tubing;
- Tedlar bag (optional);
- Instrument logbook; and
- Field logbook.

3.0 PROCEDURE

These procedures are to be followed when using the HNu in the field.

3.1 STARTUP

1. Before attaching the probe, check the function switch on the control panel to ensure that it is in the off position. Attach the probe by plugging it into the interface on the top of the readout module.
2. Turn the function switch to the battery check position. The needle on the meter should read within or above the green battery arc on the scale; if not, recharge the battery. If the red indicator light comes on, the battery needs recharging or service may be indicated.
3. Turn the function switch to any range setting. Listen for the hum of the fan motor. Check meter function by holding a solvent-based marker pen near the sample intake. If there is no needle deflection, look briefly into the end of the probe (no more than 1 or 2 sec) to see if the lamp is on; if it is on, it will give a purple glow. Do not stare into the probe any longer than 2 sec. Long-term exposure to UV light can damage the eyes. (See further information in Section 5.)

4. To zero the instrument, turn the function switch to the standby position and rotate the zero adjustment until the meter reads zero. A calibration gas is not needed since this is an electronic zero adjustment. If the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted if necessary. Allow the instrument to warm up for 3–5 min to ensure that the zero reading is stable. If necessary, readjust the zero.

3.2 OPERATIONAL CHECK

Follow the startup procedure in Section 3.1.
With the instrument set on the 0–20 range, hold a solvent-based marker near the probe tip. If the meter deflects upscale, the instrument is working.

3.3 FIELD CALIBRATION PROCEDURE

1. Follow the startup procedures in Section 3.1 and the operational check in Section 3.2.
2. Set the function switch to the range setting for the concentration of the calibration gas.
3. Attach a regulator HNu P/N 101-351 or equivalent (flow = 200 to 300 ml/min) to a disposable cylinder of isobutylene (HNu 101-351 or equivalent). Connect the regulator to the probe of the HNu with a piece of clean Tygon tubing. Turn on the valve of the regulator.
4. After 5 sec, adjust the span dial until the meter reading equals the benzene concentration of the calibration gas used, corrected to its equivalence, which should be marked on the canister (Isobutylene ~0.7X benzene).
5. Record in the field log the instrument ID No., serial No., initial and final span settings, date, time, location, concentration and type of calibration gas used, and the signature of the person who calibrated the instrument.
6. If the HNu does not function or calibrate properly, the project equipment manager is to be notified as soon as possible. Under no circumstances is work requiring monitoring with a PI–101 or HW–101 to be done with a malfunctioning instrument.

3.4 CALIBRATION TO A GAS OTHER THAN ISOBUTYLENE

The HNu may be calibrated to any certified calibration gas. However, after calibration, all subsequent instrument readings will be relative to the calibration gas used. General procedures include the following:

1. Calibrate according to procedure 3.3.
2. Partially fill and flush one-to-two times a gas bag (Tedlar recommended) with the certified National Institute of Standards and Technology (NIST) (formerly NBS) traceable calibration gas. Then fill the bag with 1–3 L of the calibration gas. If the gas is toxic, this must be done in a fume hood.
3. Feed the calibration gas into the probe with the range set for the value of the gas. After 5 sec, adjust the span control until the meter reads the value of the calibration gas.
4. Record the results of the calibration on the calibration/maintenance log and attach a new calibration sticker (if available) or correct the existing sticker to reflect the new calibration data. All subsequent readings will be relative to the new calibration gas.

3.5 OPERATION

1. Follow the startup procedure, operational check, and calibration check (refer to Section 3.1).

2. Set the function switch to the appropriate range. If the concentration of gas vapors is unknown, set the function switch to 0-20 ppm range. Adjust if necessary.
3. Prevent exposing the HNu to excessive moisture, dirt, or contaminant while monitoring the work activity as specified in the Site Health and Safety Plan.
4. When the activity is completed, or at the end of the day, carefully clean the outside of the HNu with a damp disposable towel to remove all visible dirt. Return the HNu to a secure area and place on charge. Charge after each use; the lead acid batteries cannot be ruined by over charging.
5. With the exception of the probe's inlet and exhaust, the HNu can be wrapped in clear plastic to prevent it from becoming contaminated and to prevent water from getting inside in the event of precipitation. If the instrument becomes contaminated, make sure to take necessary steps to decontaminate it. Call the Equipment Administrator if necessary; under no circumstances should an instrument be returned from the field in a contaminated condition.

4.0 MAINTENANCE

Calibration/maintenance logs are to be filled in completely whenever a PI-101 or HW-101 receives servicing. This is true of both contractor-owned and rental instruments.

The equipment manager should be called to arrange for a fresh instrument when necessary. The contractor's equipment facility is responsible for arranging all repairs that cannot be performed by the project equipment manager.

4.1 ROUTINE SERVICE

The PID's performance is affected by a number of factors. These include but are not limited to the decay of the UV lamp output over time and the accumulation of dust and other particulate material and contaminates on the lamp and in the ion chamber. Because of these factors, the PID should not be left in the field for a period of more than 2 weeks before being replaced with a fresh instrument. If a site is going to be inactive for a period of more than a week, all monitoring instruments are to be returned to the project equipment manager or his trained designee for servicing and/or reassignment. The following procedures are to be performed at the designated intervals for routine service.

Procedure	Frequency
Operational check	Before use and at instrument return
Field calibration	Before use and at instrument return
Full calibration	Bi-weekly (return instrument to equipment manager for replacement with a fresh unit)
Clean UV lamp and	Bi-weekly or as needed ion chamber
Replace UV Lamp	As needed

4.1.1 UV Lamp and Ion Chamber Cleaning

During periods of analyzer operation, dust and other foreign materials are drawn into the probe forming deposits on the surface of the UV lamp and in the ion chamber. This condition is indicated by meter readings that are low, erratic, unstable, non-repeatable, or drifting and show apparent moisture sensitivity. These deposits interfere with the ionization process and cause erroneous readings. Check for this condition regularly to ensure that the HNu is functioning properly. If the instrument is malfunctioning, call your equipment manager to arrange to have a fresh replacement.

4.1.2 Lamp eV Change

If different applications for the analyzer would require different eV lamps, separate probes, each with its own eV lamp, must be used. A single readout assembly will serve for any of the probes (9.5, 10.2, and 11.7 eV). A change in probe will require resetting of the zero control and recalibrating the instrument. The 11.7 eV lamp will detect more compounds than either of the two lower eV lamps. However, the 11.7 eV probe needs more frequent calibration; it burns out much faster than the lower eV lamps.

5.0 PRECAUTIONS

- The HNu PI–101 and HW–101 are designed to sample air or vapors only. *Do not allow any liquids or low boiling vapors to get into the probe or meter assembly.*
- High concentrations of any gas can cause erroneous readings. High humidity can also cause the instrument readings to vary significantly from the actual concentration of gases or vapors present. This is true even through the HNu cannot react to water vapor.
- High humidity, dust, and exposure to concentrations of low boiling vapors will contaminate the ion chamber, causing a steady decrease in sensitivity.
- Continued exposure to ultraviolet light generated by the light source can be harmful to eyesight. If a visual check of the UV lamp is performed *do not look at the light source from a distance closer than 6 inches with unprotected eyes.* Use eye protection (UV-blocking sunglasses or safety glasses). Only look briefly—never more than about 2 sec.

Place the instrument on charge after each use; the lead batteries cannot be ruined by over charging.

- If at any time the instrument does not check out or calibrate properly in the field, the equipment manager is to be notified immediately and a replacement obtained for the malfunctioning instrument. Under no circumstances should fieldwork requiring continuous air monitoring for organic vapors and/or gases be done with a malfunctioning Hnu or without a HNu or an approved comparable instrument.

6.0 REFERENCES

Manufacturer's Equipment Manual.

STANDARD OPERATING PROCEDURE 90.2
PHOTOIONIZATION DETECTOR (MICROTIP HL–200)

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with the photoionization detector (Microtip HL–200). The photoionization detector (PID) uses an ultraviolet-emitting lamp designed to detect, measure, and display the total concentration of airborne ionizable gases and vapors. This information is used to determine control measures such as protection and action levels.

Use of brand names in this SOP is in no way intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc., are acceptable. If alternate equipment is to be used, the contractor shall provide applicable and comparable SOPs for its maintenance and calibration.

2.0 MATERIALS

- Microtip;
- Battery pack;
- Calibration gas (100 ppm isobutylene);
- Tedlar bag;
- Tygon tubing;
- Regulator;
- Calibration logbook; and
- Field logbook.

3.0 PROCEDURE

3.1 GENERAL

1. Turn the instrument on by pressing the back of the power switch located on the handle of the Microtip.
2. The message “Warming up now, please wait” will be displayed for up to 3 min. After normal display appears, the Microtip is ready for calibration.
3. Fill a Tedlar bag with the desired calibration gas (usually 100 ppm isobutylene).
4. Press SETUP button and select the desired Cal Memory using the arrow keys (normally set to 200 ppm). Press EXIT button to leave setup function.
5. Press CAL button and expose Microtip to Zero Gas. (Usually clean outdoor air will be suitable. If any doubt exists as to the cleanliness of the background air, a commercial source of zero gas should be used.).

6. The Microtip then asks for the Span Gas concentration. Enter the known span gas concentration and then connect the Tedlar bag containing the Span Gas.
7. Press Enter, and the Microtip sets its sensitivity. Once the display reverts to normal the Microtip is calibrated and ready for use. Remove the Span Gas from the inlet probe. The instrument should be calibrated at least once a day.

3.2 BATTERY CHARGING

1. Ensure Microtip is off.
2. Set the voltage selector switch on the bottom of the battery charger to the appropriate AC line voltage.
3. Press the release button on the bottom of the Microtip and remove the battery pack by sliding it backwards.
4. Plug charger into the battery pack and then into an AC outlet and allow the battery to charge for at least 8 hours.
5. After charging, remove the charger, first from the outlet then from the battery pack, and slide the battery pack back onto the Microtip.

4.0 PRECAUTIONS

- Microtip does not carry an Intrinsic Safety Rating and must not be used in a hazardous location where flammable concentrations of gases or vapors are constantly present.
- All calibration, maintenance, and servicing of this device, including battery charging, must be performed in a safe area away from hazardous locations.
- Do not open or mutilate battery cells.
- Do not defeat proper polarity orientation between the battery pack and battery charger.
- Substitution of components may affect safety rating.

NOTE: The span gas concentration is dependent upon both the concentration of the span gas used and the rating of the UV lamp in the Microtip at time of calibration. If using 100-ppm isobutylene and the standard 10.6 eV lamp, the span gas concentration will be 56 ppm.

5.0 REFERENCE

Microtip HL-200 User's Manual. February 1990.

STANDARD OPERATING PROCEDURE 90.3
PERSONAL AIR SAMPLING PUMP (Gilian GilAir)

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with a personal air sampling pump. The personal air-sampling pump is used for sampling particulates, gases, dusts, mists, and vapors to quantify concentrations of airborne contaminants. Air is drawn in by the sampling pump at an established rate and passes through a filter-sampling medium held in a plastic cassette. Particles in the air are trapped on the filter medium and can be examined in a laboratory to determine airborne contaminant concentrations. This information is used to establish levels of protection and other control measures such as action levels.

Use of brand names in this SOP is not intended as an endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc., are acceptable. If alternate equipment is to be used, the contractor shall provide applicable and comparable SOPs for its maintenance and calibration.

2.0 MATERIALS

- Gilian GilAir sampling pump;
- Gilian Gilibrator Calibrator;
- Flow cell soap;
- Tygon tubing;
- Filter cassette(s);
- Instrument logbook; and
- Field logbook.

3.0 PROCEDURE

These procedures are to be followed when using the GilAir in the field.

3.1 SET UP

1. Attach the GilAir to the operator's waistband using the clip on the back of the pump.
2. Connect a 2–3-ft long section of Tygon tubing to the air inlet of the pump. Run the tubing across the back of the operator and drape it over the shoulder. Secure the tubing to the back and shoulder with duct or masking tape.
3. Connect the filter cassette to the open end of the tubing draped over the shoulder and uncap the plug on the opposite end of the filter cassette.
4. Turn the pump on.
5. Complete the sampling log form supplied in Pt. 763, Subpt. E, App. A from 40 CFR Ch. I (Table 90.3A). If the pump is being worn, be certain to enter the social security number of the person wearing it in the "Location of Sample" column.

3.2 FIELD CALIBRATION PROCEDURE

1. Press the MODE/HOLD button on the GilAir pump until a flashing "CAL" appears on the display.
2. Switch the On/Off switch on the GilAir pump to the "On" position. The flashing "CAL" will be steady.
3. Connect the pump to be calibrated to the air outlet of the Gilian Gilibrator.
4. Set the pump flow rate by turning the flow adjust screw.
5. When the desired flow rate has been attained, switch the pump to the off position and disconnect the Gilian Gilibrator. The unit is now ready for sample collection.
6. Record the following information in the field log: the pump and calibrator instrument ID No., serial No., initial and final flow rates, date, time, location, and the signature of the person who calibrated the instrument.
7. If the GilAir sampling pump does not function, checkout, or calibrate properly, the project equipment manager is to be notified as soon as possible. Under no circumstances is work to be done with a malfunctioning instrument.

4.0 MAINTENANCE

Calibration/maintenance logs are to be filled in completely whenever a pump or calibrator receives servicing. This is true of both contractor-owned and rental instruments.

The equipment manager should be called to arrange for a fresh instrument when necessary. The contractor's equipment facility is responsible for arranging all repairs that cannot be performed by the project equipment manager.

4.1 ROUTINE SERVICE

If a site is going to be inactive for a period of more than a week, all monitoring instruments are to be returned to the project equipment manager or his trained designee for servicing and/or reassignment. The following procedures are to be performed at the designated intervals for routine service.

Procedure	Frequency
Operational check	Before use and before instrument return
Field calibration	Before daily use and before instrument return

5.0 PRECAUTIONS

- The GilAir pump is designed to sample air only. D*o not allow any liquids or low boiling vapors to get into the meter assembly.*

6.0 REFERENCES

Manufacturer's Equipment Manual. Place the instrument on charge after each use; the lead batteries cannot be ruined by over charging.

Table 90.3A
Sampling Log Form

Sample Number	Location of Sample	Pump I.D.	Start Time	Middle Time	End Time	Flow Rate

Inspector:________________________

Date:____________________

1.0 INTRODUCTION

This Quality Assurance Plan (QAP) establishes function-specific responsibilities and authorities for data quality and defines procedures that will ensure that site investigative activities will result in the generation of reliable data. Inherent in the quality assurance (QA) program is the implementation of quality control (QC) measures. These measures provide assurance that the monitoring of quality-related events has occurred, and that the data gathered in support of the project are complete, accurate, and precise. The implementation of the QAP will help ensure the validity of the data collected and will establish a firm foundation for decisions regarding fieldwork performed at Radford Army Ammunition Plant (RFAAP).

1.1 DOCUMENT ORGANIZATION

This document is designed to be used in conjunction with the RFAAP Master Work Plan and Master Health and Safety Plan (HSP).

Redundancy generally prevalent between these three plans has been eliminated to facilitate use and development of work plan addenda (WPA).

1.2 PROJECT OBJECTIVES

Project objectives are specified in Section 1.0 of WPA.

1.3 QAP DISTRIBUTION LIST

WPA will provide a distribution list for site-specific investigations.

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2.0 PROJECT ORGANIZATION AND RESPONSIBILITIES

The contractor project organization strategy should consist of a streamlined approach for effective and efficient execution of project activities. Figure 2-1 presents a template for the contractor organizational structure for project management. Responsibilities for the implementation of the project QA program in accordance with QA/QC contractual obligation lies principally with the project staff and subcontractors. The QA manager has the responsibility to ensure the reliability and the validity of project activities and deliverables in compliance with the project QA program. An organizational chart of personnel responsible for executing these functions is to be included in site-specific Work Plan Addenda. Statements of Qualification of the project staff are to be included in site-specific addenda.

2.1 KEY PROJECT PERSONNEL

Contractor personnel responsible for implementing technical, quality, and health and safety programs are described in the following subsections.

2.1.1 Contracting Officer Representative

The Contracting Officer Representative (COR) is the main point of contact between the contractor and the U.S. Army Corps of Engineers (USACE). Responsibilities of the COR include:

- Communicating frequently with the contracting project manager (PM) with regard to daily progress of the project;
- Evaluating progress;
- Interfacing with regulatory agencies;
- Acting as liaison between USACE, RFAAP, and the designated contractor; and
- Requiring completion of corrective actions, when indicated.

2.1.2 Project Manager

The PM is responsible for ensuring that activities are conducted in accordance with contractual specifications, the Statement of Work (SOW), and approved work plans. The PM will also provide technical coordination with the Installation's designated counterpart. The PM is responsible for management of operations conducted for this project. In addition, the PM will ensure that personnel assigned the project, including subcontractors, will review the technical plans prior to each task associated with the project is initiated. The PM will monitor the project budget and schedule and will ensure availability of necessary personnel, equipment, subcontractors, and services. The PM will participate in the development of the field program, evaluation of data, reporting, and the development of conclusions and recommendations.

2.1.3 Quality Assurance Manager

The QA Manager is responsible for ensuring that the QA procedures and objectives in the project-specific work plans are met, reviewing field and analytical data to ensure adherence to QA/QC procedures, and approving the quality of data prior to their inclusion in associated reports. This may include the performance of field and laboratory audits during the investigation. In addition, the QA Manager will be responsible for the review, evaluation, and validation of analytical data for the project and will participate in interpreting and presenting analytical data. The QC Coordinator is under the technical guidance of the QA Manager to direct the task leaders on a day-to-day or as-needed basis to ensure the application of QA/QC procedures.

2.1.4 Risk Assessment

Risk Assessment comprises Human Health and Ecological Assessments. The Human Health and Ecological Risk Assessment Specialists are responsible for ensuring and coordinating the design of field investigation work to ensure that the data collected are applicable for Human Health Risk Assessment and Ecological Risk Assessment needs, respectively. The Risk Assessment Specialists will subsequently implement the necessary calculations and data analysis to establish site-specific action levels and/or identifying unacceptable risks.

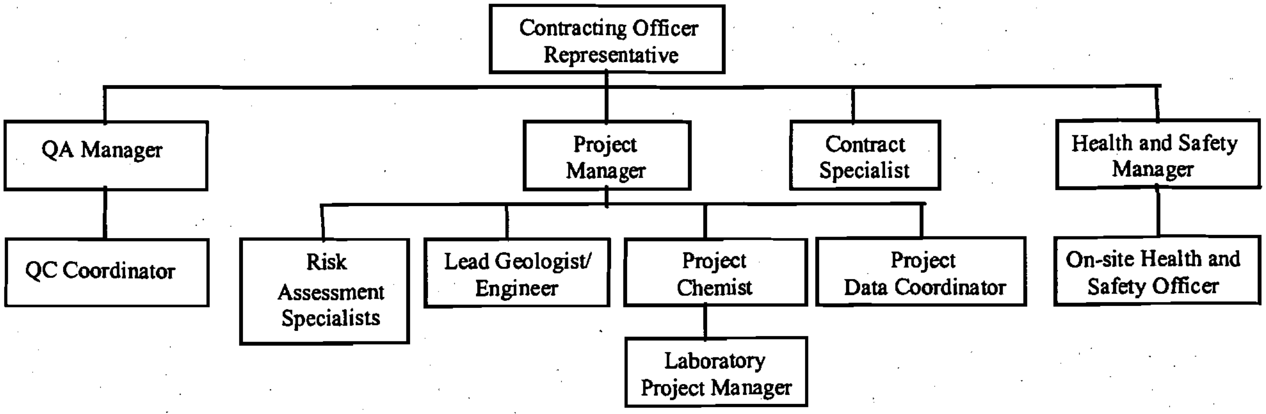
2.1.5 Lead Geologist/Engineer

The Lead Geologist/Engineer will provide management of the field activities during the fieldwork. The Lead Geologist/Engineer is responsible for ensuring that technical matters pertaining to the field program are addressed. They will participate extensively in data interpretation, report writing, and preparation of deliverables, and will ensure that work is being conducted as specified in the technical plans. In addition, the Lead Geologist/Engineer is responsible for field QA/QC procedures, and for safety-related issues. Prior to initiation of field activities, the Lead Geologist/Engineer will conduct a field staff orientation and briefing to acquaint project personnel with the sites and assign field responsibilities.

2.1.6 Project Chemist

The Project Chemist is responsible for knowing and monitoring the laboratory's compliance with the elements of the SOW issued to the laboratory by the contractor, and for day-to-day communications with the Analytical Laboratory. The Project Chemist is the first contact with the laboratory for receiving confirmation of sample delivery, receipt, and analysis; for tracking sample analysis within the required holding times and within the period of performance specified in the SOW; and for the receipt of data deliverables.

Figure 2-1
Template Project Organizational Chart



Additional responsibilities include the following: (1) perform analytical method(s) selection to meet project data quality objectives (DQOs); (2) assist in the different stages of SAP development; and, (3) provide technical expertise.

2.1.7 Laboratory Project Manager

The Laboratory PM will be responsible for the technical quality of the laboratory and adherence to the Laboratory QA Program. The contract laboratory will analyze environmental samples for parameters of interest with complete data documentation. The contractor QA Manager will monitor laboratory activities.

2.1.8 Project Data Coordinator

The Project Data Coordinator (PDC) will be responsible for tracking field and laboratory data using a computerized data management system or database management system (DBMS). The PDC is responsible for the accuracy of data entered into the data management system and will ensure that data entered into the system will correspond exactly with the data contained in the original books of entry. The PDC will also be responsible for providing to the PM, on a monthly basis, the appropriate information for the data management summary and QA section of the cost and performance reports.

2.1.9 Contract Specialist

The Contract Specialist is responsible for tracking funds for labor and materials procurement. Responsibilities include:

- Oversight of the financial status of the project;
- Preparation of monthly cost reports and invoices;
- Administration of equipment rental, material purchases, and inventory of supplies;
- Administration and negotiation of subcontracts and interaction with the Administrative Contracting Officer and Procurement Contracting Officer on contract and subcontract issues;
- Preparation of project manpower estimates; and
- Administration of contract documents.

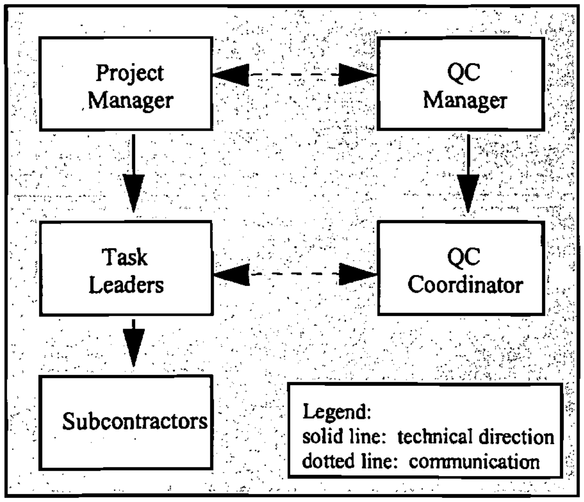
2.1.10 Health and Safety Manager

The Health and Safety Manager will review and internally approve the HSP, which will be tailored to the specific needs of the project in the task specific addendum. In consultation with the PM, the Health and Safety Manager will ensure that an adequate level of personal protection exists for anticipated potential hazards for field personnel. On-site health and safety will be the responsibility of the on-site Health and Safety Officer who will work in coordination with the PM and the project Health and Safety Manager.

2.2 LINES OF AUTHORITY

Figure 2-2 is a diagram modeling the lines of technical direction and communication within the project staff. Technical direction is communicated down the organizational structure. The PM is the central point of contact and is responsible for ensuring implementation of project quality and health and safety programs. Communication of project objectives is typically provided to project staff through meetings, reporting, and reviews.

2.2.1 Figure 2-2 Lines of Authority



2.3 KEY POINTS OF CONTACT

The names and points of contact for subcontractors will be provided in tabular form in site-specific addenda. The table will include the following information:

- Name;
- Title;
- Organization;
- Address;
- Telephone Number;
- Facsimile Number; and
- E-mail Address.

3.0 QUALITY ASSURANCE OBJECTIVES

Quality assurance is defined as the overall system of activities for assuring the reliability of data produced. The system integrates the quality planning, assessment, and corrective actions of various groups in the organization to provide the independent QA program necessary to establish and maintain an effective system for collection and analysis of environmental samples and related activities. The program encompasses the generation of complete data with its subsequent review, validation, and documentation.

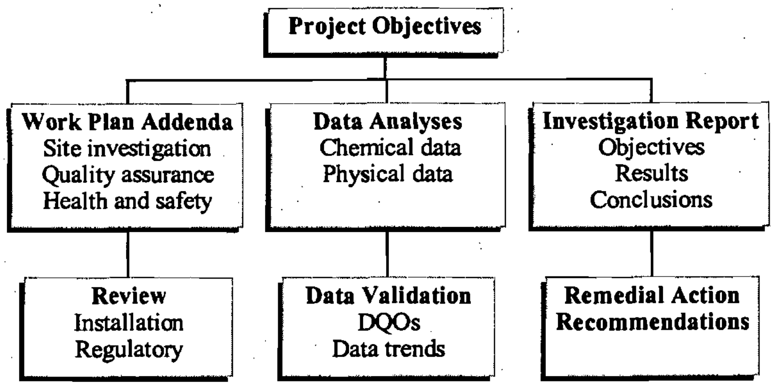
The overall QA objective is to develop and implement procedures for sample and data collection, sample shipment, and reporting. This will allow QA reviewers to establish whether field and laboratory data collected during corrective action activities meet DQOs established for each site/task. DQOs are qualitative and quantitative statements that outline the decision making process and specify the data required to support corrective actions. DQOs specify the level of uncertainty that will be accepted in results derived from environmental data. The DQO process used for developing RFAAP data quality criteria and performance specifications for data operations is consistent with the *Guidance for the Data Quality Objectives Process* (USEPA 2000 or most recent version). Site-specific DQOs for RFAAP activities will be included in WPA. The DQO process is a strategic planning approach to ensure environmental data is of the appropriate type, quantity, and quality for decision-making.

3.1 PROJECT QUALITY OBJECTIVES

Project quality objectives will be achieved through the implementation of specific procedures for data collection, error control, and generation of data of known and documented quality. Project objectives characterize critical samples, define performance criteria, and identify DQO indicators and assessment criteria for chemical measurements. An overview of project quality components is defined in Figure 3-1.

Field inspections performed by the Quality Manager will be used to ensure requirement compliance, identify specification variances, and effect appropriate corrective action for process deficiencies. Additionally, QA review of field documentation, QA audits, and monthly reporting will be used to establish that protocols for sampling and measurement are consistent with specifications contained in this QAP.

Figure 3-1
Project Quality Objectives



3.2 CHEMICAL DATA MEASUREMENTS

3.2.1 Accuracy

Accuracy is a measure of system bias and is defined quantitatively as the degree of agreement of a measurement (or an average of measurements of the same parameter), X, with an accepted reference or true value, T. The accuracy of RFAAP field activities will be qualitatively controlled through the use of standard operating procedures (SOPs) that have been developed to standardize data collection. For chemical data, accuracy of the extraction and analysis procedures will be checked quantitatively by using matrix and surrogate spikes, and blanks. The accuracy will be calculated based on the percent recovery of the spikes and concentrations of target analytes in the blanks as specified in Equation 1.

Equation 1

$$\text{Percent Recovery (\%R)} = \frac{\text{Test Value}}{\text{True Value}} 3\ 100$$

Field documentation will be used as evidence that investigative protocols follow the appropriate SOPs as presented in Appendix A. Field inspection performed by the contractor QA Manager will be used to identify deviations and execute corrective action (see Section 10.0). Consistent and proper calibration of equipment throughout site investigations, as described in this QAP, will ensure the accuracy of the measurements.

3.2.2 Precision

Precision refers to the level of agreement among repeated measurements of the same parameter. It is usually stated in terms of standard deviation, relative standard deviation, relative percent difference, range, or relative range. The overall precision of data is a mixture of sampling and analytical factors. The analytical precision is easier to control and quantify because sampling precision is unique to each site.

Sampling precision will be evaluated by obtaining one duplicate sample for every ten samples collected for each type of media (10%) and by assessing the relative percent difference (RPD) between results. The RPD will be calculated according to Equation 2:

Equation 2

$$\text{RPD (\%)} = \frac{(XA - XB)}{XM} 3\ 100$$

Where:

XA, XB = duplicate analyses

XM = mean value of duplicate analyses (XA + XB)/2

The RPD will be calculated for each analytical parameter that was detected in an environmental sample. Duplicate results for aqueous matrices should have an RPD less than 25% and solid matrices will have a RPD less than 35%. If these criteria are not met, a careful examination of the sampling techniques, sample media, and analytical procedure will be conducted to identify the cause of the high RPD and the usefulness of the data.

Analytical precision will be addressed by analysis of matrix spikes (MS) for inorganic analyses; MS and matrix spike duplicates (MSDs) for organic analyses; and laboratory duplicate sample analyses. The RPD for each MS, MSD, and duplicate analysis will be calculated and compared to control criteria. If these criteria are not met, an examination of the data will be conducted to identify the cause of the variability and usefulness of the data. The data will be qualified in accordance with U.S. Environmental Protection Agency (USEPA) Region III criteria (USEPA 1993a, 2000).

3.2.3 Representativeness

Representativeness is a measure of the degree to which the measured results accurately reflect the medium being sampled. It is a qualitative parameter, which is addressed through the proper design of the sampling program in terms of sample location, number of samples, and actual material collected as a "sample" of the population.

Sampling protocols have been developed to assure that samples collected are representative of the media. Field handling protocols (e.g., storage, handling in the field, and shipping) have also been designed to protect the representativeness of the collected samples. Proper field documentation and QC inspections will be used to establish that protocols have been followed and that sample identification and integrity have been maintained.

3.2.4 Completeness

Completeness is a measure of the amount of information that must be collected during field investigations to allow for successful achievement of investigation objectives. An adequate amount and type of data must be collected for conclusions to be valid. Missing data may reduce the precision of estimates or introduce bias, thus lowering the confidence level of the conclusions. While completeness has been historically presented as a percentage of the data that is considered valid, this does not take into account critical sample locations or critical analytical parameters.

The amount and type of data that may be lost due to sampling or analytical error cannot be predicted or evaluated in advance. The importance of lost or suspect data will be evaluated in terms of the sample location, analytical parameter, nature of the problem, decision to be made, and the consequence of an erroneous decision. Critical locations or parameters for which data is identified as inadequate will either be re-sampled and re-analyzed or the data will be appropriately qualified based on the decision of the Project Officer. The completeness goal percentage of valid data is set at 90±2% for field activities at RFAAP and will be quantitatively evaluated using Equation 3:

Equation 3

$$\text{Completeness Goal Percentage (\%C)} = \frac{\text{Number of Successful Analyses (useful data)}}{\text{Number of Requested Analyses}}\ 3\ 100$$

3.2.5 Comparability

Comparability is the confidence with which one data set can be compared to another. Comparability will be controlled by using SOPs that have been developed to standardize investigative activities. Consistent and proper calibration of equipment throughout the field exercises, as described in this QAP, will assist in the comparability of measurements. Field documentation and QA audits will be used to establish that protocols for sampling and measurement follow appropriate SOPs.

3.2.6 Sensitivity

Sensitivity requirements are expressed differently for various methods. The instrument detection limits (IDLs), the method detection limits (MDLs), and the practical quantitation limits (PQLs) published within USEPA methods are based upon a reagent water matrix, and are not reflective of typical sample matrices; therefore, care will be taken in establishing limits for laboratory analysis. The published limits may not be achievable for environmental samples, but they should compare reasonably with control samples. This compliance will be verified during data validation. Target analytes detected above the IDL or MDL but less than the PQL limits will be reported as estimated values. Target analytes detected in samples above the upper calibration standard will be diluted and re-run by the contract laboratory.

The overall QA objective is to develop and implement procedures for sample and data collection, sample shipment, and reporting that will allow QA data users to establish whether the field and laboratory data collected during the investigation meet the criteria and endpoints established in the DQOs. The QA objective will be achieved through the implementation of specific procedures for sampling, field data collection, chain-of-custody, calibration, internal QC, audits, preventive maintenance, and corrective actions as described in this QAP.

Specific DQOs should be presented in each task specific addendum, including investigation objective, sampling plan, sample number and type, and the type of chemical analyses.

3.3 LEVELS OF CONCERN

An integral part of the identification of DQOs is the determination of Levels of Concern (LOCs). These levels are compared with analytical method reporting limits (RLs) to ensure the method is capable of addressing project DQOs, preclude occurrence of false negative issues, and assess best available technology limitations (refer to Section 6.0). Although LOCs selected as potential concerns may not necessarily reflect investigation specific objectives, they are developed to ensure that the chosen analytical methods have detection limits sensitive enough to achieve compliance with appropriate site-specific screening levels or other specified criteria for soil, sediment, surface water, and groundwater.

3.3.1 Potential LOCs for Groundwater

Groundwater LOCs and To-Be Considered (TBC) guidance for RFAAP should include:

- Federal Maximum Contaminant Levels (MCLs) as updated; and
- Federal Secondary Maximum Contaminant Levels (SMCLs) as updated.

3.3.2 Potential LOCs for Surface Water and To-Be Considered Guidance

Surface water LOCs should include:

- Federal Ambient Water Quality Criteria (AWQC), as updated;
- Virginia Water Quality Standards, Department of Environmental Quality, as updated;
- USEPA Region III accepted screening benchmarks for surface water; and
- Potential LOCs for Soil and To-Be-Considered Guidance.

Soil TBC guidance should include:

- USEPA Proposed Resource Conservation and Recovery Act (RCRA) Corrective Action Levels;
- USEPA Region III risk-based concentrations; and
- USEPA Region III accepted screening benchmarks for soil.

3.3.3 Potential LOCs for Sediment and To-Be-Considered Guidance

- USEPA Region III accepted screening benchmarks for sediment.

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4.0 SAMPLING LOCATIONS AND RATIONALE

A summary of the sampling locations and rationale will be provided in WPA. Specific information to be presented includes:

- Background samples;
- Contaminants of concern;
- MDLs and RLs;
- Investigative objective;
- Levels of concern;
- Data use priorities;
- Project scope;
- Associated QA/QC samples;
- Number of samples;
- Sample type;
- Sample location;
- Specific site features that will affect sample collection, such as depth or flow conditions;
- Sampling procedures;
- Analytical methods;

Project staff is responsible for becoming familiar with the details of WPA as they pertain to their assigned work.

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5.0 SAMPLE MANAGEMENT

5.1 SAMPLE NUMBER AND TYPE

The number and types of environmental and QC samples to be collected during a specific sampling event will be included in a tabular format in task-specific addenda. QC samples are discussed in Section 8.0.

Sample collection, preservation, handling, storage, and shipping will be performed in a manner that minimizes damage, loss, deterioration, and contamination. Procedures described are designed to eliminate external contamination and to ensure data quality by using approved standardized sampling procedures. References to methods of collection and detailed SOPs are provided in Appendix A.

5.2 SAMPLE CONTAINERS

The integrity of containers for aqueous and solid samples is ensured by the use of appropriate cleaning techniques as specified by the USEPA Contract Laboratory Program (CLP). The contract laboratory will purchase pre-cleaned sample bottles for chemical analyses according to good laboratory practices. Sample container requirements will depend on the methods used for site-specific investigations and therefore will be specified in WPA.

5.3 SAMPLE PRESERVATIVES

Preservatives will be used, as applicable, to retard hydrolysis of chemical compounds and complexes, to reduce volatility of constituents, and to retard biological action during transit and storage prior to laboratory analysis. Sample containers will be pre-preserved by the laboratory. Preservation requirements for samples collected during site-specific investigations will be specified in WPA. In addition to chemical preservatives, samples for chemical analysis will be transported to the laboratory in temperature-controlled coolers. Double-bagged ice will be used to maintain the internal cooler temperature required for preservation. A temperature blank will be included in each shipping container to monitor the internal temperature.

5.4 HOLDING TIMES

Sample holding time is defined as the interval between sample collection and sample extraction/analysis, such that a sample may be considered valid and representative of the sample matrix. The allowable holding times for samples to be collected during site-specific investigations will be specified in work-plan addenda. The laboratory QA program will be responsible for ensuring the adequacy of the sample tracking system in precluding holding time deficiencies.

5.5 SAMPLE IDENTIFICATION

The sample identification number will consist of an alphanumeric designation related to the sampling location (and/or well identification for groundwater samples), media type, and sequential order according to the sampling event. If previous sampling has been performed at the site, new sample IDs will follow the previous identification scheme as closely as possible. QA/QC sample identification numbers will be numbered as above. The sample identification number should not exceed 20 alphanumeric characters. Site-specific sample identifications will be included in WPA.

5.6 DOCUMENTATION REQUIREMENTS

Information pertinent to the sampling effort will be recorded in a field logbook and the sample traced by a chain-of-custody form. Entries will be made in indelible ink on consecutively numbered pages, and corrections will consist of line out deletions that are initialed and dated (refer to SOP 10.1, Appendix A). At a minimum, field logbook entries include the following:

- Project name (cover);
- Name and affiliation of personnel on site;
- Contractor project number;
- Weather conditions;
- General description of the field activity;
- Sample location;
- Sample identification number;
- Time and date of sample collection;
- Specific sample attributes (e.g. sample collection depth flow conditions, or matrix);
- Sampling methodology (grab or composite sample);
- Sample preservation, as applicable;
- Analytical request/methods;
- Associated QA/QC samples;
- Field measurements/observations, as applicable; and
- Signature and date of personnel responsible for documentation.

SOP 10.2 in Appendix A provides specific protocols for recording for recording soil/sediment, surface water, and groundwater sampling information, as well as instrument field calibration data in field logbooks.

Each sample container will be annotated in waterproof ink, with the installation name, sample number, sampling date, analytes, and preservatives. The sample label will be permanently affixed to the sample container using polyethylene tape (refer to SOP 50.1 in Appendix A).

Telephone communication will be documented for scope of work changes and/or conditions that impact task deliverables. Related records include telephone logs, e-mail, and facsimiles.

Specific records related to investigative activities may include:

- Boring logs (refer to SOP 10.3 in Appendix A);
- Well construction diagrams (refer to SOP 20.1 in Appendix A);
- Well development records (refer to SOP 20.2 in Appendix A);
- Monitoring well and boring abandonment (SOP 20.3);
- Aquifer test records;
- Laboratory data; and
- Subcontractor permits and qualifications, utility clearance, and unexploded ordnance (UXO) clearance.

5.7 CHAIN-OF-CUSTODY REQUIREMENTS

Sampling will be evidenced through the completion of a chain-of-custody form, which accompanies the samples from the field to the laboratory. The chain-of-custody form will be annotated to indicate time and date that samples are relinquished. In addition, shipping containers will be affixed with custody seals. Once samples are relinquished to the laboratory, the laboratory chain-of-custody procedures, as described in Section 9.3, will be followed. SOP 10.4 in Appendix A describes specific protocols for using chain-of-custody forms.

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6.0 ANALYTICAL PROCEDURES

6.1 FIELD TESTING AND SCREENING

During the environmental sample collection activities conducted at RFAAP, selected physical and chemical parameters at the site should be measured. For example, specific conductance, pH, temperature, redox potential, and dissolved oxygen measurements will generally be collected in conjunction with the chemical data for groundwater and surface water characterization.

Equipment and general procedures for analysis of field samples should reference appropriate SOPs in Appendix A. As needed, additional SOPs will be developed for inclusion in the WPA. Because field instrumentation and analytical methodology are continually being updated, field personnel are required to consult manufacturers' instruction manuals for operating procedures.

6.2 LABORATORY PROCEDURES FOR CHEMICAL ANALYSES

The choice of analytical method will be based on the following consideration:

- Regulatory program requirements;
- DQOs; and
- Consideration of other practical constraints (temporal, financial, geographic).

Analytical methods will generally be derived from standard, published methods having regulatory standing. Examples include USEPA SW-846 Test Methods, test methods specified in the Code of Federal Regulations (Title 40 Code of Federal Regulations Part 136 (40 CFR 136) and 40 CFR 261) Standard Methods for the Examination of Water and Wastewater (APHA 1992), U.S. Geological Survey, etc. If alternative methods are to be employed the method validation and detection limit studies must be appended to the site-specific work plan addendum, as must be an SOP for its use.

6.3 METHOD DETECTION LIMITS

In order to ensure comparability of analytical results across sites, over time, and regardless of contractor, it is necessary to clearly establish uniform definitions for the various detection limits and uniform terminology.

6.3.1 Limit of Detection

The limit of detection (LOD) is the lowest concentration level that can be established as statistically different from a blank. The standard deviation (used to establish the LOD) was defined by replicate measures of the difference between the lowest concentration of analyte instrumentally detectable and a blank value.

6.3.2 Method Detection Limit

USEPA defines the MDL as, "the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is established from analysis of a sample in a given matrix containing the analyte."

6.3.3 Sample Quantitation Limit

The sample quantitation limit (SQL) is using the MDL modified by such factors as dilution, dry weight, etc.

6.3.4 Limit of Quantitation

The limit of quantitation (LOQ) of an individual analytical procedure is the lowest amount of analyte in a sample, which can be quantitatively established with suitable precision and accuracy. The quantitation limit is a parameter of quantitative assays for low levels of compounds in sample matrices and is used particularly for the determination of impurities and/or degradation products.

6.3.5 Reporting Limit

The RL is using the MDL multiplied by an arbitrary factor intended to assure minimum acceptable levels of precision and accuracy.

6.4 PHYSICAL TESTING METHODS

As appropriate site-specific investigations, soil and sediment samples will be collected and analyzed for selected physical analysis by American Society for Testing and Materials (ASTM) methods. Typical analyses will include percent moisture/percent solids, grain size distribution, total organic carbon (TOC), Atterberg Limits, and Unified Soil Classification System (USCS) designation.

6.4.1 Percent Moisture

When specified in WPA, percent moisture in soil will be calculated using ASTM Method D 2216-98 (ASTM 1998b). This method involves the determination of the percent water mass in a known mass of undried soil by weighing the soil before and after drying in an oven controlled at 110 degrees Celsius. The water content of a material is defined as the ratio, expressed as a percentage, of the mass of "pore" or "free" water in a given mass of material to the mass of the solid material particles. Percent solids will be reported for sediment as opposed to percent moisture.

6.4.2 Atterberg Limits

When specified in WPA, Atterberg Limits (liquid limit, plastic limit, and plasticity index) for soil and sediment samples will be calculated using ASTM Method D 4318-00 (ASTM 2000f).

6.4.3 Particle Size Distribution

When specified in WPA, particle size distribution for soil and sediment samples will be using ASTM Method D 422-63 (1998) (ASTM 1998a). This method covers the quantitative determination of the distribution of particle sizes in soil. A No. 200 sieve is used to separate particles larger than 75μm from the soil, while the distribution of particles smaller than 75μm is identified using a hydrometer (a sedimentation process. This information will be used in soil characterization and in fate and transport analyses.

6.4.4 Unified Soil Classification System

When specified in WPA, classification of soils for engineering purposes or the USCS will be based on laboratory determination of particle-size characteristics, liquid limit, and plasticity index using ASTM Method D 2487-00 (ASTM 2000b).

6.4.5 Total Organic Carbon Content

When specified in WPA, TOC of soil and sediment samples will be calculated using ASTM Method D 2974-00 (ASTM 2000d). This method involves the ignition of an oven-dried soil sample in a muffle furnace. The organic content (a percentage) is expressed as the difference of the weight of the sample before and after ignition divided by the weight of the sample before ignition.

6.4.6 Porosity

When specified in WPA, samples will be analyzed for porosity in soil and sediment using ASTM Methods D 854-00 (ASTM 2000a) for specific gravity and D 2937-00 (ASTM 2000c) for in-place density. This method calculates the porosity of soil as the ratio of the volume of voids to the total sample volume. Specific gravity and in-place density are used in the calculation.

6.4.7 Bulk Density

When specified in WPA, samples will be analyzed for bulk density in soil using ASTM Method D 4253-00 (ASTM 2000e). This method is used to calculate the maximum index density/unit weight of cohesionless, free draining soils using a vertically vibrating table. The bulk density is calculated by dividing the dried mass of the sample by the volume of the sample.

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7.0 CALIBRATION PROCEDURES

7.1 LABORATORY CALIBRATION

Prior to sample analysis, chemical calibration of each target analyte/compound must be performed to ensure analytical instrumentation is functioning within the established sensitivity range. Laboratory calibration protocols will be specified in an analytical QAP to be either retained within the contractor's file or appended to WPA. Areas to be discussed include solution validation, initial, and continuing calibration. Analytical instruments will be calibrated initially and periodically checked to ensure that the initial calibration remains valid. Generally, this verification will take the form of analysis of at calibration standard, usually at the mid-point of the calibration range, and a comparison of the percent difference or percent drift (both are abbreviated as %D) between the initial calibration response and the calibration check. The %D is calculated as:

Equation 4

$$\text{Percent Difference/Percent Drift (\%D)} = \frac{\text{Calibration Check Response or Amount}}{\text{Initial Calibration Response or Amount}}\ 3\ 100$$

7.2 INSTRUMENT/FIELD EQUIPMENT TESTING, INSPECTION, AND MAINTENANCE

Equipment and supplies purchased in support of these activities will be purchased according to the provisions of this plan, which requires a documented review of the vendor and equipment selection process and receipt inspection and/or testing as appropriate.

In summary, those procedures require that new equipment be tested with an appropriate standard or standards to ensure they function according to intended use. QC sample results from initial field use of equipment and supplies will be reviewed by the Field Manager, Laboratory Manager or his designee to identify potential causes for concern regarding new equipment and supplies received. Corrective actions will be implemented and documented according to the provisions of Section 10.0 as required.

Instrument maintenance, both routine and preventive, will be performed according to manufacturers' instructions. A preventive maintenance plan allows for periodic instrumentation checks for problems that occur frequently. The objective of a preventive maintenance plan is to rectify equipment problems before they become serious. Preventive maintenance also brings attention to those areas of the instrument susceptible to degradation from aging, toxic/corrosive attack, and clogging due to environmental factors.

Procedures for preventive maintenance are contained in each instruments associated manual under the maintenance/troubleshooting sections. Logbooks, such as those described in SOP 10.1 in Appendix A, will be maintained for each instrument used in the laboratory. Maintenance, calibration, and performance data will be entered by the operator and will be periodically reviewed by the Field/ Laboratory Manager.

An inventory of critical spare parts will be maintained on-site during field activities. Critical spare parts are defined as those that upon failure would cause a delay in field or laboratory activities of greater than

4 hours. The specific needs of the program will be established at the discretion of the Field/Laboratory Manager.

7.3 INSPECTION/ACCEPTANCE FOR SUPPLIES AND CONSUMABLES

The Field/Laboratory Manager and/or his representative will inspect materials and consumables against the purchase order specifications to verify their fitness for use. Materials received will be properly labeled and recorded on the inventory log for accuracy. An expiration date will be assigned immediately to standards, reagents, and solvents. Documentation concerning the quality of materials used on-site will be retained in the central files.

7.4 FIELD EQUIPMENT CALIBRATION AND MAINTENANCE

The proper calibration, maintenance, and documentation of field equipment are designed to assure that the field equipment is functioning optimally. Calibration and maintenance will follow manufacturer's specifications. The frequency of calibration is discussed in Section 9.8 of the Master HSP. Documentation will be kept in equipment logbooks, which are required to record usage, maintenance, calibration, and repair.

7.4.1 Water Quality Parameters

Equipment used for analyzing water quality parameters (e.g., pH, conductivity, temperature, dissolved oxygen, oxidation/reduction potential, turbidity) will be calibrated at the site daily or more frequently as conditions dictate. The calibration for each type of parameter monitored will include a daily initial measurement prior to calibration, a measurement after calibration, and measurement at the end of the day. Measurements will be documented in the field logbooks (SOPs 10.1 and 10.2 in Appendix A) by the field personnel performing the calibration.

7.4.2 Air Quality Parameters

Equipment for analyzing air quality parameters (e.g., organic vapors, lower explosive limit, and percent oxygen) will be calibrated at the site daily. The calibration will include a daily initial measurement prior to calibration, a measurement after calibration, and a measurement at the end of the day. Measurements will be documented in the field logbook forms for meter calibration (SOP 10.2 in Appendix A) by the field personnel performing the calibration. Specific SOPs for air quality instruments are given in SOP Series 90.

7.4.3 Screening

Screening kits will be calibrated upon arrival according to the manufacturer's instructions.

8.0 INTERNAL QUALITY CONTROL CHECKS

8.1 LABORATORY QUALITY CONTROL ELEMENTS

Method quality objectives (MQOs) will be specified in site-specific WPA. These MQOs provide a basis for project data review and should be evaluated during project planning for data use applicability.

8.2 SPECIAL TRAINING REQUIREMENTS AND CERTIFICATION

In addition to health and safety training as required for hazardous site workers by the Occupational Safety and Health Administration, field and laboratory personnel will receive technical training in the techniques they are expected to carry out. Training will consist of, at a minimum, on the job training by a senior staff member in the SOPs they are expected to implement, documented by virtue of a signed copy of the SOP or cover sheet for the field sampling plan. The QA Manager will retain this documentation on file.

Analysts will receive appropriate training in procedures, safety, and waste disposal. The Laboratory QA Manager, or his designee, will train analysts on analytical methods and operation of laboratory instrumentation. Analysts will be required to prove the ability to execute methods they perform with acceptable precision and accuracy through analysis of performance evaluation samples in quadruplicate, which meet the applicable QC standards of the method. Training completed by the analyst will be documented by the Laboratory QA Manager and maintained on file. These records will serve the additional purpose of providing for validation of non-standard methods of analysis.

8.3 FIELD QUALITY CONTROL SAMPLES

Field investigations at RFAAP will require the collection of several types of field QC samples including duplicate samples, rinse blanks, temperature blanks, trip blanks, and source water samples, as outlined in Table 8-1. If a target analyte is detected in a QC blank, data will be evaluated to establish if corrective action measures will be taken. Field QC elements of a QA program for field investigations at RFAAP are summarized in Table 8-2.

Table 8-1
Types of Field Quality Control Samples

Type of Control	Purpose of Sample	Collection Frequency
Duplicate Sample	To ensure precision in sample homogeneity during collection and analysis	10% of field samples per matrix
Rinse Blank	To ensure the decontamination of sampling equipment has been adequately performed; to assess cross contamination and/or incidental contamination to the sample container	One per 20 samples or one per day
Temperature Blank	To verify sample cooler temperature during transport	One temperature blank per cooler
Trip Blank	To evaluate if cross contamination occurs during shipment or storage with volatile organic analyses (VOA) samples	One trip blank per cooler of VOA samples
Source Water	To characterize decontaminated water	One per source

Table 8-2
Field QC Elements of a QA Program

Item	DQO	Parameter	Frequency of Association	Criteria Requirement
Source Water	R	Target list of parameters	per project	Less than USACE reporting limit or if detected approved by USACE
Field Duplicates	P	Target list of parameters	one per ten samples	RPD ≤ 25% aqueous; ≤ 35% solid
Trip Blank	A,R	Volatiles in water	one per cooler with volatiles	No target analytes
Rinse Blank	A,R	Target list of parameters	one per 20 samples per matrix per equipment type	No target analytes
Field Logbook	A,C	Target list of parameters	daily	Filled out and representative of investigation activities
Chain of Custody	R	Target list of parameters	every sample	Filled out correctly to include signatures; no missing or incorrect info
Chemical Parameter Forms	R	Target list of parameters	every sample	Filled out correctly to include analytical parameters; and applicable coding info
Field Instrument Calibration Logs	A	Target list of parameters	every measurement	Measurements must have associated calibration reference

Legend:
A = Accuracy
C = Completeness
P = Precision
R = Representativeness

9.0 DATA REDUCTION, VALIDATION, REPORTING, AND MANAGEMENT

The intended use of the data and the associated acceptance criteria for data quality will be established prior to initiation of the data collection. Reported data will include when appropriate, statements of precision, accuracy, representativeness, completeness, and comparability. Data processing procedures will be documented, reviewed, and revised by the QA Manager, as required to meet project-specific DQOs. The laboratory QA Manager will be responsible for data processing at the contract laboratory.

9.1 METHOD DETECTION LIMIT AND REPORTING LIMITS

MDL and RL will be included in WPA. In general, solid sample results will be reported in micrograms per kilogram (µg/kg) or milligrams per kilogram (mg/kg) depending on the method used for analysis. Aqueous sample results will in general be reported in units of micrograms per liter (µg/L) or milligrams per liter (mg/L) depending on the methods used. WPA for site-specific investigations will specify the reporting units for samples along with the associated MDLs and RLs.

The reported data will contain no more than three significant digits and will be rounded to the appropriate number of significant digits, based on certification class and dilution, after calculations have been completed.

9.2 ROUNDING RULES

The following rules will be used in data validation and reporting for rounding:

- If the figure following those to be retained is less than five, the figure is dropped, and the retained figures are left unchanged;

- If the figure following those to be retained is greater than five, the figure is dropped and the last figure is raised by one. For example, 1.26 is rounded off to 1.3; and

- If the figure following those to be retained is five, and if there are no figures other than the zeros beyond the five, the figure five is dropped, and the last-place figure is increased by one if it is an odd number or it is kept if it is an even number. For example, 1.45 is rounded off to 1.4, while 1.56 is rounded off to 1.6.

9.3 COLLECTION

Collection of analytical data will begin when samples arrive at the laboratory. Laboratory receipt procedures will be consistent with specifications contained in laboratory QA Plan. A laboratory technician will first verify that the samples noted on the chain-of-custody form coincide with the delivery of the sample containers. If a container is broken or missing, the chain-of-custody form will be annotated and the Field Operations Leader (FOL) will be notified immediately. Samples will then be logged into the laboratory data management system. The field parameter and chain-of-custody forms will then be submitted to a laboratory data technician for later correlation with the analytical results.

9.4 DATA REDUCTION

Data reduction frequently includes computation of analytical results from raw instrument data and summary statistics, including standard errors, confidence intervals, test of hypotheses relative to the parameters, and model validation. Data reduction procedures address the reliability of computations and the overall accuracy of the data reduction. The numerical transformation algorithms used for data reduction will be verified against a known problem set to ensure that the reduction methods are correct. The equations and the typical calculation sequence that should be followed to reduce the data to the acceptable format are instrument and method-specific. Where standard methods are modified, data reduction techniques will be described in a report accompanying the data.

9.4.1 Gas Chromatography/Mass Spectrometry Results

Qualitative identification will be established by obtaining extracted ion current profiles (EICPs) for the primary ion mass to charge ratio (m/z) and the secondary masses for each compound. Positive identification will be based on the following criteria:

- The intensity of the three characteristic masses of each compound must maximize in the same ratio (± 20 percent (%)), within one scan of each other;
- The relative retention time must fall within 30 seconds of the retention time of the authentic compound; and
- The relative peak heights of the three characteristic masses in the EICPs must fall within 20% of the relative intensities of these masses in a reference mass spectrum (e.g., standard analysis or reference library).

Structural isomers to be listed as separate compounds must have acceptable resolution. Acceptable resolution is achieved if, in a standard mix, the baseline to valley height between the isomers is less than 25% of the sum of the two peak heights. Otherwise, structural isomers will be identified as isomeric pairs.

The calculation for the concentration for the suspect peak will be made using the average response factor (RF) for each compound, which was obtained from the daily calibration.

Water

Equation 5

$$C_s = \frac{(A_s)(C_{is})(V_t)(D)}{(A_{is})(RF)(V_o)}$$

Where:

C_w = Compound concentration (μg/L);

A_s = Peak area of characteristic in m/z for the compound to be measured;

A_{is} = Peak area of characteristic in m/z for the internal standard;

C_{is} = Concentration of the internal standard (μg);

V_t = Final volume of total extract (μL) used in semi-volatile organic compound (SVOC) analyses;

V_o = Volume of water (L) extracted or purged;

V_i = Volume of extract injected; SVOC analyses (µL);

D = Dilution factor; and

RF = Compound response factor calculated from Equation 6.

Equation 6

$$RF = \frac{(A_s)(C_{is})}{(A_{is})(C_S)}$$

Where:

A_s = Area of the characteristic ion for the compound being measured;

A_i = Area of the characteristic ion for the specific internal standard;

C_{is} = Concentration of the specific internal standard; and

C_s = Concentration of the compound being measured.

Soil

Equation 7

$$Cs = \frac{(A_s)(C_{is})(V_t)(D)}{(A_{is})(RF)(V_i)(W_s)(M)}$$

Where:

C_s = Compound concentration in the soil sample (µg/g);

A_s = Area of the characteristic ion for the compound being measured;

C_{is} = Internal standard concentration (µg);

A_{is} = Area of characteristic ion for the specific internal standard;

V_t = Volume of total extract (µL);

V_i = Volume of extract injected (µL);

W_s = Mass of sample extracted or purged (g);

D = Dilution factor;

M = Percent dry weight of sample/100; and

RF = Compound response factor calculated from the calibration curve using the same equation as that used for water samples.

9.4.2 Gas Chromatographic Results

Calculations will be performed for each compound after it is identified. Identification will be based on the relative retention time (RRT) ratio of the suspect peak compared to the internal standard as compared to the RRT calculated from the calibration curve. The concentration of the compound will be calculated by comparing the relative RFs calculated from the calibration curve and the peak area of the compound using the following equation:

Water

Equation 9

$$C_w = \frac{(A_s)(C_s)(D)}{(A_{is})(RF)(V_s)}$$

Where:

C_w = Concentration of the compound in the sample (µg/L);

A_s = Compound peak area;

C_s = Standard (µg);

A_{is} = Internal standard peak area;

V_s = Volume of water extracted (L);

D = Dilution factor; and

RF = Compound response factor calculated from the following equation:

Equation 10

$$RF = \frac{(A_s)(C_i)}{(A_i)(C_s)}$$

Where:

A_s = Compound response measured in area counts from the calibration curve;

A_i = Internal standard response measured in area counts from the calibration curve;

C_i = Internal standard concentration; and

C_s = Compound concentration from the calibration curve.

Soil

Equation 11

$$C_s = \frac{(A_s)(C_s)(D)}{(Ai)(RF)(W_s)(M)}$$

Where:

C_s = Compound concentration in the soil sample (µg/g);

A_s = Compound response measured in area counts;

C_s = Standard concentration (µg);

Ai = Standard response measured in area counts;

W_s = Mass of sample extracted (g);

D = Dilution factor;

M = Percent dry weight of sample/100; and

RF = Compound response factor calculated from the calibration curve using the same equation as that used for water samples.

Atomic Absorption Spectrophotometry Results—Photometric absorbance is governed by the relationship presented in Equation 12.

Equation 12

$$Absorbance = \log \frac{100}{\%T} = 2 - \log \%T$$

Where:

%T = 100 - % absorption.

Percent absorption is based on the amount of light of a particular wavelength absorbed by a specific metal. Its calculation is based on the loss of light after a beam of light of a particular wavelength is passed through a flame into which a solution containing metals of interest has been aspirated.

Calibration curves establishing the absorbance relationship with concentration will be generated at various concentrations. From these curves, a comparison will be made with absorbance from sample measurement. Since absorbance is directly related to concentration, a plot of the two parameters will be linear within operable ranges and will allow for determination of unknown concentrations in solutions (direct samples or extracts) after measurement of absorbance.

Concentrations of contaminants in extracts will be calculated from instrumental responses of the extracts applied to the instrument calibration curve. The resultant concentration will then be modified by applying the appropriate dilution/concentration and sample weight or volume to obtain a final reportable concentration in the original matrix. In general, solid samples will be reported in units of µg/kg or mg/kg and aqueous results will be reported in units of µg/L or mg/L. The units used for a specific project will depend on the methods of analysis, etc.

When samples are diluted into a performance-demonstrated range, the reported concentration will contain one less significant digit than an undiluted sample. Values less than the certified RL will be reported as "less than" the RL. If a sample is diluted, the non-detected results will be reported as "less than" the RL multiplied by the dilution factor to reflect more accurately the observable limit. The dilution factor will be reported with the data.

9.5 DATA VALIDATION

9.5.1 Data Review, Validation, and Verification Requirements

Upon completion of the data collection activities, the QA Manager will perform a review of the data collected and produce a report for the PM addressing the following:

- Sampling design – What deviations were observed from the project controlling document (PCDs) in terms of numbers of samples collected, locations of sample collection points, and unexpected events or observations in the field. An assessment will be provided of the impact of such deviations on the usability or interpretation of the results;

- Sampling procedures – What deviations were observed from the PCDs in terms of the method of work applied in the collection of the samples. An assessment will be provided of the impact of such deviations on the usability or interpretation of the results;

- Sample handling – What deviations were observed from the PCDs in terms of the handling and custody of the samples, including containers, preservation, storage, etc. This will include an assessment of potential sample alias problems. An assessment will be provided of the impact of such deviations on the usability or interpretation of the results;

- Analytical procedures – What deviations were observed from the PCDs in terms of the method of work applied in the analysis of the samples. An assessment will be provided of the impact of such deviations on the usability or interpretation of the results;

- QC and calibration – What deviations were observed from the PCDs in terms of conformance to QC and calibration criteria. An assessment will be provided of the impact of such deviations on the usability or interpretation of the results. This assessment will be provided in the form of data validation reports as defined in Section 9.5.2; and

- Data Reduction and processing – What deviations were observed from the PCDs in terms of data reduction and processing specifications. An assessment will be provided of the impact of such deviations on the usability or interpretation of the results.

9.5.2 Validation and Verification Methods

Definitive data will be validated in accordance with USEPA *Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analysis*, April 1993, and USEPA *Region III Modifications to the USEPA National Functional Guidelines (NFGs) for Organic Data Review Multi-media, Multi-concentration* (OLM01.0-OLM01.9), September 1994, or the appropriate guidance in effect at the time of investigation as modified for the methods of analysis employed. Verification for organic data will be performed at Manual Level M3 and the verification for inorganic data will be performed at Manual Level IM2. Particular emphasis will be placed on holding time compliance, equipment calibration, spike recoveries, and blank results, although each required element of the verification process will be considered.

An independent reviewer as part of the validation process will fill out a checklist based on the method/protocol. This checklist will document the checks performed and the observations of the reviewer. To the fullest extent possible, the validator will work with the laboratory to resolve anomalies encountered. The validator will then apply data qualifying flags to the data summaries provided by the laboratory and compile a report on each laboratory report. These reports will consist of a summary of the findings, copies of data summaries with data qualifying flags applied (as necessary), a copy of the data validation checklist, and supporting documentation.

Laboratory deliverable packages for definitive data will be equivalent to USEPA CLP deliverable packages, containing complete QC summary reports, QA documentation, and a complete raw data package.

For first round analytical data and for screening data, an independent review of data packages will be performed to ensure compliance with specified analytical, QC, and data reduction procedures; data reporting requirements; and required accuracy, precision, and completeness measures. At a minimum, the following items will be reviewed to validate the data when applicable:

- Sample custody documents;

- QC data summaries; and

- Reasonableness of analytical results.

9.5.3 Reconciliation with Data Quality Objectives

The QA Manager in association with the PM will provide an assessment of the conformance of data gathered in the course of these activities to objectives of the work. Because the data are not intended to be compared to fixed regulatory standards for purposes of assessing compliance, formal, numeric DQOs have not been established. Nonetheless, the data must be suitable for use in assessing the nature and extent of environmental impacts; assessing the risks associated with such impacts; and as inputs to engineering decisions and designs. Thus, data that are found during the verification and validation processes to be unsuitable for use (i.e., data impacted by unacceptable deviations from plans and protocols and data found to be qualified as unreliable during the validation process) will be clearly identified and excluded from use in downstream decision-making. If, in the judgment of the PM and the technical data users, insufficient data remain for purposes of the work, additional sample collection and analysis may be performed. Data description and assessment tools as described in USEPA QA/G-9, *Guidance for Data Quality Assessment* (USEPA 1996), may be employed in the course of this reconciliation.

9.6 BLANK CONTAMINATION ASSESSMENT

Blank contamination assessment will be performed to evaluate the impact of field sampling and laboratory analysis environments on data quality. Field and laboratory QC blanks will be collected and processed at the frequency specified in Tables 8-1 and 8-2.

Field and laboratory QC blank data will be reviewed in accordance with the NFGs for Organic and Inorganic Data Review (USEPA 1994a), USEPA Region III modifications to the NFGs (USEPA 1993c; 1994b), and USEPA Region III Innovative Approaches to Data Validation (USEPA 1995).

9.6.1 Field Blanks

Equipment Rinse Blanks - The integrity of decontamination events and sample cross-contamination will be evaluated by the rinse blank. The rinse blank will be collected at the beginning of the project when equipment is first decontaminated, and thereafter at a frequency of 5%.

Trip Blanks - Potential contamination during sample collection and shipment, and in the laboratory, will be assessed through the evaluation of trip blanks for volatile contamination. Volatile contaminants detected in a trip blank and the associated samples (associated during collection and shipping) will be flagged.

9.6.2 Laboratory Blanks

Method Blanks - Method blanks will be used to evaluate for potential contamination from the laboratory environment and analytical method used to process the sample. Method blanks will be processed at the beginning and at a frequency of 10% for each analytical run by the laboratory. The blanks will be used to evaluate whether the internal laboratory environment, reagents used during analyses, analytical techniques, or the instrumentation system is sources of contamination that could affect the integrity of the sample.

The criterion for the evaluation of blank contamination applies to blanks associated with the samples, and states that no contamination should be in the blank. If contamination is detected, data associated with the blank will be carefully evaluated to identify if there is an inherent variability in the data for the lot, or if the problem is an isolated occurrence not affecting each sample in the lot.

Examples of USEPA criteria by which the blanks will be reviewed include:

Inorganic:

- Analytes detected in the environmental sample at less than five times the concentration in the associated blank will be qualified "B."

Organic:

- The sample result is qualified "B," when the compound concentration is greater than the RL but less than ten times the amount detected in the associated blank for common laboratory contaminants, (i.e., methylene chloride, acetone, 2-butanone, and common phthalate esters); and

- The sample result for other contaminants are qualified "B," when the sample concentration is greater than the RL but less than five times the amount detected in the associated blank.

In cases where more than one blank is associated with a given sample, qualification will be based upon a comparison with the associated blank having the highest concentration of the contaminant. The mean concentrations and standard deviation will be provided as a reference point. Blank qualification will be added to the data validation and the contractor PM will assess data usefulness based on the project DQOs. The PM will make project decisions (use qualified data, re-sample, re-analyze) based upon the analytical limitations of the data. Contamination assessment results will be presented in the Site Investigation Report.

9.7 REPORTING

Data for entry into the DBMS will consist of field data and sampling/analytical data. In general, field data will consist of location, well construction and field measurement data generated from field logbooks, boring logs, and field parameter forms used by the Project Geologist.

Sampling and analytical data will consist of dates, times and laboratory sample and QC results taken from chain-of-custody records and the laboratory deliverable verified against hardcopy laboratory reports.

9.8 DOCUMENTATION AND RECORDS

Bound logbooks will be used for record keeping purposes both in the field and in the laboratory with the exception of certain standard forms, which will be maintained in three ring binders. Logbooks and binders will contain a unique document control number. Pages, including loose-leaf forms, will be numbered.

Field and laboratory personnel will transmit the bound logbooks to the Field Manager or Laboratory QA Manager (or their designees) on a routine basis. The Field or Laboratory QA Manager will review original logbooks at a frequency of at least once every week, and will sign the logbook as proof of said review.

To ease data review, the person making an entry must sign and date the entry. Entries must be recorded in ink or other permanent-marking device. Drawing a line through the incorrect entry, recording the correct information, and initialing and dating the corrected entry will make correction to entries. If the reason for making the change is not immediately evident, an explanation is required. Unused portions of logbook pages must be lined out.

If computerized information is used, a hard copy that has been permanently affixed to the logbook will be acceptable as an original record of sampling and/or laboratory logging

9.8.1 Field Records

Field records, including sample collection records, chain-of-custody records, etc. will be maintained according to the SOPs applicable to the program. At a minimum, field personnel will keep a personal log of activities, noting conditions that in their judgment may bear on the on the use or interpretation of the data they acquire.

9.8.2 Laboratory Records

Once the laboratory has received samples, they will be logged into the laboratory's Laboratory Information Management System (LIMS) or into a bound laboratory notebook. Minimum information content for log in includes: field sample number; laboratory receipt date; chain- of-custody status; condition in which sample arrived (i.e., intact, cracked lids, frozen); analyses requested and other pertinent observations including temperature, preservation status, appearance, etc.

Bound logbooks must be maintained of reference materials used for analytical purposes. This will include records of dilutions or other standard preparation steps such that standards used during analysis will be traceable to purchased certified standards. The record must include the following information: date of receipt; source; purity; unique identification numbers; record of dilutions/preparation referencing original standard Identification number; and, an expiration date.

Personnel involved in doing sample extraction, digestion, or other sample preparation techniques must maintain a record of those activities in a bound logbook. Although this logbook must be specific to the operation, it need not be operator specific. The logbook should be signed and dated daily and contain the following information: samples prepared, including date and time, analysis, weights or volumes involved at beginning and end of process; standards and reagents used; QC samples prepared with the batch and the reference values of the standards if applicable; procedures used; relevant calculations and other relevant observations such as color, foaming, gas generation, etc.

9.8.3 Laboratory Deliverables

For the first round of sampling, a summary data-reporting format consisting of analytical results and a QC summary will be provided (see screening data, below). For each subsequent round of sampling and analysis, the required analytical deliverable for definitive data types from the fixed-base laboratory must include the following at a minimum:

Definitive Data

The following forms are required for organics analyses using gas chromatography/mass spectroscopy:

- Narrative and sample identification cross-reference;
- Copies of Chain of Custody documentation;
- Organic analysis data summary for field and QC samples;
- System monitoring compound/surrogate summary;
- QC Check Sample/Laboratory Check Sample (LCS) summary;
- MS and MSD summary;

- Method blank summary;
- Tune summary;
- Initial calibration summary;
- Continuing calibration summary;
- Raw data for field samples including sample prep and run logs; and
- MDLs and RLs.

The following forms are required for metals analyses:

- Narrative and sample identification cross-reference;
- Copies of Chain of Custody documentation;
- Inorganic analysis summary;
- Initial and continuing calibration summary;
- Calibration blank summary;
- ICS summary;
- Method blank summary;
- MS/PDS summary;
- Duplicate summary;
- LCS summary;
- Serial dilution summary;
- Instrument raw data;
- Sample preparation and run logs;
- Analytical sequence summary; and
- Definition of IDLs, MDLs, and RLs.

The following forms are required for other analyses:

- Narrative and sample identification cross-reference;
- Copies of Chain of Custody documentation;

- Analysis results summary;
- Initial and continuing calibration summary;
- LCS summary;
- Method blank summary;
- Sample spike summary (as applicable);
- Duplicate sample summary;
- Instrument raw data; and
- Sample prep and run logs.

Screening Data

Summary reporting will be provided:

- Narrative and sample identification cross-reference;
- Copies of Chain of Custody documentation;
- Analysis results summary; and
- QC summary.

9.8.4 Record Storage and Handling

Records will be designated as "lifetime" or "nonpermanent" prior to temporary or final storage. Nonpermanent records will be retained for three years after the completion of the fieldwork, or three years after the date the record was generated, whichever is longer. A lifetime record will be stored until authorized for destruction by either the client or legal order.

Records of either type will be catalogued prior to shipment to the storage facility. The storage facility will confirm that the received parcels contain the catalogued records and convey a receipt for the records to the originating office. The records will be made available to the originating office upon request and according to the procedures of the storage facility.

The QA Manager will review records as they are received from various sources (e.g., the client, the laboratory, subcontractors) and identify whether the records are lifetime or nonpermanent.

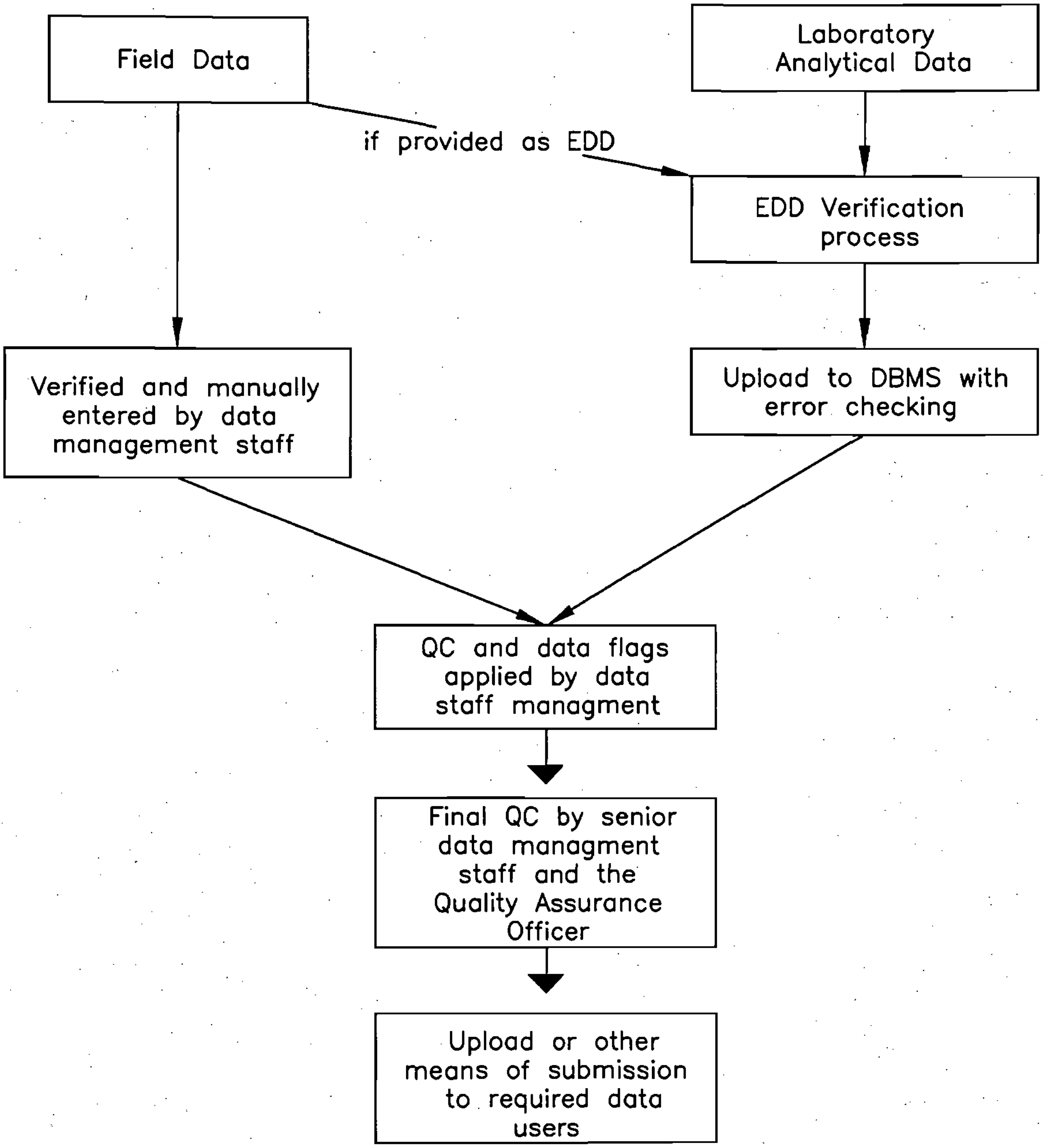
9.9 DATA MANAGEMENT

Data management will begin when the contractor transmits a request for analytical services to the laboratory, stating the number, type, sample numbers, methods for analysis, and other information necessary for the laboratory to plan a particular job. Data fields of initial input information, including map location files, a certification status check, sample identification number, parameters, dates, etc., will be established as sample containers and chain of custody documentation are prepared for shipment to the sampling team.

While in the process of collecting, documenting, packaging, and shipping samples to the laboratory, the field sampling team will transfer sample data from their notebooks to field parameter forms. Once the samples arrive at the laboratory, this information will be used to create data fields for submission to the data management staff. Status information (e.g., date sampled, date received, data extraction/analysis due) will form a part of the record.

Each step in the analytical process will result in updates to the data files. The operation performed (e.g., preparation, extraction, analysis, data review, data package prepared), the data obtained and the data that each step was completed will be entered into the system and made available for status checks. The laboratory will validate the data, perform error checking and correction, and transmit the files to the contractor, who will also perform the checks. Hard-copy documentation will also be transferred from the laboratory to the contractor.

The laboratory will archive copies of the analytical data, including original instrument magnetic tapes, for a period specified by the contract. Records will also be maintained so that historical summaries of the analyses may be generated by site, by client, or by sample type. Figure 9-1 presents a summary diagram of how these data will be handled.



RFAAP
MASTER WORK PLAN

Date: 06/13/01
Prepared By: URS Corp./DRT
Scale: NO SCALE
File Name: P:\09604-263\MWPUP\Fig 9-1

FIGURE 9-1

DATA MANAGEMENT SCHEME

10.0 CORRECTIVE ACTION

Corrective action will be initiated through the development and implementation of routine internal QC checks. Specific limits beyond which corrective action is required will be established for each system. Corrective action requirements will be implemented in response to deficiencies encountered during system inspections.

A closed-loop corrective action system will be used to address system and data quality issues. Steps comprising a closed-loop corrective action system include:

1. Defining the problem;

2. Assigning responsibility for problem investigation;

3. Investigating and determining the cause of the problem;

4. Assigning responsibility for problem resolution; and

5. Verifying that the resolution has corrected the problem.

Corrective actions will be categorized as either routine or non-routine and will require short-term or long-term action. Both types will require administrative coordination between the person initiating the corrective action and the QA staff.

10.1 ROUTINE

WPA and SOPs will establish technical procedures and the associated QC requirements. Where possible, the SOP will include specific criteria for determining the expected quality and examples of the appropriate corrective action procedures that may be taken if the criteria are not met. Routine corrective action will involve either short-term action for sporadic problems or long-term action for more chronic problems. Corrective action initiated at the project level will be reported to the QA Manager to ensure corrective action is implemented and the problem is resolved.

10.2 NON-ROUTINE

Activities that are not covered by a specific SOP require an iterative process whereby the systems and QC specifications are estimated prior to the activity and adjustments are made, as needed, during the course of the activity. A structured problem solving process is very effective in the elimination of root causes.

Documentation on the corrective action requirements, the assignment of responsibility for corrective action, due dates for completion of corrective action, and validation of completion will be maintained. Such documentation will be reviewed during system inspections.

Although documentation and monitoring of the corrective action is the responsibility of the QA Manager, the collection of data to support monitoring will be at the level at which the corrective action is implemented. The QA Manager will monitor the corrective action until remediation of the problem has been verified or it is clear that alternate actions are required. The QA Manager will review results of implemented corrective actions during management system reviews and technical systems audits. In addition, non-routine corrective action will be reported to the QA Manager in the monthly QA report.

Problems identified by assessment procedures will be resolved at the level at which they occurred, with support from upper management. Problems that cannot be resolved at this level will be reported to the QA Manager for resolution, who will establish at which management level the problem can best be resolved, and will notify the appropriate manager.

10.3 QUALITY IMPROVEMENT

Continuous development and improvement of the quality system is to be initiated through the quality improvement process. The quality improvement process (QIP) will be based on problem prevention, resolution, and corrective action. QIP goals include the timely identification and resolution of the quality problems in a manner that minimizes their impact on work products and prevents their reoccurrence.

10.4 PROBLEM PREVENTION

The preventive action program is intended to identify problems before they are adverse to quality. Inspections, self-assessments, and peer review are examples of the tools that will be used by the project staff to identify potential quality problems. As part of this program, preventative maintenance will be scheduled and performed on laboratory equipment as described in the laboratory QAP and on field equipment as described in Section 7.4, and appropriate SOPs.

Input regarding project operations will be regularly sought from clients, subcontractors, and staff. The PM will foster a no-fault attitude for problem identification, and staff will be encouraged to identify process improvement opportunities, problems, and solutions.

10.5 STOP WORK PROTOCOLS

The contractor Program Manager, PM, and QA Manager have the authority to issue a stop work order. A stop work order will be issued under conditions such that the quality of work jeopardizes the attainment of the project objectives. A stop work order must not create an operational, safety, public health, or environmental hazard.

Under a stop work order, work may not be conducted within affected activities until the responsible manager acknowledges the implementation of a corrective action in accordance with the resolution criteria of he order. Immediate notification of work stoppage will be made to RFAAP.

11.0 QUALITY ASSESSMENTS

This section discusses the inspection program used to monitor the total measurement system and to evaluate the quality of operation in the field and at the on-site laboratory. A performance inspection is a planned independent check of the operation of a system to obtain a quantitative measure of the quality of data generated, and involves the use of standard reference samples or materials which are certified as to their chemical composition or physical characteristics. Systems inspection is of a qualitative nature and consists of on-site review of a system's quality assurance system and physical facilities for sampling/analysis, calibration, and measurement.

11.1 DOCUMENT REVIEW

Project plans will be reviewed and approved prior to implementation. The contractor PM and QA Manager will provide a qualitative self-evaluation for establishing whether the prevailing management structure, polices, practices, and procedures are adequate to ensuring that the results needed are obtained. The PM will provide an independent qualitative evaluation of a particular program operation and/or organization to establish whether the prevailing management structure, policies, practices, and procedures are adequate for ensuring that the results needed are obtained.

11.1.1 Document Control

The goal of a Document Control Program is to ensure that the project documents issued or generated will be accounted for upon completion of the project. The program includes a numerical document inventory procedure and a central filing system with a designated person(s) responsible for its maintenance. Documents used or generated during the course of the project are accounted for and become a part of the project files upon completion of the task. These may include, but are not limited to, the following:

- Project deliverables;
- Investigation requirements;
- Reports and correspondence material; and
- Contract documents.

For example, QAP addenda will contain a control footer that includes:

- Document title;
- Document version; and
- Effective date (month year).

A distribution list of controlled documents will be maintained within the document control system. This system will ensure that revisions are distributed to the addressees. After technical work on a task has been completed, the accountable documents generated or used for the task work will be assembled and placed in a secure storage location. The QA Manager or their designee will then inventory accountable task documentation.

11.2 READINESS REVIEWS

Documented readiness reviews may be performed by the contracting QA Manager at the beginning of the work schedule start date and in the event of a quality-related stop work order. The readiness review will be performed to verify the following elements:

1. Work plans are approved;
2. Personnel have been suitably trained and qualified; and
3. The proper resources are available.

Work prerequisites for investigation activities include ensuring that necessary permits and licenses have been obtained. The contractor will be responsible for site approvals and preparation, coordinating with RFAAP for the extension of utilities to the study site, and regulatory compliance (i.e., obtaining necessary permits to install monitoring wells). Once site preparation is complete and permits are obtained, the contractor will be responsible for monitoring these facilities and determining compliance with permit requirements.

During the readiness review, actions will be taken as necessary by the contracting QA Manager to ensure that field activities are conducted in accordance with QAP addenda. The QA Manager will document deficiencies encountered during the readiness review and actions taken in the field to correct potential problems. Results of readiness reviews and corrective actions will be presented as a memorandum issued to the contracting PM. The memorandum will define deficiencies noted during the inspection and will note the actions taken to meet the QA requirements as defined by this Master QAP.

11.3 FIELD PERFORMANCE AUDITS

The contractor's technical audit team will perform a field audit of site activities. During this audit, current field practices will be compared to procedures outlined in the project work plans (i.e., WP, QAP, and other pertinent, industry acceptable, RFAAP-approved standards). The following elements will be evaluated during field activities at RFAAP:

- The overall level of organization and professionalism;
- Project activities;
- Document control and management;
- Level of QC conducted per each field team; and
- Task specific activities.

After audit completion, deficiencies will be discussed with the PM and FOL, and corrections will be identified. Corrective action procedures are outlined in Section 10.0.

11.4 LABORATORY PERFORMANCE AUDITS

Laboratory system audits are qualitative audits of the measurement systems, ensuring that they are properly maintained and used, and will be conducted by the Laboratory QA Manager or his designee on a quarterly basis and by the contractor QA Manager at least annually during the field investigation. Audits will include an evaluation of QA practices, procedures, and instructions; the effectiveness of implementation; and conformance with policy directives. During this evaluation, work areas, daily activities, and analytical processes will be observed, followed by review of documents and records, standards and reagents storage procedures, and housekeeping practices. These audits include the review of the following:

- Analytical and support instrumentation maintenance and calibration logs;
- Refrigerator and freezer temperature records;
- Distilled/deionized water supply records;
- Sample tracking system;
- Reference material tracking system; and
- Reagent chemical login, tracking, and disposal.

Another type of laboratory system audit is the on-site audit by the contractor QA Manager. During this audit, laboratory records and procedures will be inspected for completeness, accuracy, precision, and adherence to prescribed methods. This inspection will include:

- Following the sample chain-of-custody from time of sample receipt, through each step of analysis to data reduction, verification, and report generation;
- Examination of maintenance and calibration logbooks to ensure that maintenance and calibration are performed on a scheduled basis;
- Examination of procedures and records for data calculation, transfer, and verification;
- Spot-check of calibration, QC, and sample data from selected instruments for selected days to ensure acceptable precision, accuracy, and completeness;
- Inspection of storage areas, glassware preparation areas, and distilled/deionized water system records and procedures; and
- Examination of QA procedures and records (standard and spike solution logbooks and storage areas, control charts, and QA manuals).

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1.0 INTRODUCTION

1.1 OBJECTIVE AND SCOPE

This Master Health and Safety Plan (HSP) was developed to provide the requirements for protection of site personnel including contractors and subcontractors at Radford Army Ammunition Plant (RFAAP) (with the exception of emergency response units which will follow RFAAP procedures) who are expected to be involved with field work or have the possibility to be exposed to site hazards. In addition, an objective of the HSP is to provide general health and safety controls that will prevent and minimize personal injuries, illnesses, and physical damage to equipment and property. The plan stresses management responsibilities, preplanning for new activities, medical surveillance, training, periodic work, site evaluations and audits, accident prevention and investigation, record-keeping, Personal Protective Equipment (PPE) and Clothing, air monitoring requirements, site controls, decontamination procedures, and general safety requirements. Requirements for activities at specific solid waste management units (SWMUs), hazardous waste management units (HWMUs), and areas of concern (AOCs) are to be addressed by site-specific work plan addenda (WPA). Each site-specific WPA should address the specific health and safety hazards probable for that site.

Contractor and subcontractor personnel performing field activities will be required to read this HSP and adhere to its protocols as minimum standards. The Master HSP is written for the general site conditions and must be amended if conditions change. This HSP does not include instructions for known chemical warfare material (CWM) intrusive work activities. A copy of this HSP and WPA will be available at each work site.

1.2 REGULATIONS AND GUIDELINES

Field personnel will be required to follow applicable Federal and/or State safety and health standards, regulations, and guidance manuals. These include, but are not limited to:

- Department of the Army document AR 385-64, *U.S. Army Explosives Safety Program*;
- Department of the Army document AR 385-40 (with U.S. Army Corps of Engineers [USACE] Supplement 1), *Accident Reporting and Records*;
- Department of the Army document DA PAM 50-6, *Chemical Accident or Incident Response and Assistance Operations,* May 17, 1991;
- Department of Defense document DOD 4145.26-M, *Contractor's Safety Manual for Ammunition and Explosives,* July 1997;
- Applicable sections of Title 49, Code of Federal Regulations, Parts 100 to 199 (49 CFR 100-199), U.S. Department of Transportation regulations;
- Alliant TechSystems, *Safety, Security and Environmental Rules for Contractors and Subcontractors,* January 2000;
- 29 CFR 1910, Occupational Safety and Health Standards, General Industry;
- 29 CFR 1926, Safety and Health Regulations, Construction Industry.

- 40 CFR 260-276, Hazardous Waste Management;
- 40 CFR Subchapter C, Air Programs;
- USACE document ER 385-1-92, *Safety and Occupational Health Document Requirements for Hazardous, Toxic, Radioactive Waste (HTRW) and Ordnance and Explosive (OE) Activities,* 18 March 1994; and
- U.S. Environmental Protection Agency (USEPA) 9355.3-01, Office of Solid Waste and Emergency Response.

1.3 REFERENCES

In addition to the publications and regulations listed above, the following documents were used as reference material in the preparation of this document:

- National Institute for Occupational Safety and Health (NIOSH)/Occupational Safety and Health Administration (OSHA)/U.S. Coast Guard/USEPA, *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*, October 1985; and
- Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices, American Conference of Governmental Industrial Hygienists (ACGIH).

1.4 SITE SAFETY AND HEALTH DOCUMENTATION

Record-keeping requirements for safety and health are necessary to ensure accurate and complete monitoring of personnel. The documents that should be retained and their distribution are listed in Table 1-1.

Changes to the approved HSP will be documented using a revision form that will include the date, section, page number, existing text, revision text, rationale, and approval. This should be reviewed and approved by the USACE prior to implementation. Site personnel will be required to read this HSP and to sign a worker acknowledgment form that includes such information as a statement of acknowledgment of having read and understood and of agreement to comply with the HSP, personnel name, signature, and date. This signature form will be included in Appendix C of each Addendum HSP. The Site Health and Safety Officer (SHSO) will keep a copy of this signed form on file.

1.5 SAFETY STATEMENT

The contractor will provide a safe work environment for personnel involved in RFAAP investigative activities. The contractor will emphasize the importance of personnel injury and illness prevention at the work site.

This HSP prescribes the procedures that must be followed by site personnel. Operational changes that could affect the health and safety of personnel, the community, or the environment will not be made without prior approval of the Installation, the contractor's project manager (PM), and the contractor's health and safety manager;

Table 1-1
Health and Safety Documents and Distribution
RCRA Facility Investigation Master Health and Safety Plan
Radford Army Ammunition Plant, Radford, Virginia

Document	Distribution
Final Version of the HSP	Site personnel, Site Health and Safety Officer (SHSO), project file
Site-specific training documentation and signature page	Retained on site throughout investigative activities, SHSO, project file
Monitoring equipment maintenance and calibration records	Retained on site throughout investigative activities, SHSO, project file
HSP worker acknowledgment form, signed	Retained on site throughout investigative activities, SHSO, project file
Safety logs	Retained on site throughout investigative activities, SHSO, project file
Incident and accident reports	RFAAP, SHSO, project file, Project Health and Safety Officer (PHSO)
Employee exposure monitoring results	Retained on site throughout investigative activities, SHSO, project file
Changes to approved HSP and documentation as to why the changes were made	Site personnel, SHSO, USACE, PHSO, project file
Audit results	SHSO, PM, PHSO, project file
Debriefings	SHSO, PM, PHSO, project file

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2.0 PROJECT ORGANIZATION

Project contractors and subcontractors are subject to the requirements of this HSP when performing site investigations at RFAAP. To ensure compliance with the provision of this document, this section outlines the safety and health organizational structure and personnel roles and responsibilities.

2.1 HEALTH AND SAFETY PERSONNEL AND RESPONSIBILITIES

2.1.1 Project Manager

The PM is the primary point of contact with RFAAP, and will have overall responsibility for project operations. The PM, along with the project health and safety officer (PHSO), can require corrective actions by subcontractors for work not performed in accordance with the HSP. In addition, the PM will have the following safety and health related responsibilities:

- Managing the funding, manpower, and equipment necessary to safely conduct site operations;
- Reviewing, approving, and becoming familiar with the Master HSP and site-specific WPA;
- Furnishing copies of the Master HSP and WPA to site and subcontractor personnel for review;
- Coordinating the assignment of subcontractor personnel and ensuring that the personnel and equipment provided by the subcontractor meet the requirements of the WP and HSP;
- Assigning the SHSO and ensuring that the assigned on-site staff will enforce provisions of the approved HSP;
- Providing overall supervisory control for safety and health protocols in effect for the project; and
- Directly interfacing with the RFAAP PM and relaying safety and health concerns related to the conduct of site operations.

2.1.2 Certified Industrial Hygienist

The Certified Industrial Hygienist (CIH) is responsible for establishing, implementing, monitoring, and administering the contractor's health and safety program and ensuring that the program is in compliance with Federal, state, Army, Radford Army Ammunition Plant, and contract-specific requirements. The CIH delegates responsibilities for developing and implementing the site-specific HSP, as required, to the PHSO and the SHSO. In addition, the CIH will have the following safety and health related responsibilities:

- Reviewing and approving the HSP and site-specific WPA;
- Evaluation and authorization of changes to the HSP; and
- Continued evaluation and updating of site monitoring and PPE programs.

2.1.3 Project Health and Safety Officer

The PHSO is responsible for maintaining safety and health records, providing guidance for on-site safety and health developments, and approving safety and health plan addenda/revisions. The PHSO will also ensure that the contractor's standards are applied during the project and that the project meets established safety and health requirements. The PHSO will direct or conduct safety audits and industrial hygiene monitoring of field activities. In addition, the PHSO will have the following safety and health related responsibilities:

- Coordinating with the SHSO in the field implementation of the HSP;
- Providing consultation to the SHSO for site-related safety and health issues; and
- Reviewing safety and health documentation.

2.1.4 Site Health and Safety Officer

The SHSO is responsible for on-site enforcement of the policies and provisions contained in the HSP, and has the authority to stop work if the safety of a site worker is at risk. The SHSO will function as the communications liaison between the PM and the PHSO. In addition, the SHSO will conduct safety briefings daily prior to initiation of on-site activities. The briefings will include such topics as on-site hazards and site-specific safety and emergency procedures. In addition, the SHSO will have the following safety and health related responsibilities:

- Completion of Personnel Data Sheets for site personnel;
- Establishing work zones, decontamination stations, and controlling access to these zones;
- Confirming USACE, contractor, and subcontractor personnel's suitability for work based on OSHA and site-specific medical and training requirements;
- Implementation and documentation of the contractor's Safety and Health Requirements and/or standard operating procedures (as specified by 29 CFR 1910.120[I]);
- Ensuring proper condition, storage, and use of PPE;
- Consulting with the PHSO and/or CIH prior to downgrading or altering monitoring or PPE requirements;
- Assisting in the continued development of the HSP and other safety and health procedures;
- Investigating accidents/incidents and "near misses";
- Conducting visitor orientation;
- Enforcing the "buddy" system;
- Removing personnel from the site if they exhibit symptoms of alcohol use, drug use, or illness, monitoring site personnel for signs of chemical exposure or physical stress;
- Conducting necessary monitoring; and
- Maintaining the site safety and monitoring logs.

2.1.5 Field Operations Leader

The Field Operations Leader (FOL) is responsible for coordinating and directing the technical effort of the project staff and subcontractors during field investigation activities. The FOL is responsible for ensuring each aspect of the field effort is successfully met, including safety and health objectives. In addition, the FOL will have the following safety and health related responsibilities:

- Working with the SHSO to identify and evaluate hazards;
- Identifying safe and secure locations for drummed waste; and
- Coordinating location of utilities prior to drilling.

2.2 SUBCONTRACTOR RESPONSIBILITIES

Subcontractor personnel performing work on site are responsible for compliance with applicable Federal, state and local statutes, ordinances, and regulations regarding safety and health. Each subcontractor will prepare and conform to a safety and health plan, which provides planning at least as stringent as this plan. Each subcontractor will be responsible for providing qualified site personnel that understand and will comply with this HSP.

Subcontractors must identify a lead individual responsible for the safety and health compliance of their employees, lower-tier subcontractors, and consultants. This person will be responsible for reporting to the SHSO, and for demonstrating compliance with the safety and health procedures.

In conformance with the OSHA Hazardous Waste Site Operations (29 CFR 1910.120), each subcontractor employee proposed for on-site activities will participate in a medical surveillance program, be certified for hazardous waste field work by a licensed physician, and have successfully completed the safety and health training as required by this plan. Documentation and certification of this monitoring and training will be provided to the contractor's SHSO.

2.3 SITE PERSONNEL

Site personnel are responsible for the adherence to the HSP procedures and policies during the performance of work. Site personnel and visitors will be required to read this HSP and to sign an acknowledgment form to document their understanding of the contents. Failure to comply with this plan's provisions may lead to disciplinary actions and/or dismissal from the work site. Specific site personnel responsibilities include:

- Complying with the HSP and other required safety and health guidelines;
- Taking necessary precautions to prevent injuries;
- Continually being alert to potentially harmful situation and immediately informing the SHSO of identified conditions;
- Performing those tasks in which they are properly trained and can perform safely;
- Notifying the SHSO of special medical conditions (i.e., allergies, contact lenses, and diabetes) which could affect their ability to safely perform site operations;

- Preventing spillage and splashing of materials to the greatest extent possible;
- Practicing good housekeeping by keeping the work area neat, clean, and orderly;
- Immediately reporting injuries, no matter how minor, to the SHSO;
- Maintaining site equipment in good working order and reporting defective equipment to the SHSO;
- Reporting to work clean-shaven so respiratory protection can be worn as needed; and
- Properly inspecting and using the PPE required by the HSP or the SHSO.

2.4 VISITORS

Authorized visitors to work locations on the site will be briefed on the hazards present at that location by the SHSO. Visitors will be escorted at times and will be responsible for compliance with the requirements specified in this HSP. Visitors will not be permitted to enter potentially contaminated work zones unless they have completed the appropriate training and medical surveillance requirements, and have the proper PPE. Documentation and certification of this monitoring and training must be provided to the contractor's SHSO.

2.5 RFAAP PROJECT PERSONNEL

RFAAP personnel assigned to the safety and health coordination and administration of this project will be contacted whenever changes are to be made to the HSP. Modifications to the HSP will be addressed in site-specific WPA, including anticipated site conditions; expected levels of exposure; identification of chemical hazards not previously identified; degree of hazard associated with a required task; or addition or expansion in the Statement of Work (SOW).

3.0 HAZARD ASSESSMENT AND HAZARD CONTROL

3.1 CHEMICAL TOXICITY HAZARDS

A qualitative evaluation of the conditions at RFAAP has been made to identify the known and suspected chemical hazards at the site and to evaluate the risks associated with site activities. This evaluation is based on:

- Nature of known and suspected contaminants;
- Potential presence of contaminants at specific SWMUs;
- Potential for personnel and public exposure during various field activities;
- Effects of contaminants on human health; and
- Concentrations of contaminants.

The toxic hazards to site personnel associated with the suspected site contaminants can be assessed through comparison of actual exposures with several established occupational exposure limits. Exposure potential is defined as the probability of an individual receiving a harmful exposure. The occupational exposure limits include:

- Permissible exposure limits (PELs), established by the OSHA, may be expressed as an eight-hour time-weighted average (TWA), a short-term exposure limit (STEL), or a ceiling limit. Ceiling limits may not be exceeded. PELs are enforceable by law. STELs are allowable exposure limits for durations ranging from five to 15 minutes, without causing the eight-hour TWA to be exceeded.
- TLVs are established by ACGIH. The ACGIH TLV is defined as the TWA concentrations for a substance to which nearly workers (eight hours per day, 40 hours per week) may be repeatedly exposed, day after day, without experiencing adverse health effects. For some substances, the overall exposure to a substance is enhanced by skin, mucous membrane, or eye contact. These substances are identified by "yes" in the skin notation column.
- Immediately dangerous to life or health (IDLH) values are established by NIOSH. The IDLH values represent the maximum concentrations from which, in the event of respirator failure, one could escape within 30 minutes without a respirator and without experiencing escape-impairing symptoms or irreversible health effects.

Section 9.0 presents occupational exposure limits (if available) for potential contaminants, including OSHA PELs, ACGIH TLVs, and NIOSH IDLH values. The table also indicates if there are potential significant contributions to the overall exposure for the chemical of concern through dermal contact, and identifies the acute symptoms resulting from exposure.

Material Safety Data Sheets (MSDSs) for each hazardous substance likely to be encountered or used by field personnel during field activities will be available on site for review by requesting personnel. Information regarding possible exposure routes and symptoms of acute/chronic exposures to chemicals are summarized in the MSDS. Personnel are to be trained on the use of MSDSs and other components of the employer's written hazard communication program in order to comply with 29 CFR 1910.1200.

3.2 PHYSICAL HAZARDS

Physical hazards associated with field work include heat/cold stress, noise, and, manual lifting of heavy objects. Additional physical hazards, including contact with subsurface utilities, exposure to moving machinery, accidents associated with working in areas of vehicle traffic, inclement weather, and uneven, unstable terrain, are discussed in detail in Section 6.0 and will be included in site-specific WPA, as appropriate.

3.2.1 Heat Stress

A number of interacting factors, including environmental conditions, clothing, workload, and the individual characteristics of the worker cause heat stress. Because heat stress is probably one of the most common (and potentially serious) illnesses at sites, regular monitoring and other preventive measures are vital. The initial stage is commonly termed heat fatigue, which is usually transient and subsides with rest and replenishment of fluids.

Heat fatigue is characterized by discomfort and reduced mental awareness, with a greater effect in unacclimated workers. Medical treatment is usually not required.

Heat rash occurs in hot, humid environments where sweat is not easily removed from the surface of the skin by evaporation. The skin remains wet and as a result the sweat ducts become clogged, causing a skin rash. Symptoms include mild, blister-like red rashes and prickling sensations during heat exposure. For relief, the skin is cleaned to prevent infection and use powder or drying lotion to absorb moisture and reduce chafing. Medical supervision is usually not required.

Heat cramps are painful spasms of the muscles that occur when individuals sweat profusely in the heat and drink large quantities of water, but do not adequately replace body salt loss. Moving the victim to a cool area and replacing of water and salt loss should provide relief. Medical treatment is usually not required.

Heat syncope results in fainting, and is caused by standing immobile in heat. It is caused by pooling of venous blood in the dilated vessels of the skin and lower body. Recovery is complete and rapid following rest in a recumbent position at a cool location.

Heat exhaustion results from sustained exertion in heat where the body's cooling mechanism is overworked and cannot balance the ambient body temperature or body work load, combined with failure to replace water and salts. Symptoms include dizziness, fatigue; nausea; headache; and cool, clammy, moist skin which may be flushed or pale. Body temperature may be normal or slightly elevated. Replacement of water and salts in addition to rest is required to recover. Electrolyte replacement fluids should be taken until urine volume increases. Medical supervision may be required.

The most serious heat illness is **heat stroke**. Heat stroke is a **medical emergency** requiring immediate treatment and professional medical attention. Heat stroke is caused by a combination of factors including heavy exertion in heat, inadequate replacement of fluids, poor physical condition, and individual susceptibility. Failure of the sweat response occurs, leading to a rapidly accelerated increase in core temperature. The victim usually has hot, dry red skin, body temperature is usually quite high (105 degrees Fahrenheit (°F) or higher), and if conscious, is confused; convulsions may be present. Persons with symptoms of heat stroke requires immediate first aid and prompt hospitalization. The victim must be cooled immediately; heat stroke is fatal if treatment is incomplete or delayed.

The best cure for heat stress is prevention. Heat stress generally occurs early in the summer, prior to acclimatization. Full acclimatization takes from five to seven consecutive days of controlled exertion in heat. Individual physical conditioning, pre-existing illnesses, and use of alcohol contribute significantly to the potential for heat stress. Avoidance includes drinking plenty of fluids and taking frequent breaks. The work schedule should be revised around hot periods of day, and the SHSO should verify that workers are acclimated prior to allowing them to work for extended periods of time.

3.2.2 Cold Stress

As with high temperatures, outdoor work in low temperatures can result in risks to the health of employees exposed without adequate preparation. To minimize impacts from cold stress, the information and precautions given below will be observed.

Cold-related worker fatalities have resulted from failure to escape low environmental air temperatures, or from immersion in low temperature water. Most hypothermia cases develop in air temperatures between 30 to 50°F. The single most important aspect of life-threatening hypothermia is a fall in the deep core temperature of the body. Lower body temperature will likely result in reduced mental alertness, reduction in rational decision making, or loss of consciousness with the threat of fatal consequences.

Immersion foot and trench foot are two cold injuries, which occur as a result of exposure to cool or cold weather and persistent dampness or immersion in water. Immersion foot usually results from prolonged exposure when air temperatures are above freezing, whereas trench foot normally occurs from shorter exposure at temperatures near freezing. The symptoms for each disorder are similar and include tingling, itching, swelling, pain and/or numbness, lack of sweating, and blisters in the limbs and extremities.

Persons working outdoors in temperatures at or below freezing may be frostbitten. Extreme cold for a short time may cause severe injury to the surface of the body, or result in profound generalized cooling, causing death. Areas of the body that have a high surface-area-to-volume ratio such as fingers, toes, and ears are the most susceptible.

Frostbite occurs when there is actual freezing of the water that is contained in the body tissues. This usually occurs when temperatures are below freezing, but excessive wind can result in frostbite even when ambient temperatures are above freezing. Frostbite can occur from several types of cold exposure, such as: exposure of bare skin to cold and wind; exposure to extremely cold ambient temperatures; skin contact with rapidly evaporative liquids (gasoline, alcohol, or cleaning solvents) at temperatures below 39.2°F; or from skin contact with metallic objects whose temperatures are below freezing. The extremities are usually affected first since the body's initial response to cold stress involves decreasing the blood flow to the extremities, thereby reducing heat loss. During the initial stages of frostbite, the skin may have a prickly or tingling sensation and will later become numb with cold. Frostbite of the extremities can be categorized into:

1. Frost Nip or Initial Frostbite: Characterized by sudden blanching or whitening of skin;
2. Superficial Frostbite: Skin has a waxy or white appearance and is firm to the touch, but tissue beneath is resilient; and
3. Deep Frostbite: Tissues are cold, pale, and solid, extremely serious injury.

Hypothermia results when the body loses heat faster than it can be produced. When this occurs, the blood vessels in the skin and extremities constrict, reducing the flow of warm blood to those areas that have a high surface area to volume. This reduction in blood flow reduces heat loss and usually affects the peripheral extremities first. Ears, fingers, and toes begin to experience chilling, pain, and then numbness due to loss of both blood flow and heat. Shivering is often the first sign of hypothermia. The pain and numbness in the extremities is an indication that the heat loss is increasing, but when shivering becomes severe and uncontrollable, the heat loss in the body core has become extreme. Further heat loss produces speech difficulty, apathy, reduced mental alertness, forgetfulness, loss of manual dexterity, collapse, unconsciousness, slow respiratory rate, and finally death.

The intent of cold stress treatment is to bring the deep body core temperature back to its normal temperature of 98.6°F. Work performed in cold environments should be discontinued for workers that exhibit signs or symptoms associated with hypothermia or frostbite. Workers exhibiting those symptoms should be brought to a warm area and allowed to rest and warm-up. If a worker's clothing becomes wet, which reduces its insulation affect, the clothing should be removed and replaced by dry clothing or allowed to dry prior to resuming work. Warm, non-alcohol, decaffeinated drinks (not coffee) or soup should be given to increase the body core temperature and re-warming should be gradual.

For frostbite, the victim should be sheltered from the wind and cold and given warm drinks. If the frostbite is superficial, the frozen area(s) should be covered with extra clothing or warmed against the body. **Do not use direct heat or pour hot water over or rub the area**. Warming should be gentle and gradual. Failure to do this could lead to bleeding in the tissues and increase the possibility of infection. If the frostbite is deep, immediate medical attention should be obtained. The safe thawing of deep frostbite is beyond the expertise and facilities found on site.

3.2.3 Noise

Noise may become a physical hazard of concern at certain times due to activities, which require extensive use of heavy equipment and/or noisy portable equipment. OSHA requires employers to administer a hearing conservation program whenever employee noise exposures equal or exceed an eight-hour TWA of 85 decibels on the A-weighted scale (dBA). The hearing conservation program will include audiograms during each employee's baseline medical surveillance and annual physicals. In addition, hearing protection will be provided for use in elevated noise areas. This hearing protection equipment must attenuate employee exposure to an eight-hour TWA of 90 dBA. The SHSO will provide training on the proper use of hearing protection in accordance with 29 CFR 1910.95. The training will be conducted as a part of the pre-work safety and health briefing.

3.2.4 Manual Lifting

Activities may require personnel to move large, heavy objects by hand. The human body is subject to severe damage in the forms of back injury and hernia if caution is not observed when handling, lifting, or moving these large, heavy objects. The following general rules will be followed during manual lifting:

- Ensure that the hands and object to be lifted are free of oil, grease, and water that might prevent a firm grip;
- Keep hands and fingers away from areas that could pinch or crush the hands;
- Inspect object for metal slivers, jagged edges, burrs, and rough or slippery surfaces;
- Get as close to the object as possible;
- Ensure solid footing;

- Place feet about one shoulder width apart;
- Bend at knees to grasp weight;
- Keep the back straight;
- Get a firm hold;
- Lift gradually by straightening the legs;
- If weight is uncomfortable to lift, get help;

When placing an object down, the stance and position are identical to that for lifting. Keep the back straight, and bend legs at the knees and lower the object.

When two or more people are required to handle an object, coordination is essential to ensure that the load is lifted uniformly and that the weight is equally divided between the individuals carrying the load. When carrying the object, each person, if possible, will face the direction in which the object is being carried.

Drum handling presents physical and chemical hazards. The standard procedure for moving drums is to use the drum picker attachment for the truck forklift. The drum picker allows safe movement of drums with little risk to personnel. In some cases, however, it will be necessary for personnel to move the drums by hand into an area where they are not accessible by the truck forklift. Drums that require movement by hand should be carefully moved, to avoid pinching and/or crushing fingers or hands, by grasping the top edge of the drum with leather work gloves and rotating the drum in the direction in which you need it to be placed. Care should be taken to keep feet away from the drum base. In addition, two people are required when moving drums.

3.3 BIOLOGICAL HAZARDS

The biological hazards likely to be encountered by site personnel include insects, snakes, rodents, and poisonous plants.

3.3.1 Ticks

From April through October, particular caution will be exercised to prevent site workers from being bitten by deer ticks and potentially contracting Lyme Disease. Specific precautionary work practices include:

- Cover the body as much as possible, wearing long pants and long-sleeved shirts;
- Wear light color clothing to make spotting of ticks easier;
- Try to eliminate possible paths by which the deer tick may reach unprotected skin, by tucking bottoms of pants into socks or boots and sleeves into gloves and using duct tape to help seal cuffs and ankles;
- Wear Tyvek® coveralls for added protection in the event heavy concentrations of ticks or insects are anticipated or encountered;

- Conduct periodic and frequent (e.g., hourly) surveys of your clothing for the presence of ticks. Remove ticks and insects that become attached to clothing; and

- Use insect and tick repellents that contain the chemical n,n-diethyltoluamide (DEET). Apply repellents in accordance with manufacturers' recommendations. These repellents are readily available and include such brands as Deep Woods OFF® and Maximum Strength OFF®. Check the ingredients of the repellent because the higher the concentration of DEET, the longer the repellent will be effective.

Field personnel are encouraged to check with supervisors to ensure that use of insect repellents will not interfere with sample collection procedures.

3.3.2 Ants, Bees, Wasps, Hornets, and Yellow Jackets

Nests and hives for ants, bees, wasps, hornets, and yellow jackets often are located in ground, trees, and brush. The area will be checked for obvious nests and hives prior to clearing. If a nest or hive is found, the PM will be contacted prior to disturbing or removing the nest; and, if possible, an alternate sampling location will be selected. Bites and stings can be painful and may elicit an allergic reaction. Medical surveillance will identify individuals with life threatening allergies. These individuals will not work in areas where there is a great potential for insect stings. If simple first aid measures do not alleviate the symptoms, the victim will be taken to the nearest medical center. An attempt will be made to kill the offending insect and take it to the emergency room with the victim if this can be done quickly and without endangering personnel.

3.3.3 Snakes

Because some of the area is wooded, the possibility for encountering snakes exists. Although rare in the Virginia area, the species of greatest concern is the copperhead *(Agkistrodon contortix)*. Copperheads grow to 36 inches and can be recognized by the copper-color head and a reddish-brown hourglass pattern on the body. Copperheads are normally lethargic, but once aroused, strike vigorously and may rapidly vibrate their tails. Rocky hillsides are favorite habitats.

To minimize the threat of snake bites, personnel walking through brush will be aware of the potential for encountering snakes and will avoid actions that increase the likelihood of encounters (e.g., turning over logs). Additional caution will be exercised around sawdust or rock piles, which are known to support copperheads. The Installation and off-site hospital will be notified of the potential for having to treat snakebite victims. The victim should be transported to the nearest hospital within 30 minutes. First aid consists of applying a constriction band and washing the area around the wound to remove unabsorbed venom. Cutting and sucking the venom should be omitted (unless medical care cannot be obtained within 30 minutes).

3.3.4 Rabies

There is the likelihood to encounter wild rabid animals at the Installation. Skunks, raccoons, foxes, and bats are the wild animals most frequently found to be infected with rabies; however, warm-blooded animal can be infected. Wild animals are to be avoided especially those that are overly passive or aggressive. Report such animals to appropriate RFAAP facility personnel.

Rabies is preventable, even after being bitten, if treatment is begun soon enough. Thus, getting prompt medical attention and determining whether the animal that has bitten you is or is not infected are very important. Rabies is not curable once symptoms or signs of rabies appear.

3.3.5 Poison Ivy, Poison Oak, Poison Sumac

Personnel will be familiar with and be able to recognize poison ivy, poison oak, and poison sumac in the field (Figure 3-1). Reaction to poison ivy can be prevented if the exposed skin is washed with mild soap and water within ten minutes of contact. Contact can be prevented by site workers wearing appropriate clothing. Site workers should remove contaminated clothing and wash their hands and faces prior to entering the break area.

3.3.6 Biological Agents

Microbial hazards can potentially occur when workers handle materials with biological contamination. One source of infection for response workers is poor sanitation. Waterborne and food borne diseases can be a problem if adequate precautions are not taken to keep food and drinking water properly stored and isolated. An example of such a disease is salmonellosis. Workers must also avoid creating sanitation problems by making sure that properly designed lavatory facilities are available at the work site.

Tetanus is another biological hazard encountered on hazardous materials sites. Workers must work to avoid puncture hazards, wear appropriate protective clothing, and be current in Tetanus Inoculation.

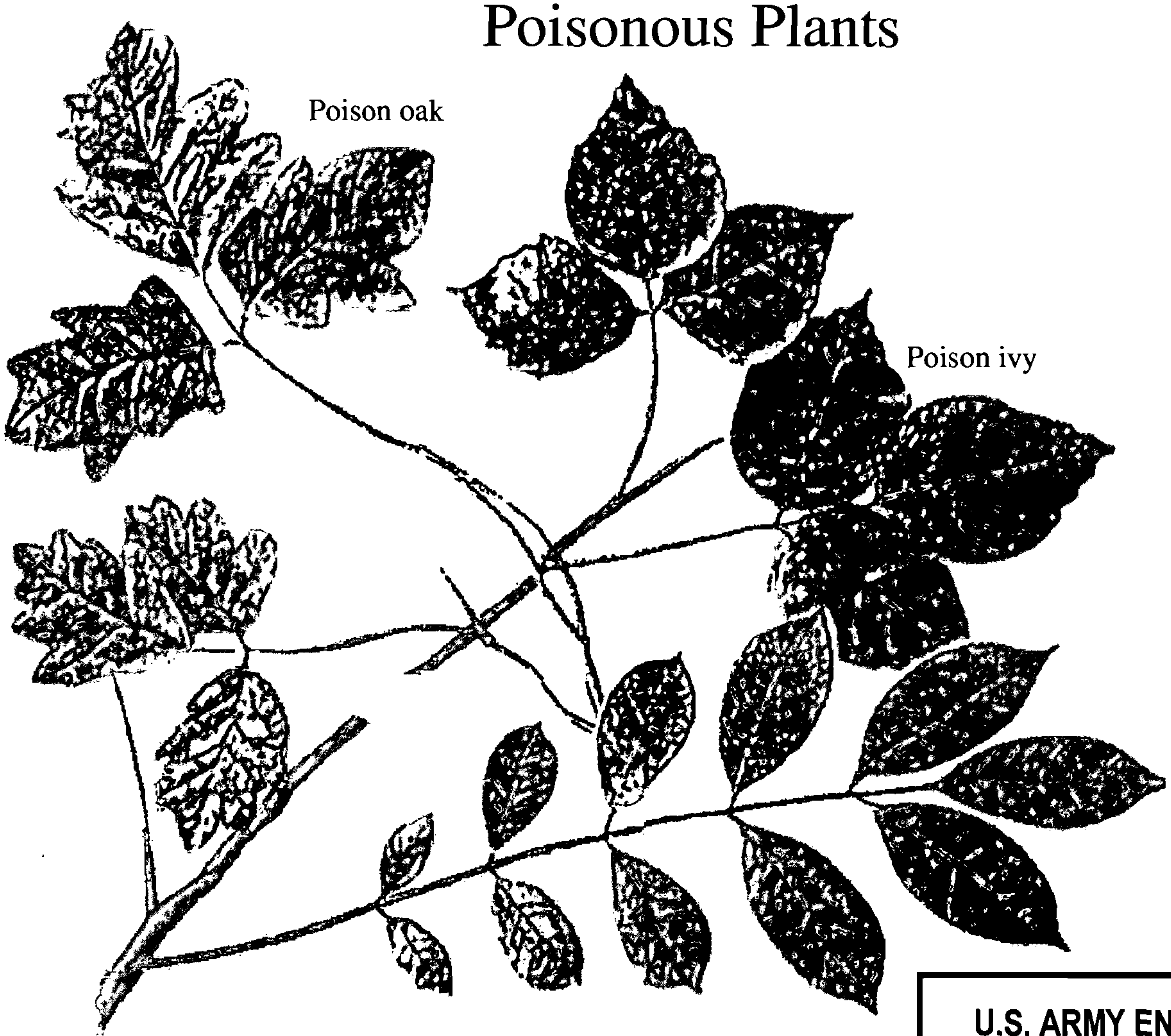
3.3.7 Bloodborne Pathogens

In July of 1992, OSHA issued a final Standard for Protection of Workers Potentially Exposed to Blood borne Pathogens (29 CFR 1910.1030). This requirement is relevant primarily for medical and research personnel. Bloodborne pathogens are pathogenic microorganisms, which may be present in human blood and can cause disease in humans. These pathogens include, but are not limited to hepatitis B virus (HBV) and human immunodeficiency virus (HIV).

Potential exposure during site activities result from workers who are infected. The OSHA standard specifically includes first aid providers and is enforceable on site, subject to the Hazardous Waste Site Work and Emergency Response Standard (29 CFR 1910.120). The basic concept of this standard is that medical care workers and anybody else administering first-aide must take the "Universal Precaution" of assuming that blood-containing fluid or persons bleeding or contaminated with blood-containing fluid is positively (infected) with both viruses.

Personal protection includes gloves, eye shields, one-way valve rescue breather devices, and training. In order to effectively protect against hazards, workers must have a basic understanding of the hazard. This is particularly true of FOLs, SHSOs, and others expected to administer first aid, if necessary.

Poisonous Plants



U.S. ARMY ENVIRONMENTAL CENTER

CONTRACT NO.	DACA31-94-D-0064		FIGURE 3-1 RADFORD ARMY AMMUNITION PLANT
ICF KAISER ENGINEERS	2113 EMMORTON PARK RD. EDGEWOOD, MD. 21040 (410) 612-6350		POISONOUS PLANTS
PREPARED	LAS	TASK NO	66228
CHECKED	LH	ICF DWG NO:	POISON_3
DATE	APRIL 1998		

4.0 TRAINING PLAN

4.1 GENERAL

Personnel (the contractor and its subcontractors) who will be conducting field work or conducting operations at this site under this task will receive basic health and safely training as specified under 29 CFR 1910.120 prior to their entry into the site. Personnel (including visitors) entering the exclusion zone using a full-face negative pressure respirator must have successfully passed a qualitative fit-test in accordance with 29 CFR 1910.1025; 1926.58; or American National Standards Institute (ANSI) within the last 12 months or more frequently as required by law and be in compliance with 29 CFR 1910.134. Documentation of fit testing is the responsibility of each subcontractor/ employer.

Contractor and subcontractor personnel will sign a statement indicating they have received site-specific training and understand site hazards and control measures. This documentation and documentation of training for each hazardous waste worker will be retained on site. In accordance with 29 CFR 1910.120, USACE EM 385-1-1 and other Federal, state and governmental regulations, site training will, as applicable, include the courses listed below.

4.2 OSHA HAZARDOUS WASTE OPERATIONS TRAINING

4.2.1 Basic 40-Hour OSHA Training

Contractor and subcontractor personnel who have the potential for exposure to the safety and health hazards discussed in this document must attend and successfully complete 40 hours of off-site Hazardous Waste Operations and Emergency Response (HAZWOPER) training. This requirement also applies to supervisory and management personnel responsible for site operations. This training must be completed and documentation presented before on-site and management/supervisory personnel are allowed to participate in site activities.

4.2.2 Three-Day On-site Training

Contractor and subcontractor personnel on site will also receive a minimum of three days of actual on-site field experience under the direct supervision of a trained, experience supervisor. This field activity training will be used to familiarize site personnel with the site-specific organization and emergency response procedures.

4.2.3 Management and Supervisory Training

Managers and supervisors who supervise on-site personnel engaged in, or who are directly responsible for, hazardous waste operations (team leader, site manager, and site health and safety officer) will have eight additional hours of specialized supervisory training. This training will include such topics as health and safety plans, training and medical surveillance requirements, spill containment and emergency response procedures, and site monitoring procedures and techniques.

4.2.4 Eight-Hour Annual Refresher

Contractor and subcontractor personnel, including management/supervisory personnel, are to receive a minimum of eight hours of refresher training annually. This training will cover relevant topics from the basic 40-hour OSHA training and eight-hour management/supervisor courses as well as other related topics and updates.

4.3 SITE-SPECIFIC AND HAZARD INFORMATION TRAINING

4.3.1 Site-Specific Information Training

Site-specific training will be used to review important topics outlined in the HSP and to inform contractor personnel and subcontractor personnel of the hazards and control techniques associated with on-site operations.

4.3.2 Hazard Information Training

Hazard information training will be presented to contractor and subcontractor personnel that provides a description of HTRW with the potential to be found on site and the potential biological, chemical, and physical hazards to be found on site.

4.4 FIRST AID AND CPR TRAINING

At least two on-site employees will be trained and certified in first aid and cardiopulmonary resuscitation (CPR) under 29 CFR 1926.50. These employees will be tasked with the responsibility of providing initial first aid response to injured employees whenever other medical support personnel are not immediately available on site. Whenever possible, the SHSO will be one of the two site personnel trained and certified in first aid/CPR. First aid training must be updated every three years and must include the bloodborne pathogen training. CPR training must be updated annually. Documentation of certifications will be on site.

4.5 BLOODBORNE PATHOGEN TRAINING

The first aid trained personnel will primarily be responsible for rendering aid in the event of accident or injury. As required by 29 CFR 1910.1030 (g)(2), site personnel with a potential for occupational exposure to blood or other potentially infectious materials will receive training. The OSHA standard specifically includes first aid providers and is enforceable on site, subject to 29 CFR 1910.120.

4.6 HEARING CONSERVATION TRAINING

According to 29 CFR 1910.95, site personnel exposed to noise levels exceeding 85 dBA eight-hour TWA will be provided with training that addresses the following:

- The effects of noise on hearing;
- The purpose of hearing protection; the advantages, disadvantages, and attenuation of various types; and the selection, fitting, use, and limitations of hearing protection devices; and
- The purpose of audiometric tests and explanation of test procedures.

4.7 HAZARD COMMUNICATION TRAINING

In compliance with requirements of the OSHA Hazard Communication (HAZCOM) Standard (29 CFR 1910.1200) the SHSO will have a written Hazard Communication Program in place. The written hazard communication program will address, at a minimum, the following: training (to include potential safety and health effects from exposure), labeling, current inventory of hazardous chemicals on site, and the location and use of MSDSs. The SHSO will arrange HAZCOM training for site personnel at the time of initial site assignment. Whenever a new hazardous substance is introduced into the work area or an employee changes job locations where new chemicals are encountered, supplemental HAZCOM training will be scheduled and presented. HAZCOM training will be documented by the SHSO using a Hazard

Communication Employee Training Record. This documentation will be maintained on site for the duration of the project, and later incorporated in the employee's personal training file.

4.8 CONFINED SPACE ENTRY TRAINING

Confined space entry activities will be performed in accordance with OSHA standards (29 CFR 1926.21 and 1910.146), NIOSH 80-106, and HQUSACE (June 1994). In addition, team members participating in these activities will have completed an OSHA-certified confined space entry training course. Rescue personnel must have additional OSHA-certified training in confined space entry rescue. In addition, they must also be certified in first aid and CPR and at least once every 12 months perform a confined space rescue or simulate the performance of a confined space rescue.

4.9 ADDITIONALLY REQUIRED OSHA TRAINING

Additional OSHA-required training will be provided if deemed necessary by the SHSO. This may include training related to specific chemical contaminants (such as lead and arsenic) and/or physical hazards such as confined space entry, fire extinguisher use, heavy equipment and hand tool operation, and specialized PPE.

4.10 BUDDY SYSTEM TRAINING

Work at this facility will be performed using the buddy system. Team members will be trained to keep in visual contact with each other. Buddy system training will also stress the need for buddy team members to remain constantly aware of slip, trip, and fall hazards, lifting hazards, symptoms associated with exposure to chemical substances, location of areas on site with restricted access, temperature extremes, and other general safety and health hazards within their work area.

4.11 DAILY SAFETY MEETINGS

Prior to commencing work each day, contractor and subcontractor personnel will be given a safety briefing by the SHSO. This briefing will identify the anticipated site activities and the potential hazards that may be encountered during that day's activities.

The safety briefing may also be used to review the following: use of safety equipment, emergency medical procedures, emergency notification signals, accident prevention, and relevant sections of the WP. As needed, these topics will be reviewed daily to ensure that site operations are carried out in a safe manner. A daily debriefing will also be held, if needed. Records of safety meetings documenting date, attendance, and topics covered will be maintained.

4.12 WEEKLY SAFETY MEETINGS

The SHSO is responsible for conducting weekly safety meeting for intrusive work to discuss status of site health and safety. These meetings will also address employee's concerns regarding safety and hazard control practices and procedures implemented at the work site.

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5.0 MEDICAL SURVEILLANCE PLAN

5.1 INTRODUCTION

In compliance with OSHA standards (29 CFR 1910.120(f), 1910.134 and 1926.65), the contractor will establish a medical surveillance program. This program will provide certification of employees to work on hazardous wastes sites and to wear respiratory protection. In addition, this program will be designed to assist in the prevention, diagnosis, and treatment of occupational illnesses and injuries sustained during operations on hazardous work sites. The medical status of site personnel will be monitored through an annual physical examination. A physician certified in occupational medicine will review medical results and monitoring data. Subcontractor personnel will be required to have a medical surveillance program in place, and be certified by a physician as medically fit to wear respiratory protection and to work at hazardous waste sites.

Medical examinations and consultations will be provided according to the following schedule:

- Prior to participating in site operations;
- At least annually for personnel covered by the program;
- Upon termination of employment or reassignment to an area where the employee had not been examined within the past six months;
- As soon as possible after the development of signs or symptoms that may indicate an overexposure to hazardous substances or health hazards; and
- More frequently if the physician deems such examination necessary to maintain employee health.

Documentation for compliance with OSHA standards (29 CFR 1926.65) will be complete and accurate and will be kept on file for at least 30 years after termination of employment. A minimum of the following information will be kept:

- Name and social security number;
- Physician's written opinions, recommendations, limitations, and test results;
- Employee medical complaints related to hazardous waste operations; and
- Information provided to the physician by the employee concerning possible exposures, accidents, etc.

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6.0 SITE SAFETY AND CONTROL

6.1 SITE SAFETY

Personnel on site will be required to follow safe work practices contained in this section, and immediately notify the SHSO of conditions that do not comply with this section. These provisions are intended to be the minimum safe practices that site personnel will follow. Site safety is the responsibility of site personnel.

6.1.1 Traversing the Site

Field personnel will do the following:

1. Become familiar with the general terrain of the site and potential physical hazards (i.e., rocky conditions, uneven terrain) that would be associated with accidental slips, trips, and falls;
2. Be cautious after periods of heavy rainfall, which may cause earth movement and slides;
3. Be attentive where they walk since pits, holes, or similar hazards may be partially covered or visually obstructed;
4. Be cautious around soil or terrain that recently may have been disturbed, relocated, or otherwise made less stable; and
5. Avoid the top edges of drop-off areas whether they have been disturbed or not.

6.1.2 Equipment

6.1.2.1 Heavy Equipment

Physical hazards exist whenever heavy equipment or machinery is used. Heavy equipment will be operated in accordance with applicable OSHA regulations found in 29 CFR 1910 and 29 CFR 1926, the requirements of EM-385-1-92, and the following guidelines:

- Transportation of the heavy equipment to the work site will be performed by a person with the proper commercial license. The operation of heavy equipment will be limited to qualified authorized personnel specifically trained in its operation;
- A competent person will visually inspect heavy equipment daily prior to operation, and report abnormalities/deficiencies to the SHSO;
- The operator will use the safety devices provided with the equipment, including seat belts, backup warning indicators, and horns;
- The safety devices will be operable;
- Heavy equipment will have required safety equipment (i.e., 20-pound A:B:C fire extinguisher, emergency stops);
- While in operation, personnel not directly required in the area will keep a safe distance from the equipment;

- The operator's cab will be kept free of non-essential items and loose items will be secured;
- Personnel will avoid moving into the path of operating equipment and areas blinded from the operator's vision;
- Exhaust from equipment must be directed so that it does not endanger workers or obstruct the view of the operator;
- When heavy equipment is operating in tight quarters, or if operators of earth-moving equipment cannot see the bucket, a secondary person will be stationed to guide the operator;
- Additional riders will not be allowed on equipment unless it is specifically designed for that purpose (i.e., there is an additional seat with a seat belt);
- As large a distance as is feasible should be maintained to prevent contact with overhead/underground utilities with a minimum clearance of ten feet between the drill rig and these utilities at times;
- No drilling is to take place without the identification of underground utility lines by a representative of the utility company(s) or by the appropriate Installation personnel;
- Drilling contractors will provide documented safety and emergency action procedures for the equipment to be operated. The drilling contractor's employees will acknowledge in writing that they have read and understand these procedures;
- Personnel working in and around the equipment will be informed of the location of the kill switch in case of an emergency; and
- When not operational, equipment must be set and locked so that it cannot be activated, released, dropped, etc.

6.1.2.2 Power and Hand Tools

Power tools have the potential for inflicting serious injury upon site personnel when not properly used and maintained. Use of improper or defective tools can contribute significantly to the occurrence of accidents. To control the hazards associated with power and hand tool operation, the requirements outlined in EM-385-1-92, *Safety, Security and Environmental Rules for Contractors and Subcontractors (ATK 2000)*, and the safe work practices listed below will be observed.

- Operations/use will be conducted by authorized and experienced personnel;
- Tools will be inspected prior to use, and defective equipment will be removed from service until repaired;
- Tools will be selected and used in the manner for which they were designed;
- Tool operators will be sure of footing and grip prior to using tools;
- Power tools designed to accommodate guards will have such guards properly in place prior to use;
- Operators will not use tools that have split handles, mushroom heads, and worn parts;

- Safety glasses or a face shield will be used if use of tools presents an eye or face hazard;
- Operators will not use makeshift tools or other improper tools;
- Operators will use non-sparking tools in the presence of explosive vapors, gases, or residue;
- Loose fitting clothing or long hair will not be permitted around moving parts;
- Hands, feet, etc. will be kept away from moving parts;
- Maintenance and adjustments to equipment will not be made while equipment is in operation and power will be disconnected prior to maintenance;
- An adequate operating area will be provided, allowing sufficient clearance and access for operation; and
- Personnel will use required protective equipment, such as chaps and gloves.

6.1.3 Electrical Hazards

Overhead power lines, electrical wiring, electrical equipment, and buried cables pose the risk of electric shock, burns, muscle twitches, heart fibrillation, and other physical injuries, as well as fire and explosion. Workers will take appropriate protective measures when working near live electrical parts, including inspection of work areas to identify potential spark sources, maintenance of a safe distance, proper illumination of work areas, provision of barriers to prevent inadvertent contact, and use of non-conductive equipment. Electrical wiring and operating procedures will be conducted in accordance with OSHA standards (29 CFR 1910.137(2)), and EM-385-1-92, which includes a minimum ten feet clearance distance from energized overhead electric lines. In addition, the following safety rules apply:

- Do not ground yourself in water, on pipes, or drains;
- Work with electrical equipment will be limited to qualified personnel;
- Keep electrical controls accessible and well marked;
- Keep wires from becoming a trip hazard;
- Lockout/Tagout power/switches when working on electrical equipment;
- Never use metal ladders when working on electrical equipment;
- Ground electric tools; and
- Always test wires for current with a voltage indicator after lockout/tagout is performed.

Electrical equipment will be kept in proper working condition and will be immediately taken out of service if a shock hazard is detected or suspected. Ground-fault circuit interrupts will be incorporated into temporary wiring and flexible cords.

6.1.4 Fire Hazards

6.1.4.1 Causes of Fires and Explosions

Although fires and explosions may arise spontaneously, they are more commonly the result of carelessness during the conduct of site activities, such as moving drums, mixing/bulking of site chemicals, and refueling of heavy or hand held equipment. Some potential causes of fires and explosions include:

- Mixing of incompatible chemicals;
- Ignition of explosive or flammable chemical gases or vapors by external ignition sources;
- Ignition of materials due to oxygen enrichment;
- Agitation of shock or friction-sensitive compounds; and
- Sudden release of materials under pressure.

6.1.4.2 Fire Prevention

Explosions and fires pose the obvious hazards of intense heat, open flames, smoke inhalation, and flying objects, and may also cause the release of toxic chemicals into the environment. Such release can threaten both on-site personnel and members of the general public living or working nearby. Site personnel involved with potentially flammable material or operations will follow the guidelines listed below and EM-385-1-92 to prevent fires and explosions:

- Potentially explosive/flammable atmospheres involving gases or vapors will be monitored using a combustible gas indicator (CGI);
- Potential ignition sources will be removed or extinguished prior to initiation of site activities involving explosive/flammable materials;
- Non-sparking and explosion-proof equipment will be used whenever the potential for ignition of flammable/explosive gases/vapors/liquids exists;
- Dilution or induced ventilation may be used to decrease the airborne concentration of explosive/ flammable atmospheres;
- Smoking will be prohibited at work sites, or in the vicinity of operations that may present a fire hazard, and the area will be conspicuously posted with signs stating "No Smoking or Open Flame within 50 feet";
- Flammable and/or combustible liquids must be handled in approved, properly labeled metal safety cans equipped with flash arresters and self-closing lids;
- Transfer of flammable liquids from one metal container to another will be done when the containers are electrically interconnected (bonded); and
- The motors of equipment being fueled will be shut off during the fueling operations.

If the potential for fire and/or explosion emergencies is present, workers will continuously monitor the work area for combustible or explosive gases when operations have the potential to generate sparks. Employees will always be on the alert for unexpected events such as ignition of chemicals or sudden release of materials under pressure, and will be prepared to act in these emergencies.

6.1.4.3 Fire Protection

The following safe work practices will be used to protect against fires:

- Flammable/combustible liquid storage areas will have at least one 4A:20B:C fire extinguisher located within 25 to 75 feet, marked with the appropriate fire symbol and no smoking signs;
- Temporary offices will be equipped with a fire extinguisher having a rating of not less than 10:ABC;
- Field vehicles and heavy equipment will be equipped with fire extinguishers; and
- At least one portable fire extinguisher having a rating of not less than 20:ABC will be located at each work site.

Employees will be trained in the proper use of fire suppression equipment. However, professionals will handle large fires that cannot be controlled with a fire extinguisher.

6.1.5 Asbestos Abatement

Asbestos removal at RFAAP will be performed in strict accordance with current OSHA and USEPA regulations. In addition, the contractor will prepare a document entailing the detailed procedure he intends to follow to remove asbestos on this project. The procedure will specify safety precautions used to protect contractor personnel. This procedure must be approved by USACE prior to commencing insulation removal. Asbestos insulation removal will be performed by qualified personnel experienced in the safe handling of asbestos in accordance with USEPA and OSHA regulations and they will be licensed to perform asbestos abatement in the State of Virginia.

6.1.6 Trenching and Excavation

Excavation activities will be conducted in accordance with EM-385-1-92 and Subpart P of 29 CFR 1926. The guidelines below are intended to reflect minimum requirements to be followed on this site.

- The location of underground installations will be identified, if applicable, prior to initiation of excavation or trenching activity;
- Excavation and trenches will be sloped between 30° and 34° for Class C soil that has been impacted by munitions disposal activities;
- The excavation(s) will be inspected and documented daily by the SHSO prior to commencement or work activities;
- Evidence of cave-ins, slides, sloughing, or surface cracks will be cause for work to cease until necessary precautions are taken to safeguard workers;
- Excavations four feet or deeper that cannot be sloped will require a registered civil engineer or soils excavations specialist, to design and install a protective system;

- Protective systems will be selected from 29 CFR 1926 Subpart P and/or designed by a registered professional civil engineer;

- Spoils and other materials will be placed two feet or more from the edge of the excavation;

- Materials used for sheeting, shoring, or bracing will be in good condition;

- Timbers will be sound, free of large or loose knots, and of appropriate dimensions for the excavation;

- Safe access will be provided into the excavation(s) by means of a gradually sloped personnel access/egress ramp; and

- Excavations of four feet or more in depth will have a means of egress at a frequency such that lateral travel to the egress point does not exceed 25 feet.

6.1.7 Confined Space Entry

A confined space is space having a limited or restricted means of entry or exit, large enough and so configured that an employee can bodily enter and perform assigned activities; however, it is not designed for continuous employee occupancy. Confined spaces can subject personnel to the accumulations of toxic or flammable contaminants, contain physical hazards, or have an oxygen-deficient atmosphere. Confined spaces include, but are not limited to the following: storage tanks, process vessels, bins, ventilation or exhaust ducts, sewers, tunnels, pipelines, underground utility vaults, and open-top spaces more than four feet in depth such as pits, trenches, tubs, vaults, and vessels. Confined space entries must be in accordance with OSHA standards (29 CFR 1926.21 and 1910.146), NIOSH 80-106, and HQUSACE (June 1994).

Confined space entry can present many health and safety hazards if not performed properly. These hazards include:

- Atmospheric (oxygen deficiency, flammable or explosive atmosphere, toxic or poisonous exposure);

- Physical (poor lighting, poor visibility, falling objects, wet and slippery surfaces, rodents and insects, trip or fall hazards);

- Environmental hazards (hot or cold temperatures, humidity, noise and vibration, harmful bacteria);

- Structural hazards (excessive depths/heights, sharp or protruding objects, movable equipment such as ladders or scaffolding);

- Energy hazards (mechanical, electrical, hydraulic, pneumatic, thermal);

- Engulfment (asphyxiation and flooding);

- Communication (echo, radio interference, inoperative radios, etc.);

- To mitigate these hazards, the following safety precautions will be taken when personnel are required to enter a confined space;

- Evaluate the confined space and identify potential hazards prior to entry;

- Prepare an inventory of confined spaces to identify whether they are permit- or non-permit-required confined spaces (as defined in 29 CFR 1910.146) and ensure they are properly labeled;

- Complete necessary confined space entry permits;

- Lockout/tag out process piping, mechanical and electrical equipment, purge tanks, if necessary, and secure tools and equipment;

- Ensure that the space is well lighted and ventilated (may require explosion proof lighting and forced ventilation equipment);

- Establish roles of team members (entrant, attendant, and supervisor) and review the contents and requirements of the confined space entry procedure with the team members (as defined in 29 CFR 1910.146);

- Review possible rescue scenarios, stress the importance of the buddy system and retrieval system (include lanyards, harnesses, extraction devices, etc.) for immediate assistance, and set up the retrieval system; and

- Perform continuous-air monitoring, in sequence, as follows:

    1. Verify oxygen content: 19.5 - 23.5 percent (%);

    2. Verify flammable atmosphere: Lower Explosive Limit (LEL) less than 10%; and

    3. Monitor for organic vapor concentrations.

Confined space entry activities will be performed in accordance with OSHA standards (29 CFR 1926.21 and 1910.146), NIOSH 80-106, and HQUSACE (June 1994). In addition, team members participating in these activities will have completed an OSHA-certified 16-hour confined space entry training course. Rescue personnel must have an additional eight hours of OSHA-certified training in confined space entry rescue.

6.1.8 Weather Hazards

Weather conditions will be taken into consideration. Heavy rains or snowfall, electrical storms, high winds, and extreme temperatures may create extremely dangerous situations for employees. Inclement weather may also impair equipment performance. Whenever unfavorable conditions arise, the FOL and SHSO will evaluate both the safety hazards and ability of the employees to effectively perform given tasks under such conditions. Activities will be halted at their discretion.

Thunderstorms pose an electrocution hazard. Outdoor work-related activities will cease and personnel on site will take refuge in buildings or in vehicles during thunderstorms.

Wind direction should be considered when positioning for sampling or conducting intrusive work. If exposure to contaminant emissions is anticipated, workers should locate upwind. Wind direction often changes abruptly and without warning, so personnel should always be prepared to reposition, if necessary.

6.1.9 Radiation Hazards

If it is ascertained that radiation hazards might be present, an external screening survey for gamma radioactivity will be performed by properly trained personnel to identify background radiation levels prior to initiation of intrusive field activities.

6.1.10 Additional Safety Items

Additional safety items include the following:

- Health and safety audits will be conducted by the PHSO to ensure that site activities are being performed in accordance with this HSP, USACE requirements, OSHA regulations, RFAAP requirements, contractor standard operating procedures (SOPs), and contract requirements;

- The SHSO will ensure that appropriate PPE is available for personnel and is used as directed in this HSP. The SHSO will be responsible for ensuring that job site hazards are properly controlled to provide safe ingress and egress from the sites. Cones and high-visibility banner guard (when deemed necessary by the SHSO) will be used to control traffic and limit access to hazardous and restricted areas;

- A tailgate safety meeting will be conducted to discuss pertinent site safety topics at the beginning of each shift, whenever new personnel arrive at the job site, as site conditions change, and whenever otherwise deemed necessary. These meetings will be conducted by the SHSO, and relevant information will be recorded in the site logbooks. Site personnel and visitors are required to attend these meetings and acknowledge their understanding and attendance by signing the health and safety field logbook. Necessary information from these meetings will be forwarded to the PHSO;

- Emphasis will be placed on compliance with state, local, and Installation motor vehicle laws, regulations, and safety guidelines as part of each daily safety briefing. Special considerations, such as current or anticipated hazardous road conditions, will be addressed;

- Emergency telephone numbers will be posted for the fire department, emergency medical response, and the nearest emergency medical clinic/hospital. These numbers are listed in Section 10 of this HSP;

- An OSHA approved eyewash station will be located within 100 feet and ten-second access to the work area;

- At least one copy of this Master HSP and its addenda will be available at each work site;

- Horseplay, practical joking or other actions that could jeopardize safety will not be tolerated;

- Running is not permitted;

- Alcoholic beverages and non-medicinal drugs are not permitted at the project site. Personnel suspected of being under the influence of alcohol or drugs will be removed from the site;

- Radios (except two-way radios), tape players, CD players or other forms of entertainment devices are prohibited during work;

- Legible and understandable precautionary labels will be affixed prominently to containers of contaminated scrap, waste, debris, and clothing;
- Monitoring equipment will not be placed on potentially contaminated surfaces;
- Personnel will avoid contact with potentially contaminated substances. Walking through puddles or mud, kneeling on the ground, or leaning against drums will be avoided;
- Removal of soil from protective clothing or equipment by blowing, shaking or other means that will disperse potential contaminants into the air is prohibited;
- Transportation and disposal of contaminated materials will comply with applicable local, State, and Federal regulations. These items will be addressed by the generator, transporter, and disposer;
- Containers will be moved with the proper equipment and will be secured to prevent dropping or loss of control during transport;
- Emergency equipment (including first aid equipment, emergency-use respirators, spill control materials, and fire extinguishers) will be located in readily accessible locations;
- Trenching, shoring, and excavation work will comply with OSHA rules;
- No food or beverages will be present or consumed in the Exclusion Zone (EZ). No tobacco products or cosmetics will be present or used in the EZ;
- Field personnel will observe each other for signs of toxic exposure. Indications of adverse effects include, but are not limited to: changes in complexion; changes in coordination; changes in demeanor; excessive salivation and papillary response; and changes in speech pattern;
- Field personnel will be cautioned to inform each other of non-visual effects of toxic exposure such as: headaches, dizziness, nausea, blurred vision, cramps; and irritation of eyes, skin, or respiratory tract; and
- Prompt remedial action will be taken whenever an inadvertent release of a hazardous material occurs.

In addition to avoiding the potential physical, chemical, and biological health and safety hazards that may be encountered in field activities, it is essential that personnel heed precautions and rules. To ensure safe work practices and conditions, the SHSO will record incidents of noncompliance with this HSP, follow up on "near miss" incidents, and rectify noted safety problems.

6.2 SITE CONTROL

6.2.1 Site Preparation

Drilling, excavation, and sampling activities will be conducted outside existing buildings. In addition, no roads will be built or buildings demolished during the RFAAP field activities. The appropriate measures for coordinating road and site access for drill rigs and other heavy equipment will be identified by the FOL.

6.2.2 Site Work Zones

To ensure against the accidental spread of hazardous substances by workers from contaminated areas to clean areas, zones will be delineated on site where intrusive investigative activities occur, and the flow of personnel in these zones will be controlled. The establishment of site work zones will help ensure that personnel are properly protected against the hazards present where they are working, that work activities and contamination are confined to the appropriate areas, and that personnel can be located and evacuated in an emergency.

The site work zones that will be used during intrusive investigative activities, as deemed necessary by the SHSO, will include:

- EZ - the contaminated area;
- Contamination Reduction Zone (CRZ) - the area where decontamination of PPE takes place; and
- Support Zone (SZ) - the uncontaminated area where workers should not be exposed to hazardous conditions.

Access to the exclusion zone and CRZ will be strictly limited to individuals who meet medical monitoring, training, and PPE requirements of the site. Visitors who have received the appropriate training, are medically qualified, and are wearing the appropriate level of protection must receive a site safety briefing and will be escorted within these zones by the SHSO. Visitors who do not meet the specified requirements will remain in the support zone.

6.2.2.1 Exclusion Zone

The EZ is a work area where the greatest hazard potential for exposure to safety and health hazards may or is known to exist. The size of the EZ will be identified by the SHSO, in coordination with USACE, and will be based on several factors including: type and amount of suspect contamination; proximity of the site to populated areas; and potential for migration of contamination off-site. Personnel entering the EZ must wear the prescribed levels of PPE. Entry and exit control points will be established at the EZ to regulate the flow of personnel and equipment into and out of the EZ. The entry and exit control points are utilized to ensure that personnel and equipment are protected and that contamination located inside the EZ is properly contained. The entry and exit control points will be established upwind from the EZ to prevent airborne contaminants from migrating into areas where personnel are working with the aid of PPE. Unprotected onlookers will be located at least 50 feet upwind of such activities. The site's prevailing wind direction will be used to select the entry and exit control points, but alternate points may need to be selected if the wind direction changes or an emergency arises which precludes the use of the designated personnel decontamination station. No eating, drinking, tobacco product use, application of cosmetics or hand-to-face activities is allowed in this area.

The outer boundary of the EZ is called the "hotline." The hotline separates the area of known or potential contamination from the rest of the site. The hotline should be physically secured or clearly marked. The EZ may be subdivided into different area of contamination. If the EZ is subdivided, different levels of PPE may be appropriate. Each sub-area of the EZ should be clearly marked to identify hazards and required levels of PPE.

6.2.2.2 Contamination Reduction Zone

The CRZ is the transition zone between the EZ and the support zone and serves as a buffer to reduce the probability of clean areas becoming contaminated or affected by hazards in the EZ. This zone should always be located upwind of the EZ. It provides additional assurance that the transfer of contamination on personnel, equipment, or in the air is limited through the use of a combination of decontamination, segregation of site operations, dilution, ventilation, and distance between the exclusion and support zones.

The CRZ is also the location of the personnel decontamination station, equipment decontamination station, and the emergency personnel decontamination station. These stations are used to effectively prevent the spread of chemical contamination into clean areas through the application of chemical specific decontamination procedures. These procedures are outlined in Section 8.0 of this HSP. No eating, drinking, tobacco product use, application of cosmetics or hand-to-face activities is allowed in this area.

Personnel in this area will be required to wear the higher of at least Level D PPE or PPE that is one level less than that worn in the EZ. Personnel will also be prepared to enter the EZ in case of emergency. The CRZ will have one accessible point to the EZ.

6.2.2.3 Support Zone

The SZ is the uncontaminated area outside the CRZ where workers are unlikely to be exposed to hazardous substances or dangerous conditions. The SZ is the appropriate location for the command post, first aid station, lunch and break areas, change area, equipment and supply center, field laboratory, and other administrative or support functions that are necessary to keep site operations in the EZ and CRZ running efficiently.

Personnel in the SZ can wear normal work clothes since this area is designated as the clean area and contaminated equipment and clothing must be left in the CRZ or EZ. Personnel located in the SZ must receive instruction in proper evacuation procedure in case of hazardous substance emergency. The SZ will be upwind and as far from the EZ as practicable.

6.2.3 Base Access and Security

RFAAP consists of areas open to the public and areas with restricted access. Access to a work site is cleared through Post Security. Approved personnel must escort visitors. Access through the main gate to RFAAP is controlled by Post Security Guards. Personnel are required to sign in and out when entering and leaving the restricted area. Visitors are issued a visitor's badge. Badges must be on personnel and in full sight.

6.2.4 On/Off-Site Communications

Successful communication between the field teams, among personnel in the various zones, and with emergency services is essential. The following communications systems, when appropriate, will be used during field activities at RFAAP:

- Walkie-talkies;
- Compressed air horn;
- Military telephone located at RFAAP;
- Cellular telephones; and
- Hand signals.

6.2.5 Site Security

Site security is provided in order to restrict unauthorized access to the site. The FOL and SHSO will be responsible for maintaining limited access to working areas of the site using fences or other physical barriers. The FOL will coordinate security with RFAAP security personnel. RFAAP security personnel will be requested to investigate suspicious activities at the field sites. Security at the site, including weekend security, will be the responsibility of RFAAP.

To maintain security at RFAAP during working hours, the FOL will:

1. Control site entrances and exits;

2. Establish a personnel identification system;

3. Be responsible for enforcing entry and exit requirements; and

Use temporary fencing where feasible. To maintain security during non-working hours, the FOL will secure the site prior to leaving at the end of the workday. Equipment and supplies will be secured or stored in locked facilities, and open borings will be covered with plywood or similar material. If excavations must be left open and unattended, the opening will be barricaded and made visible.

6.2.6 Site Sanitation

Adequate toilet facilities will be set-up in the support zone for the average number of persons on-site for a given week with adherence to OSHA guidance. Additionally, personnel hygiene washing facilities will also be set-up in the SZ. Trash receptacles will be staged on site including the exclusion zone if needed.

6.2.7 Spill Containment Program

A spill containment program will be implemented during site activities that meet drum and container handling requirements in accordance with 29 CFR 1910.120. Hazardous substances and contaminated soils, liquids, and other residues also will be handled, transported, labeled, and disposed of in accordance with this regulation. If a major spill occurs, the contractor will contact the RFAAP Fire Department immediately and, if possible, implement controls to contain and isolate the spilled substance.

7.0 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

PPE will be required during fieldwork at RFAAP. The minimum PPE required during work at RFAAP includes hardhat, safety glasses, and steel-toed boots. Because the scope of activities will differ for each phase of the project, task-specific PPE requirements and action levels will not be general for RFAAP. PPE requirements for specific tasks performed at RFAAP will be included in the site-specific WPA. The initial selection of PPE will be based on a hazard assessment, including the review of existing analytical data and related toxicological information with respect to the proposed field activities. PPE assignments are subject to change based on site conditions and task variation.

The SHSO will review the required level of protection and safety equipment for each task with the sampling crew. The decision of which protective level is most appropriate will be made by the SHSO. The CIH will be responsible for approving personal protective equipment and clothing. The level of protection selected will be based on:

- The type and measured concentration of the chemical substance having the lowest PEL, TLV, and/or IDLH concentration in the ambient atmosphere, its range of toxic properties and LEL, and the identified degree of hazard; and

- Potential for exposure to substances in the air, liquid splashes, or other direct contact with hazardous materials.

In situations where the chemical identity, concentrations, and possibility of contact are not well characterized, the appropriate level of protection will be one level higher than the suspected level of protection, based on professional experience and judgment, until the hazards can be better identified.

During specific sampling activities, the SHSO will monitor the site for potentially hazardous airborne contaminants or physical hazards using the following instrumentation:

- A photoionization detector/flame ionization detector (PID/FID) will be used to detect organic vapors. The PID/FID will be calibrated in accordance with the manufacturer's calibration instructions. If appropriate, Draeger tubes will be used to monitor for specific contaminants based on the readings from the other instruments; and

- A CGI/oxygen (CGI/O_2) meter will be used to monitor pit locations. This equipment will be used to assess ambient oxygen concentrations and the percentage of the LEL at the boring or pit. If 10% of the LEL or greater is indicated, work at the site will be stopped until the levels decrease to less than 10% LEL.

7.1 LEVELS OF PROTECTION

7.1.1 Level D Personal Protective Equipment and Clothing

This section presents the minimum level of PPE necessary for Level D. Personnel working within the exclusion zone will be required to wear, as a minimum:

- Normal work clothes or coveralls;

- Leather steel-toed work boots (with chemical resistant overboots as necessary) or chemical resistant, steel-toed boots meeting ANSI standard Z41-1983, Safety-Toe Footwear Classification 75. Approval of the boot type will be the responsibility of the SHSO;

- Eye protection, such as face shields, goggles, or safety glasses with side shields that meet ANSI standard Z87.1-1979 (Approval of eye protection equipment will be the responsibility of the SHSO);

- Hard hats meeting ANSI standard Z89.1-1986, Class A, B, and C (required for operations around heavy equipment or in the presence of overhead hazards);

- Chemical resistant (latex and nitrile) gloves; and

- Hearing protection, such as earmuffs or disposable plugs (as required).

7.1.2 Modified Level D Personal Protective Equipment and Clothing

This section presents the minimum level of PPE necessary for Modified Level D. Personnel working within the exclusion zone will be required to wear, as a minimum:

- Cotton or disposable coverall (Tyvek®) or work uniform;

- Leather steel-toed work boots (with chemical resistant overboots as necessary) or chemical resistant, steel-toed boots meeting ANSI standard Z41-1983, Safety-Toe Footwear Classification 75. Approval of the boot type will be the responsibility of the SHSO;

- Eye protection, such as face shields, goggles, or safety glasses with side shields that meet ANSI standard Z87.1-1979. Approval of eye protection equipment will be the responsibility of the SHSO;

- Hard hats meeting ANSI standard Z89.1-1986, Class A, B, and C (required for operations around heavy equipment or in the presence of overhead hazards);

- Chemical resistant (latex and nitrile) gloves; and

- Hearing protection, such as earmuffs or disposable plugs (as required).

7.1.3 Level C Personal Protective Equipment and Clothing

Level C protection consists of the following:

- Respirators: full-face air purifying, NIOSH approved, with organic vapor and high-efficiency particulate air (HEPA) filters;

- Coveralls: disposable, chemical resistant (poly-ethylene-coated Tyvek®);

- Work boots: leather steel-toed or chemical-resistant steel-toed boots meeting ANSI standard Z41-1983, Safety-Toe Footwear, and Classification 75. Approval of the boot type will be the responsibility of the SHSO;

- Hard hat: meeting ANSI standard Z89.1-1986, Class A, B, and C (required for operations around heavy equipment or in the presence of overhead hazards);

- Hearing protection: ear muffs or disposable plugs (as required); and
- Gloves: chemical-resistant (nitrile) outer with latex inner gloves.

7.1.4 Level B Personal Protective Equipment and Clothing

Level B protection consists of the following:

- SCBA or Air Line Respirator (ALR) with the required five minute escape bottle. If the individual requires corrective lenses, a prescription insert will be used. The individual will not be permitted to wear contact lenses;
- Chemically resistant clothing - overalls/coveralls;
- Gloves (inner), chemical-resistant (latex or nitrile);
- Gloves (outer), chemical-resistant (nitrile or butyl);
- Chemical resistant overboots (neoprene or polyvinyl chloride (PVC)) with steel toes and shanks;
- Hard hat; and
- Hearing protection (as required).

7.1.5 Level A Personal Protective Equipment and Clothing

Level A protection consists of the following:

- SCBA or ALR with the required five minute escape bottle. If the individual requires corrective lenses, a prescription insert will be used. The individual will not be permitted to wear contact lenses;
- Totally encapsulating chemical resistant clothing;
- Coveralls;
- Gloves (inner), chemical-resistant (latex or nitrile);
- Gloves (outer), chemical-resistant (nitrile or butyl);
- Chemical resistant overboots (neoprene or PVC) with steel toes and shanks;
- Hard hat (under suit); and
- Hearing protection (as required).

7.2 PROTOCOLS FOR CHANGING LEVELS OF PROTECTION

The level of protection provided by PPE selection will be upgraded or downgraded based on action levels from direct-reading instruments or a change in site conditions. When a significant change occurs, the hazards should be reassessed. Some indicators of the need for reassessment are:

- Commencement of a new work phase;

- Change in job tasks during a work phase;
- Change of season/weather;
- Contaminants other than those previously identified are encountered/handled;
- Change in work scope that affects the degrees of contact with contaminants; and
- Change of ambient levels of contaminants.

Changes in level of protection will be the responsibility of the SHSO in consultation with the site supervisor. In order to effect changes in protection levels, the SHSO must document the reason for change and notify the CIH.

7.3 RESPIRATOR SELECTION AND FIT TEST

The contractor will require personnel who work on potentially hazardous sites to participate in a respiratory protection program. A qualitative fit test will be performed on each individual slated for field work at least once per year or more frequently as required by law. Training on use, maintenance and cleaning of respiratory protective equipment is included as part of the employee's eight-hour annual refresher training course. Each person receives documentation of the size, brand, and model number of the air-purifying respirator that he or she is approved to use. This information will be retained in the corporate health and safety files.

8.0 PERSONNEL AND EQUIPMENT DECONTAMINATION

Decontamination procedures are necessary to protect field personnel and control the spread of contamination by either personnel or equipment. Personnel participating in the RFAAP field activities may potentially become contaminated in a number of ways, including:

- Contacting vapors, gases, mists, or particulates in the air;
- Being splashed by materials while sampling; and
- Walking on contaminated soil.

8.1 MODIFIED LEVEL D DECONTAMINATION

The SHSO will establish the level of decontamination for Modified Level D PPE based on site conditions.

- A CRZ will be located outside the "hotline" where personnel routinely enter or exit the exclusion zone. When exiting the exclusion zone, an equipment drop area will be established to stage for re-entry or decontamination. Personnel will wash/rinse chemical-resistant overboots and outer gloves. Personnel will then don the chemical-resistant overboots (if used), outer coverall, and outer gloves when in the specified CRZ;
- PPE removed will remain in the CRZ pending personnel re-donning the clothing. At the conclusion of work, PPE will be placed in plastic bags prior to disposal or transfer off site; and
- Personnel will not be permitted to exit the CRZ area until contaminated clothing and equipment are removed.

8.2 LEVEL C DECONTAMINATION

A more stringent decontamination process will be required for Level C PPE. Level C decontamination will include the following:

- A CRZ will be located outside the "hotline" where personnel routinely enter or exit the exclusion zone. When exiting the exclusion zone, an equipment drop area will be established to stage for re-entry or decontamination. Personnel will wash/rinse chemical-resistant overboots and outer gloves. Personnel will doff chemical-resistant overboots (if used), outer coverall, and outer gloves when in the specified CRZ. Air purifying respirators will be removed last;
- Personnel will be instructed in proper decontamination techniques. This will entail removal of protective clothing in an "inside out" manner. Removal of contaminants from clothing or equipment by blowing, shaking, or other means that may disperse material into the air will be prohibited;
- PPE removed will remain in the CRZ pending personnel re-donning the clothing. At the conclusion of work, PPE will be placed in plastic bags prior to disposal or transfer off site; and
- Personnel will not be permitted to exit the CRZ area until contaminated clothing and equipment have been removed.

8.3 LEVEL B DECONTAMINATION

Based on the current information available for the RFAAP field activities, it will not be necessary to use Level B PPE. Therefore, no procedures for decontamination of Level B PPE have been included. If it becomes necessary to upgrade to Level B, field operations will be suspended and a modification to this HSP will be developed to address the decontamination requirements.

8.4 LEVEL A DECONTAMINATION

Based on the current information available for the RFAAP field activities, it will not be necessary to use Level A PPE. Therefore, no procedures for decontamination of Level A PPE have been included. If it becomes necessary to upgrade to Level A, field operations will be suspended and a modification to this HSP will be developed to address the decontamination requirements.

8.5 OTHER DECONTAMINATION/DISPOSAL PROCEDURES

8.5.1 Disposable PPE

Disposable PPE will be securely contained in plastic bags placed in 55-gallon drums staged near the decontamination pad prior to disposal.

8.5.2 Equipment Decontamination

Heavy equipment (i.e., drill rig, backhoe, tools, augers, bits) will be decontaminated by steam cleaning with water from an RFAAP-approved source. Drilling and excavation equipment will be decontaminated between locations at a decontamination pad located on site. Decontamination of sampling equipment will include washing with a non-phosphate detergent and rinsing with approved decontamination water. Equipment will again be rinsed with deionized water and allowed to air dry. Decontaminated sampling equipment will be wrapped in plastic for transport to the site to prevent contamination of the equipment and materials. Wastewater generated during personnel and equipment decontamination will be temporarily containerized upon generation and transferred to RFAAP's industrial plant for disposal. PPE to be used during equipment decontamination will consist of chemical resistant gloves and boots, splash suits, eye protection, and hard hats. Glasses/goggles that are worn underneath protective suits are not approved as eye protections. Further details on decontamination procedures are provided in site-specific WPA.

8.6 DECONTAMINATION DURING MEDICAL EMERGENCIES

In the event of an emergency on site, emergency personnel are to be immediately informed of the injured person's condition, potential contaminants, and provided with pertinent chemical data available. Site personnel are to take directions from the emergency teams upon their arrival.

If immediate life-saving first aid or medical treatment is required, decontamination procedures will be omitted. Outer garments can be removed as long as it does not delay giving the proper care or aggravate the condition. Grossly contaminated clothing should be removed carefully, because clothing can transfer contaminants to people administering first aid. If the outer contaminated garments cannot be safely removed, the individual will be wrapped in plastic, rubber, or blankets to help prevent the spread of contamination to emergency personnel. On-site personnel will accompany contaminated victims to the medical facility to advise on matters involving decontamination.

8.7 PERSONNEL DECONTAMINATION SEQUENCE

8.7.1 Level D Decontamination

1. Segregated equipment drop; and
2. Hand and face wash.

8.7.2 Modified Level D Decontamination

1. Segregated equipment drop;
2. Outer boot and glove wash/rinse;
3. Outer boot and glove removal;
4. Coverall removal/disposal;
5. Inner glove removal/disposal; and
6. Hand and face wash.

8.7.3 Level C Decontamination

1. Segregated equipment drop;
2. Outer boot and glove wash/rinse;
3. Outer boot and glove removal;
4. Coverall removal/disposal;
5. Respirator removal;
6. Inner glove removal/disposal;
7. Hand and face wash; and
8. Respirator cleaning/sanitizing.

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9.0 MONITORING PLAN

9.1 INTRODUCTION

Monitoring will be conducted during site activities to evaluate the potential for personal exposure to chemical and physical hazards. Monitoring of these hazards will assist in the following:

- Evaluating site conditions prior to initiation of site activities;
- Determining the effectiveness of engineering controls, work zones, and safe work practices;
- Evaluating the threat posed by contamination to site workers, the environment, and the general public;
- Recording historical data related to exposure levels during site activities; and
- Assessing the need for upgrading or downgrading PPE requirements.

Various real-time or near real-time (NRT) direct reading instruments will be utilized whenever possible during site operations that have the potential for causing personal exposure to chemical or physical hazards. A daily air-monitoring log must be maintained by the SHSO.

9.2 MONITORING INSTRUMENTS

The following sections discuss the general types of equipment available for the monitoring of chemical and physical hazards. Where a specific instrument is named, efforts will be made to utilize that equipment since it has the best capability and sensitivity for monitoring the given hazard. Where a general type of monitoring instrument is listed to monitor a given hazard (i.e., noise), an instrument that can adequately monitor the hazard will be permitted.

9.2.1 Flame Ionization Detector/Photoionization Detector

Organic vapor readings will be taken initially and continuously in the breathing zone during intrusive activities using a FID or PID. Because the scope of work will differ for each phase of this project, action levels will not be general for RFAAP. Site-specific action levels for organic vapor readings will be presented in the HSP of each site-specific WPA.

9.2.2 Combustible Gas Indicator/Oxygen Meter

A CGI/O_2 meter will be used initially and continuously during intrusive site activities to monitor LEL and percent oxygen concentrations. Each reading will be taken at the surface of the intrusion. The action levels for the CGI/O_2 meter are presented below.

Explosimeter

- Less than 10% LEL: Continue work;
- 10 to 25% LEL: Continue monitoring and work with extreme caution and keep ignition sources away from work area; and.
- Greater than 25% LEL: Evacuate work area.

Note: For permit-required confined space entries, the space must be evacuated if the LEL exceeds 10%.

Oxygen Meter

- 19.5 to 25%: Continue work, monitor for LEL conditions; and
- Less than 19.5% or greater than 25%: Evacuate work area.

Note: For permit-required confined space entries, the space must be evacuated if oxygen is greater than 23.5%.

9.2.3 Radiation Survey Meter

If it is ascertained that a radiation hazard might be present, a radiation survey meter will be used initially and every 30 minutes during intrusive activities. Readings will be taken near intrusion surface. Site-specific WPA will discuss action levels.

9.2.4 Particulate (Dust) Monitor

If operations that generate dust will occur, dust monitoring will be performed using a direct-reading total particulate monitor in the employee-breathing zone. If there is visible dust in the breathing zone or if levels exceed one milligram per cubic meter (mg/m^3); Level C protection will be worn, including a respirator with HEPA cartridges.

9.3 TYPES OF MONITORING

The monitoring outlined in this section has been designed to allow for assessment of personnel exposure to both chemical and physical hazards. The monitoring schedule outlined in this section provides for the conduct of work area and perimeter monitoring and collection of personal breathing zone samples. Monitoring will be conducted at a frequency needed to identify exposure levels and potential IDLH conditions. The following outlines the minimum schedule for monitoring the anticipated chemical and physical hazards:

- Upon initial entry onto the site;
- When weather conditions change;
- When work begins on another portion of the site;
- Every five feet or 15 minutes during drilling; and
- At a minimum of once per hour.

9.3.1 Work Area Monitoring

The contractor personnel will monitor for chemical and physical hazards in the work area. Table 9-1 lists the anticipated chemical hazards to monitor and includes a description of type of instrument(s) to be used for each contaminant.

9.3.2 Perimeter Monitoring

Where it has been identified that there may be off-site migration potentials of airborne concentrations of hazardous substances, appropriate direct-reading air monitoring and TWA air sampling will be conducted in accordance with applicable Federal and state regulations. Sampling and analytical methods will follow USEPA or NIOSH criteria.

Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV * NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ Ionization Potential (IP)
acetone 67-64-1 dimethyl/ketone, ketone, propane, 2-propanene	1000 ppm-PEL† 500 ppm-TLV; 750 ppm-ST$^{)}$ 250 ppm-REL 2500 ppm-[10% LEL]-IDLH	Colorless liquid with a fragrant, mint-like odor.	Class IIB Combustible Liquid 0°F 2.5% 12.8%	Irritant to eyes, nose, throat; headache, dizziness; dermatitis; CNS depression	NIOSH 1300/3800 Butyl IP = 9.69 eV
acrolein 107-02-8 acraldehyde, acrylaldehyde, acrylic aldehyde, propenal, 2-propenal	0.25 mg/m^3-PEL * 0.25 mg/m^3-REL, 0.8 mg/m^3- ST† 4.58 mg/m^3-IDLH	Colorless or yellow liquid with a piercing, disagreeable odor.	Class IB Flammable Liquid -15°F 2.8% 31%	Irritant to eyes, skin, mucous membranes; decreases pulmonary function; chronic respiratory disease, delayed pulmonary edema	NIOSH 2501 Butyl IP = 10.13 eV
acrylonitrile 107-13-1 acrylonitrile monomer, AN, cyanoethylene, propenenitrile, 2-propenenitrile, VCN, vinyl cyanide	2 ppm-PEL, 10 ppm-C[15] * 1 ppm-REL, 10 ppm-C[15], Ca 85 ppm-IDLH, Ca	Colorless to pale-yellow liquid with an unpleasant odor. Note: Odor can only be detected above the PEL.	Class IB Flammable Liquid 30°F 3% 17%	Irritates eyes, skin; asphyxiant; headache; sneezing; nausea, vomiting; weakness, lightheadedness; skin vesiculation; scaling dermatitis, dizziness, exhaustion	NIOSH 1604 Butyl IP = 10.91 eV
antimony 7440-36-0 stibium	0.5 mg/m^3-PEL * 0.5 mg/m^3-REL 50 mg/m^3-IDLH	Silver-white lustrous, hard, brittle solid; scale-like crystals; or a dark-gray lustrous powder.	Noncombustible Solid‡ * * *	Irritates eyes, skin, nose, throat, mouth; cough; dizziness; headache; nausea, vomiting, diarrhea; stomach cramps; insomnia, unable to smell properly, anorexia	P&CAM 261 Any barrier that will prevent contamination IP = NA
arsenic (inorganic) 7740-38-2 (As) also applies to arsenic compound As	0.01 mg/m^3-PEL 0.01 mg/m^3-TLV, A1 0.002 mg/m^3-C, Ca 5 mg/m^3-IDLH, Ca	Metal: Silver-gray or tin-white, brittle, odorless solid.	Noncombustible solid‡ * * *	Ulceration of the nasal septum, dermatitis, gastrointestinal disturbances, respiratory irritation, hyperpigmentation of skin, peripheral nueropathy	NIOSH 7300/7900 Contact the manufacturer IP = NA
arsenic, organic compounds	0.5 mg/m^3-PEL * None-REL ND-IDLH	Appearance and odor may vary depending on the specific organic arsenic compound.	Properties vary depending upon the specific organic arsenic compound. *	In animals: irritates skin, possible dermatitis; respiratory distress; diarrhea; kidney damage; possible GI tract, possible liver damage.	NIOSH 5022 Contact the manufacturer IP=*

Table 9-1 (continued)
Chemicals/Compounds of Concern
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV [(b)] NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
asbestos 1332-21-4 actinolite, amosite, anthophyllite, chrysotile, crocidolite, tremolite	0.1 fiber/cm^3-PEL * 0.1 fiber/cm^3-REL, Ca ND-IDLH, Ca	White or greenish, blue, or gray-green fibrous, odorless solids.	Noncombustible Solids. NA NA NA	Asbestosis, restricted pulmonary function, irritates eyes, finger clubbing, breathing difficulty, interstitial fibrosis.	NIOSH 7400/7402 Any barrier that will prevent contamination IP=NA
Barium 744-39-3 barium (soluble compounds as barium salts)	0.5 mg/m^3-PEL 0.5 mg/m^3-TLV 0.5 mg/m^3-REL 1100 mg/m^3-IDLH	*	*	Upper respiratory irritation, gastrointestinal disturbances, muscle spasms, slow pulse, irritation of eyes, skin burns.	Air Sampling Contact the manufacturer
Benzene 71-43-2 benzol,, phenyl hydride	1 ppm-PEL, 5 ppm-ST 0.5 ppm-TLV, skin; 2.5 ppm ST, A1 (proposed)[(d)] 0.1 ppm-REL, 1 ppm-ST 500 ppm-IDLH, Ca	Colorless to light-yellow liquid with an aromatic odor.	Class IB Flammable Liquid 12°F 1.2% 7.8%	Irritates eyes, skin, nose, respiratory system; giddiness; headache, nausea, staggered gait; fatigue, anorexia, lassitude; dermatitis; bone marrow depressant	NIOSH 1500/1501/ 3701/3800 PVA IP=9.24 eV
Beryllium 7440-41-7 beryllium metal	0.002 mg/m^3-PEL, 0.005 mg/m^3-C, 0.025[30] * NTE 0.0005 mg/m^3-REL, Ca	Metal: A hard brittle, gray-white solid.	Noncombustible Solid in bulk form NA NA NA	Berylliosis; anorexia, weight loss, weakness, exhaustion, chest pain, cough, clubbing of fingers, cyanosis, pulmonary insufficiency; irritation of eyes; dermatitis	NIOSH 7102 Contact the manufacturer IP=NA
bis(2-chloroethoxy) methane 111-91-1 dichloromethoxyethane, 1,1'-[methylene(oxy)] bis [2-chloroehtane], dichloroethyl formal	None-PEL None-TLV None-REL None-IDLH	Colorless liquid.	Nonflammable Liquid 230°F * *	Irritates eyes, skin; wheezing, coughing, shortness of breath, burning in mouth, throat, chest	Air Sampling Tyvek Viton
bis(2-chloroethyl) ether 111-44-4 dichloroethyl ether, 2,2'-dichlorodiethyl ether; 2,2'-dichloroethyl ether	15 ppm PEL† * 5 ppm-REL, 10 ppm-ST, Ca 100 ppm-IDLH, Ca	Colorless liquid with a chlorinated solvent-like odor.	Class II Combustible Liquid 131°F 2.7% *	Irritates nose, throat, respiratory system; lacrimation; cough; nausea, vomiting; in animals: pulmonary edema; liver damage	NIOSH 1004 Teflon [4], Tychem [8] IP = *

Table 9-1 (continued)
Chemicals/Compounds of Concern
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV$^{(b)}$ NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
bis(2-chloroisopropyl) ether 108-60-1 dichloroisopropyl ether, bis(2-chloro-1-methyethyl)ether, 2,2'dichloroisopropyl ether, DCIP	None-PEL None-TLV None-REL None-IDLH	Colorless to light brown liquid.	Combustible Liquid 185°F * *	Irritates eyes, respiratory system, skin; liver, kidney damage	Air Sampling Tyvek
bis(2-ethylhexyl) phthalate 117-81-7 di-sec octyl phthalate, DEHP, di(2-ethylhelxy)phthalate, DOP, Octyl phthalate	5 mg/m^3-PEL† * 5 mg/m^3-REL, 10 mg/m^3-ST, Ca 5000 mg/m^3-IDLH, Ca	Colorless, oily liquid with a slight odor.	Class IIIB Combustible Liquid 420°F 0.3% *	Irritates eyes, mucous membrane; in animals: liver damage; teratogenic effects	NIOSH 5020 Determine based on working conditions IP = *
bromodichloromethane 75-27-4 dichlorobromomethane,	None-PEL None-TLV None-REL None-IDLH	Colorless liquid.	* * * *	Irritates eyes, nose, throat; lung irritation, dizziness, light-headedness, unconsciousness; liver damage; skin irritation	Air Sampling
bromoform 75-25-2 methyl tribromide, tribromomethane	0.5 ppm-PEL * 0.5 ppm-REL 850 ppm-IDLH	Colorless to yellow liquid with a chloroform-like odor. Note: A solid below 47°F.	Noncombustible Liquid * * *	Irritates eyes, skin, respiratory system; Central Nervous System depression; liver, kidney damage	FID PVA IP=10.48 eV
4-bromophenyl phenyl ether 101-55-3 p-bromophenyl phenyl ether, 4-bromodiphenyl ether, p-bromodiphenyl ether, 4-bromophenoxybenzene, p-bromophenoxy benzene, 1-bromo-4-phenoxybenzene	None-PEL None-TLV None-REL None-IDLH	Liquid	Combustible Liquid >233.6°F * *	Irritates eyes, skin; wheezing, coughing, shortness of breath, burning of mouth, throat, chest; convulsions, unconsciousness	Air Sampling Nitrile

Table 9-1 (continued)
Chemicals/Compounds of Concern
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV[(b)] NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
butyl benzyl phthalate 85-68-7 benzyl butyl phthalate, benzyl n-butyl phthalate, n-butyl benzyl phthalate, 1,2-benzenedicarboxylic acid, butyl phenlymethyl ester, phthalic acid, benzyl butyl ester, BBP	None-PEL None-TLV None-REL None-IDLH	Clear, colorless, slightly viscous liquid.	Combustible Liquid 451°F 1.2% *	Irritates mucous membrane, nose, throat, eyes; CNS depression; respiratory irritation, respiratory distress, difficulty breathing, light-headedness, nausea, pharyngitis, sleepiness, erythema	Air Sampling Nitrile
cadmium 7440-43-9 cadmium dust	0.005 mg/m^3-PEL * * 9 mg/m^3-IDLH, Ca	Metal: *Silver-white, blue-tinged, lustrous, odorless solid.*	Noncombustible Solid in bulk form, but will burn in powder form. * * *	Pulmonary edema, dyspnea, cough, chest tightness, substernal pain; headache; chills, muscle aches, nausea, vomiting, diarrhea, ansomnia, emphysema, proteinuria, mild anemia	NIOSH 7048 Dust: Any barrier that will prevent contamination Fume: Neoprene, nitrile IP=NA
carbon disulfide 75-15-0 carbon bisulfide	20 ppm-PEL†; 30 ppm C; 100 ppm [15] * 1 ppm-REL, 10 ppm -ST 500 ppm-IDLH	Colorless to faint-yellow liquid with a sweet ether-like odor. Note: reagent grades are foul smelling.	Class IB Flammable Liquid -22°F 1.3% 50%	Dizziness, headache, poor sleep, weakness, exhaustion, anorexia, weight loss; psychosis; polyneuropathy; Parkinson-like syndrome; ocular changes; coronary heart disease; gastritis; kidney, liver injury; eye, skin burns; dermatitis; reproductive effects, anxiety	NIOSH 1600 Teflon [4], PVA [8] IP=10.08 eV
carbon tetrachloride 56-23-5 carbon chloride carbon tet, Freon 10, Halon 104; tetrachloromethane	10 ppm-PEL†; 25 ppm-C; 200 ppm [5] 5 ppm-TLV, A3; 10 ppm-ST 2 ppm-REL ST *(60 min.)* 200 ppm-IDLH, Ca	Colorless liquid with a characteristic ether-like odor.	Noncombustible Liquid * * *	Irritates eyes, skin, CNS depression, nausea, vomiting, liver, kidney injury, drowsiness, dizziness, incoordiantion	NIOSH 1003 Teflon[4], PVA [8] IP=11.47 eV

Table 9-1 (continued)
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p-chloroaniline 106-47-8 1-amino-4-chlorobenzene, 4-chloroaniline, 4-chlorophenylamine, 4-chlorobenzenamine, p-aminochlorobenzene	None-PEL None-TLV None-REL None-IDLH	White or pale yellow crystalline solid.	Combustible Solid 235°F 2.2% *	Irritates eyes, methemoglobinemia, cyanosis; headache, drowsiness, nausea, unconsciousness; liver, kidney damage; hemorrhagic cystitis, hematuria	
chlorobenzene 108-90-7 benzene chloride, chlorobenzol, monochlorobenzene (MCB), phenyl chloride	75 ppm-PEL 10 ppm-TLV None-REL 1000 ppm-IDLH	Colorless liquid with an almond-like odor.	Class 1C Flammable Liquid 82°F 1.3% 9.6%	Irritates eyes, skin, nose; drowsiness; incoordination, CNS depression; in animals: liver, lung, kidney injury	NIOSH 1003 PVA [4]. Viton [8] IP=9.07 eV
p-chloro-m-cresol 59-50-1 4-chloro-3-methylphenol, 4-chloro-m-cresol, 3-methyl-4-chlorophenol, chlorocresol, aptal, 6-chloro-m-cresol, 6-chloro-3-hydroxytoluene	None-PEL None-TLV None-REL None-IDLH	White or slightly pink crystals with phenolic odor.	Combustible Solid 244.4°F * *	Irritates eyes, skin, mucous membranes, upper respiratory tract; dermatitis	Air Sampling
chloroform 67-66-3 trichloromethane methane trichloride *	PEL†, 50 ppm-C 10 ppm-TLV, A2 2 ppm-ST [60 min] REL 500 ppm-IDLH, Ca	Colorless liquid with a pleasant odor.	Noncombustible Liquid * * *	Irritates eyes, skin, dizziness, mental dullness, nausea, confusion; headache, anesthesia; enlarged liver; weakness, exhaustion	NIOSH 1003 Teflon [4], PVA [8] IP=11.42 eV
2-chlorophenol 95-57-8 o-chlorophenol, chlorophenolate, 1-chloro-2-hydroxybenzene, 2-hydroxychllorobenzene	None-PEL None-TLV None-REL None-IDLH	Colorless to yellow-brown liquid.	Combustible Liquid 147°F * *	Irritates eyes, skin, respiratory system; fever, motor weakness, dermatitis, convulsions; lung, liver, kidney damage; restlessness, tremors, dyspnea, coma; spasms; burns, pneumonitis, edema, coughing, wheezing, laryngitis, headache,	Air Sampling

Table 9-1 (continued)
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Chromium	0.5 mg/m^3-PEL * 0.5 mg/m^3-REL 250 mg/m^3-IDLH[as Cr(II)] 25 mg/m^3-IDLH [as Cr(III)]	Appearance and odor vary depending upon specific Chromium(II) or Chromium (III) compound.	Properties vary depending upon specific Chromium(II) or Chromium (III) compound.	Irritates eyes; sensitization dermatitis	NIOSH 7024 Contact the manufacturer IP = dependent upon specific compound
Coal Tar Pitch Volatiles 65996-93-2 anthracene, benzo(a)anthracene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, chrysene, dibenz(a,h)anthracene, fluoranthene, idenol(1,2,3-cd)pyrene, naphthalene, phenanthrene, pyrene	0.2 mg/m^3-PEL * 0.1 mg/m^3-REL, Ca 80 mg/m^3-IDLH, Ca	Black or dark-brown amorphous residue.	Combustible Solids, Properties vary depending upon the specific compound.	Dermatitis, bronchitis, carcinogen	NIOSH dependent upon specific compound Contact the manufacturer IP = dependent upon specific compound
m-cresol 108-49-4 meta-cresol, 3-cresol, m-cresylic acid, 1-hydroxy-3-methylbenzene, 3-hydroxytoluene, 3-methyl phenol	5 ppm-PEL * 2.3 ppm-REL 250 ppm-IDLH	Colorless to yellowish liquid with a sweet tarry odor. Note: A solid below 54°F.	Class IIIA Combustible Liquid 187°F 1.1% *	Irritates eyes, skin, mucous membrane; CNS effects; confusion, depression, respiratory failure; dyspnea, irregular rapid respiration, weak pulse; eye, skin burns; dermatitis; lung, liver, kidney, pancreas damage	NOSH 2546 Neoprene, Teflon [4] IP=8.98 eV
o-cresol 95-48-7 ortho-cresol, 2-cresol, o-cresylic acid, 1-hydroxy-2-methylbenzene, 2-hydroxytoluene, 2-methyl phenol	5 ppm-PEL * 2.3 ppm-REL 250 ppm-IDLH	White crystals with a sweet, tarry odor. Note: A liquid above 88°F.	Combustible Solid, Class IIIA Combustible Liquid 178°F 1.4% *	Irritates eyes, skin, mucous membrane; CNS effects; confusion, depression; respiratory failure; dyspnea, irregular rapid respiration, weak pulse; eye, skin burns; dermatitis; lung, liver, kidney, pancreas damage	NOSH 2546 Contact the manufacturer IP=8.93 eV

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p-cresol para-cresol, 4-cresol, p-cresylic acid, 1-hydroxy-4-methylbenzene, 4-hydroxytoluene, 4-methyl phenol	5 ppm-PEL * 2.3 ppm-REL 250 ppm-IDLH	Crystalline solid with a sweet, tarry odor. Note: A liquid above 95°F.	Combustible Solid, Class IIIA Combustible Liquid 187°F 1.1% *	Irritates eyes, skin, mucous membrane; Central Nervous System effects; confusion, depression, respiratory failure; dyspnea, irregular rapid respiration, weak pulse; eye, skin burns; dermatitis; lung, liver, kidney, pancreas damage	NIOSH 2546 PE/EVAL [4] IP=8.97 eVr
cyclotrimethylenetrinitramine 121-82-4 RDX, cyclonite, hexahydro-1,3,5-trinitro-1,3,5-triazine, hexogen, hexolite	* PEL† 1.5 mg/m^3-TLV 1.5 mg/m^3-REL, 3 mg/m^3-ST ND-IDLH	White crystalline powder. Note: a powerful explosive	Combustible Solid (Explosive) Explodes * *	Irritates eyes, skin; nausea, convulsions, vomiting, dizziness, headache; irritability, sleeplessness	NIOSH 0500 Contact the manufacturer IP = *
di-n-butyl phthalate 84-74-2 dibutyl phthalate, DBP, dibutyl 1,2-benzene-dicarboxylate	5 mg/m^3-PEL * 5 mg/m^3-REL 4000 mg/m^3-IDLH	Colorless to faint yellow, oily liquid with a slight aromatic odor.	Class IIIB Combustible Liquid 315°F 0.5% *	Irritates eyes, upper respiratory system, stomach	NIOSH 3020 PE/EVAL [4], Butyl [8] IP = *
o-dichlorobenzene 95-50-1 p-DCB, 1,2-Dichlorobenzene, ortho-dichlorobenzene, 0-dichlorobenzol	50 ppm-PEL, C * 50 ppm-REL, C 200 ppm-IDLH	Colorless to pale-yellow liquid with a pleasant aromatic odor.	Class IIIA Combustible Liquid 151°F 2.2% 9.2%	Irritates eyes, nose; liver, kidney damage; skin blisters	NIOSH 1003 Viton [4] IP=9.06 eV
m-dichlorobenzene 541-73-1 1,3-dichlorobenzene, meta-dichlorobenzene, m-dichlorobenzol, m-phenylenedichloride	None-PEL None-TLV None-REL None-IDLH	Clear, colorless liquid.	Combustible Liquid 146°F 2.02% 9.2%	Irritates eyes, skin, mucous membranes; anemia, necrosis; coughing, headache, drowsiness; respiratory irritation, CNS depression; kidney, liver damage; unconsciousness; dermatitis; nausea, vomiting, diarrhea	Air Sampling
p-dichlorobenzene 106-46-7 p-DCB, 1,4-dichlorobenzene, para-dichlorobenzene, dichlorocide	75 ppm-PEL† * None-REL, Ca 150 ppm-IDLH, Ca	Colorless or white crystalline solid with a mothball-like odor.	Combustible Solid, but may take effort to ignite 150°F 2.5%	Irritates eyes, swelling periorbital; profuse rhinitis; headache, anorexia, nausea, vomiting; weight loss, jaundice, cirrhosis; in animals: liver, kidney injury	NIOSH 1003 Contact the manufacturer IP=8.98 eV

Table 9-1 (continued)
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3,3'dichlorobenzidine 91-94-1 4,4'-Diamino-3,3'-dichlorobiphenyl	None-PEL * None-REL, Ca ND-IDLH, Ca	Gray to purple, crystalline solid.	* * * *	Skin sensitivity, dermatitis; headache, dizziness; caustic burns; frequent urination, dysuria; hematuria; GI upset; upper respiratory infection	NIOSH 5509 Contact the manufacturer IP=*
dichlordifluoromethane 75-71-8	1000 ppm-PEL * 1000 ppm-REL 15,000 ppm-IDLH	Colorless gas with an ether-like odor at extremely high concentrations.	Nonflammable Gas NA NA NA	Dizziness, tremor; asphyxiation, unconsciousness, cardia arrhythmias, cardiac arrest; liquid: frostbite	NIOSH 1018 Prevent skin freezing from direct contact IP=11.75 eV
1,1-dichloroethane 75-34-3 asymmetrical dichloroethane, ethylidene chloride, 1,1	100 ppm-PEL * 100 ppm-REL 3000 ppm-IDLH	Colorless, oily liquid with a chloroform-like odor.	Class IB Flammable Liquid 2°F 5.4%	Irritates skin, CNS depression; liver, kidney, lung damage	NIOSH 1003 Tychem [8] IP=11.06 eV
1,2-dichloroethane 107-06-2 ethylene dichloride, ethylene chloride, glycol dichloride	50 ppm-PEL†; 100 ppm-C; 200 ppm [5-minute maximum in any 3 hours] 10 ppm-TLV 1 ppm-REL; 2 ppm-ST 50 ppm-IDLH, Ca	Colorless liquid with a pleasant, chloroform-like odor. Note: decomposes slowly, becomes acidic and darkens in color.	Class IB Flammable Liquid 56°F 6.2% 16%	Irritates eyes, cornea opacity; CNS depression, nausea, vomiting; dermatitis; liver, kidney, CVS damage; carcinogen	NIOSH 1003 PVA [4], Teflon [8] IP=11.05 eV
1,1-dichloroethylene 75-35-4 vinylidene chloride, 1,1-DCE, 1,1-dichloroethene, VDC, vinylidene chloride monomer, vinylidene dichloride	None-PEL† * None-REL, Ca ND-IDLH, Ca	Colorless liquid or gas (above 89°F) with a mild, sweet, chloroform-like odor.	Class IA Flammable Liquid -2°F 6.5% 15.5%	Irritates eyes, skin, throat; dizziness, headache, nausea; dyspnea; liver, kidney disturbance; pneuitis;	NIOSH 1015 Contact the manufacturer IP=10.00 eV
1,2-dichloroethylene (includes the trans and cis isomers) 540-59-0 1,2-dichloroethene, acetylene dichloride, dichloroethylene	200 ppm-PEL 200 ppm-TLV None-REL 1000 ppm-IDLH	Colorless liquid with a slightly acrid, chloroform-like odor.	Class IB Flammable Liquid 36-39°F 5.6% 12.8%	Irritates eyes, respiratory system, CNS dpression	NIOSH 1003 PVA [4], Teflon [8] IP = 9.65

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2,4-dichlorophenol 120-83-2 DCP, 2,4-dcp, 4,6-dichlorophenol	None-PEL None-TLV None-REL None-IDLH	White to beige crystalline solid with phenolic odor.	Combustible Liquid 237°F * *	Irritates eyes, skin, mucous membranes, upper respiratory tract; tremors, convulsions, shortness of breath; vomiting, coma, erythema, sweating, nausea, diarrhea, cyanosis; hyperactivity, hyperpnea, abdominal pain, hemolysis, edema,	Air Sampling Tyvek Nitrile Viton
1,2-dichloropropane 78-87-5 propylene dichloride, dichloro-1,2-propane	75 ppm-PEL† * None-REL, Ca 400 ppm-IDLH, Ca	Colorless liquid with a chloroform-like odor.	Class IB Flammable Liquid 60°F 3.4% 14.5%	Irritates eyes, skin, respiratory system; drowsiness, liver, kidney damage, in animals: CNS depression,	NIOSH 1013 Contact the manufacturer IP=10.87 eV
cis-1,3-dichloropropene 10061-01-5 cis-1,3-dichloropropylene, cis-1,3-dichloro-1-propene, z-1,3-dichloro-1-propene, (z)-1,3-dichloropropene	None-PEL None-TLV None-REL None-IDLH	Colorless to amber-colored liquid.	Flammable Liquid * * *	Irritates eyes, skin, respiratory tract; dermatitis, gasping, coughing, substernal pain, respiratory distress, lacrimation, CNS depression, GI distress, edema; liver, kidney, heart injury	Air Sampling
trans-1,3-dichloropropene 10061-02-6 trans-1,3-dichloropropylene, trans-1,3-dichloro-1-propene, (e)-1,3-dichloro-1-propene, e-1,3-dichloropropene	None-PEL None-TLV None-REL None-IDLH	Clear colorless liquid.	Flammable Liquid 80.6°F * *	Irritates eyes, skin, respiratory tract; dermatitis, gasping, coughing, substernal pain, respiratory distress, lacrimation, CNS depression, GI distress, edema; liver, kidney, heart injury	Air Sampling
diethyl phthalate 84-66-2 DEP, diethylester of phthalic acid, ethyl phthalate	None-PEL† * 5 mg/m^3-REL ND-IDLH	Colorless to water-white, oily liquid with a very slight, aromatic odor.	Class IIIB Combustible Liquid, however, ignition is difficult 322°F 0.7% *	Irritates eyes, skin, nose, throat; headache, dizziness, nausea; lacrimation; possible polyneur; vestibular dysfunction; pain, numbness, weakness, exhaustion spasms in arms & legs; in animals: reproductive effects	OSHA 104 PE/EVAL [4] IP=11.07 eV

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2,4-ditemethyl phenol 105-67-9 2,4-xylenol, m-xylenol, 1-hydroxy-2,4-dimethylbenzene, 4,6-dimethylphenol, 2,4-dmp, asym-o-xylenol, 4-hydroxy-1,3-dimethylbenzene	None-PEL None-TLV None-REL None-IDLH	Colorless crystals to yellow-brown liquid.	Combustible Liquid 230°F * *	Irritates eyes, skin, nose throat, lungs; headache, nausea, vomiting; dizziness, stomach pain; liver, kidney damage; coughing wheezing, laryngitis, shortness of breath; edema, pneumonitis; sweating, erythema, cyanosis, hypernea, hemolysis, convulsions	*Air Sampling* Tyvek Nitrile Viton Neoprene Butyl
dimethyl phthalate 131-11-3 dimethyl ester of 1,2-benzenedicarboxylic acid, DMP	5 mg/m^3-PEL * 5 mg/m^3-REL 2000 mg/m^3-IDLH	Colorless, oily liquid with a slight aromatic odor. Note: a solid below 42°F.	Class IIIB Combustible Liquid 295°F 0.9% *	Irritates eyes, upper respiratory system; stomach pain	OSHA 104 IP=9.64 eV
4,6-dinitro-o-cresol 534-52-1 dinitro-o-cresol, 3,5-dinitro-2-hydroxy-toluene, DNC, DNOC, 4,6-dinitro-2-methyl	0.2 mg/m^3-PEL 0.2 mg/m^3-TLV 0.2 mg/m^3-REL 5 mg/m^3-IDLH	Yellow odorless solid.	Noncombustible Solid NA NA NA	Headache; fever; lassitude; profuse sweating, excessive thirst; tachycardia; hyperpnea, coughing, shortness of breath; coma, sense of well-being	NIOSH S166(II-S) IP = *
2,4-dinitrophenol 51-28-5 alpha-dinotrophenol, aldifen, fenoxyl carbon n, 1-hydroxy-2,4-dintrobenzene, 2,4-dnp, solfo black b, tertosulfur black pb, dinofan, maroxol-50	None-PEL None-TLV None-REL None-IDLH	Yellow, crystalline solid.	Flammable Solid * * *	Profuse sweating, fever, shortness of breath, yellow coloration of skin; increased metabolism, nausea, vomiting, collapse, cataracts, weight loss; dermatitis; fatigue, anorexia, weakness, dizziness, vertigo, headache, jaundice; abdominal pain, diarrhea	Air Sampling Tyvek Viton
2,4-dinitrotoluene 121-14-2 DNT, 2,4-dnt, dinitrotoluol, 1-methyl-2,4-dinitrobenzene, 2,4-dinitrotoluol	1.5 mg/m^3-PEL 1.5 mg/m^3-TLV, Ca 1.5 mg/m^3-REL, Ca 50 mg/m^3-IDLH, Ca	Orange-Yellow, crystalline solid with a characteristic odor.	Combustible Solid, but difficult to combust 404 °F * *	Anoxia, cyanosis, anemia, jaundice, reproductive effects	OSHA 44 Determine based on working conditions IP = *

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2,6-dinitrotoluene 606-20-2 2-methyl-1,3-dinitrobenzene, 2,6-dnt, 1,3-dinitro-2-methyl benzene	1.5 mg/m^3-PEL 1.5 mg/m^3-TLV, Ca 1.5 mg/m^3-REL, Ca 50 mg/m^3-IDLH, Ca	Orange-Yellow, crystalline solid with a characteristic odor.	Combustible Solid, but difficult to combust 404 °F * *	Anoxia, cyanosis, anemia, jaundice, reproductive effects	OSHA 44 Contact the manufacturer IP = *
di-n-octyl phthalate 117-84-0 phthalic acid, di-n-octyl ester, dnop, dinopol nop, n-dioctyl phthalate, o-benzenedicarboxylic acid, n-octyl phthalate, celluflex dip	None-PEL None-TLV None-REL None-IDLH	Light yellow, clear colored oily liquid.	Combustible Liquid 219°F * *	Irritates eyes, skin, mucous membranes, nose, larynx, respiratory system; dermatitis, erythema, kidney, liver damage; weight loss, respiratory distress, dyspnea	Air Sampling
ethyl benzene 100-41-4 ethylbenzol phenylethane	100 ppm-PEL† * 100 ppm-REL, 125 ppm-ST 800 ppm-IDLH (LEL)	Colorless liquid with an aromatic odor.	Class IB Flammable Liquid 55°F 0.8% 6.7%	Irritates eyes, skin, mucous membrane; headache, dermatitis; narcosis, coma	NIOSH 1501 Teflon [4], Viton [8] IP=8.76 eV
hexachlorobenzene 118-74-1 perchlorobenzene, hcb, hexa c.b., anticarie, bunt-cure, bunt-no-more, no-bunt, pentachlorophenyl chloride, phenyl perchloryl	None-PEL None-TLV None-REL None-IDLH	White needles.	Combustible Solid 468°F * *	Irritates eyes, skin, mucous membranes, upper respiratory tract; corneal opacity, focal alopecia, atrophic hands, hypertrichosis, hepatomegaly, porphyria, anorexia, weight loss; enlarged thyroid, lymph nodes	Air Sampling
hexachlorobutadiene 87-68-3 HCBD, heachloro-1,3-butadiene, 1,3-hexachlorobutadiene, perchlorobutadiene	None-PEL† * 0.02 ppm-REL, Ca ND-IDLH, Ca	Clear colorless liquid with a mild, turpentine-like odor.	Combustible Liquid * * *	In animals: irritates eyes, skin, respiratory system; kidney damage	NIOSH 2543 Responder [8] IP=*

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hexachlorocyclopentadiene 77-47-4 HCCPD,1,2,2,4,5,5-hexachloro-1,3-cyclopentadiene, perchlorocyclopentadiene	None-PEL† * 0.01 ppm-REL ND-IDLH	Pale-yellow to amber-colored liquid with a pungent, unpleasant odor. Note: A solid below 16°F.	Noncombustible Liquid NA NA NA	Irritates eyes, skin respiratory system; eye, skin burns; lacrimation; sneezing, cough, dyspnea, salivation, pulmonary edema; nausea, vomiting, diarrhea; in	NIOSH 2518 Butyl [8] IP=*
hexachloroethane 67-72-1 carbon hexachloride, ethane hexachloride, perchoroethane	1 ppm-PEL * 1 ppm-REL, Ca 300 ppm-IDLH, Ca	Colorless crystals with a camphor-like odor.	Noncombustible Solid * * *	Irritates eyes, skin, mucous membrane; in animals: kidney damage, carcinogen	NIOSH 1003 Contact the manufacturer IP=11.22 eV
lead (as Pb) (inorganic) 7439-92-1 (Metal) Pb	0.050 mg/m^3 -PEL† 0.050 mg/m^3-TLV, A3 0.050 mg/m^3 - REL 100 mg/m^3-IDLH	A heavy, ductile, soft, gray solid.	Noncombustible Solid in bulkform NA NA NA	Lassitude, insomnia; facial pallor, anorexia, weight loss, malnutrition; constipation, abdominal pain, colic; anemia, gingival lead line; tremor; paralysis wrist, ankles; encephalopathy; kidney disease; irritates eyes; hypotension	NIOSH 7082/7105/ 7300/7700/7701/ 7702 Any barrier that will prevent contamination IP = NA
mercury (metal) 7439-97-6	0.1 mg/m^3-PEL, C * Vapor: 0.05 mg/m^3-REL Other: 0,01 mg/m^3 -REL C 10 mg/m^3-IDLH	Silver-white, heavy, odorless liquid.	Noncumbustible Liquid NA NA NA	Irritates eyes, skin; cough, chest pain, dyspnea, tremor, insomnia, irritability, indecision, headache, weakness, exhaustion; stomatitis, salivation; GI disturbance, anorexia, weight loss, bronchitis, pneumonitis,	NIOSH 6009 Contact the manufacturer IP = ND
methyl bromide 74-83-9 bromomethane, monobromomethane	20 ppm-PEL†, C * None-REL, Ca 250 ppm-IDLH, Ca	Colorless gas with a chloroform-like odor at high concentrations. Note: A liquid below 38°F.	Flammable Gas NA 10% 16%	Irritates eyes, skin, respiratory system; muscle weakness, visual disturbance,; nausea, vomiting, headache; malaise, hand tremor; convulsions; dyspnea; skin vesiculation; incoordination,	NIOSh 2520 Butyl [4], Responder [8] IP=10.54
methyl chloride 74-87-3 chloromethane, monochloromethane	100 ppm-PEL†, 200 ppm-C; 300 ppm [5 minute maximum in any 3 hours] * None-REL, Ca 2000 ppm-IDLH, Ca	Colorless gas with a faint, sweet odor which is not noticeable at dangerous concentrations.	Flammable Gas NA 8.1% 17.4%	Dizziness, nausea, vomiting; visual disturbance, staggering, slurred speech, convulsions, coma; liver, kidney damage; liquid: frostbite; reproductive, teratogenic	NIOSH 1001 Teflon [4], Viton [8] IP=11.28 eV

Table 9-1 (continued)
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methylene chloride 75-09-2 dichloromethane, methylene dichloride	25 ppm-PEL; 125 ppm-ST 50 ppm-TLV, A2 None – REL Ca 2,300 ppm-IDLH, Ca	Colorless liquid with a chloroform-like odor. Note: A gas above 104°F.	Combustible Liquid * 13% 23%	Irritates eyes, skin, exhaustion, weakness, drowsiness, dizziness; numb tingle limbs; nausea,	NIOSH 1005, 3800 Teflon [4], PVA [8] IP = 11.32 eV
Methyl ethyl ketone 78-93-3 2-butanone, MEK, methyl acetone, ethyl methyl ketone	200 ppm-PEL† * 200 ppm-REL, 300 ppm-ST 3000 ppm-IDLH	Colorless liquid with a moderately sharp, fragrant, mint- or acetone-like odor.	Class IB Flammable Liquid 16°F 1.4% 11.4%	Irritates eyes, skin, nose; headache, dizziness, vomiting, dermatitis	NIOSH 2500, 3800 Responder [4], Butyl [8] IP=9.54 eV
Methyl isobutyl ketone 108-10-1 hexone, isobutyl methyl ketone, 4-methyl 2-pentanone, MIBK	100 ppm-PEL† * 50 ppm-REL, 75 ppm-ST 500 ppm-IDLH	Colorless liquid with a pleasant odor.	Class 1B Flammable Liquid 64°F 1.2% 8%	Irritates eyes, skin, mucous membrane; headache, narcosis, coma; dermatitis; in animals: liver, kidney damage	NIOSH 1300 Contact the manufacturer IP=9.30 eV
nickel (metal) 7440-02-0	1 mg/m^3-PEL† * 0.015 mg/m^3-REL, Ca 10 mg/m^3-IDLH, Ca	Lustrous, silvery, odorless solid.	Combustible Solid, nickel sponge catalyst may spontaneously ignite in air	Sensitive dermatitis, allergic asthma, pneuitis, carcinogen	NIOSH 7300 Contact the manufacturer IP = NA
p-nitroaniline 100-01-6 para-aminonitrobenzene, 4-nitroaniline, 4-nitrobenzenamine, p-	6 mg/m^3-PEL† * 3 mg/m^3-REL 300 mg/m^3-IDLH	Bright yellow, crystalline powder with a slight, ammonia-like odor.	Combustible Solid 390°F * *	Irritates nose, throat; cyanosis, ataxia; tachycardia, tachypnea, dyspnea, irritability; vomiting, diarrhea, convulsions; respiratory arrest; anemia; jaundice,	NIOSH 5033 Contact the manufacturer IP=8.85 eV
nitrobenzene 98-95-3 nitrobenzol, essence of mirbane, oil of mirbane	1 ppm-PEL * 1 ppm-REL 200 ppm-IDLH	Yellow, oily liquid with a pungent odor like paste shoe polish. Note: A solid below 42°F.	Class IIIA Combustible Liquid 190°F 1.8% *	Irritates eyes, skin, anoxia; dermatitis, anemia; methemoglobinemia; in animals: liver, kidney damage; testicular effects	NIOSH 2005 Buyl [8] IP=9.92 eV

Table 9-1 (continued)
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV[b] NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
p-nitrophenol 100-02-7 para-nitrophenol, 4-hydroxynitrobenzene, 4-nitrophenol, niphen, pnp, mononitrophenol	None-PEL None-TLV None-REL None-IDLH	Colorless to slightly yellow crystalline solid.	Combustible Solid 377°F • •	Irritates skin, eyes, nose, throat; headache, unconsciousness, drowsiness, nausea, cyanosis, liver, kidney damage, methemoglobinemia, CNS depression, dyspnea, sweating, dry throat, fever, muscular weakness,	Air Sampling
n-nitrosodiphenylamine 86-30-6 diphenyl, n-nitrosoamine, n-nitroso-n-phenylaniline, diphenylnitrosamine, redax, n-nitroso-n-phenylbenzenamine, nitrosodiphenylamine, vulcatard, nitrous diphenylamide, n,n-	None-PEL None-TLV None-REL None-IDLH	Yellow to brown or orange powder or flakes.	Combustible Solid • • •	Closely related chemical can cause headache, poor appetite, aching, jaundice; liver damage	Air Sampling
n-nitrosodi-n-propylamine 621-64-7 n-nitroso-n-propyl-1-propanamine, dipropylnitrosamine, dpna, ndpa, di-n-propylnitrosamine, nitrosodipropylamine, dpn, 1-dpropanamine	None-PEL None-TLV None-REL None-IDLH	Yellow liquid.	• 210.2°F • •	Exposure to closely related chemicals (nitrosamines) can cause liver damage; fatigue, poor appetite, jaundice	Air Sampling
pentachlorophenol 87-86-5 PCP, penta, 2,3,4,5,6-pentachlorophenol	0.5 mg/m^3-PEL • 0.5 mg/m^3-REL 2.5 mg/m^3-IDLH	Colorless to white, crystalline solid with a benzene-like odor.	Noncombustible Solid NA NA NA	Irritates eyes, nose throat; sneezing, cough, weakness, exhaustion, anorexia, weight loss, sweating; headache, dizziness, nausea, vomiting; dyspnea, chest pain; high	NIOSH 5512 Neoprene [4], Nitrile [8] IP = NA

Table 9-1 (continued)
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV(b) NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
phenol 108-95-2 carbolic acid, hydroxybenzene, monohydroxybenzene, phenyl alcohol, phenyl hydroxide	5 ppm-PEL * 5 ppm-REL, 15.6 ppm-C [15] 250 ppm-IDLH	Colorless to light-pink, crystalline solid with a sweet, acrid odor. Note: phenol liquefies by mixing with about 8% water.	Combustible Solid 175°F 1.8% 8.6%	Irritates eyes, nose, throat; anorexia, weight loss, weakness,exhaustion, muscle ache, pain, dark urine; cyanosis; liver, kidney damage; skin burns; dermatitis; ochronosis; tremor, convulsions, twitching	NIOSH 2546 Butyl [4], Viton [8] IP=8.50 eV
selenium 7782-49-2	0.2 mg/m³-PEL * 0.2 mg/m³-REL 1 mg/m³-IDLH	Amorphous or crystalline, red to gray solid.	Combustible Solid NA NA NA	Irritates eyes, skin, nose, throat; visual disturbance; headache; chills, fever; dyspnea, bronchitis; metallic taste, garlic breath, GI disturbance; dermatitis; eye, skin burns; in animals: anemia; liver, necrosis, cirrhosis; kidney, spleen damage	NIOSH 7300/ S190(II-7) Contact the manufacturer IP = NA
silver 7440-22-4	0.01 mg/m³-PEL * 0.01 mg/m³-RE: 10 mg/m³-IDLH	White, lustrous solid.	Noncombustible Solid, but flammable in the form of dust or powder NA NA NA	Blue-gray eyes, nasal septum, throat, skin; irritation, ulceration skin; GI disturbance	NIOSH 7300 Contact the manufacturer IP = NA
1,1,1,2-tetrachloroethane 630-20-6	None-PEL * Minimize exposure - REL	Yellowish-red liquid.	* * * *	Irritates eyes, skin; weakness, exhaustion restlessness, irregular respiration, muscle uncoordination; in animals: liver changes	NIOSH; none available PVA [8] IP = *
1,1,2,2-tetrachloroethane 79-34-5 sym-tetrachloroethane, acetylene tetrachloride	5 ppm-PEL† 1 ppm-TLV 1 ppm-REL Ca 100 ppm-IDLH, Ca	Colorless to pale-yellow liquid with a pungent, chloroform-like odor.	Noncombustible Solid NA NA NA	Nausea, vomiting, abdominal pain; tremor fingers; jaundice, hepatitis, liver tenderness; dermatitis; kidney damage; leukocytosis	NIOSH 1019 PVA [8] IP=11.10 eV
tetrachloroethylene 127-18-4 perchloroethylene (PCE), tetrachloroethene	100 ppm-PEL†, 200 ppm-C, 300 ppm [15] 25 ppm-TLV,A3;100 pm ST Minimize exposure - REL 150 ppm-IDLH, Ca	Colorless liquid with a mild, chloroform-like odor.	Noncombustible Liquid, but decomposes in fire to hydrogen chloride and phosgene NA NA NA	Irritates eyes, nose, throat; nausea; flush face, neck; dizziness, headache, somnolence; skin erythema; liver damage; incoordination	NIOSH 1003 PVA [8] IP=9.32 eV

Table 9-1 (continued)
Chemicals/Compounds of Concern
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV [(b)] NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
1,3,5,7-tetranitro-1,3,5,7-tetraazacyclooctane 2691-4-0 HMX, octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine, octogen, hw4, lx 14-0, cyclotetramethylenetetranitramine	None-PEL None-TLV None-REL None-IDLH	White crystalline solid.	* * * *	*	*
thallium	0.1 mg/m^3-PEL * 0.1 mg/m^3-REL 15 mg/m^3-IDLH	Appearance and odor vary depending on the specific soluble thallium compound.	Properties vary depending on the specific soluble thallium compound	Nausea, diarrhea, abdominal pain, vomiting; ptosis, strabismus; tremor; chest pain, pulmonary edema; chorea, psychosis; liver, kidney damage, alopecia, parasthesia legs, peri neuritis, retrosternal tightness,	NIOSH 7300 Contact the manufacturer IP = NA
toluene 108-88-3 toluol, methyl benzene, phenyl methane	200 ppm-PEL†, 300 ppm-C, 500 ppm [15] 50 ppm-TLV, skin 100 ppm-REL, 150 ppm-ST 500 ppm-IDLH	Colorless liquid with a sweet, pungent, benzene-like odor.	Class IB Flammable Liquid 40°F 1.1% 7.1%	Irritates eyes, nose; euphoria, exhaustion, weakness, confusion, dizziness, headache; dilated pupils, lacrimation; anxiety, muscle fatigue, insomnia; dermatitis; liver, kidney damage; parathesa	NIOSH 1500/1501/3800/4000 PVA [8] IP=8.82 eV
1,2,4-trichlorobenzene 120-82-1 unsym-trichlorobenzene, 1,2,4-trichlorobenzol	None-PEL† * 5 ppm-REL, C ND-IDLH	Colorless liquid or crystalline solid (below 63°F) with an aromatic odor.	Class IIIB Combustible Liquid, Combustible Solid 222°F 2.5% 6.6%	Irritates eyes, skin, mucous membrane; in animals: liver, kidney damage; possible teratogenic effects	NIOSH 5517 Viton [4], Teflon [8] IP=*
1,1,1-trichloroethane 71-55-6 methyl chloroform, chloroethane	350 ppm-PEL† * 350 ppm-REL, C [15] 700 ppm-IDLH	Colorless liquid with a mild, chloroform-like odor.	Combustible Liquid, but burns with difficulty * 7.5% 12.5%	Irritates eyes, skin; headache, lassitude, CNS depression, poor equilibrium; dermatitis; cardiac arrhythmias; liver damage	NIOSH 1003 FID IP=11.00 eV

Table 9-1 (continued)
Chemicals/Compounds of Concern
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV(b) NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
1,1,2-trichloroethane 79-00-5 ethane trichloride, vinyl trichloride	10 ppm-PEL * 10 ppm-REL, Ca 100 ppm-IDLH, Ca	Colorless liquid with a sweet, chloroform-like odor.	Combustible Liquid; forms dense soot * 6% 15.5%	Irritates eyes, nose; CNS depression; liver, kidney damage; dermatitis	NIOSH 1003 PVA [4], Teflon [8] IP=11.00 eV
trichloroethene 79-01-6 TCE, trichloroethylene, ethylene trichloride, trilene	100 ppm-PEL†; 200 ppm-C 50 ppm-TLV, A5; 100 ppm-C Ca-REL 1,000 ppm-IDLH, Ca	Colorless liquid (unless dyed blue) with a chloroform-like odor.	Combustible Liquid, but burns with difficulty * 8% 10.5%	Irritates eyes, skin; headache; visual disturbance, weakness, exhaustion, dizziness, tremor, somnolence, nausea, vomiting; dermatitis; cardia arrhythmia, liver injury, incoordination, parasthesia	NIOSH 1022 PVA [4], Teflon [8] IP=9.45 eV
trichlorofluoromethane 75-69-4 fluorotrichloromethane, Freon 11, monofluorotrichloromethane, refrigerant 11,	1000 ppm-PEL† * 1000 ppm-REL, C 2000 ppm-IDLH	Colorless to water-white, nearly odorless liquid or gas (above 75°F).	Noncombustible Liquid, Nonflammable Gas NA NA NA	Incoherence, tremors; dermatitis; cardiac arrhythmias; cardia arrest; asphyxiation; liquid: frostbite	NIOSH 1006 Contact the manufacturer IP=11.77 eV
2,4,6-trichlorophenol 88-89-1 picric acid, phenol trinitrate	0.1 mg/m^3-PEL * 0.1 mg/m^3-REL, 0.3 mg/m^3-ST 75 mg/m^3-IDLH	Yellow, odorless solid. Note: used as an aqueous solution.	Combustible Solid 302°F * *	Irritates eyes, skin; sensitive dermatitis; yellow-stained hair, skin; weakness, myalgiea, anuria, polyuria; bitter taste, GI disturbance; hepatitis, hematuria, albuminuria,	NIOSH S228(II-4) IP=*
trinitrotoluene 118-96-7 2,4,6-trinitrotoluene, 1-methyl-2,4,6-trinitrobenzene, TNT, trinitrotoluol	1.5 mg/m^3-PEL† 0.5 mg/m^3-TLV 0.5 mg/m^3-REL 500 mg/m^3-IDLH	Colorless to pale-yellow, odorless solid or crushed flakes.	Combustible Solid (Class A Explosive) * * *	Irritates skin, mucous membrane, liver damage, jaundice, cyanosis, sneezing, coughing, sore throat, perineurism, muscle pain, kidney damage, cataract, dermatitis, anemia, cardiac irregularity, leukocytosis	OSHA 44 Contact the manufacturer IP = 10.59 eV

Table 9-1 (continued)
Chemicals/Compounds of Concern
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Chemical Name/ CAS Number Synonyms	OSHA PEL ACGIH TLV[b] NIOSH REL IDLH	Physical Properties & Warning Properties	Reactivity Class Flash Point LEL UEL	Symptoms/Effects	Measurement/ PPE/ IP
2,4,6-trinitrophenol-methylnitramine 479-45-8 tetryl, n-methyl-n,2,4,6-tetranitroaniline, nitramine, 2,4,6-tetryl, 2,4,6-trinitrophenyl-n-methylnitramine	1.5 mg/m^3-PEL * 1.5 l mg/m^3-REL 750 mg/m^3-IDLH	Colorless to yellow, odorless crystalline solid.	Combustible Solid (Class A Explosive) Explodes * *	Dermatitis, itching, erythma, edema on nasal folds, cheeks, neck; keratitis, sneezing; anemia; malaise, coughing, coryza, irritability, headache, lassitude, insomnia; nausea, vomiting; liver, kidney damage	NIOSH S225(II-3) PPE Air Sampling
vinyl chloride 75-01-4 chloroethylene, chloroethane, ethylene monochloride	1 ppm-PEL, 5 ppm-C (15-min) 5 ppm-TLV, A1 Ca - REL ND-IDLH	Colorless gas or liquid (below 7°F) with a pleasant odor at high concentrations.	Flammable Gas NA 3.6% 33%	Weakness, exhaustion, abdominal pain, GI bleeding; enlarged liver; pallor or cyanosis of extremities; liquid: frostbite	NIOSH 1007 PVA [4], Tychem [8] IP=9.99 eV
xylenes (o, p, m-isomers) 95-47-6 108-38-3 106-42-3 dimethyl benzene, ortho, meta, para xylene, o, m, p-xylol	100 ppm-PEL† 100 ppm-TLV; 150 ppm ST 100 ppm-REL; 150 ppm-ST 900 ppm-IDLH	Colorless liquid with an aromatic odor.	Class IC Flammable Liquid 81 - 92°F 0.9 - 1.1% 6.7 - 7%	Irritates eyes, skin, nose, throat; dizziness, excitement, drowsiness, incoordination, staggering gait, cornea vacuolization; anorexia, nausea, vomiting, abdominal pain; dermatitis	NIOSH 1501/3800 Contact the manufacturer IP=8.44 - 8.56 eV

Table 9-1 (continued)
Chemicals/Compounds of Concern
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<u>Notes:</u>

* = No Data
NA = Not Applicable
ND = Not Determined
Ppm = Parts Per Million
eV = Electron-Volt
GI = Gastrointestinal
CNS = Central Nervous System
Source: [unless otherwise noted] U.S. Department of Health and Human Services. June 1994. NIOSH Pocket Guide to Chemical Hazards. Publication No. 94-116 (Fourth Printing, July 1996).
‡ = Moderate explosion hazard in the form of dust when exposed to flame
✱ = Source: American Conference of Governmental Industrial Hygienists (ACGIH). 1995-1996. Threshold Limit Values (TLVs) for Chemical Substances and Physical Agents and Biological Exposure Indices (BEIs). 1995.

NIOSH RELs: TWA concentrations for up to a 10-hour workday during a 40-hour workweek. A STEL is designated by "ST" preceding the value; unless noted otherwise, the STEL is a 15-minute TWA exposure that should not be exceeded at any time during a workday. A ceiling REL is designated by "C" preceding the value; unless noted otherwise, the ceiling value should not be exceeded at any time. Any substance that NIOSH considers to be a potential occupational carcinogen is designated by the notation "Ca.".

OSHA PELs: Unless noted otherwise, PELs are TWA concentrations that must not be exceeded during any 8-hour workshift of a 40-hour workweek. A STEL is designated by "ST" preceding the value and is measured over a 15-minute period unless noted otherwise. OSHA ceiling concentrations (designated by "C" preceding the value) must not be exceeded during any part of the workday; if instantaneous monitoring is not feasible, the ceiling must be assessed as a 15-minute TWA exposure. In addition, there are a number of substances that have PEL ceiling values that must not be exceeded except for specified excursions. For example, a "5-minute maximum peak in any 2 hours" means that a 5-minute exposure above the ceiling value, but never above the maximum peak, is allowed in any 2 hours during an 8-hour workday. The substances for which OSHA PELs were vacated on June 30, 1993 are indicated by the symbol "†" following OSHA PEL in this column.

Measurement Method = NIOSH methods from the 4th edition of the *NIOSH Manual of Analytical Methods*(DHHS publication 94-113) and OSHA methods from http://www.osha-slc.gov/sltc/methods

PPE = Source: NIOSH Recommendations for Chemical Protective Clothing, a Companion Guide to the Pocket Guide (http://www.cdc.gov/niosh/ncpc/ncpc1.html); Butyl = Butyl Rubber; Neoprene = Neoprene Rubber; Nitrile = Nitrile Rubber; PVA = Polyvyinyl Alcohol; Teflon = Teflon™; Viton = Viton™; PEL/EVAL = 4H™ and Silver Shield™ gloves; Responder = Responder™ suits, Tychem = Tychem 10000™ suit; only one example of appropriate PPE is provided

9.4 ACTION LEVELS

The action levels and their corresponding actions will be identified to indicate the points at which personnel on site are alerted of the presence of chemical and physical hazards. This information will be included in the SWMU-specific WPA. The action levels will be modified as necessary and will be utilized to identify the need for one or more of the following:

- Implementation of engineering controls and work practices;
- Upgrading or downgrading of levels of PPE;
- Work stoppage and/or emergency evacuation of on-site personnel; and
- Prevention and/or minimizing public exposures to hazards created by site activities.

Readings at or above the action levels will necessitate the implementation of the actions listed and will be reported to USACE and the contractor's CIH and PM. If an action level for a chemical or physical hazard is reached and site personnel are not adequately protected, the site will be evacuated and the contractor's CIH contacted to identify the requirements needed to resume site activities. The CIH will be contacted to evaluate if additional monitoring or sampling will be required and to evaluate if modifications to the PPE program will be necessary. If additional monitoring is advised which is not addressed in this plan, an amendment will be made to include the new addition(s).

9.5 NOISE MONITORING

Sound level monitoring will be used as a screening tool to identify operations that have potential for personnel exposure greater than 85 dBA, eight-hour TWA. When this action level is reached, the SHSO will further evaluate the exposure and perform noise dosimetry, if necessary, to evaluate the workers' eight-hour TWA exposure. The contractor will be contacted and informed of personal exposures in excess of an eight-hour TWA of 85 dBA. The CIH will assess the task and noise source, to evaluate if other means of control may be used to reduce the noise exposure, and will also assess the dosimetry data to ensure that the attenuated protection level is less than 90 dBA.

9.6 HEAT AND COLD STRESS MONITORING

Heat and cold stress monitoring will be conducted by the SHSO as required by this HSP. If this monitoring indicates excessive heat or cold levels, the control measures outlined in Section 3.2 will be implemented to control the heat or cold stress experienced by site personnel.

9.7 METEOROLOGICAL MONITORING

Meteorological monitoring will be conducted for wind direction and speed, temperature, and relative humidity at site activities where the potential for off-site chemical release exists. This data will be recorded on an hourly basis. The data gathered will be utilized for the placement of the support zone services. It will also be used to calculate the EZ and to alert site personnel to hazardous site conditions.

9.8 CALIBRATION AND MAINTENANCE OF MONITORING EQUIPMENT

The monitoring instruments require frequent charging and routine cleaning to ensure that they will function properly when needed. The SHSO will be in charge of training personnel in proper use and care of monitoring equipment.

Monitoring equipment will be calibrated at least once daily prior to use. A calibration log will be kept for each instrument. This log will also contain detailed descriptions of problems encountered with the instrument, along with records of factory calibration and repair.

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10.0 EMERGENCY RESPONSE AND CONTINGENCY PLAN

Prior to engaging in removal activities at the site, the contractor will plan for possible emergencies and have available adequate supplies and manpower to respond. In addition, site personnel will be trained in the provisions of this emergency response plan, the communication systems, and the evacuation routes. The rally points will be established on a daily basis, depending upon the location of work, weather conditions, type of operations taking place, and access to the locations or rally points. The plan will be reviewed and revised as necessary by the SHSO to ensure that it is adequate and up-to-date with prevailing site conditions. Regular exercises on the evacuation, personnel injury, fire/explosion, and spill/release procedures will be conducted.

10.1 PRE-EMERGENCY PLANNING

10.1.1 Identification of Local Emergency Services

Prior to conducting site operations, the contractor will contact the local and site emergency response authorities to inform them of the nature of site activities to be performed and the potential hazards that these activities pose to investigation personnel, the environment, and the general public. Personnel will be informed of the type of emergency services available and will be given the contact telephone numbers for these services. In the event that evacuation of the public is required due to either normal site conditions or an emergency event, the SHSO is responsible for contacting the appropriate local authorities that execute and coordinate an evacuation. Table 10-1 lists the telephone numbers for local and site emergency services, as well as essential personnel involved with the field activities.

10.1.2 Other Hazard Information

In the event additional site or task hazard information becomes available during the conduct of field activities, this information will be assessed by the SHSO to evaluate if the contingency plans in this section need to be updated.

10.2 EMERGENCY RESPONSE RESPONSIBILITIES

10.2.1 On-Scene Incident Commander

In case of an emergency, the SHSO assumes the responsibility of On-Scene Incident Commander (OSIC). An alternate person to assume this role, in the event that the SHSO is unavailable will be identified before the start of fieldwork and included in the site-specific Heath and Safety Plan Addenda. The OSIC has responsibility for directing on-site and off-site response personnel and for advising RFAAP of the emergency as soon as possible.

10.2.2 On-Site Emergency Response Services

Contractor and/or subcontractor personnel will be trained to provide first aid treatment for minor injuries. At least two persons on site will be first aid and CPR certified. In the event that a field team member has to perform first aid or CPR, the contractor's blood borne pathogens program will be implemented.

The SHSO will ascertain if the injury requires further treatment. If emergency response is needed, the SHSO or other designee will call the RFAAP emergency response office at 7323 or 7325 (from on-post

Table 10-1
Emergency Telephone Numbers
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Contact	Telephone Number
Emergency Response Services	
Installation Fire Department**	16 (on post)
Installation Security Police**	7325 (on post) (540) 639-7325 (off post)
Installation Safety Department**	7294 (on post) (540) 639-7294 (off post)
Installation Spill Response**	7323, 7324 or 7325 (on post) (540) 639-7323, 7324, or 7325 (off post)
Installation Medical Facility** (RFAAP Hospital)	7323 or 7325 (on post) (540) 639-7323 or 7325 (off post)
Local Police Department	911
New River Valley Medical Center	(540) 731-2530 – Emergency Department
National Poison Control Center	(800) 222-1222
National Response Center	(800) 424-8802
Regional USEPA Emergency Response	(215) 814-9016
Chemical Manufacturers Association Chemical Referral Center	(800) 262-8200

Directions from the Main Gate:

New River Valley Medical Center

2900 Lamb Circle

Radford, VA 24073

Take Route 114 (Peppers Ferry Rd) toward Radford to first traffic light. Turn left onto US Route 11 South (Lee Highway) and go across the bridge over the New River. Turn left after crossing the bridge continuing on US Route 11 and go to Virginia Route 177 South (Tyler Road and turn right. Proceed on VA 177 South (Tyler Road) and cross over Interstate 81. New River Valley Medical Center is on the left.

** These telephone numbers are referenced from the Alliant TechSystems publication, *Safety, Security and Environmental Rules for Contractors and Subcontractors*, January 2000.

telephone) or (540) 639-7323 or (540) 639-7325 (from off-post telephone). RFAAP personnel will be dispatched as the emergency first responder.

10.2.3 Off-Site Emergency Response Services

Off-site emergency response services that may be needed in case of a site emergency include medical and law enforcement personnel. Fire protection and Emergency Medical Technician services are available on post. If additional services are necessary, the post emergency system contacts the appropriate fire, police, medical, and emergency transport facility. If emergency response is needed, the SHSO or other designee will call the RFAAP emergency response office at 7323 or 7325 (from on-post telephone) or (540) 639-7323 or (540) 639-7325 (from off-post telephone). RFAAP personnel will be dispatched as the emergency first responder.

10.3 EMERGENCY TRAINING

Site personnel will receive specialized training involving health and safety hazards. This training will be given by the SHSO and conducted before initiating site activities.

The content of this training will include the items listed below, and will be documented using the site training log.

- Emergency chain of command;
- Communication methods and signals;
- Emergency equipment and PPE;
- Removing injured personnel from the site; and
- Emergency contacts, telephone numbers, and hospital routes.

10.4 EMERGENCY SITE CONTROL AND SECURITY

In an emergency, it is imperative that site control and security be maintained. To control site personnel, the OSIC will use a site entry/exit log to ensure personnel are present or accounted for at the assembly point. Depending on the weather and nature of emergency, the following will, as applicable, be used to maintain site security:

- Close, but do not lock gates as evacuation occurs;
- Erect flagging or barrier tape to prevent accidental entry; and
- Use a megaphone to alert personnel to stay clear of the site.

10.5 ON-SITE EMERGENCY EQUIPMENT

Emergency equipment will be maintained in proper working order and inspected by the SHSO at least weekly to ensure completeness and effectiveness. The results of the inspection will be documented in the safety logbook. In the event that a disposable item is used, the SHSO will ensure they are replaced immediately. Site operations will not be conducted if the required emergency equipment is not available on site. The following is a list of the required emergency equipment and storage location:

- First Aid/Burn Kit – Vehicles in CRZ;
- Eye Wash/Shower – Within 100 feet of CRZ;
- CPR Mask – Each first aid kit;
- Disposable latex Gloves – Each first aid kit;
- 10B:C Rated Fire Extinguisher – Vehicles within 100 feet of CRZ; and
- Blood-borne Pathogen Kit – Each first aid kit.

10.6 MEDICAL FACILITIES

A map showing the route to the New River Valley Medical Center is included as Figure 10-1.

10.7 CONTINGENCY PLANS

The following paragraphs contain emergency-specific contingency plans. These plans outline the procedures for mitigating each of the potential emergencies. These contingency plans specify the minimum emergency procedures and may be subject to alteration by the SHSO, based on actual or changing site conditions. The Installation and the contractor's CIH must approve changes to these contingency plans.

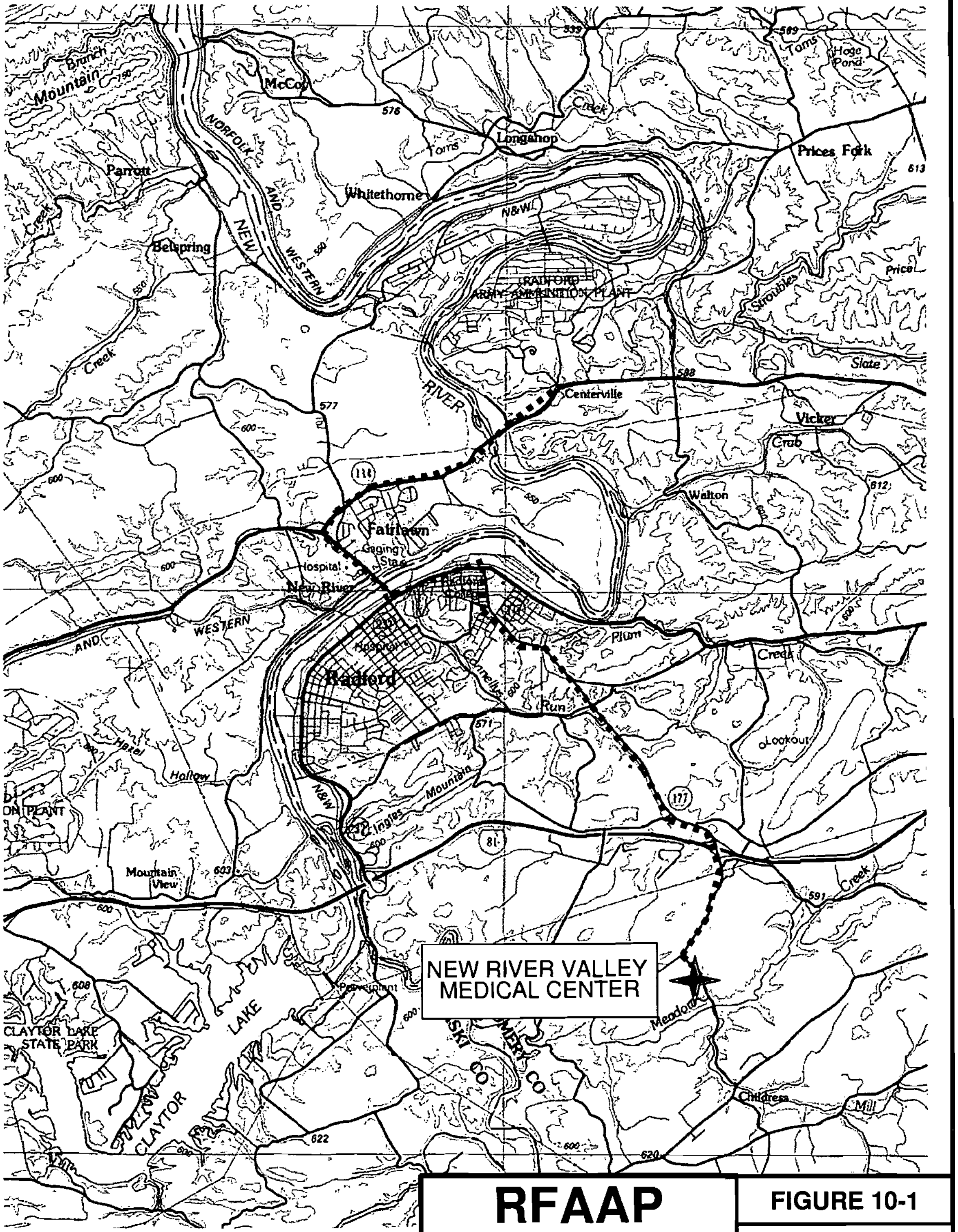
10.7.1 Site Evacuation

Site personnel will be briefed daily on evacuation routes and procedures for each work site or activity. In the event of an emergency that necessitates site evacuation, either a portable air horn or a vehicle horn will be used to alert site personnel of an evacuation emergency. A head count will be completed by the SHSO at the assembly area and further evacuation instructions or responses coordinated at that point. Once the safety of personnel is established, the RFAAP Fire Department (reached by dialing 16 from a government telephone) will be notified immediately. See Table 10-1 for the list of emergency numbers.

Following an emergency alarm signal, access to the area of the incident will be restricted. Physical barriers or tape will be used to delineate the restricted area. Site control will be the responsibility of the SHSO, who will establish the new work area boundaries, if necessary. Future entries into the restricted areas will require the permission of the SHSO.

10.7.2 Chemical Spills/Vapor Releases

In case of an environmental release of chemical material at RFAAP, the SHSO will act to control or stop the spread of contamination if possible. The SHSO will instruct a person on site to immediately contact the RFAAP spill control personnel by dialing 7323 or 7325 from a government telephone or (540) 639-7323 or 7325 from a commercial or cellular telephone to inform them of the possible or immediate need for local evacuation. If a significant release has occurred, RFAAP personnel will alert other response teams as necessary. Following these emergency calls, the reporting individual will then notify the PM, Task Manager, PHSO, and CIH.



RFAAP

MASTER HEALTH AND SAFETY PLAN

FIGURE 10-1

MAP TO HOSPITAL

Date: Dec. 2001	**Prepared by:** URS Corp./ADW **URS Proj No.:** 09604-263
Scale: None	**File Name:** RAD_HOSP_REV_2.07_rev.ppt

In addition, spill response equipment for cleanup of small-scale releases, including absorbent material and spare containers, will be in place at the site. It will also be noted that workers at the site will already be equipped with protective clothing suitable for cleanup of spills (i.e., Tyvek® suits and/or air purifying respirators).

In case of a spill, release, or detection of an undefined odor, site personnel will:

1. Ensure that they are safe, alert coworkers, and inform a supervisor.
2. Assess the situation and identify the appropriate safe response procedure.
3. Evacuate non-essential personnel to safe areas.
4. Locate the source of spillage or release; monitor with PID, FID, and CGI/O_2 meter to ensure Level of Protection (LOP) is appropriate; control, containerize, or otherwise stabilize the spill, if it is safe to do so.
5. Decontaminate reusable equipment; appropriately dispose of expendables, restock spill response equipment, and ready safety gear for the next contingency.
6. Debrief personnel.
7. Take corrective actions to prevent similar occurrences and revise the contingency plan if needed.

10.7.3 Fire or Explosion

In case of a fire or explosion, the emergency evacuation procedures will be followed. The RFAAP Fire Department will be immediately notified. Upon the emergency response team's arrival, the SHSO or FOL will advise the fire commander of the location, nature, and identification of the hazardous situation. If it can be done safely by personnel trained in the use of a fire extinguisher, and if the SHSO approves, small or incipient fires may be controlled or extinguished using ABC-type fire extinguishers, water, or brush fire flails. A small fire is defined as a fire that can be extinguished with a 4A:20B:C type fire extinguisher. Personnel will not attempt to extinguish a fire, even a small one, involving explosives. Personnel controlling fires will do so from an upwind position and will withdraw from the site if breathing smoke or fumes cannot be avoided.

ABC-type dry chemical portable fire extinguishers (five pounds or greater) will be provided on motorized field equipment, at the work location, and in the immediate place where flammable materials are located.

10.7.4 Injury/Medical Emergency

Personnel should always be on the alert for signs and symptoms of illnesses related to chemical, physical, and disease factors on site. Severe injuries resulting from accidents and chemical overexposure must be recognized as emergencies and treated as such. At least two personnel currently certified in first aid and CPR must be present on site. These persons will be provided equipment and trained in protection form blood-borne pathogens according to 29 CFR 1910.1030.

In case of a personnel injury, the SHSO will be notified of the injury. First aid should be performed for limiting further injury or stabilizing the victim. Personnel with current first aid training must identify the injury or illness and apply emergency first aid, as necessary. Victims will be decontaminated before administering first aid (as long as this can be done without further injuring the victim). For serious injuries requiring medical support, emergency response personnel will be summoned by calling 7323 or 7325 from a government telephone or (540) 639-7323 or (540) 639-7325 from a commercial/cellular telephone.

Personnel are not to move or transport victims unless doing so does not pose an immediate threat to their life, or if timely response of emergency medical services is not possible. For less serious injuries, personnel will be transported by non-emergency vehicle to the New River Valley Medical Center.

The SHSO or FOL are responsible for making certain that an accident report form is completed and submitted to the PM. The PM or an appropriate designee will immediately notify the Installation by telephone and submit the report to the RFAAP safety personnel within 24 hours of the incident. This report will be filed on USACE Eng. Form 3394 and the required OSHA report forms.

10.8 EMERGENCY RESPONSE AND DECONTAMINATION PROCEDURES

Decontamination procedures and facilities are defined in Section 8.0. A person who becomes ill or injured in the exclusion zone must be decontaminated to the maximum extent possible. If the injury or illness is minor, full decontamination will be completed and first aid administered before transport to a medical facility. If the patient's condition is serious, at least partial decontamination will be completed. First aid will be administered while awaiting an ambulance or paramedics. Injuries and illnesses must be reported immediately to USACE and the PM.

10.9 EMERGENCY CONTACT/NOTIFICATION SYSTEM

Emergency notifications will be made to the RFAAP emergency telephone numbers contained in Table 10-1.

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