RAAP 050506\050210

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

WORK PLAN ADDENDUM NO. 18
RCRA Facility Investigation at Solid Waste Management Unit 41

FINAL DOCUMENT
DECEMBER 2003

PREPARED BY:

URS

5540 Falmouth Street, Suite 201
Richmond, Virginia 23230
(804) 965-9000 main
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ARCHITECT-ENGINEER SERVICES
CONTRACT NO. DACA31-00-D-0011
DELIVERY ORDER NO. 0055

McKenna, Jim

From: Tesner, John E NAB02 [John.E.Tesner@nab02.usace.army.mil]
Sent: Tuesday, April 06, 2004 11:48 AM
To: Jim McKenna (E-mail)
Subject: FW: SWMU 41 Field Investigation

Jim-
This is as we discussed this morning.
JT

-----Original Message-----
From: James_O_Spencer@URSCorp.com [mailto:James_O_Spencer@URSCorp.com]
Sent: Tuesday, April 06, 2004 9:34 AM
To: Tesner, John E
Cc: Darren_Renne@URSCorp.com
Subject: SWMU 41 Field Investigation

John:
The following is a synopsis of our soil field investigation activities to date and recommended activities to complete the field work:

Area A (Lower Area)

- Soil borings - 4 planned soil borings for site characterization and chemical sampling (41SB2-41SB5) - completed per work plan
- Chemical sampling from 4 soil borings completed per work plan (3 samples from each boring + QA/QC)
- Additional site characterization borings completed that were not included in work plan (for visual ID of soil types and potential waste, etc.) = 6 (including one boring in proposed test pit location)

Conclusions:
The 10 soil borings (including one in test pit area) allowed for a more complete assessment for the presence or absence of buried material, etc. in this area than possible with the original scope of 4 borings and one test pit. It is therefore recommended that the 3 discrete soil samples proposed for the test pit be collected from an additional boring completed within Area A. Section 1.3.2 of the work plan (page 1-34 first bullet) allows for the substitution of additional borings for the test pit.

Area B (Upper Area)

- Soil borings - 6 planned soil borings for site characterization and chemical sampling (41SB5-41SB11) - completed per work plan
- Chemical sampling from 6 soil borings completed per work plan (3 samples from each boring + QA/QC)
- Additional site characterization borings completed that were not included in work plan (for visual ID of soil types and potential waste, etc.) = 16 - Collected waste characterization sample of buried material for expedited TCLP, etc. analysis.

Conclusions:
The 22 soil borings have allowed for:

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

W. Tayloe Murphy, Jr.
Secretary of Natural Resources

Street address: 629 East Main Street, Richmond, Virginia 23219
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Fax (804) 698-4500 TDD (804) 698-4021
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Robert G. Burnl
Director

(804) 698-4000
1-800-592-548

30 March 2004

Mr. James McKenna
Radford Army Ammunition Plant
SIORF-SE-EQ
P.O. Box 2
Radford, VA 24141-0099

RE: Work Plan Addendum 018 RCRA Facility Investigation at Solid Waste Management Unit 41 (WPA 18)

Dear Mr. McKenna:

This office has reviewed the referenced draft document and concurs with WPA 18. No revisions to the document are required. Please provide one copy of the Final WPA 18 document to this office on CD when completed.

If you have any questions, please call me at 804.698.4308.

Sincerely,

Mark Leeper

Mark S. Leeper
Remedial Project Manager

cc: Norman L. Auldridge – WCRO, DEQ
Durwood Willis – DEQ
Robert Thompson, Region III, U.S.EPA, 3HS13

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

Thursday 2/27/2004 faxed to Dursen Reams, URS

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

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
SWMU 41
Draft revised *Work Plan Addendum 18*
Document submittal and review

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's December, 2003 draft revised *Work Plan Addendum 18* for the investigation of SWMU 41, located at the Radford Army Ammunition Plant (RFAAP). Based upon our review, the draft revised *Work Plan Addendum 18* for the investigation of SWMU 41 is approved. In accordance with Part II. (E)(5)of RFAAP's Corrective Action Permit, *Work Plan Addendum 18* is now considered final. Please forward two copies of the final *Work Plan Addendum 18* to EPA for our files.

15

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

Sincerely,

Robert Thomson

Robert Thomson, PE
Federal Facilities Branch

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

ATK
ALLIANT TECHSYSTEMS

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

January 7, 2004

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

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

Dear Mr. Thomson:

Enclosed is one certified copy of Work Plan Addendum 18, RCRA Facility Investigation at SWMU 41, Final December 2003 Radford Army Ammunition Plant for your review and comment or approval. Your additional three 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. Attached are our responses to the comments contained in your December 8, 2003 letter.

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,

JJ Redder
For 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

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Virginia Department of Environmental Quality
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Corps of Engineers, Baltimore District
ATTN: CENAB-EN-HM
10 South Howard Street
Baltimore, MD 21201

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

Coordination:
J. McKenna

04-815-5
JMcKenna/JJRedder

Concerning the following:

Work Plan Addendum 18
RCRA Facility Investigation at SWMU 41, Final December 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: Anthony R. Skinner
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

Response to USEPA Comments Dated 08 December 2003
for
Draft Work Plan Addendum No. 18
September 2003

General Response

Please note that the plan of action and associated programmatic funding for SWMU 41 has been and continues to be discussed on an annual basis during the Installation Action Plan (IAP) workshop and is captured in the most current version of that document (FY 2004). The plan of action for SWMU 41 assumes that it is a source that has not released to groundwater, but might require some sort of remedial action (i.e. cap at Area B and no further action at Area A). Work Plan Addendum 018 (and generally work plan addenda for RFAAP's SWMUs) was developed to collect data sufficient to test and validate the assumptions for the plan of action in order to advance the program as efficiently and expeditiously as possible. Additions to this strategy have been added upon regulator request; for example the inclusion of full suite sampling for chemical analytes, however, the core strategy remains unchanged. Should the sampling proposed in WPA 018 indicate the underlying assumptions were not valid, such a scenario may require further effort possibly including further characterization, sampling, or remediation. It is requested that these response-to-comments be viewed in the context of the plan of action assumptions for SWMU 41.

Specific Comments

EPA Comment 1:

<u>**Section 1.2.1, Site Background - Environmental Setting, page 1-6**</u>: This section refers to various structures in the vicinity of Solid Waste Management Unit (SWMU) 41 and references Figure 1-2 for their locations. These structures are not labeled on Figure 1-2, requiring the reader to guess which structures outlined on Figure 1-2 are being referred to in this section. Please revise Figure 1-2 to include labels for structures referred to in the text.

RFAAP Response

Comment noted. Current National Security policies in effect for RFAAP preclude labeling or identification of structures on figures included in reports made available to the public. It should be noted that the structures shown on Figure 1-2 are not associated with SWMU 41 and are presented for informational purposes only.

EPA Comment 2:

<u>**Section 1.2.5, Conceptual Site Model, page 1-25:**</u> It is stated in this section, "potentially affected media include surface soil, subsurface soil, surface water, and sediment." Groundwater should also be included as a potentially affected media, since the limited data presented in Table 1-4 indicate that groundwater at the site is impacted. In addition, the conceptual site model (CSM) Figures 1-13 and 1-4 do include groundwater as an exposure pathway. Please revise the

text to indicate that groundwater is a potentially affected media at the site. Otherwise, there is a need to note how groundwater will be dealt with at this site.

RFAAP Response

Because of the complexity of the groundwater pathway (i.e., karst and fractured bedrock flow regime) in the Main Manufacturing Area (MMA) and SWMU 41, the groundwater pathway at SWMU 41 will be investigated under WPA 009 and subsequent groundwater studies of the MMA. The CSM will be revised to include information on how the groundwater pathway will be addressed at SWMU 41.

EPA Comment 3:

Please provide justification/discussion in the final Work Plan for not including dioxins in the analysis of surface water/sediment at SWMU 41.

RFAAP Response

Dioxin/furan sampling will be conducted to assess for the presence of these constituents in buried waste material (burned material/ash) and in underlying soil. Sufficient samples are proposed for the RFI to evaluate potential migration of dioxin/furans from waste material to soil. Given that the waste material is buried at SWMU 41 and that dioxins are nearly insoluble and immobile in soil, sampling of surface water/sediment is not warranted at this time. Dioxin/furan data from the RFI will be evaluated to assess whether additional sampling for these constituents is required.

EPA Comment 4:

Section 1.3, Planned Field Activities, page 1-30: This section indicates that a portable photoionization detector (PID) will be used for screening during the investigation. A PID alone may not detect volatile organic compounds (VOCs) with higher ionization potentials than the electron volt used in the PID. A flame ionization detector (FID) is better suited for screening such VOCs. Since the presence or absence of VOCs were not investigated in the past, it must be insured that a detector or combination of detectors which will permit the detection of all VOCs will be used during the investigation.

RFAAP Response

The Work Plan proposes the use of a portable photoionization detector (PID) for screening volatile organic compounds (VOCs) to assess the level of personal protective equipment (PPE). The level of PPE is dependent upon the readings (Section 3.5) using a 10.6 eV lamp. PIDs have traditionally been considered as "detection" instruments used as "protection" monitors alerting workers to potentially hazardous conditions and are adequate for general field screening. It is true that there are VOCs with higher ionization potentials including the chloroalkanes (trichloroethanes, dichloroethanes, chloromethane, etc.) that are detected on the FID; however, it is considered unlikely that significant concentrations will be found at SWMU 41. The 10.6 eV lamp is capable of detecting 172 VOCs and the instrument and procedures have been used and met health and safety requirements for past RFAAP investigations. Another consideration would be that the use of a FID would bring an ignition (hydrogen gas generated) source to the sampling site, which is not desirable given that explosives are a COPC for the site.

EPA Comment 5:
Table 1-1, Applicable MWP Activities and Related SOPs, page 1-5: Table 1-1 of the WPA lists Air Monitoring under Section 9.0 of the Master Work Plan (MWP). However, Section 9.0 of the June 2002 version of the MWP is the "References" section, and there is not a section included for Air Monitoring. Additionally, page 1-4 of the WPA states "Table 1-1 lists the specific MWP investigative activities planned." No air monitoring is planned as an investigative activity in the WPA. Please remove or modify the reference to Section 9.0 and reference the correct sections of the MWP for the investigative activities planned in the WPA.

RFAAP Response
The reference in Table 1-1 refers to Section 9.0 of Volume III of the Master Work Plan (MWP) rather than Section 9.0 of Volume I. Table 1 will be modified to reference Section 9.0 of Volume III. Air monitoring is component of the health and safety plan outlined in Volume III Section 9 of the MWP and therefore is a MWP investigative activity.

EPA Comment 6:
Section 1.3.4, Surface Water, Sediment, and Spring/Seep Sampling, on page 1-37 states that six surface water and sediment sample pairs will be collected from nearby perennial and intermittent streams targeting immediately upstream, midstream and downstream locations. While the EPA BTAG understands the importance of targeting upstream samples to evaluate the impact of the site on downstream samples, it is more important to target depositional areas where contaminants would accumulate from the site. Given that most intermittent streams are small, high gradient systems, the stream adjacent to Area B may not represent a significant depositional area for contaminants. An evaluation of depositional patterns within the streams should be performed to determine what sampling locations are appropriate.

RFAAP Response
Comment noted. The surface water and sediment samples proposed in Stroubles Creek and its unnamed tributary will be collected from depositional areas based on conditions observed during the sampling event.

EPA Comment 7:
Table 1-9, Summary of Proposed RFI Borings, on page 1-35 presents a summary of the proposed soil borings, including the location and purpose of each boring. The table shows that only one out of four samples from Area A and three out of six samples from Area B are being collected from inside Areas A and B respectively. It is unclear what is meant by inside and outside these Areas. If the assumption is made that inside means within the areas where geophysical anomalies were found, it is unclear why so few samples are being collected inside Areas A (1 out of 4) and B (3 out of 6) where the highest contamination should be expected. Additional justification should be provided for the sampling approach.

RFAAP Response

The designation "inside" and "outside" of Areas A and B are designed to identify the lateral and vertical extent of the waste areas (red water ash, etc). Sample locations designated as "inside" on Table 1-9 are presumed to be within the waste area(s) as inferred from geophysical data (Area B) and historical data analysis (Areas A and B). "Inside" samples are designed to collect data regarding the chemical nature of the waste as well as assess vertical migration, if present. The sample locations designated as "outside" on Table 1-9 are intended to characterize the lateral extent of the waste areas at Areas A and B.

In Area A, there are 12 soil boring samples, 3 test pit samples, and 3 QA/QC samples proposed (and two existing historical samples) in an approximate 50 X 75 feet (ft) area (0.084 acre); this would be equivalent to 238 samples on a one acre site. In Area B, there are 18 soil boring samples, 3 test pit samples, and 3 QA/QC soil samples proposed in an approximate 100 X 150 ft (0.344 acre); this would be equivalent to 70 samples on a one acre site.

Given the size of these areas, existing data (including soil boring data from Area A) and the planned IAP action, the sampling approach (test pits and soil borings) is considered appropriate to identify waste areas and characterize the lateral and vertical extent of waste and associated constituents in soil.

EPA Comment 8:

<u>**Figures 1-13 and 1-14**</u>: Please include exposures for the residential scenario. Also, please note that current/future construction activities can lead to onsite development that may disturb the subsurface soil and bring it up onto the surface. This may make it necessary to evaluate surface and subsurface soil as total soil in the risk assessment.

RFAAP Response

The CSM will be modified to indicate that exposures for a future residential scenario will be considered in addition to the current and future industrial scenario. The standard protocol used previously for the residential scenario risk assessment for other sites at RFAAP has considered the potential disturbance of soil and the potential need to evaluate surface and subsurface soil as total soil in the risk assessment.

EPA Comment 9:

<u>**Figure 1-16, Proposed Sampling Locations Area B:**</u> The legend for this figure identifies a closed circle symbol as representing the soil boring locations but the symbol used on the figure is an open circle symbol. The closed circle symbol is used on Figure 1-15 as identified in the legend for that figure. Please reconcile this discrepancy and correct the symbols on the figure or the legend accordingly.

RFAAP Response

The closed circle symbol is correct for the soil boring locations. The symbols on Figure 1-16 will be changed to closed circles.

EPA Comment 10:
Figure 1-17 shows the surface water, sediment, and spring/seep sampling locations for Areas A and B. The sampling locations shown are not located in the streams on the map. This error should be corrected.

RFAAP Response
Figure 1-17 will be revised to show the surface water and sediment samples within the stream locations instead of adjacent. Seep sample locations on Figure 1-17 are correctly positioned at the locations of seeps at SWMU 41.

EPA Comment 11:
Figure 1-17, Surface Water, Sediment, and Spring/Seep Sampling Locations, page 1-38: This figure contains the sampling locations for surface water, sediment, and springs/seeps. There are two symbols on the figure; it is assumed the triangle is surface water/sediment sampling locations and the closed circle is spring/seep sampling locations. Please add a legend to the figure to clearly identify the symbols used on the figure.

RFAAP Response
A legend will be added to Figure 1-17 to identify the sample symbols used on this figure.

EPA Comment 12:
Section 1.3.4, Surface Water, Sediment, and Spring/Seep Sampling, on page 1-39 lists the analytical parameters for surface water and sediment samples from the site. Sediment should also be analyzed for total organic carbon and grain size. Surface water should be analyzed for hardness so that site-specific water quality criteria can be developed for metals.

RFAAP Response
The text will be modified to add analyses of total organic carbon and grain size for sediment and hardness for surface water (two representative sample locations per stream will be selected).

EPA Comment 13:
Please provide a complete hardcopy of the final Facility-Wide Background Study (2002) for the EPA toxicologist to use as a reference in future reviews.

RFAAP Response
An additional hardcopy of this document will be provided to EPA under separate cover.

27/

EPA Comments Regarding: APPENDIX D - ARGONNE NATIONAL LABORATORY DRAFT GEOPHYSICAL SURVEYS - SWMU 41

EPA Comment 14:

<u>**Appendix D, pages D-1 through D-16:**</u> The references to figures and appendices in this section are not clear. For example on page D-1, it is stated that "Appendix A describes in more detail the theory and operations of these methods." It is unclear where this information is located. It is possible the information is in Appendix A or within Appendix D, as Appendix D.2. Please reference the specific standard operating procedures (20.7 and 20.8) within Appendix A or the methods described in Appendix D.2. Additionally, the figures in Appendix D are referenced incorrectly. The figures in Appendix D are labeled D.1 through D.5 but referred to within the text of Appendix D as Figures 1 through 5. Please revise the references in the text of Appendix D to refer to Figures D.1 through D.5.

> **RFAAP Response**
>
> The references included in the text of Appendix D will be revised to indicate the correct reference sections and figures in Appendix D and standard operating procedures, as appropriate.

4

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

December 8, 2003

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
SWMU 41
Review of draft *Work Plan Addendum 18*

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's draft *Work Plan Addendum 18* for the investigation of SWMU 41, located at the Radford Army Ammunition Plant (RFAAP). Outlined below, please find EPA's comments based upon that review:

1. **Section 1.2.1, Site Background - Environmental Setting, page 1-6**: This section refers to various structures in the vicinity of Solid Waste Management Unit (SWMU) 41 and references Figure 1-2 for their locations. These structures are not labeled on Figure 1-2, requiring the reader to guess which structures outlined on Figure 1-2

are being referred to in this section. Please revise Figure 1-2 to include labels for structures referred to in the text.

2. **Section 1.2.5, Conceptual Site Model, page 1-25:** It is stated in this section that "potentially affected media include surface soil, subsurface soil, surface water, and sediment." Groundwater should also be included as a potentially affected media, since the limited data presented in Table 1-4 indicate that groundwater at the site is impacted. In addition, the conceptual site model (CSM) Figures 1-13 and 1-4 do include groundwater as an exposure pathway. Please revise the text to indicate that groundwater is a potentially affected media at the site. Otherwise, there is a need to note how groundwater will be dealt with at this site.

3. Please provide justification/discussion in the final Work Plan for not including dioxins in the analysis of surface water/sediment at SWMU 41.

4. **Section 1.3, Planned Field Activities, page 1-30:** This section indicates that a portable photoionization detector (PID) will be used for screening during the investigation. A PID alone may not detect volatile organic compounds (VOCs) with higher ionization potentials than the electron volt used in the PID. A flame ionization detector (FID) is better suited for screening such VOCs. Since the presence or absence of VOCs were not investigated in the past, it must be insured that a detector or combination of detectors which will permit the detection of all VOCs will be used during the investigation.

5. **Table 1-1, Applicable MWP Activities and Related SOPs, page 1-5:** Table 1-1 of the WPA lists Air Monitoring under Section 9.0 of the Master Work Plan (MWP). However, Section 9.0 of the June 2002 version of the MWP is the "References" section, and there is not a section included for Air Monitoring. Additionally, page 1-4 of the WPA states "Table 1-1 lists the specific MWP investigative activities planned." No air monitoring is planned as an investigative activity in the WPA. Please remove or modify the reference to Section 9.0 and reference the correct sections of the MWP for the investigative activities planned in the WPA.

6. **Section 1.3.4, Surface Water, Sediment, and Spring/Seep Sampling, on page 1-37** states that six surface water and sediment sample pairs will be collected from nearby perennial and intermittent streams targeting immediately upstream, midstream and downstream locations. While the EPA BTAG understands the importance of targeting upstream samples to evaluate the impact of the site on downstream samples, it is more important to target depositional areas where contaminants would accumulate from the site. Given that most intermittent streams are small, high gradient systems, the stream adjacent to Area B may not represent a significant depositional area for contaminants. An evaluation of depositional patterns within the streams should be performed to determine what sampling locations are appropriate.

7. **Table 1-9, Summary of Proposed RFI Borings, on page 1-35** presents a summary of the proposed soil borings, including the location and purpose of each boring. The table shows that only one out of four samples from Area A and three out of six samples from Area B are being collected from inside Areas A and B

respectively. It is unclear what is meant by inside and outside these Areas. If the assumption is made that inside means within the areas where geophysical anomalies were found, it is unclear why so few samples are being collected inside Areas A (1 out of 4) and B (3 out of 6) where the highest contamination should be expected. Additional justification should be provided for the sampling approach.

8. **Figures 1-13 and 1-14**: Please include exposures for the residential scenario. Also, please note that current/future construction activities can lead to onsite development that may disturb the subsurface soil and bring it up onto the surface. This may make it necessary to evaluate surface and subsurface soil as total soil in the risk assessment.

9. **Figure 1-16, Proposed Sampling Locations Area B:** The legend for this figure identifies a closed circle symbol as representing the soil boring locations but the symbol used on the figure is an open circle symbol. The closed circle symbol is used on Figure 1-15 as identified in the legend for that figure. Please reconcile this discrepancy and correct the symbols on the figure or the legend accordingly.

10. **Figure 1-17** shows the surface water, sediment and spring/seep sampling locations for Areas A and B. The sampling locations shown are not located in the streams on the map. This error should be corrected.

11. **Figure 1-17, Surface Water, Sediment, and Spring/Seep Sampling Locations, page 1-38:** This figure contains the sampling locations for surface water, sediment, and springs/seeps. There are two symbols on the figure; it is assumed the triangle is surface water/sediment sampling locations and the closed circle is spring/seep sampling locations. Please add a legend to the figure to clearly identify the symbols used on the figure.

12. **Section 1.3.4, Surface Water, Sediment, and Spring/Seep Sampling, on page 1-39** lists the analytical parameters for surface water and sediment samples from the site. Sediment should also be analyzed for total organic carbon and grain size. Surface water should be analyzed for hardness so that site-specific water quality criteria can be developed for metals.

13. Please provide a complete hardcopy of the final Facility-Wide Background Study (2002) for the EPA toxicologist to use as a reference in future reviews.

APPENDIX D ARGONNE NATIONAL LABORATORY DRAFT GEOPHYSICAL SURVEYS - SWMU 41

14. **Appendix D, pages D-1 through D-16:** The references to figures and appendices in this section are not clear. For example on page D-1, it is stated that "Appendix A describes in more detail the theory and operations of these methods." It is unclear where this information is located. It is possible the information is in Appendix A or within Appendix D, as Appendix D.2. Please reference the specific standard operating procedures (20.7 and 20.8) within Appendix A or the methods described in Appendix D.2.

41

Additionally, the figures in Appendix D are referenced incorrectly. The figures in Appendix D are labeled D.1 through D.5 but referred to within the text of Appendix D as Figures 1 through 5. Please revise the references in the text of Appendix D to refer to Figures D.1 through D.5.

This concludes EPA's review of the Army's draft *Work Plan Addendum 18* for the investigation of SWMU 41, located at RFAAP. The referenced draft *Work Plan* is disapproved by EPA in its current form, and must be revised to reflect the comments above. Per Part II, Section E.4.e. of the EPA RCRA Corrective Action Permit, the Army is required to revise the draft document and submit a revised draft copy to EPA for review within 60 days of the receipt of EPA comments on the draft document. Part II, Section E.4.f. of the Permit allows for an additional 20 days for issuing the revised draft document to EPA, provided that timely notice is given, i.e. within 10 days. Additional time extensions can be requested under Part II, Section F. of the permit.

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

Sincerely,

Robert Thomson

Robert Thomson, PE
Federal Facilities Branch

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

McKenna, Jim

rom: Jenkins, Joanne
ent: Monday, November 03, 2003 8:25 AM
To: McKenna, Jim
Cc: Davie, Robert
Subject: RE: NHPA, Work Plan Addendum 18

Jim,

I have looked at the areas you plan on sampling. There are no historic properties. Therefore your actions will have no effect on historic properties.

Thanks,

Joanne Jenkins
Industrial Specialist
Government Staff
DSN 931-7480 COM 540-639-7480

-----Original Message-----
From: McKenna, Jim
Sent: Thursday, October 30, 2003 2:25 PM
To: Jenkins, Joanne
Subject: NHPA, Work Plan Addendum 18

Joanne:

Work Plan Addendum 18 identifies sampling work that will occur at Solid Waste Managment Unit 41 in the TNT area. The WPA has maps that show sampling locations. Need to review for possible interference with historic sites.

Jim

McKenna, Jim

From: McKenna, Jim
Sent: Thursday, October 16, 2003 3:05 PM
To: 'Tony Perry'; 'john e tesner'
Cc: Davie, Robert; Redder, Jerome
Subject: FW: Review of WPA 18 and soil screening documents

fyi.

-----Original Message-----
From: Williams, Keith J Mr USACHPPM [mailto:keith.j.williams@us.army.mil]
Sent: Thursday, October 16, 2003 2:49 PM
To: McKenna, Jim
Subject: Review of WPA 18 and soil screening documents

Hi Jim,
Attached are the review memos for WPA 18 and the soil screening report. Hard copies will follow in the mail.

Thanks,
Keith

MCHB-TS-REH (40)

MEMORANDUM FOR Radford Army Ammunition Plant ATTN: SOSRF-OP-EQ (Jim McKenna), PO Box 2, Radford, VA 24143-0002

SUBJECT: Draft Work Plan Addendum No. 18 RCRA Facility Investigation at Solid Waste Management Unit 41, September, 2003

1. The US Army Center for Health Promotion and Preventive Medicine reviewed the subject document on behalf of the Office of The Surgeon General pursuant to AR 200-1 (Environmental Protection and Enhancement). Thank you for the opportunity to review this document. We concur with the conclusions and recommendations contained in this report.

2. The scientist reviewing this document and our point of contact is Mr. Keith Williams, Environmental Health Risk Assessment Program, at DSN 584-7722 or commercial (410) 436-7722.

FOR THE COMMANDER:

DAVID A. REED
Program Manager
Environmental Health Risk
Assessment

CF:
HQDA(DASG-HS-PE)
USAMEDCOM (MCHO-CL-W)
USACE (CENWO-HX-H)
USAEC (SFIM-AEC-ER)
IMA, NERO (SFIM-NE-PW-ER)

COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

Street address: 629 East Main Street, Richmond, Virginia 23219
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W. Tayloe Murphy, Jr.
Secretary of Natural Resources

Robert G. Burnley
Director
(804) 698-4000
1-800-592-5482

October 7, 2003

Mr. James McKenna
Radford Army Ammunition Plant
SIORF-SE-EQ
P.O. Box 2
Radford, VA 24141-0099

RE: Work Plan Addendum No. 18, SWMU 41
Soil Screening Report SWMU 8
Soil Screening Report SWMU 36

Dear Mr. McKenna:

Thank you for providing the staff the opportunity to review and comment on the referenced documents. The staff has the following comments:

Work Plan Addendum No. 18, SWMU 41

Figure 1-16. The symbol for soil boring in the legend (closed black circle) does not correspond to the symbol used in the figure (open circle). Also, Table 1-9 indicates that soil samples SB 6, 7 and 8 will be taken outside Area B, while the figure clearly shows the samples to be within the inferred boundary line.

Figure 1-15. Table 1-9 indicates that soil samples SB 3, 4 and 5 will be taken outside Area A, while Figure 1-15 shows the samples within the inferred boundary line. Please explain.

Soil Screening Reports SWMUs 8 and 36

There are no additional comments on the Soil Screening Reports for SWMUs 8 and 36.

Please do not hesitate to contact Jennifer Jones, 804-698-4328, or myself if you have questions concerning these comments.

Sincerely,

Durwood W Willis

Durwood Willis
Federal Facilities Program Manager

CC: Norman L. Auldridge, VDEQ - WCRO

x1.

ATK
ALLIANT TECHSYSTEMS

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

September 5, 2003

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

Subject: Work Plan Addendum 18, RCRA Facility Investigation at SWMU 41,
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is one certified copy of Work Plan Addendum 18, RCRA Facility Investigation at SWMU 41, Radford Army Ammunition Plant for your review and comment or approval. Your additional five 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.

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
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Mark Leeper
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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

03-815-140
JMcKenna/JJRedder

Concerning the following:

Work Plan Addendum 18
RCRA Facility Investigation at SWMU 41
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: Anthony R Skinner
PRINTED NAME: Anthony R. Skinner
TITLE: LTC, CM, Commanding
Radford AAP

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

03-815-140
JMcKenna/JJRedder

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

WORK PLAN ADDENDUM NO. 18
RCRA Facility Investigation at Solid Waste Management Unit 41

FINAL DOCUMENT
DECEMBER 2003

PREPARED BY:

URS

5540 Falmouth Street, Suite 201
Richmond, Virginia 23230
(804) 965-9000 main
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ARCHITECT-ENGINEER SERVICES
CONTRACT NO. DACA31-00-D-0011
DELIVERY ORDER NO. 0055

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 and multiple site-specific Work Plan Addenda.

The Master Work Plan 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 Master Work Plan is a generic plan designed to streamline site-specific Work Plan addenda development, review, and approval.

Each Work Plan Addendum 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 Master Work Plan, is developed as a concise document, focused on site-specific investigations.

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SWMU 41 RCRA FACILITY INVESTIGATION
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6'

LIST OF ABBREVIATIONS AND ACRONYMS

%	Percent
AES	Atomic Emission Spectroscopy
ASTM	American Society for Testing and Materials
bgs	Below Ground Surface
BTAG	Biological Technical Assistance Group
CFR	Code of Federal Regulations
CLP	Contract Laboratory Program
CN	Cyanide
CNCl	Cyanogen Chloride
COR	Contracting Officer's Representative
CSM	Conceptual Site Model
dBA	Decibels on the A-Weighted Scale
DC	Direct Current
DQO	Data Quality Objective
DNT	Dinitrotoluene
ECD	Electron Capture Detector
ELCD	Electrolytic Conductivity Detector
EM	Electromagnetic
EPIC	Environmental Photographic Interpretation Center
ERA	Ecological Risk Assessment
ERIS	Environmental Restoration Information System
ft	Feet
g	Gram
GC	Gas Chromatography
GPS	Global Positioning System
HAZCOM	Hazard Communication
HCN	Hydrocyanic Acid
HHRA	Human Health Risk Assessment
HPLC	High Performance Liquid Chromatography
HQ	Hazard Quotient
HRGC/HRMS	High-resolution Gas Chromatography/High-resolution Mass Spectrometry
HSP	Health and Safety Plan
HSPA	Health and Safety Plan Addendum
HTRW	Hazardous, Toxic, and Radioactive Waste
Hz	Hertz
ICP	Inductively Coupled Plasma
IDM	Investigation-Derived Material
MCL	Maximum Contaminant Level
MDL	Method Detection Limit
µg/L	Micrograms Per Liter
µL	Microliter
µm	Micrometer
mg/kg	Milligrams Per Kilogram
mg/L	Milligrams Per Liter
mL	Milliliter
MHSP	Master Health and Safety Plan

LIST OF ABBREVIATONS AND ACRONYMS
(CONTINUED)

mm	Millimeter
MMA	Main Manufacturing Area
MQAP	Master Quality Assurance Plan
MS	Mass Spectrometer
MS/MSD	Matrix Spike/Matrix Spike Duplicate
MSDS	Material Safety Data Sheet
msl	Mean Sea Level
MWP	Master Work Plan
nm	Nanometer
OCDD	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin
OCDF	1,2,3,4,6,7,8,9-Octachlorodibenzofuran
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCDD	Polychlorinated Dibenzo-p-dioxins
PCDF	Polychlorinated Dibenzofurans
PETN	Pentaerythritol Tetranitrate
PID	Photoionization Detector
PM	Project Manager
ppb	Parts Per Billion
PPE	Personal Protective Equipment
ppm	Parts Per Million
ppq	Parts Per Quadrillion
ppt	Parts Per Trillion
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance / Quality Control
QAP	Quality Assurance Plan
QAPA	Quality Assurance Plan Addendum
RA	Risk Assessment
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFAAP	Radford Army Ammunition Plant
RFI	RCRA Facility Investigation
RL	Reporting Limit
SHSO	Site Health and Safety Officer
SOP	Standard Operating Procedure
SOW	Statement of Work
SVOC	Semivolatile Organic Compound
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TCL	Target Compound List
TCLP	Toxicity Characteristic Leaching Procedure

LIST OF ABBREVIATONS AND ACRONYMS
(CONTINUED)

TEF	Toxicity Equivalence Factor
TEQ	Toxicity Equivalent Concentration
TNT	Trinitrotoluene
TOC	Total Organic Carbon
TOX	Total Organic Halogen
TWA	Time Weighted Average
URS	URS Group, Inc.
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VDEQ	Virginia Department of Environmental Quality
VI	Verification Investigation
VOC	Volatile Organic Compound
WPA	Work Plan Addendum

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1.0 WORK PLAN ADDENDUM

In accordance with Contract Number DACA31-00-D-0011, Delivery Order No. 55, URS Group, Inc. (URS) has been tasked by the United States Army Corps of Engineers (USACE), Baltimore District to perform a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) at Solid Waste Management Unit (SWMU) 41, the Red Water Ash Burial Ground, located in the southeast section of the Main Manufacturing Area (MMA) at the Radford Army Ammunition Plant (RFAAP), Radford, Virginia (Figure 1-1). This RFI Work Plan for SWMU 41 is presented as an addendum (Work Plan Addendum No. 18) to, and incorporates by reference, the elements of the RFAAP Master Work Plan (MWP; URS 2002).

1.1 INTRODUCTION

The project objectives of the RFI at SWMU 41 are to:

- Generate sufficient data to conclusively define and describe what soil-related risk exists to human health and the environment;

- Define possible contaminant sources and the nature and extent of possible soil contamination; and

- Reach a final decision regarding what future soil-related action is warranted at this site.

Figure 1-2 shows the layout of SWMU 41. Even though the 1987 RCRA Facility Assessment (RFA) shows one area, SWMU 41 actually consists of two inactive non-contiguous disposal areas for red water ash, a byproduct of combustion of trinitrotoluene (TNT) production wastewater, (i.e., “red water”):

1) A lagoon that received rinsate from ash-transport vehicle rinsing (hereinafter referred to as the Area A); Area A consists of an unlined lagoon approximately 50 feet by 75 feet, which has been backfilled (USEPA 1987); and

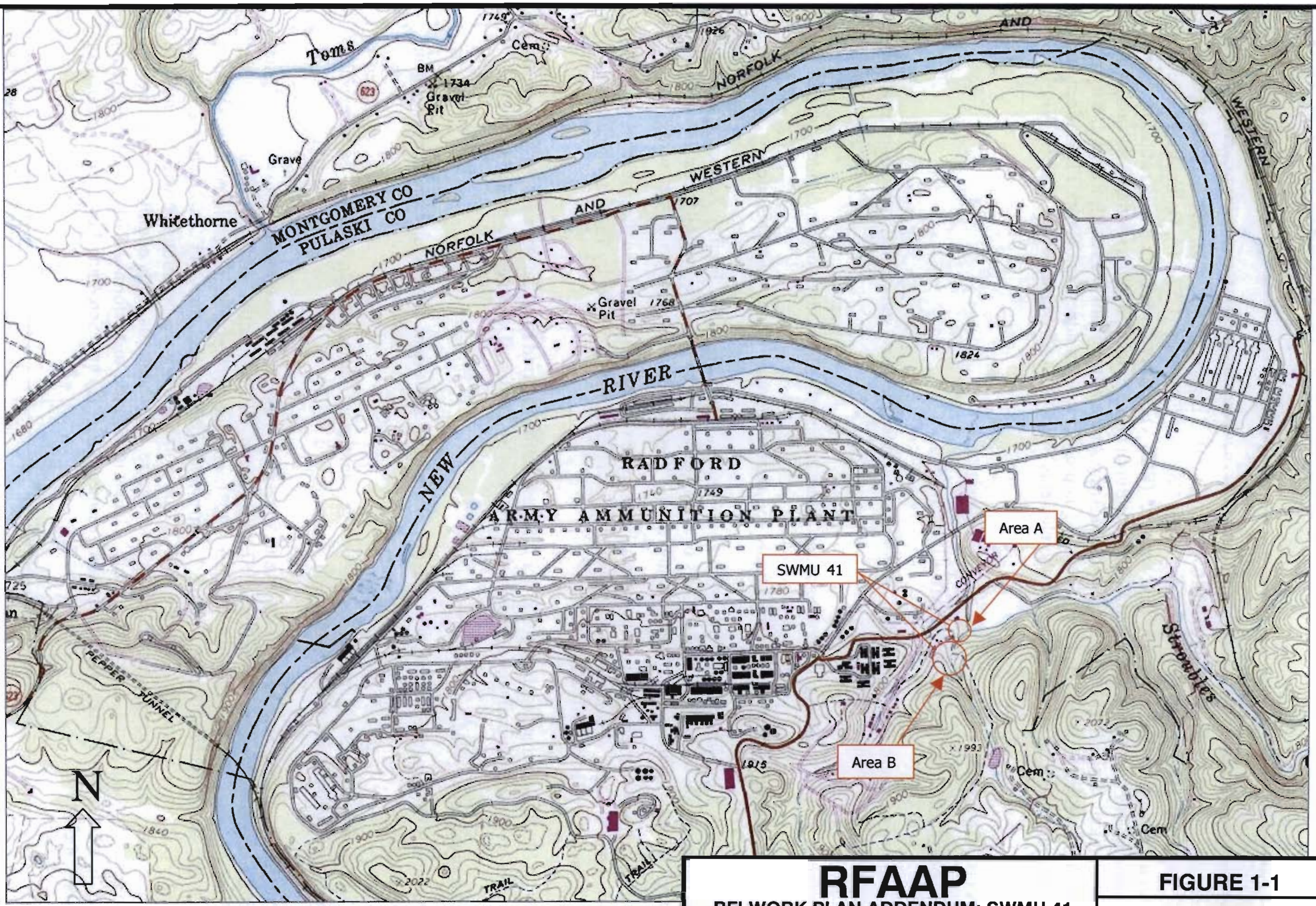
2) A burial area that received red water ash (hereinafter referred to as the Area B); Area B consists of a clay-lined burial area approximately 100 feet by 150 feet (Dames & Moore 1992).

The investigation at SWMU 41 is designed to:

- Physically investigate SWMU 41 to define the nature and extent of previous waste management practices;

- Collect and chemically analyze representative samples of surface/subsurface soil, surface water, spring/seep discharges (if available), and sediment; and

- Provide data that can be used to evaluate residual risk through comparison to United States Environmental Protection Agency (USEPA) Region III Residential and Industrial Risk-Based Concentrations (RBCs) (USEPA October 2003), and the background inorganic constituent point estimate concentrations reported in the Facility-Wide Background Study (IT 2002). In accordance with USEPA Region III guidance, RBCs for non-carcinogenic constituents will be adjusted downward to a Hazard Quotient of 0.1 to ensure the chemicals with additive effects are not prematurely eliminated during screening. Data will be used to perform a Risk Assessment (RA) subdivided into a Human Health Risk Assessment (HHRA) and Screening-Level Ecological Risk Assessment.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 41

Date: AUGUST 2003

Prepared by: KDC/DR

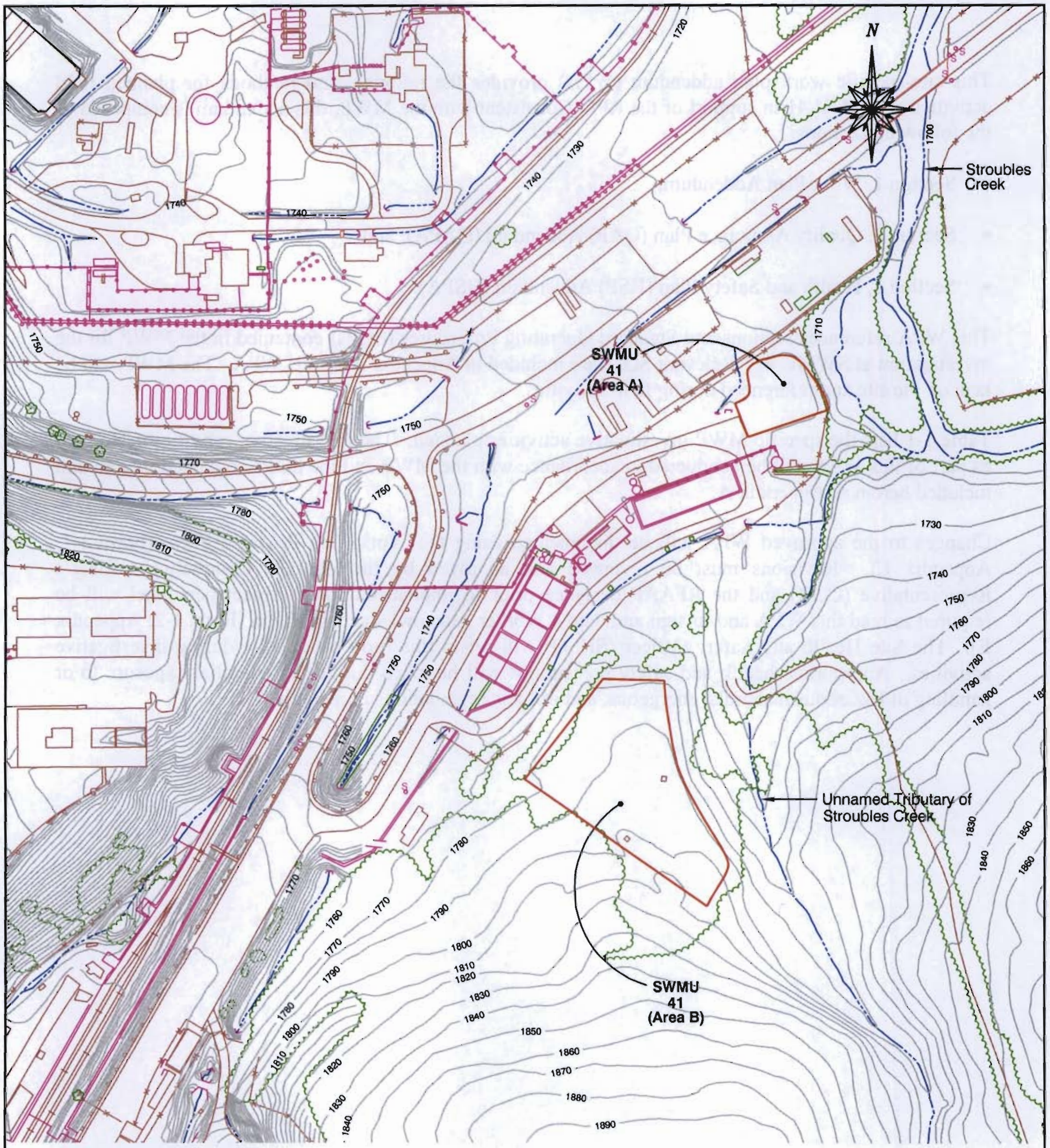
Scale: 1" = 2,000'

File Name: 09604-325-155/Figure 1-1.ppt

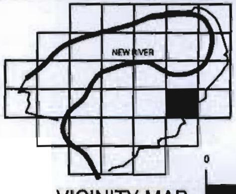
FIGURE 1-1

SITE LOCATION MAP

7'



(SOURCE: MODIFIED FROM HERCULES, INC., 1992)



VICINITY MAP
N.T.S.

0 200
1 inch = 200 feet

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 41

Date: AUGUST 2003	Prepared By: KDC/DR
Scale: AS SHOWN	File Name: 09604-325-155

FIGURE 1-2

SITE TOPOGRAPHY LAYOUT

This site-specific work plan addendum (WPA) provides the rationale and methods for planned field activities at SWMU 41 in support of the RFI. Consistent with the MWP, this addendum is composed of the following sections:

- Section 1, Work Plan Addendum;
- Section 2, Quality Assurance Plan (QAP) Addendum (QAPA); and
- Section 3, Health and Safety Plan (HSP) Addendum (HSPA).

This WPA references sections and Standard Operating Procedures (SOPs) contained in the MWP for the investigation at SWMU 41. Relevant SOPs are included in Appendix A of this WPA. The MWP will be kept on the site and referenced during field activities.

Table 1-1 lists the specific MWP investigative activities planned. The investigative activities performed as part of this WPA will be conducted in accordance with the MWP and the SOPs contained therein and included herein as Appendix A.

Changes to the approved WPA will be documented using the Work Plan Revision Form (Form 1-1; Appendix E). Revisions must be reviewed and approved by the USACE Contracting Officer's Representative (COR) and the RFAAP designee prior to implementation. Project personnel will be required to read this WPA and to sign and date a Worker Acknowledgement Form (Form 1-2; Appendix E). The Site Health and Safety Officer (SHSO) will retain this form on the site during investigative activities. Appropriate health and safety precautions will be taken due to the potential exposure to or handling of hazardous materials, energetics, and/or their degradation compounds.

Table 1-1

Applicable MWP Activities and Related SOPs

Subject	MWP Section	Standard Operating Procedures (SOPs) MWP Appendix A and Appendix A to WPA No. 18
Installation Description	2.0	Not Applicable
Environmental Setting	3.0	Not Applicable
Documentation	4.3	10.1 Field Logbook 10.2 Surface Water, Groundwater, and Soil/Sediment Field Logbooks 10.3 Boring Logs 10.4 Chain-of-Custody Form
Sample Management	5.1	50.1 Sample Labels 50.2 Sample Packaging
Decontamination Requirements	5.12	80.1 Decontamination
Investigation-Derived Material	5.13	30.6 Containerized Material 70.1 Investigation-Derived Material
Surface Water Investigation	5.3	30.3 Surface Water Sampling 30.4 Sediment Sampling with Scoop or Tube Sampler 40.1 Multiparameter Water Quality Monitoring Instrument
Geophysical Surveys	5.5	20.8 Magnetic and Metal Detection Surveys
Subsurface Investigation	5.2 5.8 9.2 (1)	20.3 Well and Boring Abandonment 20.4 Test Pits 20.11 Drilling Methods and Procedures 30.1 Soil Sampling 30.7 Sampling Strategies 30.9 Collection of Soil Samples by USEPA SW-846 Test Method 5035 for Volatile Organic Compounds Using Disposable Samplers 90.1 Photoionization Detector (HNu Model PI-101 and HW-101)

(1) Refers to section 9.2 in MWP Volume III

1.2 DESCRIPTION OF CURRENT CONDITIONS

1.2.1 Site Background – Environmental Setting

Section 3.0 of the MWP presents information regarding the environmental setting of the RFAAP. This Section and Section 1.2.3 of the WPA present project-specific environmental setting information.

Physiography – SWMU 41 is situated at approximately 1,815 to 1,725 feet (ft) above mean sea level (msl) in the southeast section of the MMA at RFAAP. This portion of the MMA is characterized by gently to steeply sloping ridges, and a general downward slope to the north. SWMU 41 is situated topographically lower than areas to the south and topographically higher than areas to the north, east, and west (Figure 1-1).

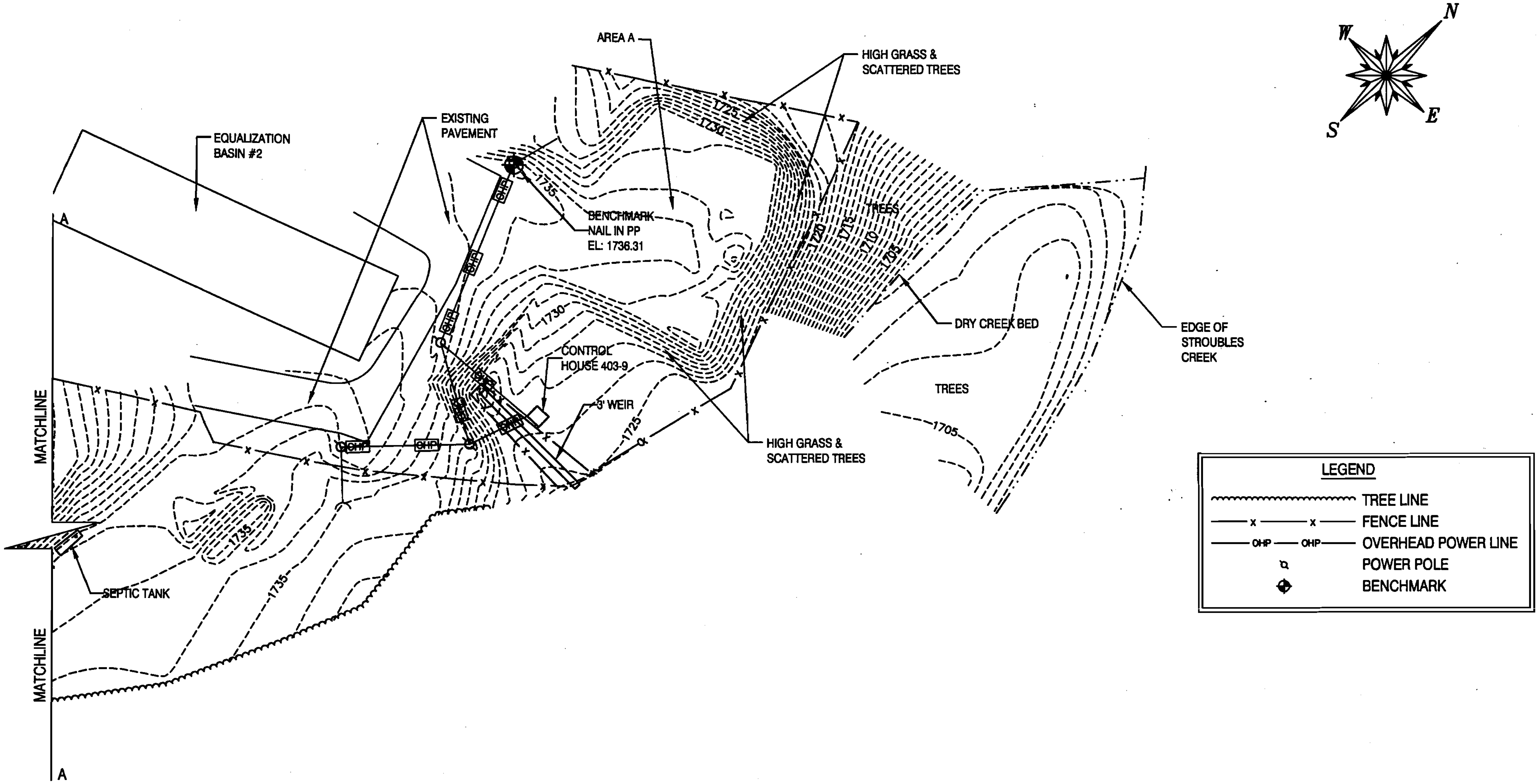
The immediate SWMU 41 area consists of two non-contiguous disposal areas, a backfilled lagoon (Area A) and a burial area (Area B). The lagoon is located approximately 100 feet west of Stroubles Creek. The elevation of the lagoon is approximately 1,730 to 1,735 feet above msl. The immediate vicinity of the Area A is steeply sloping toward the north, east, and south. The general slope in the Area A is northeast towards Stroubles Creek (Figure 1-3). Area B is approximately 600 feet south-southwest of the lagoon and approximately 150 feet west of a tributary of Stroubles Creek. The elevation of Area B ranges from approximately 1,800 to approximately 1,785 feet above msl. South of Area B, the topography slopes steeply upwards to an approximate elevation of 1,835 feet above msl. The land on the northeastern periphery of Area B slopes steeply down to the tributary of Stroubles Creek and the area north and northwest of Area B slopes down from Area B (Figure 1-4).

Tanks/Structures – Structures adjacent to SWMU 41 (Figure 1-2) include two equalization basins located approximately 100 feet northwest of Area B and approximately 50 feet south-southwest of Area A. Each equalization basin consists of contiguous below grade reinforced concrete tanks. These units currently receive storm water from the inactive TNT Area (ATK 2003). The equalization basins subsequently discharge to the RFAAP Industrial Wastewater Treatment Plant (ATK 2003). Piping and associated appurtenances from the equalization basins traverse along the southern boundary of Area A. Other structures near SWMU 41 include a maintenance shop area adjacent to the north of Area A comprised of several small structures and storage areas (Figure 1-2).

Surface Water – Figure 1-5 shows the surface water drainage patterns near SWMU 41. Overland storm water runoff originates from the southwest upgradient of Area B. Area B borders an ephemeral flowing drainage ditch leading to an un-named tributary of Stroubles Creek on the northwest. Overland drainage from Area B flows approximately 100 feet northwest and north to the drainage ditch and flows east approximately 150 feet down a moderately sloped scarp directly to the un-named tributary. The un-named tributary originates approximately 0.7 miles southeast of the SWMU areas, flows along the eastern edge of Area B, and then flows approximately 400 feet to the confluence with Stroubles Creek.

Overland storm water flow originates upgradient from the west of Area A in well-defined storm water drainage ditches that flow along the perimeter of the equalization basins and on paved road surfaces along the western perimeter of Area A.

2



NOTE:

HORIZONTAL & VERTICAL DATUM BASED ON ON-SITE CONTROL MONUMENTS AS SHOWN ON RFAAP PROJECT SITE MAP DATED 8/19/92

0 50
1 INCH = 50 FEET

RFAAP

RFI Work Plan Addendum : SWMU 41

Date: AUGUST 2003

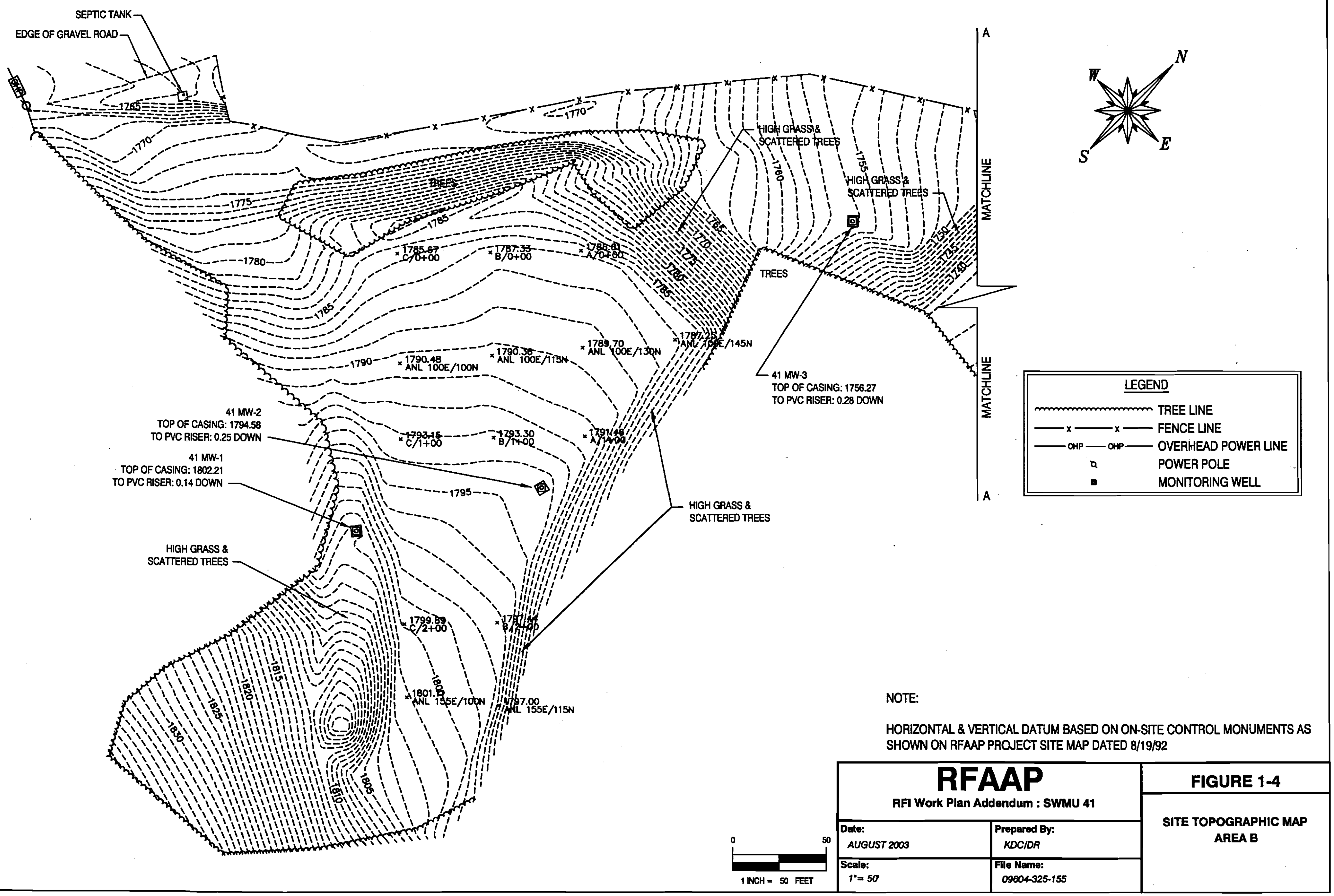
Prepared By: KDC/DR

Scale: 1"= 50'

File Name: 09604-325-155

FIGURE 1-3

SITE TOPOGRAPHIC MAP AREA A



NOTE:

HORIZONTAL & VERTICAL DATUM BASED ON ON-SITE CONTROL MONUMENTS AS SHOWN ON RFAAP PROJECT SITE MAP DATED 8/19/92

RFAAP

RFI Work Plan Addendum : SWMU 41

Date: *AUGUST 2003*

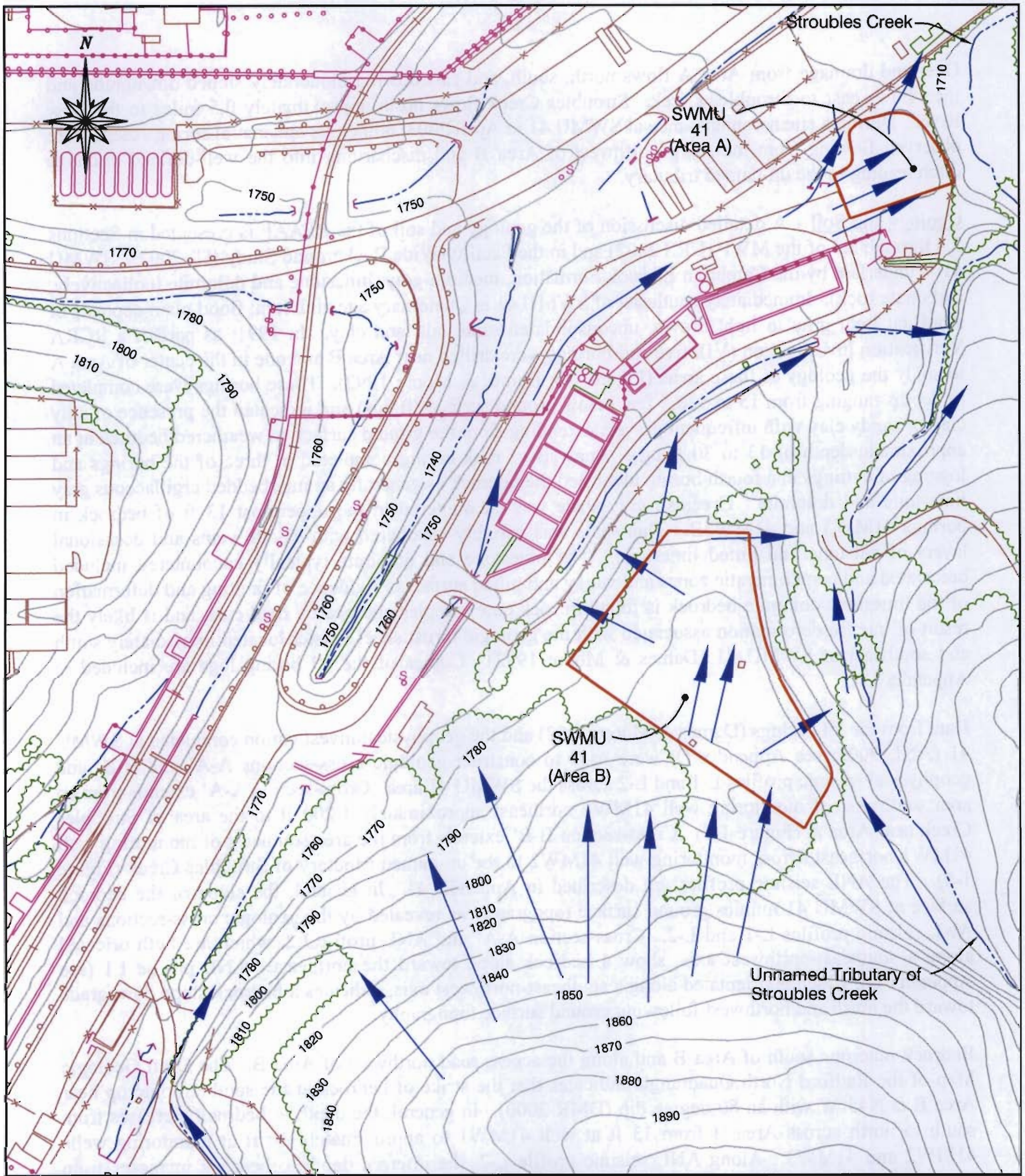
Prepared By: *KDC/DR*

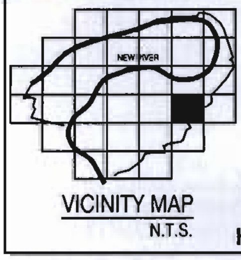
Scale: *1"= 50'*

File Name: *09604-325-155*

FIGURE 1-4

SITE TOPOGRAPHIC MAP AREA B





VICINITY MAP
N.T.S.

1 inch = 150 feet

(SOURCE: MODIFIED FROM HERCULES, INC., 1992)

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 41

Date: AUGUST 2003	Prepared By: KDC/DR
Scale: AS SHOWN	File Name: 09604-325-155

FIGURE 1-5

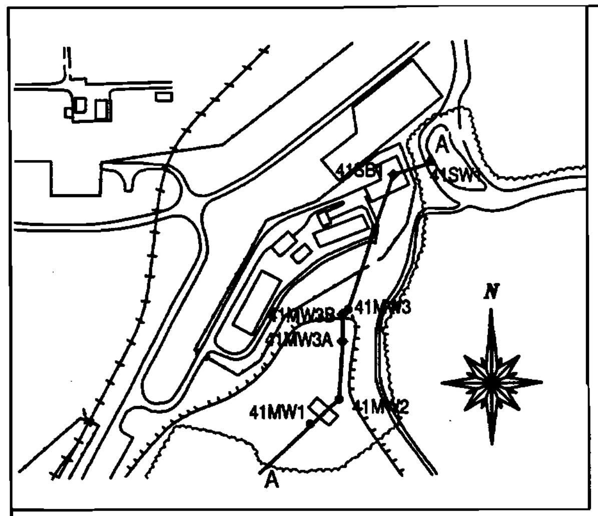
STORM WATER RUNOFF AND SURFACE WATER PATHWAYS

Overland drainage from Area A flows north, south, and east down a moderately sloped downgrade and then flows east to Stroubles Creek. Stroubles Creek flows north approximately 0.5 miles to the New River. During a site reconnaissance at SWMU 41 in April 2003, numerous ephemeral springs/seeps were observed flowing from the scarp northwest of Area B and discharging into the well-defined drainage ditch leading to the un-named tributary.

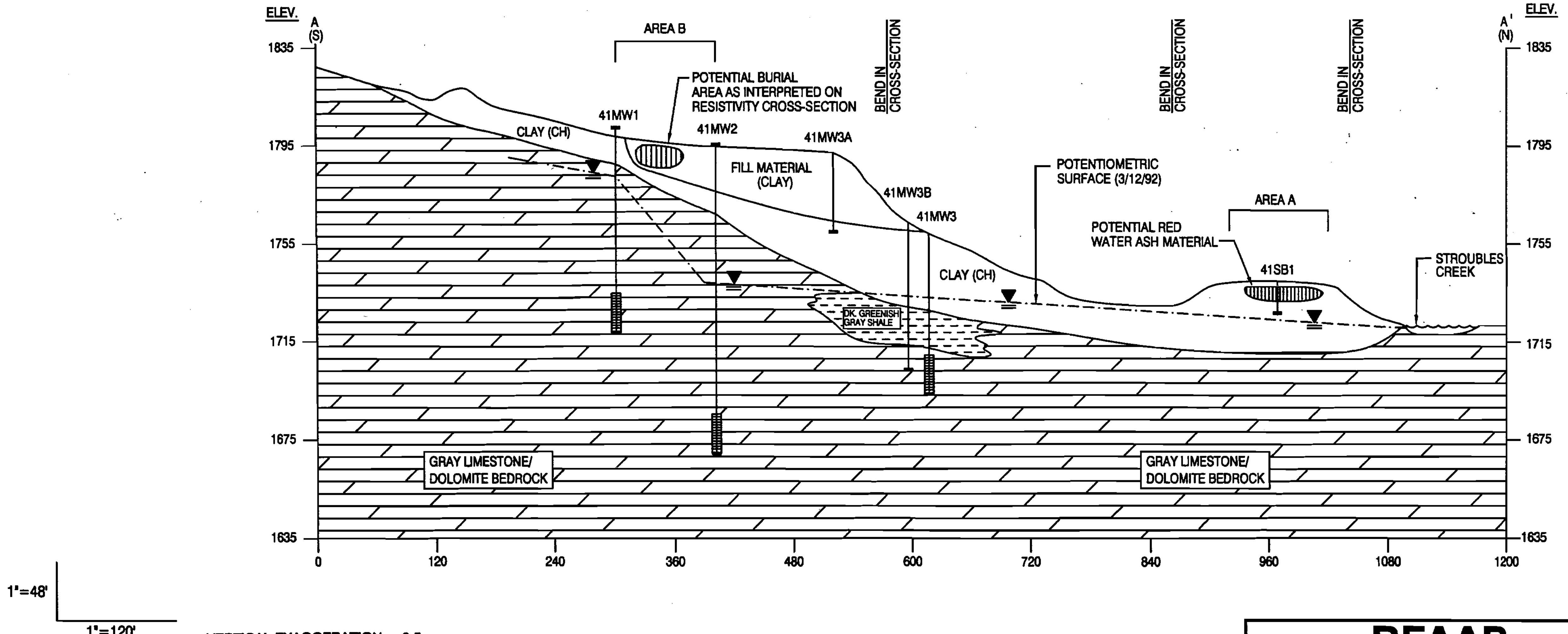
Geology and Soil – A detailed discussion of the geology and soil of the RFAAP is presented in Sections 3.4 through 3.7 of the MWP (URS 2002) and in the Facility-Wide Background Study (IT, 2002). SWMU 41 is underlain by the Cambrian Elbrook Formation, medium-gray, limestone and dolomite (collectively, carbonate rock). Immediately southeast of SWMU 41 is Quaternary age alluvium; flood plain deposits of stratified light gray to light brown, unconsolidated sand, silt, and clay. In 1991, as part of a RCRA Verification Investigation (VI), five soil borings were drilled near Area B and one in the center of Area A to study the geology of these areas (Figure 1-6; Dames & Moore 1992). These borings were completed to depths ranging from 15 to 120.5 feet below ground surface (ft bgs) and indicated the presence of silty clay or sandy clay with infrequent gravels extending from the ground surface to weathered bedrock at an approximate depth of 13 to 30 ft bgs. Analysis of rock coring completed in three of the borings and logging of cuttings in a fourth boring identified the bedrock as generally an interbedded argillaceous gray limestone and dolomite. Greenish gray shale was encountered in the uppermost 13 ft of bedrock in borings 41MW3 and 41MW3B. This shale was variably weathered with calcite veins and occasional layers of siltstone and pitted limestone. The limestone and dolomite typically encountered included brecciated and conglomeratic zones and vuggy and pitted surfaces. Evidence of faulting and deformation of the limestone/dolomite bedrock is found in rock core samples and nearby road cuts, and is likely the result of intense deformation associated with the geologic thrust sheet fenster located immediately south and southeast of SWMU 41 (Dames & Moore 1992). Copies of the VI boring logs are included in Appendix C.

Data from the VI borings (Dames & Moore 1992) and the geophysical investigation conducted at SWMU 41 (ANL 2003; see Appendix D) were used to construct geologic cross-sections A-A' and B-B' and geophysical seismic profiles L-1 and L-2 across the SWMU 41 area. Cross-section A-A' extends from an area southwest of monitoring well 41MW1 northeast approximately 1,200 ft to the area of Stroubles Creek near Area A (Figure 1-7). Cross-section B-B' extends from the area southeast of monitoring well 41MW1 northeast across monitoring well 41MW2 to the un-named tributary of Stroubles Creek (Figure 1-8). The ANL seismic profiles are described in Appendix D. In general, the slope of the bedrock surface at SWMU 41 mimics ground surface topography as revealed by the geologic cross-sections and ANL seismic profiles L-1 and L-2. Cross-section A-A' and ANL profile L2, which are both oriented along a southeast-northwest axis, show a bedrock slope toward the northeast. ANL profile L1 (see Appendix D), which is orientated along a southeast-northwest axis, indicates a bedrock slope downgrade toward the north and northwest following ground surface topography.

Bedrock outcrops south of Area B and along the access road northwest of Area B. The Draft Geologic Map of the Radford North Quadrangle indicates that the strike of bedrock at the southern outcrop near Area B is N45°W with an 80-degree dip (DMR 2000). In general, the depth to bedrock increases from south to north across Area B from 13 ft at well 41MW1 to approximately 30 ft at monitoring wells 41MW2 and 41MW3. Along ANL seismic profile L-2, the inferred depth to bedrock increases from approximately 30 ft bgs at the southwest end of the profile to approximately 37 ft at the northeast end of the profile. Along ANL seismic profile L-1, the inferred depth to bedrock increases from 5 ft or less bgs to 60 ft bgs at the northwest end of the profile.



CROSS-SECTION
N.T.S.



VERTICAL EXAGGERATION = 2.5

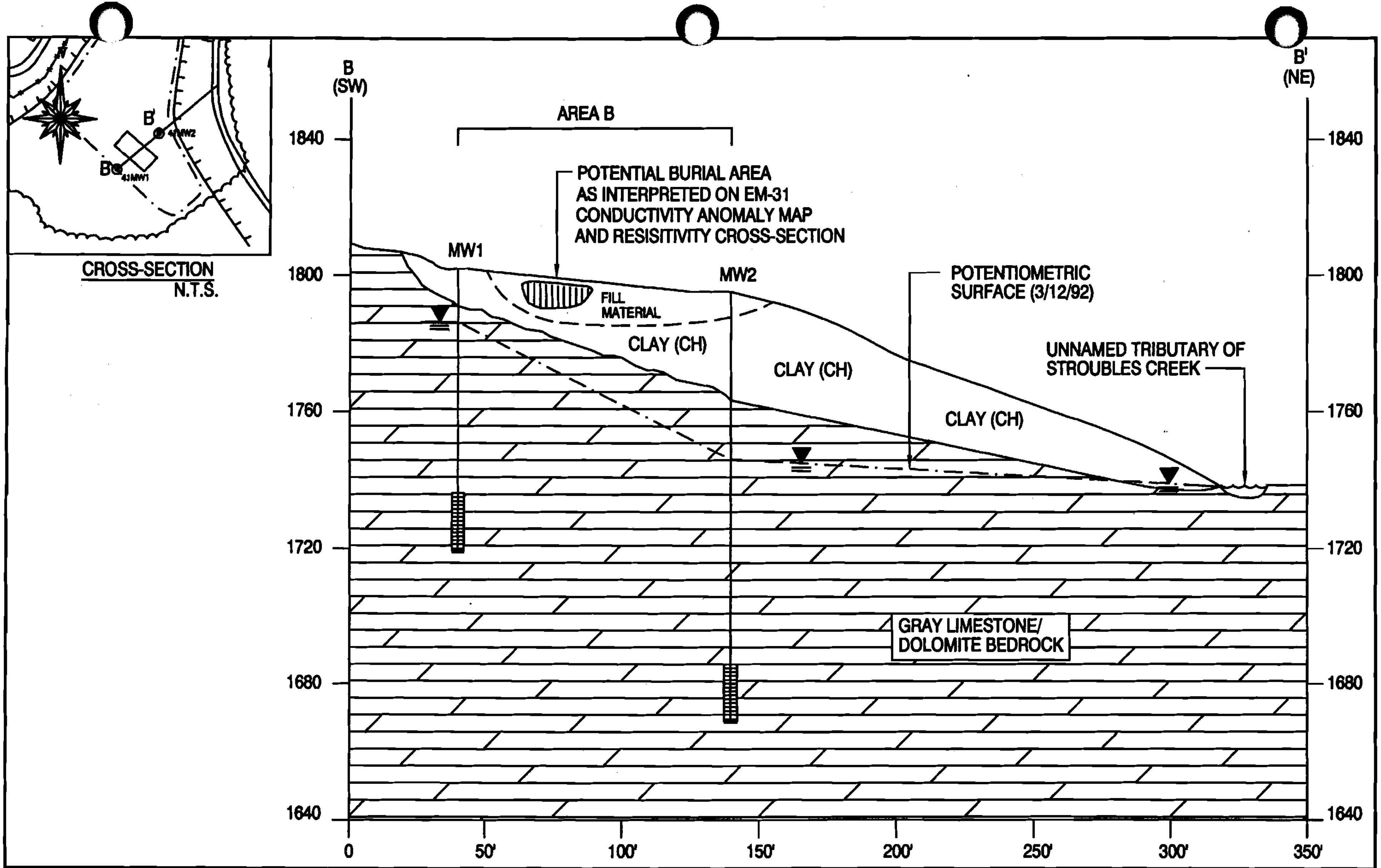
RFAAP

RFI Work Plan Addendum : SWMU 41

Date: *AUGUST 2003*	**Prepared By:** *KDC/DR*
Scale: *As Shown*	**File Name:** *09604-325-155*

FIGURE 1-7

GEOLOGIC CROSS-SECTION A-A'



1"=40'

1"=50' VERTICAL EXAGGERATION = 1.25

RFAAP

RFI Work Plan Addendum : SWMU 41

Date: *AUGUST 2003*	**Prepared By:** *KDC/DR*
Scale: *As Shown*	**File Name:** *09604-325-155*

FIGURE 1-8

GEOLOGIC
CROSS-SECTION B-B'
AREA B

Soil at SWMU 41 consists of the Unison-Urban Land Complex (IT 2002). Soil classification is not practical in urban land areas because the original soil has been physically altered or obscured. Based on information presented in the Facility-Wide Background Study (IT 2002), in an undisturbed area of SWMU 41, the Unison-Urban Land Complex soil has a 15-inch thick surface layer of dark brown loam and a 43-inch thick subsoil of yellowish-red, sticky plastic clay underlain by a red sandy clay loam to a depth of 58 inches. This clay-rich layer is typically underlain by brown sand to approximately ten ft bgs, which then grades into a brown clay. In general, permeability is moderate in Unison soil, natural fertility is low, and organic matter content is low to moderate. The soil is medium to strongly acidic.

<u>Groundwater</u> – A detailed discussion of regional and RFAAP hydrogeology is presented in Section 3.8 of the MWP (URS 2002). One upgradient monitoring well (41MW1) and two downgradient monitoring wells (41MW2 and 41MW3) were installed at Area B during the VI to monitor groundwater present within bedrock and alluvium (Figure 1-6; Table 1-2). Stabilized potentiometric levels measured during the VI (March 1992) ranged from 1,785.12 ft msl (41MW1) to 1,731.61 ft msl (41MW2). The measured potentiometric surface was below the top of bedrock surface at 41MW1 and 41MW2 and was approximately four ft above the bedrock surface at 41MW3. Groundwater flow patterns at Area B likely mimic surface topography with flow toward the north and northeast and to the un-named tributary of Stroubles Creek. During the VI, a hydraulic gradient of 0.4 ft/ft was measured between 41MW1 and 41MW2. A shallower hydraulic gradient of 0.08 ft/ft was measured between 41MW2 and 41MW3 (Dames & Moore 1992). Local groundwater discharge in the SWMU 41 area likely occurs at several ephemeral seeps identified in the area northwest of Area B (along the access road adjacent to the equalization basins) and at the embankment adjacent to Stroubles Creek and its un-named tributary.

1.2.2 Site Background – History

The RCRA Facility Assessment (RFA; USEPA 1987) identified SWMU 41 (the Red Water Ash Burial Ground) as having the potential to release contaminants into the environment. The SWMU is included in the RCRA Permit for Corrective Action (USEPA 2000b).

SWMU 41 consisted of two non-contiguous disposal areas for red water ash, a combustion product from burning trinitrotoluene (TNT) production wastewater. From approximately 1967 to 1974 and again from 1983 to 1986, RFAAP manufactured TNT by the continuous-type process (ATK 2003), which employed chemical recycling and resulted in a smaller quantity of more concentrated waste than older batch-type operations. Table 1-3 presents typical wastewater characteristics (Department of the Army 1987).

In TNT manufacture, a red-colored wastewater known as "red water" is produced (Department of the Army 1987). Red water generated from continuous-type TNT manufacturing (versus batch-type manufacture) at RFAAP was concentrated by evaporation and the residue burned in rotary kilns located in the former TNT manufacturing area (USATHMA 1976). The ash produced from these kilns was reportedly disposed of in SWMU 41 from 1967 to 1971 (Dames & Moore 1992). According to USATHMA, "[Beginning in] 1972, the red water was concentrated by evaporation to a 35% liquor and sold to the paper industry (USATHMA 1976)."

Table 1-2
Summary of Existing Soil Borings and Monitoring Well Construction Data
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Identification	Type	Date Installed or Advanced	Screened Zone	Elevation TOC (ft msl)	Surface Elevation (ft msl)	Boring Depth (ft bgs)	Depth to Bedrock (ft bgs)	Screened Interval (ft BTOC)	DTW (ft BTOC) 3/12/92	Percent Gravel/Sand/Fines/ Sample Depth[a,b]	Soil Symbol USCS/AL[c]
41MW1	Monitoring Well	10/10/1991	Bedrock	1805.15		81.5	13.0	60.0-80.0	20.03	0.0/67.4/32.6/0-2	CH/CH
41MW2	Monitoring Well	9/6/1991	Bedrock	1797.45		125.0	30.0	105.5-120.5	52.05	0.0/15.1/84.6/20-22	CH/CH
41MW3	Monitoring Well	10/17/1991	Bedrock	1759.35		62.0	30.0	45.0-60.0	27.74	49.0/21.7/29.3/15-17	SC/CH
41MW3A	Soil Boring	10/15/1991	N/A	N/A		27.0	N/A	N/A	N/A	N/A	N/A
41MW3B	Soil Boring	10/16/1991	N/A	N/A		55.0	30.0	N/A	N/A	N/A	N/A
41SB1	Soil Boring	10/25/1991	N/A	N/A		15.0	N/A	N/A	N/A	N/A	N/A

Notes:

TOC = Top of Casing
BTOC = Below Top of Casing
DTW = Depth to Water
N/A = Not Applicable
ft = feet
msl = mean sea level
bgs = below ground surface

a = Gravel - retained on #4 sieve
Sand - passed #4 sieve but retained by #200 sieve
Fines - pass #200 sieve

b = Depth of sample in ft bgs

c = USCS - Unified Soil Classification System
AL - Atterberg Limits Soil Classification
NP - Not Plastic

Table 1-3
Typical TNT Wastewater Characteristics – Continuous-Type Process
(milligrams per kilogram (mg/L) unless noted otherwise)

Parameter	24-Hour Composite Sample	Grab Sample
TNT	20.3	145
pH	2.5	2.05
COD	64	274
Nitrate (as N)	213	53
Sulfate (as SO_4)	1,821	842
Color (units)	161	228
Total Solids	2,792	1,160
Volatile Solids	1,377	960
Suspended Solids	619	224
Temperature (degrees F)	95	–
Flow (gal/lb TNT)	11.2	11.2

Source: Department of the Army, Technical Manual TM 5-814-8, *Evaluation Criteria Guide for Water Pollution Prevention, Control, and Abatement Programs*

1.2.3 Previous Investigations

1.2.3.1 Verification Investigation – 1992

Dames & Moore reported the results of a VI in 1992 (Dames & Moore 1992). The VI was performed after the RFA in 1987 (USEPA 1987) and the issuance of a RCRA permit in 1989 (USEPA 1989). The following information summarizes the VI findings.

Area A – The VI program at Area A included the completion of one soil boring (41SB1) to 15 ft bgs in the center of Area A (Figure 1-6) and the collection of two soil samples for chemical analysis of TAL Metals, SVOCs, and explosives. Material reported as "probably red water ash" was encountered in 41SB1 from approximately 6 to 13 ft bgs (Dames & Moore 1992). One soil sample was collected at a depth of 8 to 10 ft bgs from "apparent" red water ash material. A second soil sample was collected below the red water ash material at the boring termination (14 to 15 ft bgs). Sixteen metals were detected in each soil sample with aluminum, arsenic, chromium, iron, and manganese detected within the range of the Facility-Wide background point estimates (IT 2002; Table 1-4).

The planned VI program at Area A included the collection of a surface water sample from a seep along the bank of Area A prior to the seep entering the tributary of Stroubles Creek. However, this seep was not active during the VI program, so a substitute sample of surface water was collected from the adjacent tributary of Stroubles Creek (Figure 1-6). Surface water sample 41SW1 was collected for analysis of

TAL metals, semivolatile organic compounds (SVOCs), explosives, total organic carbon (TOC), total organic halogens (TOX), and pH. Detections reported in this sample included seven metals, 2,4,6-trinitrotoluene, TOC, and TOX (Table 1-5). Constituent concentrations were below the current adjusted Tap Water RBC and USEPA Region III Biological Technical Assistance Group (BTAG) screening levels for surface water (Table 1-5).

Area B – Dames & Moore installed three groundwater monitoring wells near Area B to "evaluate the potential impact of buried red water ash on the groundwater quality in the vicinity of the burial area (Figure 1-6; Dames & Moore 1992)." Groundwater samples were collected from these three wells for analysis of TAL Metals, SVOCs, explosives, TOC, TOX, and pH. Detections reported in one or more groundwater samples included 11 metals, bis(2-ethylhexyl)phthalate, TOC, and TOX. Concentrations of vanadium and bis(2-ethylhexyl)phthalate in sample 41MW2 exceeded their respective Tap Water RBCs (Table 1-6). Other constituents were detected at concentrations below their current adjusted Tap Water RBCs.

1.2.3.2 Installation Assessment (Aerial Photograph Interpretation) – 1992

The Environmental Photographic Interpretation Center (EPIC), under the direction of USEPA, performed an assessment of multiple SWMUs at RFAAP using selected aerial photographs from 1937 to 1986 USEPA 1992).

Activity at SWMU 41 was first noted at this site in a 1970 photograph and reportedly continued through the 1986 photographs (USEPA 1992). A trench, a possible trench scar, and mounded material were visible on the 1971 photographs. The report noted that, "The trench appears to be empty at this time (USEPA 1992)." "Between 1975 and 1981, the lagoon in the northern portion of this site had undergone filling and by 1981, [no more than] a small ground scar was visible in the southern portion of the site, which was undergoing re-vegetation (USEPA; Figure 1-9)." It was also noted that, "Between 1981 and 1986, the southern area had received a considerable amount of fill material (USEPA 1992)." The 1986 photograph indicated that the majority of the site was "devoid of vegetation and significant filling appeared to have taken place" (USEPA 1992; Figure 1-10).

Table 1-4
Summary of Detected Analytes For Soil Samples Collected At SWMU 41
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

SITE ID FIELD ID SAMPLE DATE DEPTH (feet bgs) MATRIX UNITS	PQLs mg/kg	41SB1 RVFS*44 25-Oct-91 8.0 CSO mg/kg	41SB1 RVFS*45 25-Oct-91 14.0 CSO mg/kg	Adjusted Soil Industrial RBC mg/kg	Adjusted Soil Residential RBC mg/kg	Background Upper 95% UTL [3] mg/kg
TAL Metals						
Aluminum	14.1	25,400	20,600	102,200	7,821	40,041
Arsenic	30	8.1	11.5	1.9	0.426	15.80
Barium	1	140	84.5	7,154	547.5	209.0
Calcium	100	62,800	821 B	--	--	--
Chromium	4	32.7 B	60.1	306.6	23.5 [1]	65.3
Cobalt	3	12.8	15.9	2,044	156.4	72.3
Copper	7	19.7	21.8	4,088	312.9	53.5
Iron	1,000	24,400	40,000	30,660	2,346	50,962
Lead	2	74.7	37.3	750	400 [2]	27
Magnesium	50	40,800	4950 B	--	--	--
Manganese	0.275	1,560	885	2,044	156.4	2,543.0
Nickel	3	20.8	25.2	2,044	156.4	62.8
Potassium	37.5	2,080	1440 B	--	--	--
Sodium	150	2040 B	887 B	--	--	--
Vanadium	0.775	48.7	54.3	30.7	2.35	108.0
Zinc	30.2	241	87.7	30,660	2,346	202
Semivolatile TICs						
Heptadecane	NA	0.38 S	ND	--	--	--
Nonadecane	NA	0.38 S	ND	--	--	--
Total Unknown TICs	NA	(3)304	ND	--	--	--

Notes:

B = Analyte was detected in corresponding method blank; values are flagged if the sample concentration is less than ten (10) times the method blank concentration for common laboratory constituents and five (5) times for all other constituents

RBC = USEPA, Region III, Risk-Based Concentration, October 15, 2003 Non-carcinogenic constituents have been adjusted to reflect an HQ of 0.1

TICs = Tentatively identified compounds that were detected in the GC/MS library scans

PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method

TAL = Target Analyte List

CSO = Chemical soil

ft bgs = Feet below ground surface

mg/kg = Milligrams per kilogram

ND = Analyte was not detected

(1) = Chromium VI value used

(2) = Lead screening values taken from OSWER

(3) = Background Point Estimates from the Facility-Wide Backgorur Study Report Equal to 95% Upper Tolerance Limit

☐ = Concentration Above Soil Industrial RBC

☐ = Concentration Above Soil Residential RBC

Table 1-5
Summary of Detected Analytes For Surface Water Samples Collected At SWMU 41
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

SITE ID FIELD ID SAMPLE DATE DEPTH (feet) MATRIX UNITS	PQLs µg/l	41SW1 RDWC*76 10-Mar-92 0.0 CSW µg/l	Adjusted Tap Water RBC µg/l	Draft BTAG Fresh Water Screening Levels µg/l
TAL Inorganics				
Barium	20	55.9	256	10,000.0
Calcium	500	58,500	--	--
Iron	38.1	199	1,095	320
Magnesium	500	29,300	--	--
Manganese	2.75	27.8	73.0	14,500
Potassium	375	1,850	--	--
Sodium	500	149,000	--	--
Explosives				
2,4,6-Trinitrotoluene	0.635	1.38	1.83	--
Other				
Total Organic Carbon	1,000	6,010	--	--
Total Organic Halogens	1	82.4	--	--
pH	NA	7.99	--	--

Notes:

CSW = Chemical surface water

RBC = USEPA, Region III, Risk-Based Concentration, October 15, 2003
Non-carcinogenic constituents have been adjusted to reflect an HQ of 0.1

USEPA = United States Environmental Protection Agency

NA = Not available

PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method

TAL = Target Analyte List.

µg/L = Micrograms per liter

☐ = Concentration above Tap Water RBC

BTAG = Biological Technical Assistance Group

Table 1-6
Summary of Detected Analytes For Groundwater Samples Collected At SWMU 41
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

SITE ID FIELD ID SAMPLE DATE DEPTH (feet) MATRIX UNITS	PQLs µg/l	41MW1 RDWC*69 3-Mar-92 70.0 CGW µg/l	41MW2 RDWC*70 3-Mar-92 113.0 CGW µg/l	41MW3 RDWC*68 4-Mar-92 53.0 CGW µg/l	41MW3 RDWC*71 4-Mar-92 53.0 CGW µg/l	Adjusted Tap Water RBC µg/l
TAL Inorganics						
Aluminum	30	<38	68	<38	<38	3,650
Barium	20	19.9	81.9	16.5	15.7	255.5
Calcium	500	24,000	232,000	121,000	122,000	–
Lead	10	<1.26	1.41	<1.26	3.58	–
Magnesium	500	31,400	215,000	64,000	65,000	–
Manganese	2.75	45.4	39	10.1	10.2	73
Potassium	375	938	1,710	2,570	2,940	–
Silver	2	0.321	0.962	<0.25	<0.25	18.25
Sodium	500	960,000	6,500,000	221,000	224,000	–
Vanadium	40	<11	34.1	14.6	15.3	1.1
Zinc	50	<21.1	31.8	<21.1	<21.1	1,095
Semivolatiles						
Bis(2-ethylhexyl)phthalate	10	<4.8	5.64	<4.8	<4.8	4.78
Total Unknown TICs	NA	ND	(7)84	ND	(3)47	–
Other						
Total Organic Carbon	1,000	38,000	82,100	24,400	23,300	–
Total Organic Halogens	1	77.8	89.2	36.1	95	–
pH	NA	7.87	7.08	7.07	7.13	–

Notes:

CGW = Chemical groundwater
RBC = USEPA, Region III, Risk-Based Concentration, October 15, 2003
Non-carcinogenic constituents have been adjusted to reflect an HQ of 0.1
USEPA = United States Environmental Protection Agency
NA = Not available
ND = Analyte was not detected
PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method
TAL = Target Analyte List
TICs = Tentatively identified compounds that were detected in the GC/MS library scan
µg/L = Micrograms per liter

☐ = Concentration above Tap Water RBC

RFAAP RFI WORK PLAN ADDENDUM: SWMU 41		FIGURE 1-9
Date: *AUGUST 2003*	**Prepared by:** *KDC/DR*	AERIAL PHOTOGRAPH - USEPA, 1992 (1981)
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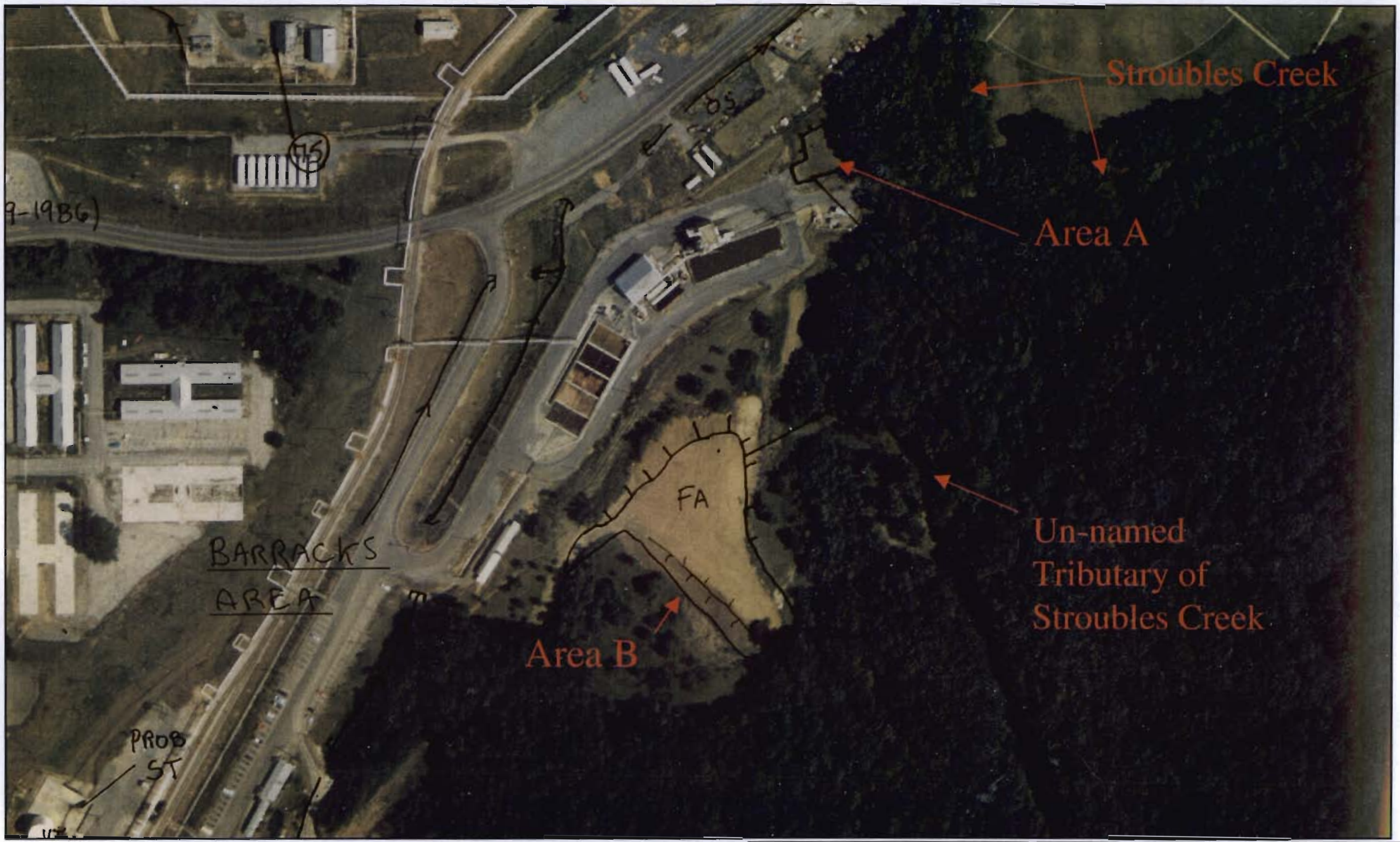

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RFI WORK PLAN ADDENDUM: SWMU 41

Date: AUGUST 2003

Prepared by: KDC/DR

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FIGURE 1-10

AERIAL PHOTOGRAPH
- USEPA, 1992
(1986)

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1.2.4 Data Gap Analysis

Limited sampling and analysis have occurred at SWMU 41 and data are incomplete for physical and chemical information (Table 1-7). In addition, the horizontal and vertical extent of the Area A and Area B require field verification.

Target Compound List (TCL) Volatile Organic Compounds (VOCs) – Samples were not collected for TCL VOC analysis during the previous investigations. Therefore, TCL VOCs represent a data gap and will be analyzed in surface soil, subsurface soil, surface water, and sediment samples.

TCL Semivolatile Organic Compounds – Polynuclear Aromatic Hydrocarbons (PAHs) – Limited TCL SVOC analysis was performed during the Dames & Moore VI in 1992. PAH analysis was not conducted during the previous investigations. Therefore, in order to meet the objectives of this RFI, TCL SVOCs and PAHs will be analyzed in surface soil, subsurface soil, surface water, and sediment samples.

TCL Polychlorinated Biphenyls (PCBs) – Samples were not collected for TCL PCB analysis during the previous investigations. Therefore, TCL PCBs represent and data gap and will be analyzed in surface soil and sediment samples.

TCL Pesticides/Herbicides – Samples were not collected for TCL Pesticide/Herbicides analysis during the previous investigations. Therefore, TCL Pesticides/Herbicides represent a data gap and will be analyzed in surface soil and sediment samples.

Explosives – Limited explosives analysis was performed during the Dames & Moore VI in 1992. Nitroglycerin and pentaerythritol tetranitrate (PETN) analysis were not conducted during the previous investigations. Therefore, in order to meet the objectives of this RFI, explosives, including nitroglycerin and PETN, will be analyzed in surface soil, subsurface soil, surface water, and sediment samples.

TAL Inorganics – Limited TAL Inorganics analysis was performed during the Dames & Moore VI in 1992. Therefore, in order to meet the objectives of this RFI, TAL Inorganics will be analyzed in surface soil, subsurface soil, surface water, and sediment samples.

Dioxins/Furans – Dioxin/furans may be formed during a variety of combustion processes. Previous activities documented at the site include burial of red water ash from the combustion of TNT wastewater. Samples were not collected for dioxins/furans analysis during the previous investigations. Therefore, dioxins/furans represent a data gap and will be analyzed in selected surface soil and subsurface soil samples with identifiable ash material.

Other – Limited physical testing of soil at SWMU 41 was conducted during the VI and consisted of grain size analysis and Atterberg Limits (Table 1-2). Other site-wide soil physical/geotechnical and chemical properties such as Total Organic Content and pH that affect constituent mobility are unknown. Therefore, particular physical properties of subsurface soil represent a data gap. Because no RA (including ecological risk screening) has been performed, potential threats to human health and ecological receptors have yet to be identified and therefore, the results of a RA represent a data gap.

Planned field activities in support of this RFI WPA, as presented in Section 1.3, are designed to address the data gaps presented in the previous sections. Table 1-8 presents the Data Gap Completion Plan.

Table 1-7
Data Gap Analysis

	Item	Physical	Chemical
SWMU 41	Area A	Surface Soil Samples	Chemical Data
		Subsurface Soil Samples	Chemical Data
	Area B	Surface Soil Samples	Chemical Data
		Subsurface Soil Samples	Chemical Data
	Buried Material	Buried Material Samples	Chemical Data/Waste Characteristics Data
		Burial Material Volume and Location	Not Applicable
	Site-Wide Soil Characteristics	Physical/ Geotechnical Properties	Total Organic Content, and pH
	Surface Water/ Sediment and Seeps/Springs	Physical Properties	Chemical Data

Table 1-8
Data Gap Analysis Completion Plan

	DATA GAPS			COMPLETION PLAN
	Item	Physical	Chemical	
SWMU 41	Area A	Surface Soil Samples	Chemical Data	Advance soil borings (§1.3.2), collect samples for chemical analysis
		Subsurface Soil Samples	Chemical Data	
	Area B	Surface Soil Samples	Chemical Data	
		Subsurface Soil Samples	Chemical Data	
	Buried Material	Buried Material Samples	Chemical Data	Excavate test pits (§1.3.1), collect samples for chemical analysis
		Buried Material Location	N/A	
	Surface Water/Sediment and Seeps/Springs	Physical Properties	Chemical Data	Collect samples of surface water and sediment for chemical analysis and evaluate in-stream physical properties
	Site-Wide Soil Characteristics	Physical / Geotechnical Properties	N/A	Collect samples for geotechnical and physical properties analysis (§1.3.2).

N/A = Not Applicable § = Section Number

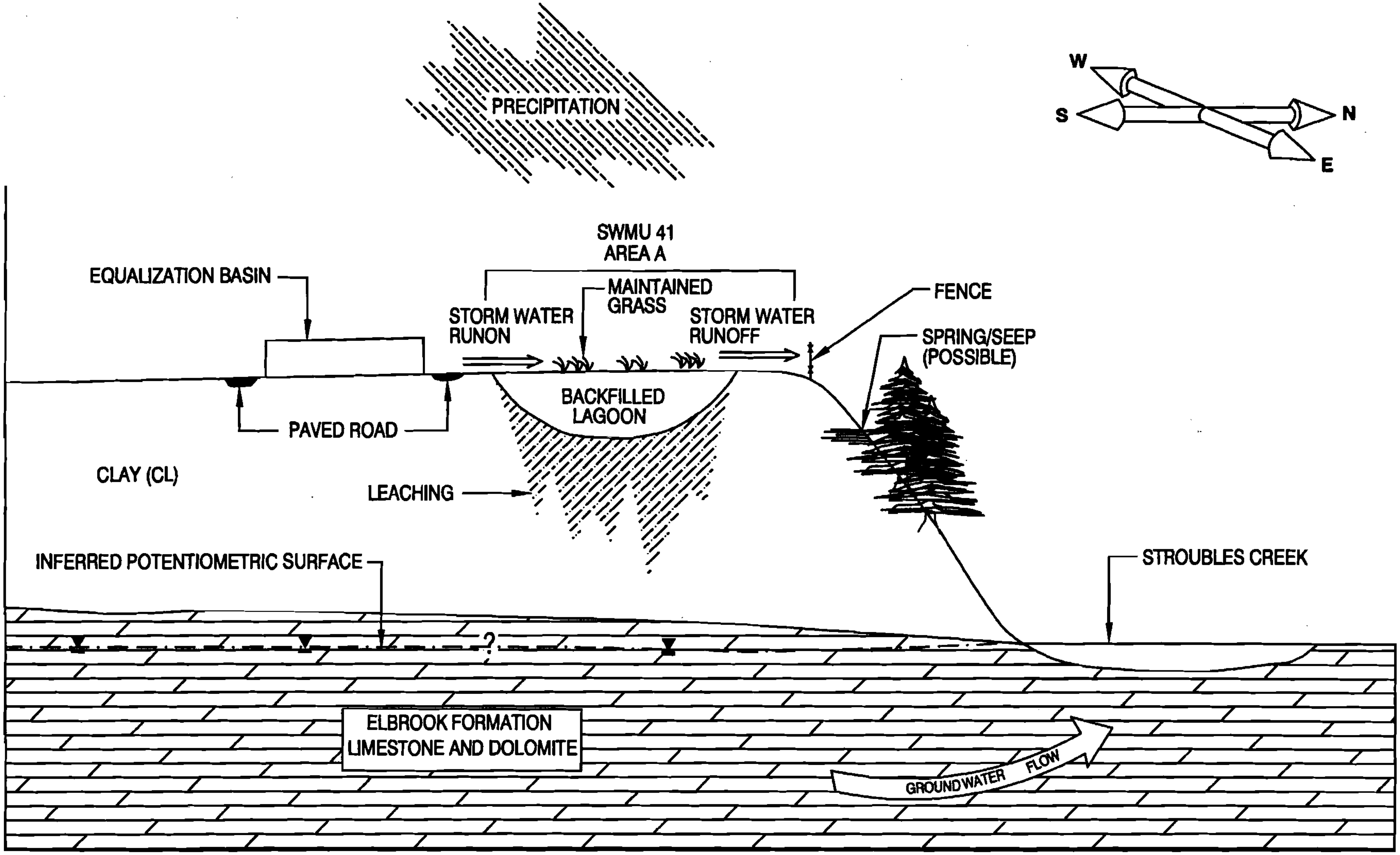
1.2.5 Conceptual Site Model

Conceptual Site Models (CSMs) for SWMU 41 are presented on Figure 1-11 (Area A) and 1-12 (Area B). Potentially affected media include surface soil, subsurface soil, groundwater, surface water, and sediment. Topographic relief in the Burial Area and the Lagoon Area is gentle to moderate and relief adjacent to these areas is moderate to steep. Precipitation likely infiltrates the ground surface and/or flows toward Stroubles Creek and its un-named tributary. Although current and probable future land-use scenarios are limited to industrial operations, both industrial and residential exposure scenarios will be considered.

Figure 1-13 presents the potential exposure pathways in Area A and Figure 1-14 presents the potential exposure pathways for in Area B. Receptors for a potential future residential scenario and for the current industrial scenario include possible future residents, site workers, contruction workers, and terrestrial, aquatic, and benthic biota.

Burial activities potentially release constituents to the environment by direct deposition, by leaching of material through site soil, and by storm water erosion of site soil. Direct deposition potentially affects surficial soil, leaching potentially affects subsurface soil, and storm water erosion/runoff and the presence of seeps/springs potentially affect surface soil, surface water, and sediment. Although burial material was covered to grade with clean fill, insufficient information exists to rule out surface soil as a potentially affected medium.

Due to the complexity of the groundwater pathway (i.e., potential karst features and a fractured bedrock flow regime) in the MMA and at SWMU 41, the groundwater pathway at SWMU 41 will be investigated under WPA No. 009 and subsequent groundwater studies at the MMA.



CONCEPTUAL DRAWING - NO SCALE IMPLIED

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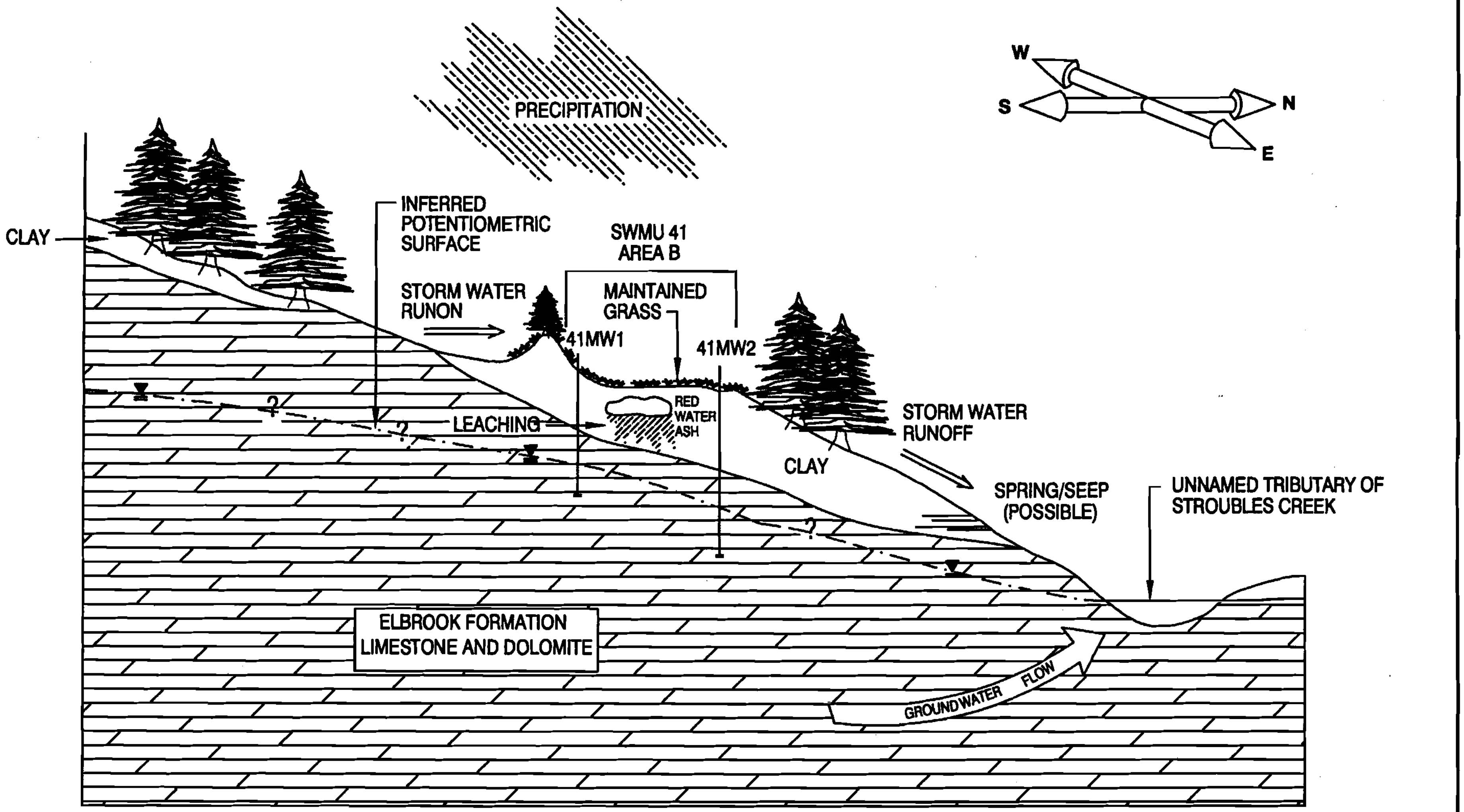
Scale: *N.T.S.*	**File Name:** *09604-325-155*

FIGURE 1-11

CONCEPTUAL SITE MODEL
AREA A



CONCEPTUAL DRAWING - NO SCALE IMPLIED

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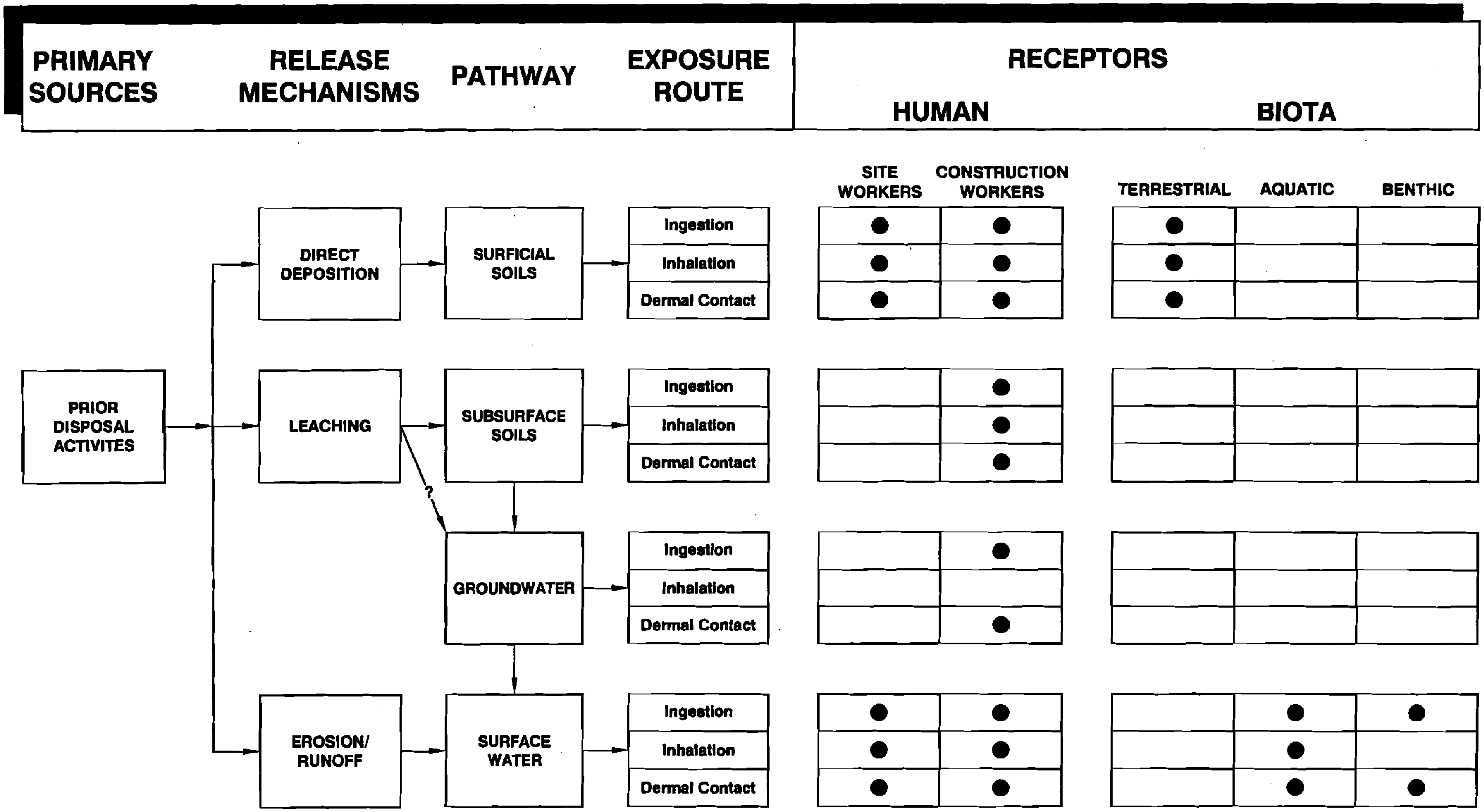
FIGURE 1-12

CONCEPTUAL SITE MODEL AREA B



Pathway	Exposure Route	Human: Site Workers	Human: Construction Workers	Biota: Terrestrial	Biota: Aquatic	Biota: Benthic
SURFICIAL SOILS	Ingestion	●	●	●		
	Inhalation	●	●	●		
	Dermal Contact	●	●	●		
SUBSURFACE SOILS	Ingestion		●			
	Inhalation		●			
	Dermal Contact		●			
GROUNDWATER	Ingestion		●			
	Inhalation					
	Dermal Contact		●			
SURFACE WATER	Ingestion	●	●		●	●
	Inhalation	●	●		●	
	Dermal Contact	●	●		●	●

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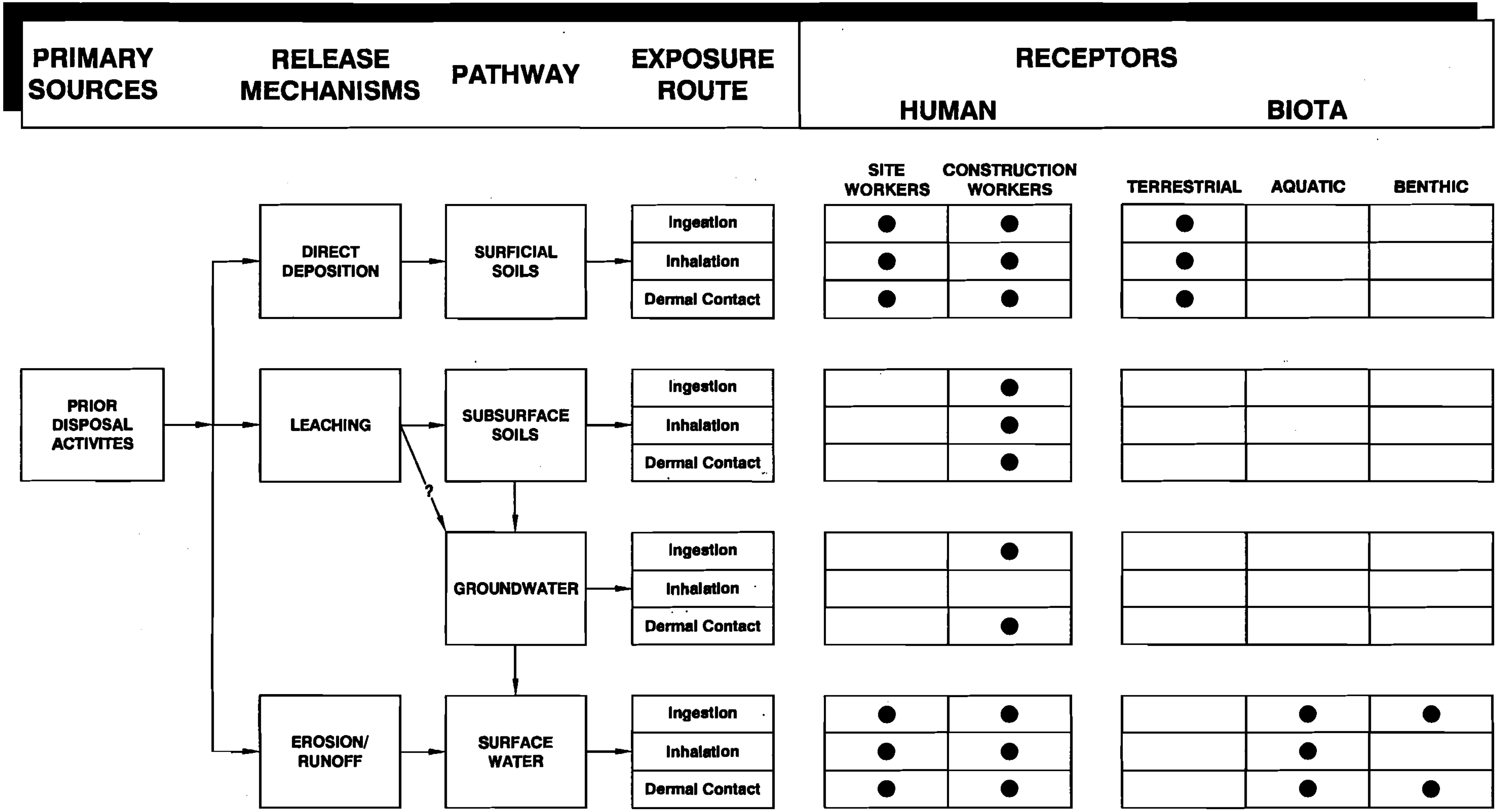
FIGURE 1-13

CONCEPTUAL SITE
MODEL DIAGRAM
AREA A



Pathway	Exposure Route	Site Workers	Construction Workers	Terrestrial	Aquatic	Benthic
Surficial Soils	Ingestion	●	●	●		
	Inhalation	●	●	●		
	Dermal Contact	●	●	●		
Subsurface Soils	Ingestion		●			
	Inhalation		●			
	Dermal Contact		●			
Groundwater	Ingestion		●			
	Inhalation					
	Dermal Contact		●			
Surface Water	Ingestion	●	●		●	●
	Inhalation	●	●		●	
	Dermal Contact	●	●		●	●

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FIGURE 1-14

CONCEPTUAL SITE MODEL DIAGRAM AREA B

1.3 PLANNED FIELD ACTIVITIES

The SWMU 41 RFI field program is designed to address the data gaps presented in Table 1-7. The selection of the areas to be investigated and soil samples to be collected considered the following and follows SOP 30.7, Sampling Strategies, Section 3.2.1, Biased Sampling (included in Appendix A):

- The size and shape of SWMU 41;
- Evaluation of the potential for leaching of constituents through site soil;
- Generation of data that can be used to evaluate residual risk through a screening comparison to USEPA Region III RBCs (Residential and Industrial), the Facility-Wide Background Study (IT 2002) and a RA subdivided into HHRA and Screening-Level Ecological Risk Assessment (ERA); and
- Assessment of the nature of the subsurface geology.

The MWP is referenced where routine activities will be performed in accordance with the MWP specifications. Variances to the specifications will be documented in this WPA. Components of the investigation will include the following:

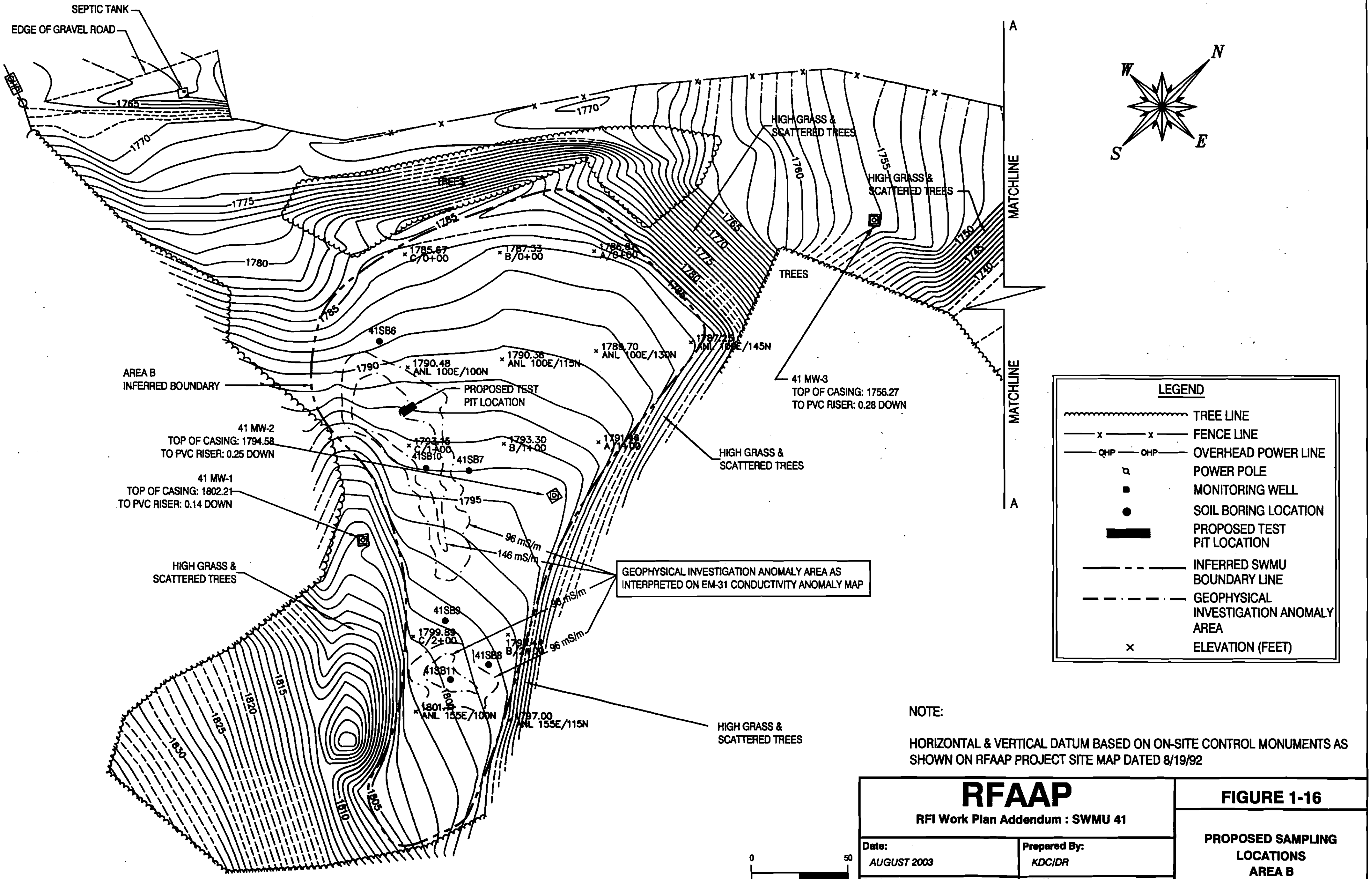
- Area B geophysical anomaly excavation and soil/burial material sampling;
- Area A excavation and soil/lagoon material sampling;
- Soil boring with surface and subsurface soil sample collection by direct push technology methods (i.e. Geoprobe®);
- Geotechnical soil sample collection and analysis;
- Spring/seep sampling and analysis; and
- Surface water and sediment sampling and analysis.

Other related components of the investigation will include boring abandonment, stratigraphic logging of soil borings, sample management, portable photoionization detector (PID) screening, documentation, laboratory analysis, quality assurance practices, evaluation of the data relative to the most-current USEPA Region III RBCs (Residential and Industrial), and performance of a RA (see MWP Sections 6.0 and 7.0). Investigative activities will be conducted in accordance with the SOPs in the MWP and in accordance with the Master Health and Safety Plan. Table 1-1 identifies the SOPs that will be followed as part of the investigation.

1.3.1 Geophysical Survey

Argonne National Laboratory (ANL) performed a geophysical survey of SWMU 41 during the time period of August through September 2002 to characterize both the lateral and vertical extent of the former burial area (Area B) used for the TNT red water ash disposal (ANL, 2003). Subsurface information obtained by the geophysical surveys was used to develop the CSM and focus the proposed sampling activities (discussed in the next section) to assess the nature and extent of TNT red water ash disposed at SWMU 41.

Surface geophysical surveys using two-dimensional resistivity profiling, seismic refraction tomography, and EM-31 terrain-conductivity mapping were performed at Area B of SWMU 41. ANL also performed vertical seismic profiles in three monitoring wells adjacent to SWMU 41 to help guide the seismic interpretations. USACE New England District personnel collected downhole electrical and natural-gamma logs to help



NOTE:

HORIZONTAL & VERTICAL DATUM BASED ON ON-SITE CONTROL MONUMENTS AS SHOWN ON RFAAP PROJECT SITE MAP DATED 8/19/92

0 50

1 INCH = 50 FEET

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FIGURE 1-16

PROPOSED SAMPLING LOCATIONS AREA B

Test pit excavations will follow the protocols set forth in SOP 20.4, Test Pits. Proposed deviations from SOP 20.4 are as follows:

- Proposed soil borings will be advanced prior to the final selection of the test pit locations to validate the assumptions used to locate the test pits. Test pit locations will be field assessed and refined based upon an examination of the soil boring logs and actual site conditions. If an examination of the boring logs and site conditions suggests that a test pit will not penetrate into buried material or add significant value to the investigation, then additional soil borings will be substituted in lieu of a test pit (material in Area B may be up to 30 feet below ground surface);

- The test pits will be approximately ten feet long by two feet wide by twelve feet deep;

- Excavated material will be placed into a roll-off container and staged on the site. Following the test pit excavations, one composite sample will be collected for RCRA waste characterization (IDM, Section 1.3.4) from the accumulated material;

- Three discrete samples will be collected from the each test pit and will represent:
  - One sample of excavated buried material or lagoon material;
  - One sample of sidewall material; and
  - One sample from test pit bottom.

- Discrete samples will be collected in accordance with SOP 30.1, Section 3.2 for surface soil samples;

- Discrete samples will be analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/herbicides, TCL PCBs, explosives (including nitroglycerin and PETN), TAL Inorganics including mercury, and dioxins/furans in accordance with the Master Quality Assurance Plan (MQAP) and Section 2.0 of this WPA;

- The test pits will be digitally photographed, sketched, and a description will be recorded in the field notebook (SOP 10.1). In addition, the corners of the test pits will be established to the nearest meter using geographic positioning system (GPS) equipment and incorporated into the existing site survey;

- Following excavation and sampling, the test pits will be backfilled to within two feet of existing grade with clean self-compacting stone or similarly acceptable material. The top two feet of the excavation will be backfilled with clean soil. Appropriate geotextile filter fabric will be placed on top of the self-compacting stone before backfilling with clean soil to minimize soil infiltration into the stone backfill material. Soil will be mounded sufficiently during backfilling to compensate for potential settling of the fill over time. Placement of a suitable grass seed and straw will complete the restoration of the excavation areas.

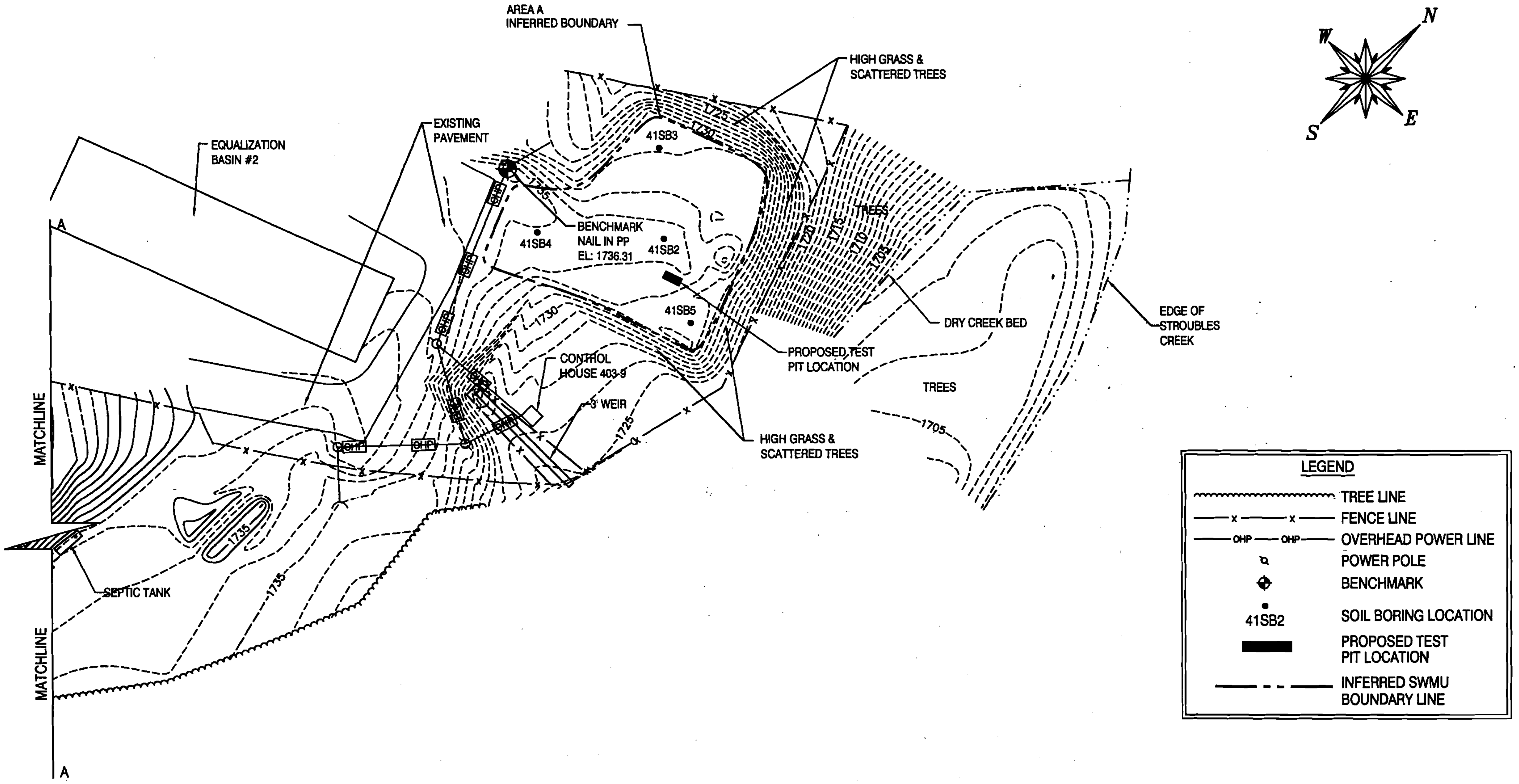
1.3.3 Soil Borings

Ten soil borings will be advanced at SWMU 41 to:

- Screen data and establish constituents of potential concern;

- Evaluate potential chemical impacts;

- Collect soil samples for analysis of physical/geotechnical characteristics; and



NOTE:

HORIZONTAL & VERTICAL DATUM BASED ON ON-SITE CONTROL MONUMENTS AS SHOWN ON RFAAP PROJECT SITE MAP DATED 8/19/92

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FIGURE 1-15

PROPOSED SAMPLING LOCATIONS AREA A

constrain the resistivity models. The complete draft geophysical report and methods are presented in Appendix D.

Geophysical surveys for SWMU 41 consisted of two seismic-refraction profiles, two two-dimensional electrical-resistivity imaging (2D-ERI) profiles, and one electromagnetic (EM-31) survey (Appendix D, Figure D.1). Also shown on Figure D.1 are the locations of the resistivity lines, the seismic profiles, and the areal coverage provided by the EM-31 grid (33-feet major profile lines are shown).

The seismic refraction tomography profiling, 2D-ERI, and electromagnetic terrain-conductivity surveying were conducted at SWMU 41 in order to delineate the horizontal and vertical boundaries of the burial area (Area B). The geophysical data suggest the location of the SWMU 41 related red water ash disposal (Figure D.2).

Seismic refraction tomography mapped the bedrock as a surface sloping towards the north and northwest, with a slight decrease in velocity in the 50X and 115X on seismic profile 41-Seis-L1, which is also observed on seismic profile 41-Seis-L2. This velocity change indicates rather tenuously a lithologic or structural break (consistent with a weaker bedrock zone modeled by 2D-ERI profile 41-Resist-L1). Other significant structural features were not indicated for the bedrock.

The 2D-ERI profiling modeled a zone of extremely low resistivity (<10 ohm-m) underlying the upper 10 feet of the SWMU 41 ground surface between coordinates 110X and 290X on profile 41-Resist-L1. This low resistivity roughly coincides with the extent of electrically conductive zones (area of low resistivity) mapped by the EM-31 survey. The 2D-ERI data suggests a maximum burial depth of approximately 10-12 feet bgs if the low resistivity zone represents possible waste materials. This area of low resistivity may extend to greater depths to the northwest at coordinate 50X on the profile.

1.3.2 Test Pit Excavation

Geophysical data obtained by ANL (ANL 2003) indicate the possible horizontal and vertical extent of zones that are interpreted as:

- The probable horizontal extent of buried material;
- The probable depth of buried material; and
- The possible presence of a subsurface trench (Area B).

Two test pits will be excavated, one in Area B (Test Pit #1) and one in Area A (Test Pit #2). The test pits will be developed to ground truth portions of the geophysical data from the Area B, to collect representative samples of buried materials from both SWMU areas, and to obtain physical information regarding the nature of burial and buried material at the site. This decision depends upon the assumption that the field geologist will be able to differentiate buried material from *in situ* soil. Ash material is expected to be apparently different from native soil. The test pits may need to be offset after initial trenching. Three test pit offsets on ten-foot centers will be allowed prior to test pit relocation (i.e., offsets greater than 30 feet).

The proposed test pit locations are presented on Figure 1-15 and Figure 1-16. The location of test pit #1 was chosen based on the presence of identified geophysical anomalies on the EM-31 conductivity anomaly map in the southern end of Area B. Test Pit #2 will be located between the center portion of Area A and the moderate-to-steep downgrade leading to Stroubles Creek.

- Ground truth geophysical data.

Proposed boring locations are presented on Figure 1-15 and Figure 1-16. Table 1-9 presents a summary of the proposed borings, including the location and purpose of each boring. Table 2-4 (Section 2.4) presents the proposed chemical sampling and analysis plan.

Table 1-9
Summary of Proposed RFI Borings

	Boring Location		**Purpose of Boring**		
Boring Identification	**Inside Area A or Area B (1)**	**Outside Area A or Area B (1)**	**Chemical Analysis**	**Physical Analysis**	**Stratigraphic Analysis**
Area A					
41SB2	✓		✓		✓
41SB3		✓	✓		✓
41SB4		✓	✓	✓	✓
41SB5		✓	✓	✓	✓
Area B					
41SB6		✓	✓		✓
41SB7		✓	✓	✓	✓
41SB8		✓	✓	✓	✓
41SB9	✓		✓		✓
41SB10	✓		✓		✓
41SB11	✓		✓		✓

(1) Inside of Area A and Area B refers to areas presumed to be within the waste areas as inferred from geophysical data (Area B) and historical data analysis and are designed to collect data regarding the chemical nature of the waste as well as the vertical migration, if present. Outside of Area A or Area B refers to areas intended to characterize the lateral extents of the waste at Area A and Area B.

Soil borings will be advanced to refusal or above the groundwater table using direct push technology consistent with the procedures outlined in SOP 20.11. Bedrock is anticipated to be present at approximately 12 to 30 feet bgs. A four-foot Macro-Core® device will be used to collect the samples. Stratigraphic logs will be prepared for each boring location in accordance with the procedures outlined in SOP 10.3 in the Appendix A.

During direct push activities, subsurface soil samples will be screened for the presence of VOCs using a PID consistent with SOP 90.1 included in Appendix A. To meet the objectives of the investigation and to fill the data gaps identified in Section 1.2.4, soil samples will be collected from each boring including:

- A surface sample will be collected from each boring (i.e., 0 to 6 inches bgs, below gravel, vegetative, or organic layers; 6 to 12 inches bgs for VOCs); and
- Two subsurface samples will be collected from each boring, with samples collected from an intermediate zone (approximately 6 to 15 feet bgs targeting suspected contamination, i.e. red water ash) and from the terminational zone (above refusal or the groundwater table).

Each of the samples will be analyzed for TCL VOCs, TCL SVOCs, PAHs, explosives (including nitroglycerin and PETN), TAL Inorganics including mercury consistent with the requirements of the MQAP and Section 2.0 of this WPA. In addition, ten selected soil samples will be analyzed for TCL pesticides/herbicides (surface soil), PCBs (surface soil and sediment), and dioxins/furans (targeting burned material/ash). The location of the soil borings will be established to the nearest meter using GPS equipment.

In addition to samples submitted for chemical analysis, up to four soil samples representative of each major change in primary lithology (i.e., clay, silt, sand, gravel) will be collected for analysis of physical and geotechnical properties (Section 5.8 of the MWP; applicable American Society for Testing and Materials). Samples will be analyzed for the following parameters in accordance with the QAPA in Section 2.5.4 of this document:

- Grain-size analysis (American Society for Testing and Materials (ASTM) D 422-98);
- Atterberg limits (ASTM D 4318-00);
- Soil moisture content (ASTM D 2216-98e1);
- Hydraulic Conductivity (ASTM D 5084-00e1-2000);
- Soil Bulk Density (ASTM D 4253-00);
- Soil Porosity (ASTM D 854-02 and D 2937-00e1);
- Total organic content (ASTM D 2974-00); and
- pH (ASTM D 4972-01).

These analyses are intended to enhance the understanding of the physical nature of site soil to provide data necessary for constituent migration modeling, if necessary. Proposed boring locations have been placed on or adjacent to resistivity data collection lines to facilitate ground truthing of geophysical data.

1.3.4 Surface Water, Sediment, and Spring/Seep Sampling

The following section discusses the proposed surface water, sediment, and spring/seep investigation to be conducted at SWMU 41 using methods for grab sampling that are suitable for sampling surface water, sediment, and springs/seeps as described in SOPs 30.3 and 30.4 in Appendix A. The objectives of the sampling program are to:

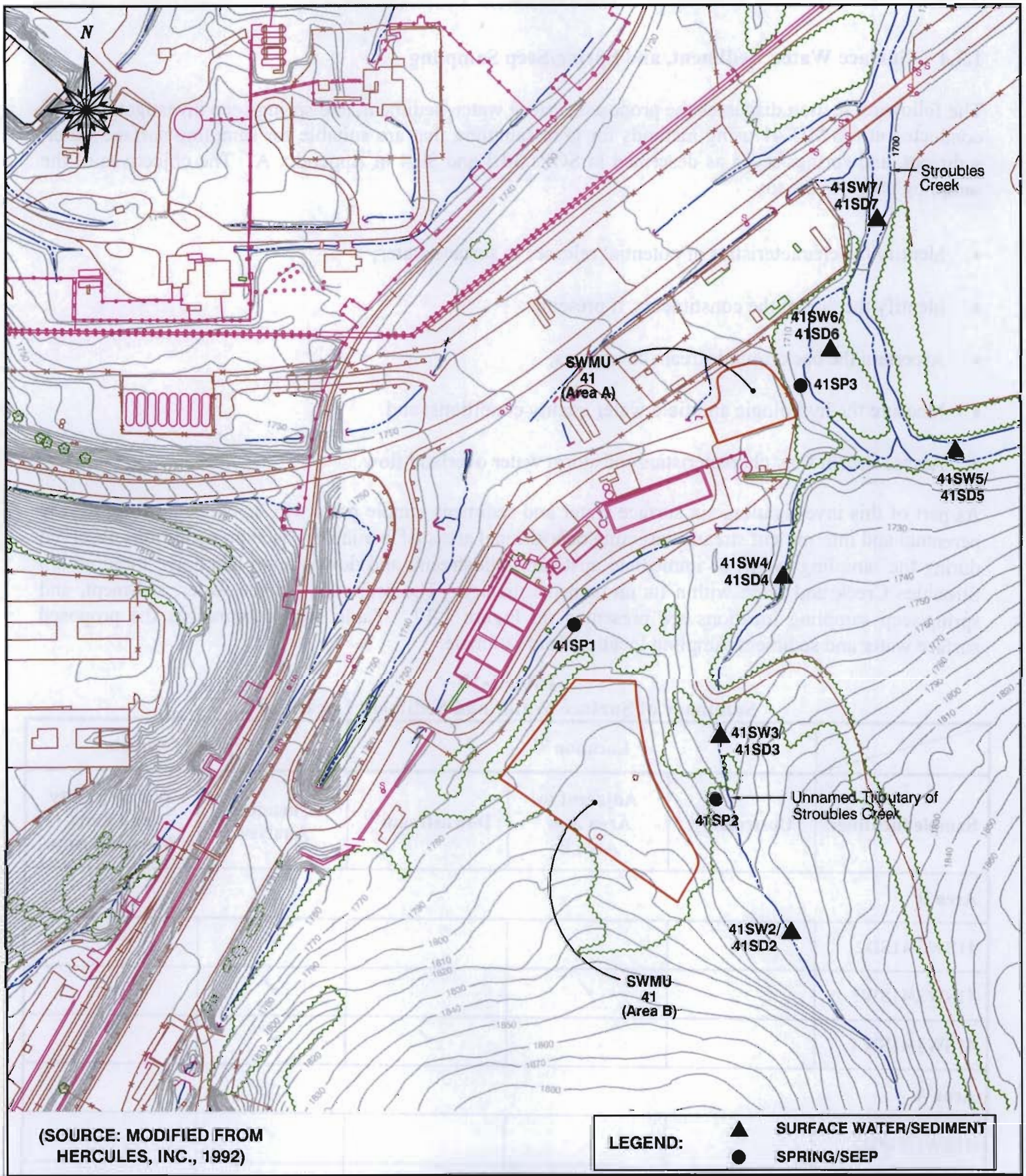
- Identify the characteristics of potential releases to surface water;
- Identify the fate of the constituents, if present;
- Ascertain the background stream conditions;
- Measure the hydrologic and field water quality conditions; and
- Assess stream flow characteristics and storm water overland flow.

As part of this investigation, six surface water and sediment sample pairs will be collected from nearby perennial and intermittent streams targeting depositional areas (if available, based on conditions observed during the sampling event) of immediate upstream, midstream, and downstream locations: three within Stroubles Creek and three within its un-named tributary. The proposed surface water, sediment, and spring/seep sampling locations are presented on Figure 1-17. Table 1-10 summarizes the proposed surface water and sediment sampling locations and rationale.

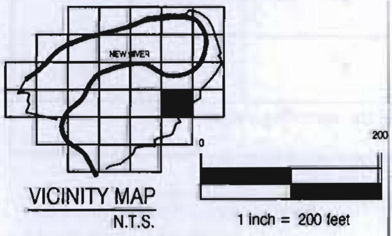
Table 1-10
Summary of Surface Water and Sediment Locations

	Location (1)			**Purpose of Sample**	
Sample Identifier	**Upstream (2)**	**Adjacent to Area A or Area B**	**Downstream (2)**	**Chemical Analysis**	**Water Quality and Flow Measurements**
Area B					
41SW2/41SD2	✓			✓	✓
41SW3/41SW3		✓		✓	✓
41SW4/41SW4			✓	✓	✓
Area A					
41SW5/41SD5	✓			✓	✓
41SW6/41SD6		✓		✓	✓
41SW7/41SD7			✓	✓	✓

(1) = Sampling locations will target depositional areas, if available, based on conditions observed during the sampling event
(2) = Upstream and Downstream references are relative to the specified areas (Area A or Area B)



(SOURCE: MODIFIED FROM
HERCULES, INC., 1992)



VICINITY MAP
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FIGURE 1-17

SURFACE WATER,
SEDIMENT, AND
SPRING/SEEP
SAMPLING LOCATIONS

Up to three samples will be collected from ephemeral spring and/or seep discharges or standing water on cut and fill areas, if present. Specifically, spring/seep discharges have been observed in the following locations:

- Along the road cut between Area B and equalization basins to the north;
- Between Area B and the unnamed tributary of Stroubles Creek; and
- Between Area A and Stroubles Creek.

The surface water, sediment, and spring/seep samples will be analyzed for TCL VOCs, TCL SVOCs, PAHs, TCL Pesticides/Herbicides/PCBs (sediment), explosives (including nitroglycerin and PETN), perchlorate (aqueous samples), TAL Inorganics, grain size (sediment), and total organic content (sediment, two samples per stream). The surface water and spring/seep samples will be collected by submerging and direct filling sample containers. The sediment samples will be collected by the scoop and trowel method to sample exposed sediment or sediment in surface water less than 6-inches deep, with nominal flow.

This proposed field activities include an assessment of water quality at each of the designated surface water collection sites. Parameters that will be assessed include total hardness (two samples per stream), temperature, pH (relative to the standard hydrogen electrode constant), dissolved oxygen, salinity, specific electrical conductance (conductivity), reduction-oxidation potential, depth, percent saturation, resistivity, and total dissolved solids. These parameters will be measured in the field using the Multiparameter Water Quality Monitoring Instrument as outlined in SOP 40.1.

Surface water hydrology will be assessed at each stream site and will include an estimate of stream flow. Stream flow will be estimated by using a float and calculating the following equation:

$$\boxed{FLOW = ALC \div T}$$

Where:
A = Average cross-sectional area of the stream (stream width multiplied by the average water depth)
L = Length of the stream reach measured (usually 20 feet)
C = A coefficient or correction factor (0.8 for rocky bottoms and 0.9 for muddy or smooth bottoms)
T = Time, in seconds, for the float to travel the length of L

During sample collection, field personnel will screen the samples for the presence of VOCs using a PID consistent with SOP 90.1 included in Appendix A. Logs will be prepared for each sample location in accordance with the procedures outlined in SOP 10.2 in Appendix A. The sample locations will be established to the nearest meter using GPS equipment. See SOP 30.3 for more information regarding stream sampling.

1.3.5 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration and USEPA regulations regarding the identification, handling, and disposal of non-hazardous and hazardous investigation-derived material (IDM). Activities will be performed in accordance with the Installation safety rules, protocols, and SOP 70.1. Table 1-11 summarizes the suspected nature (hazardous versus non-hazardous) of the materials expected to be generated during field investigative activities.

Table 1-11
Handling and Disposal of Investigation-Derived Materials
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Area	Material	Description	Quantity	Concern	Action	Expected Nature of Material
SWMU 41	Soil cuttings	From 14 borings	Approx. two 55-gal drums	COCs	TCLP VOCs, TCLP SVOCs, Ignitability, Corrosivity, Paint Filter Liquids, and Explosives	Non-hazardous. Concentrations are not expected to exceed TCLP, or pH limits.
SWMU 41	Decontamination water	Aqueous IDM	Approx. three 55-gal drums	IDM	TCLP VOCs, TCLP SVOCs, Ignitability, Corrosivity, Chemical Oxygen Demand, and Explosives	Non-hazardous. Concentrations are not expected to exceed TCLP, or pH limits.
Test Pit Excavations	Soil	Soil Stockpiled from Trench Excavation	Approx. 10-20 cubic yards	IDM	TCLP VOCs, TCLP SVOCs, Ignitability, Corrosivity, Paint Filter Liquids, and Explosives	Non-hazardous. Concentrations are not expected to exceed TCLP, or pH limits.
SWMU 41	PPE	Miscellaneous IDM	Approx. three 55-gal drums	IDM	Evaluate Soil and Water Results	Non-hazardous material. Will be disposed of as IDM.

Notes:

SWMU = Solid Waste Management Unit
Approx. = Approximately
COC = Chemical of Concern
IDM = Investigation-Derived Material
TCLP = Toxicity Characteristics Leaching Procedure
COD = Chemical Oxygen Demand
PPE = Personal Protective Equipment and Clothing
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound
gal = Gallon

2.0 QUALITY ASSURANCE PLAN ADDENDUM

2.1 INTRODUCTION

This QAPA establishes function-specific responsibilities and authorities to ensure data quality for investigative activities at RFAAP. The project objectives will be met through the execution of the SOPs included in the MWP and appended to this document. The applicable SOPs are referenced below. Specific QC requirements include development of DQOs, performance of internal QC checks, and execution of appropriate analytical procedures during investigative activities. This QAPA is designed to be used in conjunction with the MQAP. Table 2-1 provides a list of general quality assurance (QA) measures that will be implemented as specified in the MQAP.

Table 2-1
Quality Assurance Measures Discussed in the MQAP

Quality Assurance Measure	Section in MQAP	SOP No. (MWP Appendix A and Appendix A of WPA No. 18)
Project Organization and Responsibilities	2.0	--
Lines of Authority	2.2	--
Chemical Data Measurements	3.2	--
Levels of Concern	3.3	--
Site Investigation	4.0/5.0	20.11, 30.1, 30.6, 30.7, 30.9, 50.1, 50.2, 70.1, 80.1
Documentation Requirements	5.6	10.1, 10.2, 10.3, 50.1
Chain-of-custody Requirements	5.7	10.4, 50.2
Calibration Procedures	7.0	90.1
Data Reduction, Validation, Reporting, and Management	9.0	--
Corrective Action	10.0	--
Quality Assessments	11.0	--

The distribution list for submittals associated with the Soil Sampling Investigation is defined in the Facility Permit (USEPA, 2000b). At least six copies of draft documents and three copies of the final plans, reports, notifications, or other documents submitted as part of the RCRA Facility Investigation for SWMU 41 are to be submitted to the USEPA Regional Administrator, and shall be sent Certified Mail, Return Receipt Requested, overnight mail, or hand-carried to:

USEPA Region III
Federal Facilities Branch (3HS13)
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

In addition, one copy each such submission shall be sent to:

Commonwealth of Virginia
Department of Environmental Quality
Waste Division
629 East Main Street
Richmond, Virginia 23219

Commonwealth of Virginia
Department of Environmental Quality
West Central Regional Office
Executive Office Park, Suite D
5338 Peters Creek Road
Roanoke, VA 24109

Moreover, one or more copies of each such submission shall be sent to:

John E. Tesner, P.E.
USACE, Baltimore District
ATTN: CENAB-EN-HM
10 South Howard Street
Baltimore, Maryland 21201

Tony Perry
US Army Environmental Center
5179 Hoadley Road, ATTN: SFIM-AEC-ERP
Aberdeen Proving Ground, MD 21010-5401

James McKenna
Radford Army Ammunition Plant
Route 114, Peppers Ferry Road
Building 220
Radford, Virginia 24141-0099

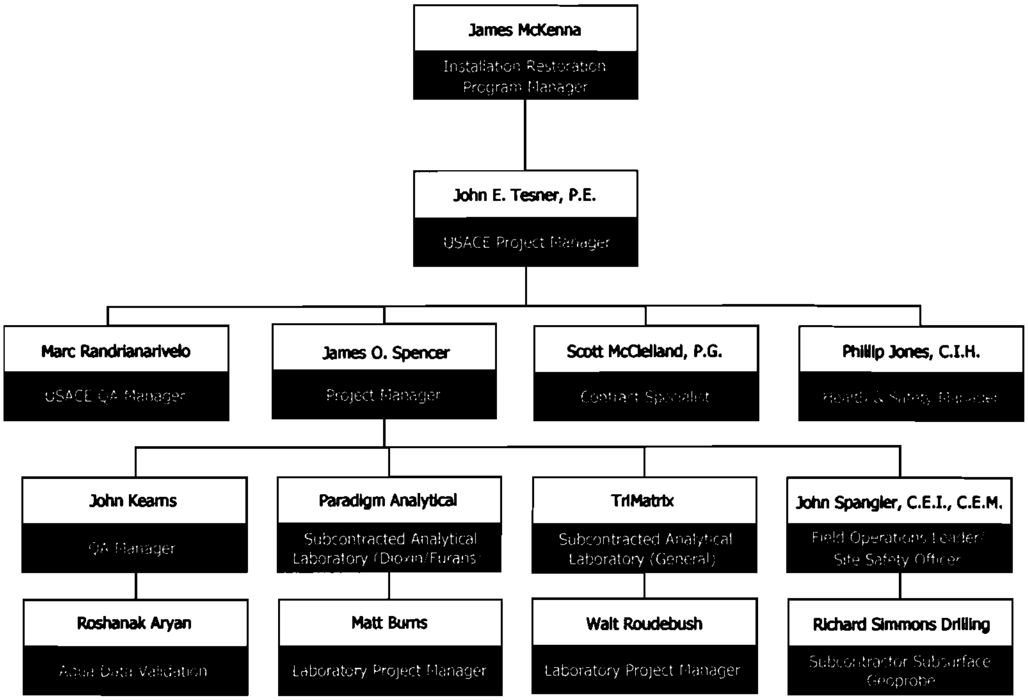
Dennis Druck
USACHPPM
5158 Blackhawk Road
ATTN: MCHB-TS-HER
Aberdeen Proving Ground, MD 21010-5403

2.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

2.2.1 Contractor and Subcontractor Responsibilities

Contractor and subcontractor personnel requirements for implementing the technical, quality, and health and safety programs are described in Section 2.1 of the MQAP. Figure 2-1 presents the identification and the organization of project management personnel.

Figure 2-1
Project Organizational Chart



2.2.2 Key Points of Contact

Table 2-2 provides the names and points of contact for URS personnel and subcontractors.

The Project Manager (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 initiation of each task associated with the project. 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.

Table 2-2
Contractor and Subcontractor Key Points of Contact

Contractor	Key Point of Contact
Project Manager, James O Spencer Email: James O Spencer@URSCorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5420; Fax: 804.965.9764
Health and Safety Manager, Phillip Jones Email: Phillip_L_Jones@URSCorp.com	URS Group, Inc. 1400 Union Meeting Road, Suite 202 Blue Bell, Pennsylvania 19422-1972 Tel: 215.619.4160; Fax: 215.542.3888
Quality Assurance Manager, John Kearns Email: John_Kearns@URSCorp.com	URS Group, Inc. 849 International Drive, Suite 320 Linthicum, Maryland 21090 Tel: 410.859.5049; Fax: 410.859.5049
Data Validator, Roshanak Aryan Email: Roshanak_Aryan@URSCorp.com	URS Group, Inc.-Measurement Systems Group 849 International Drive, Suite 320 Linthicum, Maryland 21090 Tel: 410.859.5049; Fax: 410.859.5049
Field Operations Leader and Site Health and Safety Officer, John Spangler Email: John_Spangler@URSCorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5419; Fax: 804.965.9764
Subcontractor	**Key Point of Contact**
Analytical Laboratory Services, General TriMatrix Laboratories, Inc. Email: RoudebushW@TriMatrixLabs.com	Walt Roudebush 5560 Corporate Exchange Court Grand Rapids, MI 49512 Tel: 616.975.4500; Fax: 616.940.4470
Analytical Laboratory Services, Dioxins / Furans Paradigm Analytical Laboratories, Inc. Email: RMB@ParadigmLabs.com	Matthew Burns 5500 Business Drive Wilmington, North Carolina 28405 Tel: 910.350.1903; Fax 919.552.0066
Subsurface Drilling (Geoprobe®) Richard Simmons Drilling Email: RSDrilling@AOL.com	Richard Simmons Drilling 60 Drill Rig Drive Buchanan, Virginia 24066 Tel: 540.254-2289; Fax: 540.254-1268

The Field Operations Leader will provide management of the field activities during the fieldwork. The Field Operations Leader is responsible for ensuring that technical matters pertaining to the field-sampling 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 Field Operations Leader is responsible for field QA/QC procedures and for safety-related issues. Prior to initiation of field activities, the Field Operations Leader will conduct a field staff orientation and briefing to acquaint project personnel with the sites and assign field responsibilities.

The Health and Safety Manager will review and internally approve the HSPA that 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 SHSO who will work in coordination with the PM and the project Health and Safety 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 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. QC coordination 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.

The Data Validator is responsible for analytical data evaluation and review to provide information on analytical data limitations based on specific quality control criteria. Responsibilities of the Data Validator include establishing if data meet the project technical, quality control criteria, assessing the usability and extent of bias of data not meeting the specific technical, and quality criteria. The reviewer will establish a dialogue with the data users prior to and after review to answer questions, assist with interpretation, and to provide the validation reports.

The Contract Specialist is responsible for tracking funds for labor and materials procurement and oversight of the financial status of the project. Responsibilities include:

- 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; and
- Preparation of project manpower estimates and administration of contract documents.

2.3 QUALITY ASSURANCE OBJECTIVES

QA is defined as the overall system of activities for assuring the reliability of data produced. Section 2.1, of this WPA, references investigative, chemical, and regulatory measures associated with the QA Objectives of this project. Conformance with appended SOPs will ensure attainment of QA objectives. 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 DQO process is a strategic planning approach to ensure environmental data is of the appropriate type, quantity, and quality for decision-making. Project-specific DQOs are included in Table 2-3 for investigative activities. The overall QA objective is to develop and implement procedures for sample and data collection, shipment, evaluation, and reporting that will allow reviewers to assess whether the field and laboratory procedures meet the criteria and endpoints established in the DQOs. 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. *Guidance for the Data Quality Objectives Process* (USEPA 1994), and *Data Quality Objective Process for Hazardous Waste Sites* (USEPA 2000a) formed the basis for the DQO process and development of RFAAP data quality criteria and performance specifications.

The DQO process consists of the seven steps specified below.

1. **State the Problem:** Define the problem to focus the study. Specific activities conducted during this process step include (1) the identification of the planning team and the primary decision-maker, (2) the statement of the problem, and (3) the identification of available resources, constraints, and deadlines.

    1) The planning team consists of the RFAAP, USACE, USEPA, Virginia Department of Environmental Quality (VDEQ), the RFAAP operating contractor, and URS; Relative to the implementation of this Work Plan Addendum, the primary decision-maker is RFAAP, in consultation with USACE, USEPA, VDEQ, the RFAAP operating contractor, and URS;

    2) RFAAP seeks to assess whether concentrations of hazardous constituents are present at SWMU 41 exceeding USEPA Region III RBCs, Federal Maximum Contaminant Concentrations (MCLs), and/or USEPA Region III Draft BTAG screening levels; and

    3) The RCRA Facility Investigation project budget has been established, the project team has been identified, and a project schedule has been developed.

2. **Identify the Decision:** Define the decision statement that the study will attempt to resolve. Activities conducted during this step of the process involve (1) identification of the principal study question(s) and (2) definition of resultant alternative actions.

    1) Principal study questions include:

        i. Are concentrations of hazardous constituents present at SWMU 41 in excess of relevant screening criteria identified in the USEPA Site Screening Process and do the site conditions pose an unacceptable risk to human health or the environment?

        ii. What are the nature and extent of buried materials at SWMU 41?

Table 2-3
Summary of Project Data Quality Objectives

DQO Element	Project DQO Summary
Problem Statement	• The nature and extent of potential contamination of the Burial Area and the Lagoon Area at SWMU 41 are currently unknown. • Possible risks to human health and the environment are currently unknown.
Identify Decision/Study Question	• Analyze geophysical data in conjunction with excavation of the Burial Area test pit • Collect samples representative of buried materials • Conduct surface/subsurface soil boring and sampling outside the Burial Area and the Lagoon Area to characterize potential impacts to surrounding soil • Collect subsurface soil samples for analysis of physical properties to aid in assessing the nature of possible constituent migration
Decision Inputs	• Geophysical Data: EM, magnetic gradient, down-hole logging, resistivity • Field investigation data: soil borings and samples, surface water/sediment samples, test pit logs and samples, spring/seep samples • Chemical analyses: submit soil samples to USACE-validated off-site analytical laboratory for analyses
Study Boundaries	• Physical horizontal boundary of SWMU 41 will be defined within the scope of the RFI by combining geophysical soil boring, and test pit information. • Sample points are designed to collect samples representative of buried materials, nearby, and potentially affected soil.
Decision Rule	• Comparison to USEPA Region III Draft BTAG Screening Levels • Comparison to USEPA Region III RBCs, (USEPA April 2003 or most recent) • Geophysical data will be calibrated to soil boring data and test pit data and will be used to estimate the extent of fill material.
Tolerable Limits on Decision Errors	• SW-846 Test Methods reporting limits. USEPA Contract Laboratory Program (CLP)-like raw data package suitable for validation (level M3 for organic, level IM2 for inorganic). • Improper estimation of the location of buried material will require test pit relocation.
Optimize the Design for Obtaining Data	• Test pits, soil borings, and surface water/sediment locations have been selected to provide information meeting the DQOs. • The ground-truthing of geophysical data will provide for calibrated geophysical data and facilitate CSM Data Gap refinement.

2) The resultant alternative actions include:

   i. If concentrations of hazardous constituents are present at SWMU 41 in excess of relevant screening criteria, then the team plans additional risk assessment activities and possibly additional investigation of the site; and

   ii. If the nature and extent of buried material is ascertainable from the planned field activities, then these conditions will be reported within the RFI Report.

3. **Identify Inputs to the Decision**: Identify information inputs required for resolving the decision statement and determining which inputs require environmental measures. This step of the process includes identification of the data that will be required to make the decision, identification of the information sources, identification of data required for establishment of study action levels, and confirmation of appropriate field sampling and analytical methods. The kinds of information that is needed to resolve the decision statement and the sources of this information include the following:

   1) RBCs in the most recent version of the USEPA Region III Risk-Based Concentration Table for soil using the residential and industrial scenarios;

   2) RBCs in the most recent version of the USEPA Region III Risk-Based Concentration Table for tap water, federal Maximum Contaminant Levels, and Virginia State Water Control Board Water Quality Criteria;

   3) USEPA RCRA Hazardous Waste Characteristics threshold levels;

   4) Method Detection Limits (MDLs) and Reporting Limits (RLs) for the most recent suite of CLP TCL and TAL constituents and other constituents based on the findings of the background data review;

   5) Results of an examination of site use, operational history, environmental setting, groundwater and surface water use and characteristics, and soil exposure characteristics;

   6) Details of a visual inspection of each SWMU area; and

   7) Validated results of chemical analyses performed on site samples.

4. **Define the Boundaries:** Define decision statement spatial and temporal boundaries. This step specifies (1) the spatial boundary, (2) the target population characteristics, applicable geographic areas and associated homogeneous characteristics, and (3) the constraints on sample collection.

   1) Physical horizontal boundary of SWMU 41 will be defined within the scope of the RFI by combining site historical data, previous site investigation findings, geophysical investigation findings, and soil boring information;

   2) The media that will be investigated include surface soil, subsurface soil, surface water, sediment, and buried material within the SWMU areas; and

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3) Practical constraints that could interfere with sampling include steep grade, property access, weather, boring refusal, and insufficient stream, spring, or seep flow.

5. **Develop a Decision Rule:** Define (1) the parameters of interest, (2) the action levels, and (3) develop a decision rule.

   1) Parameters of interest include:

      a) TAL Inorganics with mercury, TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/herbicides (surface soil and sediment), TCL PCBs (soil and sediment), explosives (including nitroglycerin and PETN), perchlorate (aqueous), COD, and dioxin/furans (soil or ash);

      b) Grain-size analysis, Atterberg Limits, moisture content, hydraulic conductivity, soil porosity, soil bulk density, and pH;

      c) Buried material location, volume, and physical characteristics; and

      d) Depth to bedrock and groundwater for soil borings; and

      e) Surface water hydrology characteristics and water quality measurements.

   2) Action levels include:

      a) Action levels for risk screening include USEPA Region III RBCs, USEPA Region III Draft BTAG screening levels, USEPA MCLs, Virginia State Water Control Board Water Quality Criteria, as well as the background soil inorganic constituent concentrations as reported in the Facility-Wide Background Study Report; and

      b) MDLs and RLs, as specified herein, will ensure that data quality is sufficient for its intended use. The selected laboratories are within the CLP network, the proposed Test Methods have been validated by USACE, and it is assumed that sources of analytical errors will be small and known.

   3) Decision rules include:

      a) Constituents of potential concern will be identified by comparing maximum detected concentrations (or a 95% Upper Confidence Limit if appropriate) to established action levels in order to decide the need for further evaluation, investigation, or response action;

      b) Analytical laboratory decision rules are presented in this QAPA and the laboratory QAPs. These include specific action levels and decision rules based on accuracy and precision;

      c) If boring refusal is encountered at less than the expected depth for each SWMU area, then the boring will be offset five feet and advanced to the depth of previous refusal prior to collection of additional samples; and

      d) Results of site activities will be used to refine the site conceptual model and will be used in remedial alternative decisions.

6. **Specify Acceptable Limits on Decision Errors:** Specify the decision-maker's tolerable limits on decision errors. This step includes identification of (1) parameter range of interest, (2) decision errors, (3) potential parameter values and probability tolerance for decision errors.

   1) MDLs and RLs are established for each analyte within the suite of parameters sought. MDLs and RLs below the action levels will ensure the data meets the DQOs. The contract laboratory will provide a CLP-like raw data package (Level IV). Data validation will be conducted based on this QAPA, the MQAP, the USACE Shell Document, and relevant USEPA Region III guidance.

   2) The main baseline condition decision error is to decide that the true mean concentration of a site-related contaminant does not exceed the action level for further study when in fact the mean concentration exceeds the action level and further action is needed (Type I, false rejection). Conversely, consequences of incorrectly deciding that the true mean concentration of a site-related contaminant is above the action level when in fact the mean concentration is below the action level include spending un-necessary resources to study further or remediate a site with insignificant risk (Type II, false acceptance).

   3) Information from previous studies and physical features of each SWMU area was used to develop a field sampling plan design that allow for a low probability of decision error.

7. **Optimize Data Design:** Identify data collection activities commensurate with data quality specifications. This final step in the process consists of (1) reviewing DQO outputs and existing environmental data, (2) developing data collection design alternatives, and (3) documentation of operational details and theoretical assumptions.

   1) DQO outputs will be reviewed based on the data collection activities; the validity of the data could be verified if necessary based on the review;

   2) Data collection is based upon site-specific characteristics and the end use of the data; and

   3) This addendum contains the proposed sampling design program based on the DQOs. Project documentation will be implemented in accordance with the MWP.

2.4 SAMPLE MANAGEMENT

Sample management objectives will be met through adherence to the sample identification procedures (identification convention), documentation requirements, and chain-of-custody procedures in the MWP.

2.4.1 Number and Type

Table 2-4 provides an itemization of the sample identifiers, sample depths (if applicable), and analytical parameters for environmental samples proposed during this investigation.

2.4.2 Sample Containers, Preservation Requirements, and Holding Times

Table 2-5 identifies analytical parameters, container and preservation requirements, and holding times.

2.4.3 Sample Identification

The sample identification number will conform to past nomenclature at SWMU 41. The identification will consist of an alphanumeric designation related to the sampling location, media type, and sequential

Table 2-4
Summary: Proposed Sample Identifiers, Depths, and Analytical Methods
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

		Chemical Analysis													Physical Analysis							
Sample ID	Depth (ft bgs)	TAL Metals/CV Mercury/Cyanide (Unfiltered) SW-846 Method 6010B/7471A/9012A	TAL Metals/CV Mercury/Cyanide (Filtered) SW-846 Methods 6010B/7471A/9012A	Pesticides/PCBs/Herbicides SW-846 Methods 8081A/8082/8151A	VOCs SW-846 Method 8260B	SVOCs SW-846 Method 8270C	Dioxins/Furans SW-846 Method 8290	PAHs SW-846 Method 8310	Explosives/Nitroglycerin/PETN SW-846 Methods 8330m/8332	Perchlorate Method EPA 314.0	TCLP Full List	Chemical Oxygen Demand EPA Method 410.4	pH (corrosivity) SW-846 Method 9040B	Paint Filter Test SW-846 Method 9095	Total Organic Content ASTM D2974-00	Grain Size ASTM D422-92	Atterburg Limits ASTM D4318-00	Moisture Content ASTM D2216-98E1	pH ASTM D4972-01	Hydraulic Conductivity ASTM D5084-00e1-2000	Soil Porosity ASTM D854-02 and D2937-00e1	Soil Bulk Density ASTM D4253-00
Soil																						
Soil Borings																						
41SB2A	0-1	X		X	X	X		X	X													
41SB2B	6-15	X			X	X	X	X	X													
41SB2C	15-30	X			X	X	X	X	X													
41SB3A	0-1	X			X	X		X	X													
41SB3B	6-15	X			X	X		X	X													
41SB3C	15-30	X			X	X		X	X													
41SB4A	0-1	X			X	X		X	X													
41SB4B	6-15	X			X	X		X	X													
41SB4C	15-30	X			X	X		X	X													
41SB5A	0-1	X		X	X	X		X	X													
41SB5B	6-15	X			X	X	X	X	X													
41SB5C	15-30	X			X	X	X	X	X													
41SB6A	0-1	X			X	X		X	X													
41SB6B	6-15	X			X	X		X	X													
41SB6C	15-30	X			X	X		X	X													
41SB7A	0-1	X		X	X	X		X	X													
41SB7B	6-15	X			X	X	X	X	X													
41SB7C	15-30	X			X	X	X	X	X													
41SB8A	0-1	X			X	X		X	X													
41SB8B	6-15	X			X	X		X	X													
41SB8C	15-30	X			X	X		X	X													
41SB9A	0-1	X			X	X		X	X													
41SB9B	6-15	X			X	X		X	X													
41SB9C	15-30	X			X	X		X	X													
41SB10A	0-1	X		X	X	X		X	X													
41SB10B	6-15	X			X	X	X	X	X													
41SB10C	15-30	X			X	X	X	X	X													
41SB11A	0-1	X			X	X		X	X													
41SB11B	6-15	X			X	X		X	X													
41SB11C	15-30	X			X	X		X	X													
D-1	TBD	X			X	X		X	X													
D-2	TBD	X			X	X		X	X													
D-3	TBD	X			X	X		X	X													
MS/MSD	TBD	X			X	X		X	X													
MS/MSD	TBD																					
Sediment																						
41SD2	N/A	X		X	X	X		X	X													
41SD3	N/A	X		X	X	X		X	X													
41SD4	N/A	X		X	X	X		X	X													
41SD5	N/A	X		X	X	X		X	X													
41SD6	N/A	X		X	X	X		X	X													
41SD7	N/A	X		X	X	X		X	X													
D-4	TBD	X		X	X	X		X	X													
MS/MSD	TBD	X		X	X	X		X	X													
Test Pits																						
41TP1S	6	X			X	X		X	X													
41TP1PB	12	X			X	X		X	X													
41TP1F	*	X		X	X	X	X	X	X													
41TP2S	6	X			X	X		X	X													
41TP2PB	12	X			X	X		X	X													
41TP2F	*	X		X	X	X	X	X	X													
D-5	TBD																					
IDM																						
41IDM-H2O									X**		X	X	X									
41IDM-SOIL									X**		X		X	X								
41IDM-TP									X**		X		X	X								
Geotechnical																						
41GT1															X	X	X	X	X	X	X	X
41GT2															X	X	X	X	X	X	X	X
41GT3															X	X	X	X	X	X	X	X
41GT4															X	X	X	X	X	X	X	X
Aqueous																						
Spring/Seeps																						
41SP1	N/A	X	X		X	X		X	X	X												
41SP2	N/A	X	X		X	X		X	X	X												
41SP3	N/A	X	X		X	X		X	X	X												
Surface Water																						
41SW2	N/A	X	X		X	X		X	X	X												
41SW3	N/A	X	X		X	X		X	X	X												
41SW4	N/A	X	X		X	X		X	X	X												
41SW5	N/A	X	X		X	X		X	X	X												
41SW6	N/A	X	X		X	X		X	X	X												
41SW7	N/A	X	X		X	X		X	X	X												
DUP	N/A	X	X		X	X		X	X	X												
MS	N/A	X	X		X	X		X	X	X												
MSD	N/A	X	X		X	X		X	X	X												

Notes:

ft bgs = Feet Below Ground Surface
TAL = Target Analyte List
PCB =Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
PETN = Pentaerythritol Tetranitrate
TCLP = Toxicity Characteristic Leaching Procedure
ASTM = American Society for Testing and Materials
SB = Soil Boring
SD = Sediment
TP = Test Pit
S = Sidewall
PB = Pit Bottom
F = Fill Material
IDM = Investigation-Derived Material
GT = Geotechnical Sample
SP = Spring Water
SW = Surface Water
MS/MSD = Matrix Spike/Matrix Spike Duplicate
TBD = To be Determined
N/A = Not Applicable

* = Sample will be taken where fill is encountered
PETN) and will not be analyzed for nitroglycerin

Table 2-5
Summary of Sample Container, Preservation Method, and Holding Time Requirements
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

PARAMETER	SAMPLE CONTAINER		PRESERVATION METHODS	HOLDING TIMES
	Quantity	Type		
SOLID SAMPLES				
TCL Volatile Organic Compounds	3	5-gram Encore samplers, zero headspace	Cool to 4 ± 2 °C; sodium bisulfate (low level), methanol (high level)	must be analyzed within 48 hours or transferred to soil purge vial with preservative within 48 hours for analysis within 14 days
TCL Semivolatile Organic Compounds	1	500-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
TCL Pesticides/Aroclors	2	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
Herbicides	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
Polyaromatic Hydrocarbons	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
Explosives/Nitroglycerin/PETN	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
TAL Metals	1	250-ml wide mouth polyethylene container, Teflon®-lined cap	Cool to 4 ± 2 °C	Metals: 6 months Mercury: 28 days
Dioxin/Furans	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C, Dark	Extraction: 30 days Analysis: 45 days
SOLID WASTE CHARACTERIZATION				
TCLP VOCs	1	125-mL wide-mouth glass vial, Teflon®-lined cap	Cool to 4 ± 2°C	Leaching: 14 days Analysis: 14 days
TCLP SVOCs (8270C, 8081A, & 8151A)	2	500-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 14 days Extraction: 7 days Analysis: 40 days
TCLP Metals	1	250-mL wide-mouth polyethylene container, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 14 days Analysis: 6 months Mercury analysis: 28 days
Explosives	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 14 days Analysis: 40 days
Corrosivity, Paint Filter	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Corrosivity: 7 days Paint Filter: –
AQUEOUS SAMPLES				
TCL Volatile Organic Compounds	3	40-mL, glass vials, Teflon®-lined septum cap, zero headspace	HCl to pH < 2, Cool to 4 ± 2°C	14 days
TCL Semivolatile Organic Compounds	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Herbicides	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Polyaromatic Hydrocarbons	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Explosives/Nitroglycerin/PETN	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Unfiltered TAL Metals	1	500-ml, polyethylene container	HNO_3 to pH<2, Cool to 4 ± 2 °C	ICP: 6 months Mercury: 28 days
Field Filtered TAL Metals	1	500-ml, polyethylene container	HNO_3 to pH<2, Cool to 4 ± 2 °C	ICP: 6 months Mercury: 28 days
Perchlorate	1	500-mL, polyethylene bottle	Cool to 4 ± 2 °C	28 days
AQUEOUS WASTE CHARACTERIZATION				
TCLP VOCs	3	40-mL, glass vials, Teflon®-lined septum cap, zero headspace	Cool to 4 ± 2 °C	Leaching: 7 days Analysis: 14 days
TCLP SVOCs (8270C, 8081A, & 8151A)	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 7 days Extraction: 7 days Analysis: 40 days
TCLP Metals	1	500-ml, polyethylene container	Cool to 4 ± 2 °C	Leaching: 14 days Analysis: 6 months Mercury analysis: 28 days
Explosives	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Corrosivity	1	125-ml, polyethylene container	Cool to 4 ± 2 °C	7 days
COD	1	250-ml, polyethylene container	H_2SO_4 to pH<2, Cool to 4 ± 2 °C	28 days

<u>Notes:</u>
TAL = Target Analyte List
TCL = Target Compound List
mL = milliliter
g = gram

HNO_3 = Nitric Acid
H_2SO_4 = Sulfuric Acid
HCl = Hydrochloric Acid
°C = Degrees Celsius

order according to the sampling event. The identification number will not exceed thirty-two characters for entry into Environmental Restoration Information System (ERIS). Samples will be coded in the following order to ensure a unique identification.

- **Site Location Code:** The first two characters will be the SWMU number (i.e., 41 for SWMU 41).
- **Sample/Media Type:** The next two characters will be the sample/media types. In this case, the characters will be SB for soil borings, SW for surface water, SD for sediment, SP for springs/seeps, and TP for Test Pits.
- **Sampling Location Number**: The next one or two characters will be the number of the sampling location (e.g., 3, 4, 5).
- **Sample Depth:** The sample representing zero to six inches bgs will be designated with an "A" after the boring number. The sample collected from intermediate depths of the boring, or from below fill materials, will be designated with a "B" following the boring number. Samples representative of fill materials will be designated with an "F." Samples collected from above bedrock, at the base of the boring will be designated with a "C." For the Test Pit samples, additional qualifiers will include "S" for sidewall and "PB" for pit bottom.
- **Duplicate:** Duplicate samples will be identified with a "D" designation followed by a numeric designation corresponding to the sequence of duplicates collected (e.g., D-1). A record of the sample that corresponds to the duplicate will be kept in the field logbook. In this manner, duplicates will be submitted as blind duplicates, eliminating the potential for laboratory bias in analysis.

Sample Identification Examples:

1) A subsurface soil sample collected above the termination depth of boring location four at SWMU 41 would be identified as sample 41SB4C (for SWMU 41, soil boring four, and "C" which stands for the soil above bedrock at that location).
2) QC Samples: QC samples will be identified by date (month, day, year), followed by QC sample type, and sequential order number at one digit. The QC sample types include Matrix Spike, Matrix Spike Duplicate (MS/MSD), Rinse Blank (R), and Trip Blank (T).

2.4.4 Documentation

SOPs 10.1 and 10.2 in Appendix A and Section 9.8 of the MQAP specify documentation protocols.

2.5 ANALYTICAL PROCEDURES

TriMatrix Laboratories Inc. will perform off-site analytical activities (Paradigm Laboratories Inc. will perform the dioxins/furans analyses). Analytical methods to be used and associated MDLs and RLs are identified in Table 2-6 through 2-13. Laboratory analyses will be in accordance with USEPA SW-846 Test Methods (except for perchlorate, USEPA Method) for the analysis of the following:

Table 2-6
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL VOCs (by EPA Method 8260B)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aqueous Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
1,1,1-Trichloroethane	71-55-6	0.000326	0.005	0.184	1	2.0E+02	N	3.2E+03	3.2E+02	2.9E+05	2.9E+04	2.2E+04	2.2E+03	9.4E+03	3.0E-01	3.1E-02
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	0.000275	0.005	0.137	1	–	N	5.9E+04	5.9E+03	3.1E+07	3.1E+06	2.3E+06	2.3E+05	–	–	–
1,1,2,2-Tetrachloroethane	79-34-5	0.000219	0.005	0.197	1	–	C	5.3E-02	5.3E-02	1.4E+01	1.4E+01	3.2E+00	3.2E+00	2.4E+03	3.0E-01	–
1,1,2-Trichloroethane	79-00-5	0.000294	0.005	0.223	1	5.0E+00	C	1.9E-01	1.9E-01	5.0E+01	5.0E+01	1.1E+01	1.1E+01	9.4E+03	3.0E-01	3.1E-02
1,1-Dichloroethane	75-34-3	0.000249	0.005	0.126	1	–	N	8.0E+02	8.0E+01	1.0E+05	1.0E+04	7.8E+03	7.8E+02	1.6E+05	3.0E-01	–
1,1-Dichloroethene	75-35-4	0.000443	0.005	0.276	1	7.0E+00	N	3.5E+02	3.5E+01	5.1E+04	5.1E+03	3.9E+03	3.9E+02	1.2E+04	–	–
1,2-Dibromoethane	106-93-4	0.000101	0.005	0.221	1	5.0E-02	C	7.5E-04	7.5E-04	3.4E-02	3.4E-02	7.5E-03	7.5E-03	1.8E+04	5.0E+00	–
1,2-Dibromo-3-chloropropane	96-12-8	0.000267	0.010	0.439	5	2.0E-01	Cl/C	4.2E-01	4.2E-02	2.0E+00	2.0E+00	4.6E-01	4.6E-01	–	–	–
1,2-Dichlorobenzene	95-50-1	0.000175	0.005	0.210	1	6.0E+02	N	2.7E+02	2.7E+01	9.2E+04	9.2E+03	7.0E+03	7.0E+02	7.6E+02	1.0E-01	3.5E-02
1,2-Dichloroethane	107-06-2	0.000274	0.005	0.874	1	5.0E+00	C	1.2E-01	1.2E-01	3.1E+01	3.1E+01	7.0E+00	7.0E+00	2.0E+04	8.7E+02	–
cis-1,2-Dichloroethene	156-59-2	0.000074	0.005	0.112	1	7.0E+01	N	6.1E+01	6.1E+00	1.0E+04	1.0E+03	7.8E+02	7.8E+01	1.2E+04	3.0E-01	–
trans-1,2-Dichloroethene	156-60-5	0.000381	0.005	0.175	1	1.0E+02	N	1.2E+02	1.2E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	1.2E+04	3.0E-01	–
1,2-Dichloropropane	78-87-5	0.000265	0.005	0.210	1	5.0E+00	C	1.6E-01	1.6E-01	4.2E+01	4.2E+01	9.4E+00	9.4E+00	5.7E+03	3.0E-01	–
1,2,3-Trichlorobenzene	87-61-6	0.000536	0.005	0.158	1	–	–	–	–	–	–	–	–	5.0E+01	1.0E-01	4.0E-02
1,2,4-Trichlorobenzene	120-82-1	0.000134	0.005	0.260	1	7.0E+01	N	7.2E+00	7.2E-01	1.0E+04	1.0E+03	7.8E+02	7.8E+01	5.0E+01	1.0E-01	4.0E-02
1,3-Dichlorobenzene	541-73-1	0.000102	0.005	0.054	1	–	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	7.6E+02	–	–
1,4-Dichlorobenzene	106-46-7	0.000235	0.005	0.085	1	7.5E+01	C	4.7E-01	4.7E-01	1.2E+02	1.2E+02	2.7E+01	2.7E+01	7.6E+02	1.0E-01	1.1E-01
2-Butanone	78-93-3	0.001250	0.010	2.240	20	–	N	7.0E+03	7.0E+02	6.1E+05	6.1E+04	4.7E+04	4.7E+03	3.2E+06	–	–
2-Hexanone	591-78-6	0.000447	0.010	1.932	20	–	N	–	–	–	–	–	–	4.3E+05	–	–
4-Methyl-2-pentanone	108-10-1	0.000852	0.010	0.463	20	–	N	6.3E+03	6.3E+02	–	–	–	–	4.6E+05	1.0E+02	–
Acetone	67-64-1	0.004510	0.010	4.148	20	–	N	5.5E+03	5.5E+02	9.2E+05	9.2E+04	7.0E+04	7.0E+03	9.0E+06	–	–
Benzene	71-43-2	0.000273	0.005	0.121	1	5.0E+00	C	3.4E-01	3.4E-01	5.2E+01	5.2E+01	1.2E+01	1.2E+01	5.3E+03	1.0E-01	–
Bromochloromethane	74-97-5	0.000570	0.005	0.122	1	–	–	–	–	–	–	–	–	1.1E+04	3.0E+03	–
Bromodichloromethane	75-27-4	0.000245	0.005	0.136	1	–	C	1.7E-01	1.7E-01	4.6E+01	4.6E+01	1.0E+01	1.0E+01	1.1E+04	4.5E+02	–
Bromoform	75-25-2	0.000131	0.005	0.228	1	–	C	8.5E+00	8.5E+00	3.6E+02	3.6E+02	8.1E+01	8.1E+01	–	–	–
Bromomethane	74-83-9	0.000343	0.005	0.304	1	–	N	8.5E+00	8.5E-01	1.4E+03	1.4E+02	1.1E+02	1.1E+01	–	–	–
Carbon disulfide	75-15-0	0.000733	0.005	0.153	5	–	N	1.0E+03	1.0E+02	1.0E+05	1.0E+04	7.8E+03	7.8E+02	2.0E+00	–	–
Carbon tetrachloride	56-23-5	0.000305	0.005	0.142	1	5.0E+00	C	1.6E-01	1.6E-01	2.2E+01	2.2E+01	4.9E+00	4.9E+00	3.5E+04	3.0E-01	–
Chlorobenzene	108-90-7	0.000107	0.005	0.115	1	1.0E+02	N	1.1E+02	1.1E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	5.0E+01	1.0E-01	–
Chloroethane	75-00-3	0.000395	0.005	0.225	1	–	C	3.6E+00	3.6E+00	9.9E+02	9.9E+02	2.2E+02	2.2E+02	–	–	–
Chloroform	67-66-3	0.000246	0.005	0.238	1	–	C/N	1.5E-01	1.5E-01	1.0E+04	1.0E+03	7.8E+02	7.8E+01	1.2E+03	3.0E-01	–
Chloromethane	74-87-3	0.000395	0.005	0.250	1	–	N	1.9E+02	1.9E+01	–	–	–	–	–	–	–
Cyclohexane	110-82-7	0.000319	0.010	0.258	5	–	N	1.2E+04	1.2E+03	–	–	–	–	–	–	–
cis-1,3-Dichloropropene[1]	10061-01-5	0.000392	0.005	0.114	1	–	C	4.4E-01	4.4E-01	2.9E+01	2.9E+01	6.4E+00	6.4E+00	2.4E+02	3.0E-01	–
trans-1,3-Dichloropropene[1]	10061-02-6	0.000341	0.005	0.110	1	–	C	4.4E-01	4.4E-01	2.9E+01	2.9E+01	6.4E+00	6.4E+00	2.4E+02	3.0E-01	–
Dichlorodifluoromethane	75-71-8	0.000493	0.005	0.162	1	–	N	3.5E+02	3.5E+01	2.0E+05	2.0E+04	1.6E+04	1.6E+03	1.1E+04	–	–
Dibromochloromethane	124-48-1	0.000493	0.005	0.162	1	–	C	1.3E-01	[illegible]	3.4E+01	3.4E+01	7.6E+00	7.6E+00	1.1E+04	–	–
Ethylbenzene	100-41-4	0.000218	0.005	0.112	1	7.0E+02	N	1.3E+03	1.3E+02	1.0E+05	1.0E+04	7.8E+03	7.8E+02	3.2E+04	1.0E-01	1.0E-02
Isopropylbenzene	98-82-8	0.000189	0.005	0.138	1	–	N	6.6E+02	6.6E+01	1.0E+05	1.0E+04	7.8E+03	7.8E+02	–	–	–
Methyl acetate	79-20-9	0.000668	0.010	1.974	10	–	N	6.1E+03	6.1E+02	1.0E+06	1.0E+05	7.8E+04	7.8E+03	–	–	–
Methylcyclohexane	108-87-2	0.000167	0.010	0.283	5	–	N	6.3E+03	6.3E+02	–	–	–	–	–	–	–
methyl tert-Butyl ether	1634-04-4	0.000580	0.005	0.074	1	–	C	2.6E+00	2.6E+00	7.2E+02	7.2E+02	1.6E+02	1.6E+02	–	–	–
Methylene chloride	75-09-2	0.000318	0.005	0.135	4	5.0E+00	C	4.1E+00	4.1E+00	3.8E+02	3.8E+02	8.5E+01	8.5E+01	1.1E+04	3.0E-01	–

Table 2-6 (Continued)
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL VOCs (by EPA Method 8260B)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations								USEPA Region III Draft BTAG Screening Levels		
		Soil		Water													
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aqueous Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
Styrene	100-42-5	0.000277	0.005	0.201	1	1.0E+02	N	1.6E+03	1.6E+02	2.0E+05	2.0E+04	1.6E+04	1.6E+03	--	1.0E-01	--
Tetrachloroethene	127-18-4	0.000238	0.005	**0.115**	1	5.0E+00	C	1.0E-01	1.0E-01	5.3E+00	5.3E+00	1.2E+00	1.2E+00	8.4E+02	3.0E-01	5.7E-02
Toluene	108-88-3	0.000219	0.005	0.101	1	1.0E+03	N	7.5E+02	7.5E+01	2.0E+05	2.0E+04	1.6E+04	1.6E+03	1.7E+04	1.0E-01	--
Trichloroethene	79-01-6	0.000386	0.005	0.106	1	5.0E+00	C	2.6E-02	[illegible]	7.2E+00	7.2E+00	1.6E+00	1.6E+00	2.2E+04	3.0E-01	--
Trichlorofluoromethane	75-69-4	0.000390	0.005	0.240	1	--	N	1.3E+03	1.3E+02	3.1E+05	3.1E+04	2.3E+04	2.3E+03	1.1E+04	--	--
Vinyl Chloride[2]	75-01-4	0.000180	0.005	0.290	1	2.0E+00	C	1.5E-02	[illegible]	4.0E+00	4.0E+00	9.0E-02	9.0E-02	1.2E+04	3.0E-01	--
Xylenes	1330-20-7	0.000735	0.005	0.405	3	1.0E+04	N	2.1E+02	2.1E+01	2.0E+05	2.0E+04	1.6E+04	1.6E+03	6.0E+03	1.0E-01	4.0E-02

Notes:

BTAG = Biological Technical Assistance Group Screening Level, Draft 1995
CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by TriMatrix
mg/kg = Milligram Per Kilogram
µg/L = Microgram Per Liter
RBC = Risk-Based Concentration
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table
-- = No Risk Criteria Available

C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
C! = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
(1) = RBC value is for 1,3-Dichloropropene
(2) = RBCs presented are for early-life, except industrial soil RBC, which is for adult
TCL = Target Compound List
VOC = Volatile Organic Compound
bold = Reporting limit was not low enough to meet screening criteria - but MDL does
▨ = Screening criteria cannot be met

Table 2-7
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL SVOCs (by EPA Method 8270C)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aqueous Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
1,1'-Biphenyl	92-52-4	0.00418	0.17	0.0690	5	--	N	3.0E+02	3.0E+01	5.1E+04	5.1E+03	3.9E+03	3.9E+02	--	--	--
1,2,4,5-Tetrachlorobenzene	95-94-3	0.00657	0.17	0.3088	5	--	N	1.1E+01	1.1E+00	3.1E+02	3.1E+01	2.3E+01	2.3E+00	5.0E+01	1.0E-01	--
2,2'-oxybis(1-Chloropropane)	108-60-1	0.00434	0.17	0.0477	5	--	C	2.6E-01	2.6E-01	4.1E+01	4.1E+01	9.1E+00	9.1E+00	--	--	--
2,4,5-Trichlorophenol	95-95-4	0.00305	0.17	0.0431	5	--	N	3.7E+03	3.7E+02	1.0E+05	1.0E+04	7.8E+03	7.8E+02	6.3E+01	1.0E-01	--
2,4,6-Trichlorophenol	88-06-2	0.00319	0.17	0.0341	5	--	C	6.1E+00	6.1E+00	2.6E+02	2.6E+02	5.8E+01	5.8E+01	9.7E+02	1.0E-01	--
2,4-Dichlorophenol	120-83-2	0.00279	0.17	0.0456	5	--	N	1.1E+02	1.1E+01	3.1E+03	3.1E+02	2.3E+02	2.3E+01	3.7E+02	1.0E-01	--
2,4-Dimethylphenol	105-67-9	0.00594	0.17	0.0483	5	--	N	7.3E+02	7.3E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	2.1E+03	1.0E-01	2.9E-02
2,4-Dinitrophenol	51-28-5	0.00520	0.33	0.0817	10	--	N	7.3E+01	7.3E+00	2.0E+03	2.0E+02	1.6E+02	1.6E+01	1.5E+02	1.0E-01	--
2,4-Dinitrotoluene	121-14-2	0.00367	0.17	0.0343	5	--	N	7.3E+01	7.3E+00	2.0E+03	2.0E+02	1.6E+02	1.6E+01	2.3E+02	--	--
2,6-Dinitrotoluene	606-20-2	0.00349	0.17	0.0305	5	--	N	3.7E+01	3.7E+00	1.0E+03	1.0E+02	7.8E+01	7.8E+00	--	--	--
2-Chloronaphthalene	91-58-7	0.00253	0.17	0.0455	5	--	N	4.9E+02	4.9E+01	8.2E+04	8.2E+03	6.3E+03	6.3E+02	6.2E+02	--	--
2-Chlorophenol	95-57-8	0.00378	0.17	0.0376	5	--	N	3.0E+01	3.0E+00	5.1E+03	5.1E+02	3.9E+02	3.9E+01	9.7E+02	1.0E-01	--
2-Methylnaphthalene	91-57-6	0.00312	0.17	0.0381	5	--	N	1.2E+02	1.2E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	--	--	7.0E-02
2-Methylphenol	95-48-7	0.00405	0.17	0.0319	5	--	N	1.8E+03	1.8E+02	5.1E+04	5.1E+03	3.9E+03	3.9E+02	--	1.0E-01	6.3E-02
2-Nitroaniline	88-74-4	0.00369	0.17	0.0638	5	--	N	1.1E+02	1.1E+01	3.1E+03	3.1E+02	2.3E+02	2.3E+01	--	--	--
2-Nitrophenol	88-75-5	0.00561	0.17	0.0584	5	--	--	--	--	--	--	--	--	--	--	--
3,3'-Dichlorobenzidine	91-94-1	0.00477	0.17	0.0570	5	--	C	1.5E-01	1.5E-01	6.4E+00	6.4E+00	1.4E+00	1.4E+00	--	--	--
3-Nitroaniline	99-09-2	0.00293	0.17	0.0638	5	--	CI/N	1.1E+01	1.1E+00	3.1E+02	3.1E+01	--	--	--	--	--
4,6-Dinitro-2-methylphenol	534-52-1	0.00353	0.17	0.0805	5	--	N	3.7E+00	3.7E-01	1.0E+02	1.0E+01	7.8E+00	7.8E-01	--	--	--
4-Bromophenyl-phenylether	101-55-3	0.00323	0.17	0.0417	5	--	--	--	--	--	--	--	--	--	--	--
4-Chloro-3-Methylphenol	59-50-7	0.00389	0.17	0.1530	5	--	--	--	--	--	--	--	--	--	--	--
4-Chloroaniline	106-47-8	0.00142	0.17	0.0467	5	--	N	1.5E+02	1.5E+01	4.1E+03	4.1E+02	3.1E+02	3.1E+01	--	--	--
4-Chlorophenyl-phenylether	7005-72-3	0.00491	0.17	0.0435	5	--	--	--	--	--	--	--	--	--	--	--
4-Methylphenol	106-44-5	0.00305	0.17	0.0361	5	--	N	1.8E+02	1.8E+01	5.1E+03	5.1E+02	3.9E+02	3.9E+01	--	1.0E-01	6.7E-01
4-Nitroaniline	100-01-6	0.00524	0.17	0.0494	5	--	C/CI	3.3E+00	3.3E+00	1.4E+02	1.4E+02	2.4E+02	2.4E+01	--	--	--
4-Nitrophenol	100-02-7	0.00546	0.33	0.0656	10	--	--	--	--	--	--	--	--	1.5E+02	1.0E-01	--
Acenaphthene	83-32-9	0.00407	0.17	0.0725	5	--	N	3.7E+02	3.7E+01	6.1E+04	6.1E+03	4.7E+03	4.7E+02	5.2E+02	1.0E-01	1.6E-02
Acenaphthylene [1]	208-96-8	0.00364	0.17	0.0334	5	--	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	1.0E-01	4.4E-02
Acetophenone	98-86-2	0.00232	0.17	0.1028	5	--	N	6.1E+02	6.1E+01	1.0E+05	1.0E+04	7.8E+03	7.8E+02	--	--	--
Anthracene	120-12-7	0.00244	0.17	0.0412	5	--	N	1.8E+03	1.8E+02	3.1E+05	3.1E+04	2.3E+04	2.3E+03	1.0E-01	1.0E-01	8.5E-02
Atrazine	1912-24-9	0.00384	0.17	0.0828	5	3.0E+00	C	3.0E-01	3.0E-01	1.3E+01	1.3E+01	2.9E+00	2.9E+00	--	--	--
Benzaldehyde	100-52-7	0.00428	0.17	0.1523	5	--	N	3.7E+03	3.7E+02	1.0E+05	1.0E+04	7.8E+03	7.8E+02	--	--	--
Benzo(a)anthracene	56-55-3	0.00435	0.17	0.0500	5	--	C	9.2E-02	9.2E-02	3.9E+00	3.9E+00	8.7E-01	8.7E-01	6.3E+00	1.0E-01	2.6E-01
Benzo(a)pyrene	50-32-8	0.00386	0.17	0.0349	5	2.0E-01	C	9.2E-03	9.2E-03	3.9E-01	3.9E-01	8.7E-02	8.7E-02	--	1.0E-01	4.3E-01
Benzo(b)fluoranthene	205-99-2	0.00487	0.17	0.0519	5	--	C	9.2E-02	9.2E-02	3.9E+00	3.9E+00	8.7E-01	8.7E-01	--	1.0E-01	3.2E+00
Benzo(g,h,i)perylene [Alt]	191-24-2	0.00179	0.17	0.0436	5	--	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	1.0E-01	6.7E-01
Benzo(k)fluoranthene	207-08-9	0.00235	0.17	0.0267	5	--	C	9.2E-01	9.2E-01	3.9E+01	3.9E+01	8.7E+00	8.7E+00	--	1.0E-01	--
Bis(2-chloroethoxy)methane	111-91-1	0.00279	0.17	0.0433	5	--	--	--	--	--	--	--	--	1.1E+04	--	--
Bis(2-chloroethyl)ether	111-44-4	0.00462	0.17	0.0596	5	--	C	9.6E-03	9.6E-03	2.6E+00	2.6E+00	5.8E-01	5.8E-01	--	--	--

Table 2-7 (Continued)
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for
TCL SVOCs (by EPA Method 8270B)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and ReportingLimits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aqueous Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
Bis(2-ethylhexyl)phthalate	117-81-7	0.00406	0.17	**0.1400**	5	6.0E+00	C	4.8E+00	4.8E+00	2.0E+02	2.0E+02	4.6E+01	4.6E+01	3.0E+01	–	1.3E+00
Butylbenzylphthalate	85-68-7	0.00469	0.17	0.0465	5	–	N	7.3E+03	7.3E+02	2.0E+05	2.0E+04	1.6E+04	1.6E+03	3.0E+00	–	6.3E-02
Caprolactam	105-60-2	0.00383	0.33	0.1052	5	–	N	1.8E+04	1.8E+03	5.1E+05	5.1E+04	3.9E+04	3.9E+03	–	–	–
Carbazole	86-74-8	0.00348	0.17	**0.0341**	5	–	C	3.3E+00	3.3E+00	1.4E+02	1.4E+02	3.2E+01	3.2E+01	–	–	–
Chrysene	218-01-9	0.00365	0.17	0.0367	5	–	C	9.2E+00	9.2E+00	3.9E+02	3.9E+02	8.7E+01	8.7E+01	–	1.0E-01	3.8E-01
Dibenz(a,h)anthracene	53-70-3	**0.00422**	0.17	0.0527	5	–	C	9.2E-03	9.2E-03	3.9E-01	3.9E-01	8.7E-02	8.7E-02	–	1.0E-01	6.3E-02
Dibenzofuran	132-64-9	0.00275	0.17	**0.0453**	5	–	N	1.2E+01	1.2E+00	2.0E+03	2.0E+02	1.6E+02	1.6E+01	–	–	5.4E-01
Diethylphthalate	84-66-2	0.00339	0.17	0.0543	5	–	N	2.9E+04	2.9E+03	8.2E+05	8.2E+04	6.3E+04	6.3E+03	3.0E+00	–	2.0E-01
Dimethylphthalate	131-11-3	0.00355	0.17	0.0373	5	–	N	3.7E+05	3.7E+04	1.0E+07	1.0E+06	7.8E+05	7.8E+04	3.0E+00	–	7.1E-02
Di-n-butylphthalate	84-74-2	0.00683	0.17	0.1370	5	–	N	3.7E+03	3.7E+02	1.0E+05	1.0E+04	7.8E+03	7.8E+02	3.0E-01	–	1.4E+00
Di-n-octylphthalate	117-84-0	0.00380	0.17	0.0313	5	–	N	1.5E+03	1.5E+02	4.1E+04	4.1E+03	3.1E+03	3.1E+02	3.0E-01	–	6.2E+00
Fluoranthene	206-44-0	0.00284	0.17	0.0478	5	–	N	1.5E+03	1.5E+02	4.1E+04	4.1E+03	3.1E+03	3.1E+02	4.0E+03	1.0E-01	6.0E-01
Fluorene	86-73-7	0.00508	0.17	0.0316	5	–	N	2.4E+02	2.4E+01	4.1E+04	4.1E+03	3.1E+03	3.1E+02	4.3E+02	1.0E-01	1.9E-02
Hexachlorobenzene	118-74-1	0.00489	0.17	**0.0365**	5	1.0E+00	C	4.2E-02	4.2E-02	1.8E+00	1.8E+00	4.0E-01	4.0E-01	3.7E+00	–	2.2E-02
Hexachlorobutadiene	87-68-3	0.00331	0.17	**0.0391**	5	–	CI	7.3E+00	7.3E-01	2.0E+02	2.0E+01	1.6E+01	1.6E+00	9.3E+00	–	1.1E-02
Hexachlorocyclopentadiene	77-47-4	0.00381	0.17	0.0238	5	5.0E+01	N	2.2E+02	2.2E+01	6.1E+03	6.1E+02	4.7E+02	4.7E+01	5.2E+00	–	–
Hexachloroethane	67-72-1	0.00506	0.17	**0.0500**	5	–	CI	3.7E+01	3.7E+00	1.0E+03	1.0E+02	7.8E+01	7.8E+00	5.4E+02	–	–
Indeno(1,2,3-cd)pyrene	193-39-5	0.00393	0.17	**0.0384**	5	–	C	9.2E-02	9.2E-02	3.9E+00	3.9E+00	8.7E-01	8.7E-01	–	1.0E-01	6.0E-01
Isophorone	78-59-1	0.00239	0.17	0.0990	5	–	C	7.0E+01	7.0E+01	3.0E+03	3.0E+03	6.7E+02	6.7E+02	1.2E+05	–	–
Naphthalene	91-20-3	0.00316	0.17	**0.0397**	5	–	N	6.5E+00	6.5E-01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	1.0E+02	1.0E-01	1.6E-01
Nitrobenzene	98-95-3	0.00399	0.17	**0.0615**	5	–	N	3.5E+00	3.5E-01	5.1E+02	5.1E+01	3.9E+01	3.9E+00	2.7E+04	–	–
N-Nitrosodi-n-propylamine	621-64-7	**0.00305**	0.17	0.0345	5	–	C	9.6E-03	[illegible]	4.1E-01	4.1E-01	9.1E-02	9.1E-02	–	–	–
N-Nitrosodiphenylamine	86-30-6	0.00338	0.17	0.0645	5	–	C	1.4E+01	1.4E+01	5.8E+02	5.8E+02	1.3E+02	1.3E+02	5.9E+03	–	2.8E-02
Pentachlorophenol	87-86-5	0.00278	0.33	**0.0400**	10	1.0E+00	C	5.6E-01	5.6E-01	2.4E+01	2.4E+01	5.3E+00	5.3E+00	1.3E+01	1.0E-01	3.6E-01
Phenanthrene [1]	85-01-8	0.00248	0.17	0.0439	5	–	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	6.3E+00	1.0E-01	2.4E-01
Phenol	108-95-2	0.00602	0.17	0.0247	5	–	N	1.1E+04	1.1E+03	3.1E+06	3.1E+04	2.3E+04	2.3E+03	7.9E+01	1.0E-01	4.2E-01
Pyrene	129-00-0	0.00321	0.17	0.0455	5	–	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	–	1.0E-01	6.7E-01

Notes:

BTAG = Biological Technical Assistance Group Screening Level, Draft 1995
CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by TriMatrix
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
RBC = Risk-Based Concentration
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table
-- = No Risk Criteria Available

C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
CI = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
1 = RBC value for pyrene was used for these compounds
TCL = Target Compound List
SVOC = Semivolatile Organic Compound
bold = Reporting limit was not low enough to meet screening criteria - but MDL does
■ = Screening criteria cannot be met

Table 2-8
Summary of Method Detection Limits, Reporting Limits, and Risk Screening Criteria for PAHs (by EPA Method 8310)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, VA

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aquatic Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
Acenaphthene	83329	0.0269	0.10	0.2060	1.2	--	N	3.7E+02	3.7E+01	6.1E+04	6.1E+03	4.7E+03	4.7E+02	5.2E+02	1.0E-01	1.6E-02
Acenaphthylene [1]	208968	0.0233	0.21	0.3140	1.2	--	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	1.0E-01	4.4E-02
Anthracene	120127	0.0003	0.021	0.0092	1.2	--	N	1.8E+03	1.8E+02	3.1E+05	3.1E+04	2.3E+04	2.3E+03	1.0E-01	1.0E-01	8.5E-02
Benzo(a)anthracene	56553	0.0007	0.021	0.0179	0.062	--	C	9.2E-02	9.2E-02	3.9E+00	3.9E+00	8.7E-01	8.7E-01	6.3E+00	1.0E-01	2.6E-01
Benzo(a)pyrene	50328	0.0020	0.021	0.0175	0.062	2.0E-01	C	9.2E-03	9.2E-03	3.9E-01	3.9E-01	8.7E-02	8.7E-02	--	1.0E-01	4.3E-01
Benzo(b)fluoranthene	205992	0.0014	0.021	0.0278	0.09	--	C	9.2E-02	9.2E-02	3.9E+00	3.9E+00	8.7E-01	8.7E-01	--	1.0E-01	3.2E+00
Benzo(g,h,i)perylene [1]	191242	0.0054	0.021	0.0444	1.2	--	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	1.0E-01	6.7E-01
Benzo(k)fluoranthene	207089	0.0012	0.021	0.0169	0.12	--	C	9.2E-01	9.2E-01	3.9E+01	3.9E+01	8.7E+00	8.7E+00	--	1.0E-01	--
Chrysene	218019	0.0016	0.021	0.0152	1.2	--	C	9.2E+00	9.2E+00	3.9E+02	3.9E+02	8.7E+01	8.7E+01	--	1.0E-01	3.8E-01
Dibenzo(a,h)anthracene	53703	0.0037	0.021	0.0634	0.24	--	C	9.2E-03	[illegible]	3.9E-01	3.9E-01	8.7E-02	8.7E-02	--	1.0E-01	6.3E-02
Fluoranthene	206440	0.0038	0.021	0.0476	1.2	--	N	1.5E+03	1.5E+02	4.1E+04	4.1E+03	3.1E+03	3.1E+02	4.0E+03	1.0E-01	6.0E-01
Fluorene	86737	0.0013	0.021	0.0335	1.2	--	N	2.4E+02	2.4E+01	4.1E+04	4.1E+03	3.1E+03	3.1E+02	4.3E+02	1.0E-01	1.9E-02
Indeno(1,2,3-cd)pyrene	193395	0.0017	0.021	0.0174	0.062	--	C	9.2E-02	9.2E-02	3.9E+00	3.9E+00	8.7E-01	8.7E-01	--	1.0E-01	6.0E-01
Naphthalene	91203	0.0204	0.10	0.2060	0.62	--	N	6.5E+00	6.5E-01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	1.0E+02	1.0E-01	1.6E-01
Phenanthrene [1]	85018	0.0015	0.021	0.0212	1.2	--	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	6.3E+00	1.0E-01	2.4E-01
Pyrene	129000	0.0037	0.021	0.0233	1.2	--	N	1.8E+02	1.8E+01	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	1.0E-01	6.7E-01

Notes:

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CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
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mg/kg = Milligram Per Kilogram
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USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table
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C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
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N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
1 = the RBC for pyrene was used for these compounds
PAH = Polynuclear Aromatic Hydrocarbon
bold = Reporting limit was not low enough to meet screening criteria - but MDL does
▨ = Screeing critiera cannot be met

Table 2-9
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL Pesticides and Herbicides (by EPA Method 8081A and 8151A)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammuniton Plant, Radford, Virginia

Compounds by Method 8081A	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aquatic Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
4,4'-DDD	72-54-8	0.000236	0.020	0.0016	0.10	--	C	2.8E-01	2.8E-01	1.2E+01	1.2E+01	2.7E+00	2.7E+00	6.0E-01	1.0E-01	1.6E-02
4,4'-DDE	72-55-9	0.000175	0.020	0.0025	0.10	--	C	2.0E-01	2.0E-01	8.4E+00	8.4E+00	1.9E+00	1.9E+00	1.1E+03	1.0E-01	2.2E-03
4,4'-DDT	50-29-3	0.000180	0.020	0.0018	0.10	--	C	2.0E-01	2.0E-01	8.4E+00	8.4E+00	1.9E+00	1.9E+00	1.0E-03	1.0E-01	1.6E-03
Aldrin	309-00-2	0.000304	0.020	0.0019	0.05	--	C	3.9E-03	3.9E-03	1.7E-01	1.7E-01	3.8E-02	3.8E-02	3.0E+00	1.0E-01	--
alpha-BHC	319-84-6	0.000303	0.020	0.0015	0.05	--	C	1.1E-02	1.1E-02	4.5E-01	4.5E-01	1.0E-01	1.0E-01	--	--	--
alpha-Chlordane[1]	5103-71-9	0.000434	0.020	0.0024	0.05	2.0E+00	C	1.9E-01	1.9E-01	8.2E+00	8.2E+00	1.8E+00	1.8E+00	4.3E-03	1.0E-01	--
gamma-Chlordane[1]	5103-74-2	0.000703	0.020	0.0023	0.05	2.0E+00	C	1.9E-01	1.9E-01	8.2E+00	8.2E+00	1.8E+00	1.8E+00	4.3E-03	1.0E-01	--
beta-BHC	319-85-7	0.001130	0.020	0.0039	0.05	--	C	3.7E-02	3.7E-02	1.6E+00	1.6E+00	3.5E-01	3.5E-01	--	--	--
delta-BHC[2]	319-86-8	0.000618	0.020	0.0025	0.05	--	C	1.1E-02	1.1E-02	4.5E-01	4.5E-01	1.0E-01	1.0E-01	--	--	--
Dieldrin	60-57-1	0.000309	0.020	0.0034	0.10	--	C	4.2E-03	4.2E-03	1.8E-01	1.8E-01	4.0E-02	4.0E-02	1.9E-03	1.0E-01	--
Endosulfan I[3]	959-98-8	0.000910	0.020	0.0026	0.05	--	N	2.2E+02	2.2E+01	6.1E+03	6.1E+02	4.7E+02	4.7E+01	5.6E-02	--	--
Endosulfan II[3]	33213-65-9	0.000214	0.020	0.0021	0.10	--	N	2.2E+02	2.2E+01	6.1E+03	6.1E+02	4.7E+02	4.7E+01	5.6E-02	--	--
Endosulfan sulfate	1031-07-8	0.000503	0.020	0.0022	0.10	--	--	--	--	--	--	--	--	--	--	--
Endrin	72-20-8	0.000298	0.020	0.0036	0.10	2.0E+00	N	1.1E+01	1.1E+00	3.1E+02	3.1E+01	2.3E+01	2.3E+00	2.3E-03	1.0E-01	--
Endrin aldehyde	7421-93-4	0.00110	0.020	0.0053	0.10	--	--	--	--	--	--	--	--	--	--	--
Endrin ketone	53494-70-5	0.000275	0.020	0.0020	0.10	--	--	--	--	--	--	--	--	--	--	--
gamma-BHC (Lindane)	58-89-9	0.000194	0.020	0.0016	0.05	2.0E-01	C	5.2E-02	5.2E-02	2.2E+00	2.2E+00	4.9E-01	4.9E-01	8.0E-02	1.0E-01	--
Heptachlor	76-44-8	0.000706	0.020	0.0021	0.05	4.0E-01	C	1.5E-02	1.5E-02	6.4E-01	6.4E-01	1.4E-01	1.4E-01	3.8E-03	--	--
Heptachlor epoxide	1024-57-3	0.000455	0.020	0.0022	0.05	2.0E-01	C	7.4E-03	7.4E-03	3.1E-01	3.1E-01	7.0E-02	7.0E-02	3.8E-03	1.0E-01	--
Methoxychlor	72-43-5	0.001590	0.020	0.0032	0.50	4.0E+01	N	1.8E+02	1.8E+01	5.1E+03	5.1E+02	3.9E+02	3.9E+01	3.0E-02	1.0E-01	--
Toxaphene	8001-35-2	0.023345	0.170	0.066	1.0	3.0E+00	C	6.1E-02	■ [illegible]	2.6E+00	2.6E+00	5.8E-01	5.8E-01	2.0E-04	--	--

Compounds by Method 8151A	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-based Concentrations							USEPA Region III BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC ug/L	Adjusted Tap Water RBC ug/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aquatic Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
2,4,5,-T	93-76-5	0.005	0.05	0.076	0.50	--	N	3.7E+02	3.7E+01	1.0E+04	1.0E+03	7.8E+02	7.8E+01	--	--	--
2,4,5-TP (Silvex)	93-72-1	0.002	0.05	0.066	0.50	5.0E+01	N	2.9E+02	2.9E+01	8.2E+03	8.2E+02	6.3E+02	6.3E+01	--	--	--
2,4-D	94-75-7	0.021	0.20	0.696	5.0	7.0E+01	N	3.7E+02	3.7E+01	1.0E+04	1.0E+03	7.8E+02	7.8E+01	--	--	--
2,4-DB	94-82-6	0.025	0.20	0.692	5.0	--	N	2.9E+02	2.9E+01	8.2E+03	8.2E+02	6.3E+02	6.3E+01	--	--	--
Dalapon	75-99-0	0.074	0.25	1.341	5.0	2.0E+02	N	1.1E+03	1.1E+02	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	--	--
Dicamba	1918-00-9	0.004	0.20	0.075	0.50	--	N	1.1E+03	1.1E+02	3.1E+04	3.1E+03	2.3E+03	2.3E+02	--	--	--
Dichlorprop	120-36-5	0.024	0.20	0.618	5.0	--	--	--	--	--	--	--	--	--	--	--
Dinoseb	88-85-7	0.003	0.20	0.275	1.0	7.0E+00	N	3.7E+01	3.7E+00	1.0E+03	1.0E+02	7.8E+01	7.8E+00	--	--	--
MCPA	94-74-6	2.1	20	73.9	250	--	N	1.8E+01	■	5.1E+02	5.1E+01	3.9E+01	3.9E+00	--	--	--
MCPP	93-65-2	2.1	20	66.8	250	--	N	3.7E+01	■	1.0E+03	1.0E+02	7.8E+01	7.8E+00	--	--	--

Notes:

BTAG = Biological Technical Assistance Group Screening Level, Draft 1995
CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by TriMatrix
mg/kg = Milligram Per Kilogram
µg/L = Microgram Per Liter
RBC = Risk-Based Concentration
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table
-- = No Risk Criteria Available

C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
Cl = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
1 = Chlordane value is for sum of isomers
2 = Endosulfan value is for sum of isomers
3 = Alpha BHC RBC values used for delta BHC
TCL = Target Compound List

bold	= Reporting limit was not low enough to meet screening criteria - but MDL does
■	= Screening criteria cannot be met

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Table 2-10
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for PCBs (by EPA Method 8082) and Perchlorate (by EPA Method 314.0)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammuniton Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil		Water		Water										
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC ug/L	Adjusted Tap Water RBC ug/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aqueous Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
Aroclor 1016	12674-11-2	0.017	0.066	**0.0753**	0.3	5.0E-01	Cl	2.6E+00	2.6E-01	7.2E+01	7.2E+00	5.5E+00	5.5E-01	1.4E-02	1.0E-01	2.3E-02
Aroclor 1221	11104-28-2	0.005	0.033	0.1470	0.5	5.0E-01	C	3.3E-02	[illegible]	1.4E+00	1.4E+00	3.2E-01	3.2E-01	1.4E-02	1.0E-01	2.3E-02
Aroclor 1232	11141-16-5	0.005	0.033	0.0794	0.3	5.0E-01	C	3.3E-02	[illegible]	1.4E+00	1.4E+00	3.2E-01	3.2E-01	1.4E-02	1.0E-01	2.3E-02
Aroclor 1242	53469-21-9	0.004	0.033	0.0609	0.3	5.0E-01	C	3.3E-02	[illegible]	1.4E+00	1.4E+00	3.2E-01	3.2E-01	1.4E-02	1.0E-01	2.3E-02
Aroclor 1248	12672-29-6	0.006	0.033	0.0432	0.2	5.0E-01	C	3.3E-02	[illegible]	1.4E+00	1.4E+00	3.2E-01	3.2E-01	1.4E-02	1.0E-01	2.3E-02
Aroclor 1254	11097-69-1	0.003	0.033	0.0341	0.1	5.0E-01	C/Cl	3.3E-02	[illegible]	1.4E+00	1.4E+00	1.6E+00	1.6E-01	1.4E-02	1.0E-01	2.3E-02
Aroclor 1260	11096-82-5	0.007	0.033	0.0481	0.2	5.0E-01	C	3.3E-02	[illegible]	1.4E+00	1.4E+00	3.2E-01	3.2E-01	1.4E-02	1.0E-01	2.3E-02

Perchlorate	—	n/a	n/a	0.54	2.0	*USEPA screening criteria under development*

Notes:

BTAG = Biological Technical Assistance Group Screening Level, Draft 1995
CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by TriMatrix
mg/kg = Milligram Per Kilogram
µg/L = Microgram Per Liter
RBC = Risk-Based Concentration
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table

-- = No Risk Criteria Available
C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
Cl = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
PCB = Polychlorinated Biphenyls
bold = Reporting limit was not low enough to meet screening criteria - but MDL does
▨ = Screening criteria cannot be met

Table 2-11
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for Explosives (SW8330, SW8330M and SW8332), Soil and Water Samples
RFI Work Plan for SWMU 41
Radford Army Ammunition Plant

Compounds by Method 8330	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III BTAG Screening Levels		
		Soil		Water												
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aqueous Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
1,3,5-Trinitrobenzene	99-35-4	0.140	0.50	0.150	0.65	–	N	1.1E+03	1.1E+02	3.1E+04	3.1E+03	2.3E+03	2.3E+02	–	–	–
1,3-Dinitrobenzene	99-65-0	0.159	0.50	**0.185**	0.65	–	N	3.7E+00	3.7E-01	1.0E+02	1.0E+01	7.8E+00	7.8E-01	1.2E+03	–	–
2,4,6-Trinitrotoluene	118-96-7	0.167	0.50	0.118	0.65	–	CI	1.8E+01	1.8E+01	5.1E+02	5.1E+01	3.9E+01	3.9E+01	–	–	–
2,4-Dinitrotoluene	121-14-2	0.142	0.50	0.150	0.65	–	N	7.3E+01	7.3E+00	2.0E+03	2.0E+02	1.6E+02	1.6E+01	2.3E+02	–	–
2,6-Dinitrotoluene	606-20-2	0.250	1.0	0.217	0.65	–	N	3.7E+01	3.7E+00	1.0E+03	1.0E+02	7.8E+01	7.8E+00	–	–	–
2-Amino-4, 6-dinitrotoluene[1]	355-72-78-2	**0.151**	0.50	0.261	1.0	–	N	7.3E+00	7.3E-01	2.0E+02	2.0E+01	1.6E+01	1.6E+00	–	–	–
2-Nitrotoluene	88-72-2	0.266	1.0	0.175	0.65	–	N	4.6E-02	4.6E-03	1.2E+01	1.2E+00	2.8E+00	2.8E-01	–	–	–
3-Nitrotoluene	99-08-1	0.184	1.0	0.413	2.0	–	N	1.2E+02	1.2E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	–	–	–
4-Amino-2,6-dinitrotoluene[1]	1946-51-0	**0.162**	0.50	0.263	1.0	–	N	7.3E+00	7.3E-01	2.0E+02	2.0E+01	1.6E+01	1.6E+00	–	–	–
4-Nitrotoluene	99-99-0	0.251	1.0	0.488	2.0	–	N	6.2E-01	6.2E-02	1.7E+02	1.7E+01	3.8E+01	3.8E+00	–	–	–
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	2691-41-0	0.229	1.0	0.277	1.0	–	N	1.8E+03	1.8E+02	5.1E+04	5.1E+03	3.9E+03	3.9E+02	–	–	–
Nitrobenzene	98-95-3	0.102	0.50	**0.142**	0.65	–	N	3.5E+00	3.5E-01	5.1E+02	5.1E+01	3.9E+01	3.9E+00	2.7E+04	–	–
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	121-82-4	0.158	0.50	**0.109**	0.65	–	C	6.1E-01	6.1E-01	2.6E+01	2.6E+01	5.8E+00	5.8E+00	–	–	–
Tetryl (Methyl-2,4,6-trinitrophenylnitramine)	479-45-8	0.169	1.0	0.433	2.0	–	N	3.7E+02	3.7E+01	1.0E+04	1.0E+03	7.8E+02	7.8E+01	–	–	–
Compound by Method 8330M																
PETN	78-11-5		10		60	–	–	–	–	–	–	–	–	–	–	–
Compound by Method 8332																
Nitroglycerin	55-63-0	1.99	10	20.0	60	–	C	4.8E+00	4.8E+00	2.0E+02	2.0E+02	4.6E+01	4.6E+01	–	–	–

Notes:

BTAG = Biological Technical Assistance Group Screening Level, Draft 1995
CAS = Chemical Abstract Service
Method Detection and Reporting Limits for 8330 provided by TriMatrix
Method Detection and Reporting Limit for 8332 provided by CompuChem
MDL = Method Detection Limit
mg/kg = milligram per kilogram
µg/L = microgram per liter
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-based Concentration (RBC) values from the October 15, 2003 RBC Table
C/N = Carcinogenic or Non-carcinogenic status

C = Carcinogenic
CI = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from June 17, 2003 version of the Alternate RBC table; see USEPA Region III guidance
N = Noncarcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
– = No RBC available
MCL = Maximum Contaminant Level
(1) = RBC value is for the sum of the isomers called aminodinitrotoluenes

bold = Reporting limit was not low enough to meet screening criteria - but MDL does
▨ = Screening criteria cannot be met

Table 2-12
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for Dioxins/Furans (by EPA Method 8290)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations								USEPA Region III Draft BTAG Screening Levels		
		Soil		Water												
		MDL pg/g	Reporting Limit pg/g	MDL ppq	Reporting Limit ppq	ppq	C/N	Tap water RBC ppq	Adjusted Tap Water RBC ppq	Soil RBC (Industrial) pg/g	Adjusted Soil RBC (Industrial) pg/g	Soil RBC (Residential) pg/g	Adjusted Soil RBC (Residential) pg/g	Aquatic Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
2,3,7,8-TCDD	1746-01-6	0.137	1	2.95	10	3.00E+01	C	4.5E-01	▨ 4.5E-01	1.9E+01	1.9E+01	4.3E+00	4.3E+00	1.0E-05	1.0E-02	--
1,2,3,7,8-PeCDD	40321-76-4	0.155	5	7.61	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,7,8-HxCDD	39227-28-6	0.225	5	5.08	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,6,7,8-HxCDD	57653-85-7	0.106	5	4.20	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,7,8,9-HxCDD	19408-74-3	0.520	5	**6.73**	50	--	C	1.1E+01	1.1E+01	4.6E+02	4.6E+02	1.0E+02	1.0E+02	--	--	--
1,2,3,4,6,7,8-HpCDD	35822-39-4	0.302	5	8.30	50	--	--	--	--	--	--	--	--	--	--	--
OCDD	3268-87-9	1.050	10	18.4	100	--	--	--	--	--	--	--	--	--	--	--
2,3,7,8-TCDF	51207-31-9	0.153	1	2.87	10	--	--	--	--	--	--	--	--	--	--	--
1,2,3,7,8-PeCDF	57117-41-6	0.331	5	11.1	50	--	--	--	--	--	--	--	--	--	--	--
2,3,4,7,8-PeCDF	57117-31-4	0.299	5	16.8	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,7,8-HxCDF	70648-26-9	0.270	5	9.27	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,6,7,8-HxCDF	57117-44-9	0.243	5	8.03	50	--	--	--	--	--	--	--	--	--	--	--
2,3,4,6,7,8-HxCDF	60851-34-5	0.349	5	7.08	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,7,8,9-HxCDF	72918-21-9	0.503	5	9.57	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,6,7,8-HpCDF	67562-39-4	0.254	5	9.11	50	--	--	--	--	--	--	--	--	--	--	--
1,2,3,4,7,8,9-HpCDF	55673-89-7	0.134	5	7.07	50	--	--	--	--	--	--	--	--	--	--	--
OCDF	39001-02-0	0.553	10	9.28	100	--	--	--	--	--	--	--	--	--	--	--

Notes:

BTAG = Biological Technical Assistance Group Screening Level, Draft 1995
CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by TriMatrix
pg/g = Picogram Per Gram
ppq = Parts Per Quadrillion
RBC = Risk-Based Concentration
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table

-- = No Risk Criteria Available
C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
Ct = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
bold = Reporting limit was not low enough to meet screening criteria - but MDL does
▨ = Screeing critiera cannot be met

Table 2-13
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TAL Metals (by EPA Method 6020/6010B/7000 Series)
Soil and Water Samples
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits						USEPA MCLs	USEPA Region III Risk-Based Concentrations							USEPA Region III Draft BTAG Screening Levels		
		Soil			Water													
		Analytical Method	MDL mg/kg	Reporting Limit mg/kg	Analytical Method	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg	Aquatic Fresh Water µg/L	Soil mg/kg	Sediment mg/kg
Aluminum	7429-90-5	6010B	1.935	10	6010B	20.7	100	–	N	3.7E+04	3.7E+03	1.0E+06	1.0E+05	7.8E+04	7.8E+03	2.5E+01	1.0E+00	–
Antimony	7440-36-0	6020	0.016	0.50	6020	0.083	1.0	6.0E+00	N	1.5E+01	1.5E+00	4.1E+02	4.1E+01	3.1E+01	3.1E+00	3.0E+01	4.8E-01	1.5E+02
Arsenic	7440-38-2	6020	0.047	0.40	6020	0.0823	1.0	1.0E+01	C	4.5E-02	4.5E-02	1.9E+00	1.9E+00	4.3E-01	4.3E-01	4.8E+01	3.3E+02	5.7E-02
Barium	7440-39-3	6010B	0.185	1.0	6010B	2.59	10	2.0E+03	N	2.6E+03	2.6E+02	7.2E+04	7.2E+03	5.5E+03	5.5E+02	1.0E+04	4.4E+02	–
Beryllium	7440-41-7	6010B	0.022	1.0	6010B	0.295	4.0	4.0E+00	N	7.3E+01	7.3E+00	2.0E+03	2.0E+02	1.6E+02	1.6E+01	5.3E+00	2.0E-02	–
Cadmium	7440-43-9	6010B	0.293	1.0	6020	0.033	0.50	5.0E+00	N	1.8E+01	1.8E+00	5.1E+02	5.1E+01	3.9E+01	3.9E+00	5.3E-01	2.5E+00	1.2E+00
Calcium	7440-70-2	6010B	5.243	50	6010B	30.8	200	–	–	–	–	–	–	–	–	–	–	–
Chromium (VI)[1]	7440-47-3	6010B	0.507	5.0	6020	0.150	1.0	1.0E+02	N	1.1E+02	1.1E+01	3.1E+03	3.1E+02	2.3E+02	2.3E+01	2.0E+00	7.5E-03	5.0E-03
Cobalt	7440-48-4	6010B	0.213	1.0	6010B	2.05	10	–	N	7.3E+02	7.3E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	3.5E+04	1.0E+02	–
Copper	7440-50-8	6010B	0.236	1.0	6010B	3.22	10	1.3E+03	N	1.5E+03	1.5E+02	4.1E+04	4.1E+03	3.1E+03	3.1E+02	6.5E+00	1.5E+01	3.4E+01
Cyanide	57-12-5	9012A	0.0356	0.50	9012A	3.36	10.0	2.0E+02	N	7.3E+02	7.3E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	5.2E+00	5.0E-03	–
Iron	7439-89-6	6010B	0.366	2.0	6010B	5.66	100	–	N	1.1E+04	1.1E+03	3.1E+05	3.1E+04	2.3E+04	2.3E+03	3.2E+02	1.2E+01	–
Lead[2]	7439-92-1	6020	0.013	1.0	6020	0.080	1.0	1.5E+01	–	–	–	7.5E+02	7.5E+02	4.0E+02	4.0E+02	3.2E+00	1.0E-02	4.7E+01
Magnesium	7439-95-4	6010B	2.699	50	6010B	50.5	200	–	–	–	–	–	–	–	–	–	4.4E+03	–
Manganese (non-food)	7439-96-5	6010B	0.122	1.0	6010B	2.02	10	–	N	7.3E+02	7.3E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	1.5E+04	3.3E+02	–
Mercury[3]	7439-97-6	7471A	0.008	0.10	7470A	0.115	0.40	2.0E+00	N	1.1E+01	1.1E+00	3.1E+02	3.1E+01	2.3E+01	2.3E+00	1.2E-02	5.8E-02	1.5E-01
Nickel	7440-02-0	6020	0.025	0.50	6020	0.158	1.0	–	N	7.3E+02	7.3E+01	2.0E+04	2.0E+03	1.6E+03	1.6E+02	1.6E+02	2.0E+00	2.1E+01
Potassium	7440-09-7	6010B	5.39	20	6010B	48.0	200	–	–	–	–	–	–	–	–	–	–	–
Selenium	7782-49-2	6020	0.300	1.0	6020	0.148	2.0	5.0E+01	N	1.8E+02	1.8E+01	5.1E+03	5.1E+02	3.9E+02	3.9E+01	5.0E+00	1.8E+00	–
Silver	7440-22-4	6020	0.008	3.0	6020	0.015	0.50	–	N	1.8E+02	1.8E+01	5.1E+03	5.1E+02	3.9E+02	3.9E+01	1.0E-04	9.8E-06	1.0E+00
Sodium	7440-23-5	6010B	24.469	100	6010B	41.3	200	–	–	–	–	–	–	–	–	–	–	–
Thallium	7440-28-0	6020	0.029	0.50	6020	0.045	0.20	2.0E+00	N	2.6E+00	2.6E-01	7.2E+01	7.2E+00	5.5E+00	5.5E-01	4.0E+01	1.0E-03	–
Vanadium	7440-62-2	6010B	0.200	1.0	6010B	3.14	10	–	N	1.1E+01	1.1E+00	3.1E+02	3.1E+01	2.3E+01	2.3E+00	1.0E+04	5.0E-01	–
Zinc	7440-66-6	6010B	0.724	4.0	6010B	5.28	20	–	N	1.1E+04	1.1E+03	3.1E+05	3.1E+04	2.3E+04	2.3E+03	3.0E+01	1.0E+01	1.5E+02

Notes:

BTAG = Biological Technical Assistance Group Screening Levels, Draft 1995
CAS = Chemical Abstract Service
MCL = Maximum Contaminant Level
MDL = Method Detection Limit
Method Detection and Reporting Limits Provided by TriMatrix
mg/kg = Milligram Per Kilogram
µg/L = Microgram Per Liter
RBC = Risk-Based Concentration
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the October 15, 2003 RBC Table
-- = No Risk Criteria Available

C/N = Carcinogenic or Non-Carcinogenic Status
C = Carcinogenic
CI = Carcinogenic with a hazard quotient of 0.1; non-carcinogenic RBCs taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
1 = Chromium MCL is for total
2 = Lead criteria are Action Levels; see USEPA Region III guidance
3 = Mercuric chloride soil RBC value used
TAL = Target Analyte List

bold	= Reporting limit was not low enough to meet screening criteria - but MDL does
▨	= Screening criteria cannot be met

- TAL Inorganics;
- TCL VOCs;
- TCL SVOCs;
- TCL pesticides/herbicides/PCBs (soil and sediment);
- PAHs;
- Perchlorate (aqueous);
- Explosives including nitroglycerin and PETN; and
- Dioxins/furans (soil).

Samples of IDM (decontamination water and soil) will be characterized for disposal purposes by analyzing for the following:

- Toxicity Characteristic Leaching Procedure (TCLP) – Complete List (solid);
- TAL Metals (aqueous);
- Corrosivity (aqueous);
- Chemical Oxygen Demand (aqueous, by USEPA Method 410.4);
- Explosives (solid, by SW-846 Methods 8330m and 8332);
- Reactivity (ATK internal visual method); and
- Paint Filter Test (solid).

2.5.1 Organics

The following techniques will be used for determination of organic constituents.

2.5.1.1 VOCs by SW8260B

The aqueous samples are prepared for analysis by purge-and-trap Method 5030 and the solid samples are prepared by purge-and-trap Method 5035. The volatile compounds are introduced into the gas chromatograph by the purge-and-trap method or by other methods (see Section 1.2 of Method SW8260B). The analytes are introduced directly to a wide-bore capillary column or cryofocused on a capillary pre-column before being flash evaporated to a narrow-bore capillary for analysis. The column is temperature-programmed to separate the analytes, which are then detected with a mass spectrometer (MS) interfaced to the gas chromatograph (GC). Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. (Wide-bore capillary columns normally require a jet separator, whereas narrow-bore capillary columns may be directly interfaced to the ion source.) Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

2.5.1.2 SVOCs by SW8270C

The samples are prepared for analysis by GC/MS using Method 3510C for aqueous media and Method 3540C for solid media, or other appropriate methods. The semivolatile compounds are introduced into the GC/MS by injecting the sample extract into a GC with a narrow-bore fused-silica capillary column. The GC column is temperature-programmed to separate the analytes, which are then detected with a MS, connected to the gas chromatograph. Analytes eluted from the capillary column are introduced into the mass spectrometer via a direct connection. Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

2.5.1.3 Pesticides by SW8081A

A measured volume or weight of sample (approximately one liter for liquids, and two to 30 g (g) for solids) is extracted using the appropriate matrix-specific sample extraction technique. Liquid samples are extracted at neutral pH with methylene chloride using Method 3520C (continuous liquid-liquid extractor), or other appropriate technique. Solid samples are extracted using Method 3540C (Soxhlet) or other appropriate technique. A variety of cleanup steps may be applied to the extract, depending on the nature of the matrix interferences and the target analytes. Suggested cleanups include alumina (Method 3610), Florisil (Method 3620), silica gel (Method 3630), gel permeation chromatography (Method 3640), and sulfur (Method 3660). After cleanup, the extract is analyzed by injecting a one-microliter (µL) sample into a gas chromatograph with a narrow- or wide-bore fused silica capillary column. The GC column is temperature-programmed to separate the analytes. An electron capture detector (ECD) or an electrolytic conductivity detector (ELCD) detects analytes eluted from the capillary column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

2.5.1.4 Herbicides by SW8151A

Method 8151 provides extraction, derivatization, and gas chromatographic conditions for the analysis of chlorinated acid herbicides in water, soil, and waste samples. Samples are extracted with diethyl ether and then esterified with either diazomethane or pentafluorobenzyl bromide. Organic acids, especially chlorinated acids, cause the most direct interference with the determination by methylation. Phenols, including chlorophenols, may also interfere with this procedure. The determination using pentafluorobenzylation is more sensitive, and more prone to interferences from the presence of organic acids or phenols than by methylation. The derivatives are assessed by gas chromatography with an electron capture detector (GC/ECD). The results are reported as acid equivalents. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

2.5.1.5 PCBs by SW8082

A measured volume or weight of sample (approximately one liter for liquids, and two to 30 g for solids) is extracted using the appropriate matrix-specific sample extraction technique. Aqueous samples are extracted at neutral pH using Method 3510C, or other appropriate technique. Solid samples are extracted using Method 3540C (Soxhlet) or other appropriate technique. Extracts for PCB analysis may be subjected to a sulfuric acid/potassium permanganate cleanup (Method 3665) or sulfuric acid cleanup (Method 3660 B) designed specifically for these analytes. This cleanup technique will remove (destroy) many single component organochlorine or organophosphate pesticides. Therefore, Method 8082 is not applicable to the analysis of those compounds. Instead, use Method 8081. After cleanup, the extract is analyzed by injecting a 2 µL aliquot into a gas chromatograph with a narrow- or wide-bore fused silica capillary column. An electron capture detector (ECD) detects analytes eluted from the capillary column. Comparing and summing the response of at least three peaks within specified retention time windows to a five-point calibration curve accomplishes quantitation. The chromatographic data may be used to identify the seven Aroclors found in Section 1.1 of Method SW8082, individual PCB congeners, or total PCBs.

2.5.1.6 Dioxins and Furans by SW8290

Method 8290 provides procedures for the detection and quantitative measurement of polychlorinated dibenzo-p-dioxins (tetra- though octa-chlorinated homologues; PCDDs) and polychlorinated dibenzofurans (tetra- though octa-chlorinated homologues; PCDFs) in a variety of environmental matrices and at parts-per-trillion (ppt) to parts-per-quadrillion (ppq) concentrations. A specified amount of sample is spiked with a solution containing specified amounts of each of the nine isotopically ($^{13}C_{12}$) labeled PCDDs/PCDFs. The sample is then extracted according to a matrix specific extraction procedure. The samples are prepared for analysis by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS) using the matrix specific extraction (refer to Method 8290) and analyte specific cleanup procedures (refer to Method 8290). A high-resolution capillary column (60 m DB-5, J&W Scientific, or equivalent) is used in this method. However, no single column is known to resolve isomers.

In order to ascertain the concentration of the 2,3,7,8-TCDF (if detected on the DB-5 column), the sample extract must be reanalyzed on a column capable of 2,3,7,8-TCDF isomer specificity (e.g., DB-225, SP-2330, SP-2331, or equivalent). Quantitation of the individual congeners, total PCDDs and total PCDFs is achieved in conjunction with the establishment of a multi-point (five points) calibration curve for each homologue, during which each calibration solution is analyzed once. The identification of 1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin (OCDD) and nine of the fifteen substituted congeners, for which a ^{13}C-labeled standard is available in the sample fortification and recovery standard solutions, is based on their elution at their exact retention time (within 0.005 retention time units measured in the routine calibration) and simultaneous detection of the two most abundant ions in the molecular ion region. The remaining six substituted congeners (i.e., 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF); 1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (HxCDD); 1,2,3,6,7,8-Hexachlorodibenzofuran (HxCDF); 1,2,3,7,8,9-HxCDF; 2,3,4,6,7,8-HxCDF, and 1,2,3,4,7,8,9-Heptachlorodibenzofuran (HpCDF)), for which no carbon-labeled internal standards are available in the sample fortification solution, and other identified PCDD/PCDF congeners are identified by their relative retention times from the routine calibration data, and the simultaneous detection of the two most abundant ions in the molecular ion region. The identification of 1,2,3,4,6,7,8,9-Octachlorodibenzofuran (OCDF) is based on its retention time relative to $^{13}C_{12}$-OCDD and the simultaneous detection of the two most abundant ions in the molecular ion region. Confirmation is based on a comparison of the ratios of the integrated ion abundance of the molecular ion species to their theoretical abundance ratios. A calculation of the toxicity equivalent concentration (TEQ) of each sample is made using international consensus toxicity equivalence factors (TEFs), and the TEQ is used to identify if the concentrations of target compounds in the sample are high enough to warrant confirmation of the results on a second GC column.

2.5.1.7 PAHs by SW8310

Method 8310 provides high performance liquid chromatographic (HPLC) conditions for the detection of parts per billion (ppb) levels of certain PAHs in water, soil and sediment matrix. Aqueous samples are extracted at neutral pH with methylene chloride using Method 3520C (continuous liquid-liquid extractor), or other appropriate technique. Solid samples are extracted using Method 3540C (Soxhlet) or other appropriate technique. Prior to HPLC analysis, the extraction solvent must be exchanged to acetonitrile. To achieve maximum sensitivity with this method, the extract must be concentrated to one milliliter (mL). If interferences prevent proper detection of the analytes of interest, the method may also be performed on extracts that have undergone cleanup using silica gel column cleanup (Method 3630). A five to 25 µL aliquot of the extract is injected into an HPLC with ultraviolet (UV) and fluorescence detectors identify compounds in the eluent. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

2.5.1.8 Explosives by SW8330 and SW8332

Test Methods 8330 and 8332 provide for the analysis of ppb levels of certain explosives residues in water, soil and sediment matrices using HPLC using a UV detector. Before use of these methods, sample preparation techniques must be used. Two sample preparation techniques are available:

1) Low-Level Salting-out Method with No Evaporation: Aqueous samples of low concentration are extracted by a salting-out extraction procedure with acetonitrile and sodium chloride. The small volume of acetonitrile that remains un-dissolved above the salt water is drawn off and transferred to a smaller volumetric flask. It is back-extracted by vigorous stirring with a specific volume of salt water. After equilibration, the phases are allowed to separate and the small volume of acetonitrile residing in the narrow neck of the volumetric flask is removed using a Pasteur pipette. The concentrated extract is diluted 1:1 with reagent grade water. An aliquot is separated on a C-18 reverse phase column, analyzed at 254 nanometers (nm), and confirmed on a cyanide (CN) reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

2) Soil and sediment samples are air dried at room temperature to a constant weight. Approximately 2g are extracted using acetonitrile in an ultrasonic bath for eighteen hours. Five mL of supernatant is combined with five mL of calcium chloride solution and is shaken and left to stand for fifteen minutes. The supernatant is prepared for analysis by filtering through a 0.45 µm Teflon filter. This extract is then separated on a C-18 reverse phase column, determined at 254 nm, and confirmed on a CN reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

2.5.2 Inorganics

The following techniques will be used for determination of inorganic constituents.

2.5.2.1 Target Analyte List Metals by ICP SW6010/6020/7000 Series

Prior to analysis, samples are prepared by Method 3010A for aqueous media and Method 3050B for solid media, or other appropriate methods. When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved before analysis. This method describes multi-elemental determinations by Inductively Coupled Plasma (ICP) - Atomic Emission Spectroscopy (AES) using sequential or simultaneous optical systems and axial or radial viewing of the plasma. The instrument measures characteristic emission spectra by optical spectrometry.

Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by radio frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and photosensitive devices monitor the emission line intensities.

Background correction is required for trace element determination. Background must be measured adjacent to analyte lines on samples during analysis. The position selected for the background-intensity measurement, on either or both sides of the analytical line, will be defined by the complexity of the spectrum adjacent to the analyte line. In one mode of analysis, the position used should be as free as possible from spectral interference and should reflect the same change in background intensity as occurs at the analyte wavelength measured. Background correction is not required in cases of line broadening where a background correction measurement would actually degrade the analytical result. The possibility of additional interferences named in Section 3.0 of Method 3050B should also be recognized and appropriate corrections made; tests for their presence are described in Section 8.5 of Method 3035B. Alternatively, users may choose multivariate calibration methods. In this case, point selections for background correction are superfluous since entire spectral regions are processed.

2.5.2.2 Mercury by SW7470A (aqueous samples) and SW7471A (soil/solid samples)

Prior to analysis, the liquid, solid, or semi-solid samples must be prepared according to the procedure discussed in the method. Methods 7470A and 7471A, cold-vapor atomic absorption techniques are based on the absorption of radiation at 253.7 nm by mercury vapor. The mercury is reduced to the elemental state and aerated from solution in a closed system. The mercury vapor passes through a cell positioned in the light path of an atomic absorption spectrophotometer. Absorbance (peak height or area) is measured as a function of mercury concentration. Quantitation is accomplished by comparing the response of the peak to a five-point calibration curve.

2.5.2.3 Target Analyte List Metals by ICP SW6020 Series

Inductively coupled plasma-mass spectrometry (ICP-MS) is applicable to the determination of sub-ppb concentrations of a large number of elements in water samples and in waste extracts or digests. Prior to analysis, samples that require total ("acid-leachable") values must be digested using appropriate sample preparation methods (such as Methods 3005 - 3051). Acid digestion prior to filtration and analysis is required for groundwater, aqueous samples, industrial waste, soil, sludge, sediment, and other solid waste for which total (acid-leachable) elements are required. When dissolved constituents are required, samples must be filtered and acid-preserved prior to analysis. No digestion is required prior to analysis for dissolved elements in water samples.

Method 6020 describes the multi-elemental determination of analytes by ICP-MS. The method measures ions produced by a radio frequency inductively coupled plasma. Analyte species originating in a liquid are nebulized and the resulting aerosol transported by argon gas into the plasma torch. The ions produced are entrained in the plasma gas and introduced, by means of an interface, into a mass spectrometer. The ions produced in the plasma are sorted according to their mass-to-charge ratios and quantified with a channel electron multiplier. Interferences must be assessed and valid corrections applied or the data flagged to indicate problems. Interference correction must include compensation for background ions contributed by the plasma gas, reagents, and constituents of the sample matrix.

2.5.2.4 Cyanide by SW9010C and SW9012B

Samples will be analyzed for total cyanide by SW-846 Test Methods 9010C and 9012B, distillation followed by colorimetric analysis. Hydrocyanic acid (HCN) is released through reflux-distillation and absorbed in a scrubber containing sodium hydroxide solution. The cyanide ion is assessed colorimetrically by converting it to cyanogen chloride (CNCl).

2.5.2.5 Perchlorates by EPA Method 314.0 (aqueous samples)

Perchlorate will be analyzed using ion chromatographic method USEPA Method 314.0. The perchlorate is measured by the peak height or area generated from the sample elution through an anion separator column with a conductivity detector and quantitation is accomplished by comparing the response of the peak within a retention time window to a five-point calibration curve. The sample eluent contains a support resin, p-cyanophenol to deactivate potential active sites. Samples with large particulates should be filtered to avoid damage to the column and flow systems.

2.5.3 Waste Samples

2.5.3.1 TCLP Extraction

For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8-micrometer (μm) glass fiber filter, is defined as the TCLP extract. For wastes containing greater than or equal to 0.5% solids, the liquid, if present, is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes. Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8-μm-glass fiber filter. If compatible (i.e., multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration. Extracts are analyzed using the analytical methods described above.

2.5.3.2 Ignitability by 1010A

For liquid wastes by Method 1010A, the sample is heated at a slow, constant rate with continual stirring. A small flame is directed into the cup at regular intervals with simultaneous interruption of stirring. The flash point is the lowest temperature at which application of the test flame ignites the vapor above the sample. For solid wastes (if appropriate), in a preliminary test, the test material is formed into an unbroken strip or powder train 250 millimeters (mm) in length. An ignition source is applied to one end of the test material to learn whether combustion will propagate along 200 mm of the strip within a specified time. Materials that propagate burning along a 200-mm strip within the specified time are then subjected to a burning rate test. Materials that do not ignite or propagate combustion as described above do not require further testing. In the burning rate test, the burning time is measured over a distance of 100 mm and the rate of burning is calculated. The test method described here is based on the test procedure adopted by the U.S. Department of Transportation from the United Nations regulations for the international transportation of dangerous goods and is contained in Appendix E to Part 173 of Title 49 of the Code of Federal Regulations (CFR).

2.5.3.3 Corrosivity by Method SW9045C (solid) or Method SW9040B (aqueous)

The corrosivity of a sample will be based on its pH. The pH of a liquid sample is either analyzed electrometrically using a glass electrode in combination with a reference potential or a combination electrode. The measuring device is calibrated using a series of standard solutions of known pH. For soil/solid waste samples, the sample is mixed with reagent water, and the pH of the resulting aqueous solution is measured.

2.5.3.4 Chemical Oxygen Demand by Method 410.4

Sample, blanks, and standards in sealed tubes are heated in an oven or block digestor in the presence of dichromate at 150°C. After two hours, the tubes are removed from the oven or digestor, cooled, and measured spectrophotometrically at 600 nm.

2.5.3.5 Reactivity

Reactivity is qualitatively assessed on the site microscopically for typical crystalline structures characteristic of the explosives manufactured at the facility.

2.5.4 Physical/Geotechnical Analysis

As discussed in Section 1.3.2, four soil samples will be collected for analysis of physical/geotechnical parameters. A USACE-approved laboratory will conduct analyses. Analyses will be conducted for the following:

- Grain-size analysis (ASTM D 422-98);
- Atterberg limits (ASTM D 4318-00);
- Soil moisture content (ASTM D 2216-98e1);
- Hydraulic Conductivity (ASTM D 5084-00e1-2000);
- Soil Bulk Density (ASTM D 4253-00);
- Soil Porosity (ASTM D 854-02 and D 2937-00e1);
- Total organic content (ASTM D 2974-00); and
- pH (ASTM D 4972-01).

2.6 INTERNAL QUALITY CONTROL CHECK

Internal QC components that will be used by URS during operations at RFAAP are presented below and in Section 8.0 of the MQAP. The internal quality components include the field QC samples and the laboratory QC elements to be followed. Rinse blanks, trip blanks, and field duplicates will be collected during the acquisition of environmental samples at RFAAP. Table 2-14 presents guidelines for the collection of QC samples that will be taken in conjunction with environmental sampling. Field QC acceptance criteria are summarized in Table 2-15.

Table 2-14
Field Quality Control Samples

Control	Purpose of Sample	Collection Frequency
Field Duplicate	Ensure precision in sample homogeneity during collection and analysis	10% of field samples per matrix
Rinse Blank	Ensure the decontamination of sampling equipment has been adequately performed; to assess cross contamination and/or incidental contamination to the sample container	1 per 20 samples per matrix per sample technique
Temperature Blank	Verify sample cooler temperature during transport	1 temperature blank per cooler
Trip Blank	Assess if cross contamination occurs during shipment or storage with aqueous VOC samples	1 trip blank per cooler containing aqueous VOC samples

Table 2-15

Field Quality Control Elements Acceptance Criteria

Item	DQO	Parameter	Frequency of Association	Criteria Goal
Field Duplicate	P	Inorganics	1 per 10 samples	RPD ≤ 20% Aqueous; difference ± RL* RPD ≤ 35% Solid; difference ± 2xRL*
		Organics	1 per 10 samples	RPD ≤ 40% Aqueous; difference ± RL* RPD ≤ 60% Solid; difference ± 2xRL*
Trip Blank	A,R	VOCs in water	1 per cooler with aqueous VOCs	No target analytes detected greater than the RL
Rinse Blank	A,R	Entire	1 per 20 samples per matrix per equipment type	No target analytes detected greater than the RL
Chain of Custody Forms	R	Entire	Every sample	Filled out correctly to include signatures; no missing or incorrect information.
Representative Sampling Forms	R	Entire	Every sample	Filled out correctly to include signatures; no missing or incorrect information.
Field Logbook	R	Entire	Every sample	Filled out correctly to include analytical parameters; map file data; and applicable coding information.
Field Instrument Calibration Logs	A	Entire	Every measurement	Measurements must have associated calibration reference

Legend: A = Accuracy C = Comparability R = Representativeness P = Precision

* The difference will be evaluated when either of the field duplicate results is less than the reporting limit.

2.6.1 Laboratory Quality Control Elements

The laboratory QC elements are summarized in Table 2-16. Specific laboratory analytical QC criteria and corrective actions are summarized in Tables 2-17 through 2-25 for the parameters specified in Section 2.5.

Table 2-16

Analytical Quality Control Elements of a Quality Assurance Program

Item	DQO	Parameter	Frequency of Association	Criteria Requirement
Analytical Method	C	Entire	Each analysis	Method analyses based on USEPA methods as defined in Section 2.5
Chemical Data Packages	C	Entire	Each lot/batch	Pass peer review and formal QA/QC check.
Laboratory Chain of Custody	R	Entire	Each lot/batch	Custody of sample within laboratory fully accounted for and documented
Laboratory System Controls	A,C,P, R	Entire	During laboratory operations	No deficiencies
Holding Time	A,C,P, R	Entire	Each analysis	No deficiencies (USEPA Region III Modifications)
Method Blanks	A,R	Entire	Each lot/batch	No target analytes detected in the method blanks greater than RL
Laboratory Control Spike	A	Entire	Each lot/batch	Must meet criteria as defined in Tables 2-17 through 2-25
Matrix Spikes and Duplicates	A,P	Entire	Each lot/batch	Must meet criteria as defined in Tables 2-17 through 2-25
Surrogates	A	Entire	Organic fractions, including QC samples	Must meet criteria as defined in Tables 2-17 through 2-25
Serial dilution	A	Metals	Inorganic Fractions, Each lot/batch	Must meet criteria as defined in Table 2-19

Legend: A = Accuracy C = Comparability R = Representativeness P = Precision

Table 2-17

Quality Control Method Criteria for Volatile Organic Compounds by USEPA SW-846 8260B

Procedure	Frequency	Acceptance Criteria		Corrective Action
Initial Calibration 5-pt curve (linear) 6-pt curve (2° order)	Set-up, major maintenance, or for drift correction	RRF > 0.10/0.30 for SPCCs RSD ≤ 30% for CCCs response factors RSD for analytes ≤ 15% or r>0.995 (linear) or r>0.99 (2° order)		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment target list with a percent recovery = 80-120%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Every 12 hours	RRF > 0.10/0.30 for SPCCs %Difference for RF of CCCs ±30% from initial calibration. Mean for analytes ≤ 20% as no individual target exceeds 40%D		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Method Blank	Every day/batch.	No target analytes greater than the RL		Document source of contamination. Re-analysis is required for positive results associated with blank contamination.
Tuning BFB	Prior to calibration and every 12 hours	Must meet tuning criteria		Re-tune, re-calibrate, and re-analyze affected sample analyses.
Laboratory Control Spike	Every batch	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 50-150% or RPD of 50%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Internal Standards	Every sample	<u>Recommended Standards</u> fluorobenzene chlorobenzene-d_5 1,4-dichlorobenzene-d_4	Retention time ±30 seconds of mid point of initial calibration Area changes within a factor of two (-50% to +100%)	Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples associated with standards outside criteria. A third analytical run may be required at a dilution.
Surrogate	Every sample	<u>Recommended Standards</u> toluene-d_8 4-bromofluorobenzene 1,2-dichloroethane-d_4 dibromofluoromethane	Laboratory generated control limits not to exceed 50-150%	If surrogate compounds do not meet criteria, there should be a re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 per matrix	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 50-150% or RPD of 50%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 2-18
Quality Control Method Criteria for Semivolatile Organic Compounds by USEPA SW-846 8270C

Procedure	Frequency	Acceptance Criteria		Corrective Action
Initial calibration 5-pt curve (linear) 6-pt curve (2° order)	Set-up, major maintenance, or for drift correction	RRF > 0.05 for SPCCs RSD $\leq$30% for CCC compounds RSD for target analytes $\leq$ 15% or r>0.995 (linear) or r>0.99 (2° order)		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment target list with a percent recovery = 70-130%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	12 hours	RRF > 0.05 for SPCCs %Difference for RF of CCCs ±30% from initial calibration Mean for analytes $\leq$ 20% as no individual target exceeds 40%D		Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria.
Internal standards	Every sample	Retention time ±30 seconds from mid point of initial calibration Area changes by a factor of two (-50% to +100%)		Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with internal standards outside criteria.
Tuning DFTPP	12 hours	Must meet tuning criteria.		Re-tune, re-calibrate, and re-analyze affected sample analyses.
Method Blank	Per extraction batch	No target analytes greater than the RL		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	Every batch	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 10-150% or RPD of 50%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Internal Standards	Every sample	Recommended Standards phenanthrene-d10 chrysene-d12 perylene-d12 1,4-dichlorobenzene-d4 naphthalene-d8 acenaphthalene-d10	Retention time ±30 seconds of mid point of initial calibration Area changes within a factor of two (-50% to +100%)	Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples associated with standards outside criteria. A third analytical run may be required at a dilution.
Surrogate Spikes	Every sample	Recommended Standards nitrobenzene-d_5 2-fluorobiphenyl p-terphenyl-d14 phenol-d5 2,4,6-tribromophenol 2-fluorophenol	Laboratory generated control limits not to exceed 10-150%	If two base/neutral or acid surrogates are out of specification, or if one base/neutral or acid extractable surrogate has a recovery of less than 10%, then there should be a re-extraction and re-analysis to confirm that the non-compliance is due to sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 samples per matrix	Standards Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 10-150% or RPD of 60%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 2-19
Quality Control Method Criteria for Polynuclear Aromatic Hydrocarbons by USEPA SW-846 8310

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Initial calibration 5-pt curve (linear) 6-pt curve (2° order)	Set-up, major maintenance, or for drift correction for each column used during analysis	%RSD<20% or r>0.995 (linear) or r>0.99 (2° order)		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment of target list with a percent recovery = 85-115%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Every ten samples or twelve hours	%D ± 15% of the response factor from the initial curve. The mean may be used as long as no individual target exceeds 30%D		Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria.
Method Blank	1 per batch	No target analytes detected greater than the reporting limit		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	1 per batch	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 40-150% or RPD of 60%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Surrogate Spikes	Every sample	<u>Standards</u> A similar compound that is not expected to be found at the site	Laboratory generated control limits not to exceed 30-150%	If surrogate compounds do not meet criteria, there should be a re-extraction and re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 samples per matrix	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 40-150% or RPD of 60%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.
Target Analyte Confirmation	Every positive detection	RPD ≤ 40%		Report the higher of the two concentrations unless a positive bias is apparent and qualify.

Table 2-20
Quality Control Method Criteria for Explosives by USEPA SW-846 8330 and 8332

Procedure	Frequency of QC Procedure	Acceptance Criteria		Corrective Action
Initial Calibration Curve 5-pt curve (linear) 6-pt curve (2° order)	Set-up, major maintenance, or for drift correction for each column used for analysis	%RSD<20% or r>0.995 (linear) or r>0.99 (2° order)		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment of target list with a percent recovery = 85-115%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Every ten samples or twelve hours	%D ± 15% of the response factor from the initial curve. The mean may be used as long as no individual target exceeds 30%D		Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria.
Method Blank	1 per batch	No target analytes detected greater than the reporting limit		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	1 per batch	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 40-150% or RPD of 60%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Surrogate Spikes	Every sample	<u>Standards</u> A similar compound that is not expected to be found at the site	Laboratory generated control limits not to exceed 30-150%	If surrogate compounds do not meet criteria, there should be a re-extraction and re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies.
Matrix Spike and Duplicate	1 per 20 samples per matrix	<u>Standards</u> Full compliment target list	Laboratory generated control limits not to exceed recovery limits of 40-150% or RPD of 60%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.
Target Analyte Confirmation	Every positive detection	RPD ≤ 40%		Report the higher of the two concentrations unless a positive bias is apparent and qualify.

Table 2-21
Quality Control Method Criteria for Target Analyte List Metals by USEPA SW-846 6020/ 6010B/7471A/ 7470A/ 9010C/ 9012A

Procedure	**Frequency of QC Procedure**	**Acceptance Criteria**		**Corrective Action**
Tune (MS)	Daily	Analyzed a minimum of four times with RSD < 5% for analytes in the solution.		Sample analysis cannot begin until this criterion is met.
Mass Calibration (MS)	Daily	Difference < 0.1 amu from true value.		Adjust to the correct value.
Resolution Check (MS)	Daily	Peak width <0.9 amu at 10% peak height		Sample analysis cannot begin until this criterion is met.
Initial Calibration Curve (MS, ICP, Hg, & CN)	Daily, major maintenance, or to correct drift.	MS & ICP Option 1: 1-standard and a blank with a low level standard at RL.	Low level check standard ± 20%.	The standards for that element must be re-prepared and re-analyzed again.
		MS & ICP Option 2: 3-standards and a blank	r > 0.99 for each element	
		Hg - 5-standards and a blank	r > 0.99	
		CN - 6 standards and a blank	r > 0.99	
Distilled Standards (CN)	Once per calibration	One high and one low distilled standard within ± 10% of the true value		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification (MS, ICP, Hg, & CN)	Immediately following initial calibration.	MS & ICP - A second source full compliment of target list with a percent recovery = 90-110%		Sample analysis cannot begin until this criterion is met.
		Hg - A second source full compliment of target list with a percent recovery = 80-120%		
		CN - A second source full compliment of target list with a percent recovery = 85-115%		
Initial Calibration Blank (MS, ICP, Hg, & CN)	Immediately following initial calibration verification.	No target analytes detected at concentration above the RL.		Sample analysis cannot proceed until this criterion is met.
Interference Check (MS & ICP)	Beginning of each sample analytical run.	Recovery ±20% of true value.		Terminate the analysis, correct the problem, re-calibrate, re-verify the calibration, and reanalyze associated samples.
Continuing Calibration Check (MS, ICP, Hg, & CN)	Every 10 samples and end of analytical run.	MS & ICP - Recovery ±10%.		Reanalyze; if the CCV fails again, stop analysis, the problem corrected, the instrument recalibrated, and the calibration re-verified prior to continuing sample analyses.
		Hg - Recovery ±20%.		
		CN - Recovery ±15%.		
Continuing Calibration Blank (MS, ICP, Hg, & CN)	Every 10 samples and end of analytical run.	No target analytes detected at concentration above the RL.		Sample sequence should not continue until this criterion is met. Demonstrate "clean". Affected samples will be reanalyzed.
Preparation Blank (MS, ICP, Hg, & CN)	1 per batch per matrix	No target analytes detected at concentration above the RL.		Document source of contamination. Re-digestion/re-analysis is required for positive results associated with blank contamination, unless DQOs are still met.
Laboratory Control Sample	1 per batch per matrix	Standards	80-120% recovery	Recoveries indicating a low bias require a redigestion/ reanalysis.

(MS, ICP, Hg, & CN)		Full compliment target list.	Soil use generated limits	Recoveries indicating a high bias require a redigestion/ reanalysis for associated positive field samples. Qualify data biased high or biased low as appropriate.
Matrix Spike and Duplicate or Sample Duplicate (MS, ICP, Hg, & CN)	1 per 20 samples per matrix	<u>Standards</u> Full compliment target list.	75-125% recovery; ICP & Hg: RPD≤25; CN: : RPD≤20; MS: [analyte]>100xIDL -RPD≤20; Soil use generated limits	Qualify associated data biased high or biased low as appropriate.
Post Digestion Spike (PDS) (MS & ICP)	1 per 20 samples per matrix	<u>Standards</u> Full compliment target list.	75-125% recovery	
Serial Dilution (MS & ICP)	1 per 20 samples per matrix	Used to assess new matrices	For sample results >5x RL for ICP or >20x RL for MS, %D between diluted and undiluted sample result ≤10%.	Chemical or physical interference indicated. Investigate to identify cause.
Internal Standards (MS)	Every Analytical Sequence	Standards & Blanks	80-120% of initial calibration intensity	Terminate the analysis, correct the problem, re-calibrate, re-verify the calibration, and reanalyze associated samples.
		Samples	30-120% of initial calibration intensity	Reanalyze at consecutive five fold dilutions until criteria is met.

Table 2-22
Quality Control Method Criteria for Pesticides, Herbicides, and PCBs by USEPA SW-846 8081A, 8082, and 8151A

Procedure	**Frequency of QC Procedure**	**Acceptance Criteria**		**Corrective Action**
Initial calibration curve 5-pt curve (linear) 6-pt curve (2° order)	Set-up, major maintenance	%RSD<20% or r>0.995 (linear) or r>0.99 (2° order)		Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	A second source full compliment of target list with a percent recovery = 85-115%		Sample analysis cannot begin until this criterion is met.
Continuing Calibration Check	Bracketing samples	%D recovery ± 15% of the response factor from the initial curve or mean with no individual peak >30%		Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria.
Endrin/4,4-DDT Breakdown	Bracketing samples	endrin degradation ≤15%. 4,4-DDT degradation ≤15%.		If criterion is not met, system must be deactivated and the affected samples reanalyzed.
Instrument Blank	After continuing calibration and highly contaminated samples.	No target analytes detected greater than the RL.		Demonstrate "clean". Affected samples will be reanalyzed.
Method Blank	Per extraction batch	No target analytes detected greater than the RL.		Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Spike	Per extraction batch	<u>Standards</u> Full target list for 8081A and a mix of 1016 & 1260 for 8082	Laboratory generated control limits not to exceed recovery limits of 30-150% or RPD of 60%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Surrogate Spikes	Every sample	<u>Standards</u> TCMX and DCB	Laboratory generated control limits not to exceed 30-150%	Investigate to assess cause, correct the problem, and document actions taken; re-extract and re-analyze sample. Specific method cleanups may be used to eliminate or minimize sample matrix effects. If still out, qualify.
Matrix Spike and Duplicate	1 per 20 samples per matrix	<u>Standards</u> Full target list for 8081A and a mix of 1016 & 1260 for 8082	Laboratory generated control limits not to exceed recovery limits of 30-150% or RPD of 60%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. Specific method cleanups may be used to eliminate or minimize sample matrix effects.
Target Analyte Confirmation	Every positive detection	RPD ≤ 40%		Report the higher of the two concentrations unless a positive bias is apparent and qualify.

Table 2-23
Quality Control Method Criteria for Chemical Oxygen Demand by USEPA Method of Chemical Analysis for Water and Wastes 410.4

Procedure	Frequency of QC Procedure	Acceptance Criteria	Corrective Action
Initial calibration curve 5-pt curve	Major maintenance, instrument modification, per manufacturer's specifications	r>0.995 (linear) or r>0.99 (2° order)	Sample analysis cannot begin until this criterion is met.
Initial Calibration Verification	Immediately following every initial calibration	Recovery ±10% of true value	Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standards. If the ICV fails a second time, initial calibration must be repeated.
Continuing Calibration Check	Every 10 samples, end of analytical run	Recovery ±10% of true value	Sample analysis cannot proceed until this criterion is met. Reanalyze CCC. If the CCC fails second time, the analysis must be terminated, the problem corrected, the instrument re-calibrated, and the calibration re-verified prior to continuing sample analyses.
Continuing Calibration Blank	Every 10 samples, end of analytical run	No target analytes detected greater than the RL.	If not within criteria, terminate the analysis, correct the problem, re-calibrate, and reanalyze each sample analyzed since the last acceptable CCB.
Method Blank	1 per 20 samples or batch per matrix	No target analytes detected greater than the RL.	Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination.
Laboratory Control Sample	1 per 20 samples per matrix	Laboratory generated control limits not to exceed recovery limits of 60-140% or RPD of 30%	Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate.
Matrix Spike and Duplicate	1 per 20 samples per batch, per matrix	Laboratory generated control limits not to exceed recovery limits of 60-140% or RPD of 30%	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

Table 2-24

Quality Control Method Criteria for Dioxins and Furans by USEPA SW-846 8290

<table>
<tr><th>Procedure</th><th>Frequency</th><th colspan="4">Acceptance Criteria</th><th>Corrective Action</th></tr>
<tr><td>Perfluorokerosene (PFK) Tune</td><td>Prior to initial calibration and every 12 hours</td><td colspan="4">Minimum resolving power 10,000
Deviation between exact and theoretical m/z shall be <0.005 amu or 5 ppm.</td><td>Re-tune, re-calibrate.</td></tr>
<tr><td>Window Defining Mix (WDM)</td><td>Prior to initial and continuing calibration</td><td colspan="4">No criteria, defines descriptor switching times of scan range (m/z).</td><td>Must meet criteria prior to sample analysis.</td></tr>
<tr><td>Isomer Specificity Check (ISC)</td><td>Prior to initial and continuing calibration</td><td colspan="4">DB5 column: 2,3,7,8-TCDD:1,2,3,9-TCDD peaks resolved with a valley ≤25%.
DB225: 2,3,7,8: 2,3,4,7-TCDF and 1,2,3,9-TCDF peaks resolved with a valley ≤25%.</td><td>Must meet criteria prior to sample analysis.</td></tr>
<tr><td rowspan="9">Initial calibration curve (5-pt curve)</td><td rowspan="9">Set-up, major maintenance</td><td colspan="4">RSD ±20% for standard compounds
RSD ±30% for reference compounds.
The signal to noise ratio must be ≥2.5 for each selected ion current profile.
Isotopic ratio must be within the following established control limits.</td><td rowspan="9">Must meet criteria prior to sample analysis. Data reviewer should review and judge the target compounds against the acceptance criteria.</td></tr>
<tr><td># of Cl ions atoms</td><td>Ion Type</td><td>Theoretical Ratio</td><td>Control limits</td></tr>
<tr><td>4</td><td>M/M+2</td><td>0.77</td><td>0.65 - 0.89</td></tr>
<tr><td>5</td><td>M+2/M+4</td><td>1.55</td><td>1.32 - 1.78</td></tr>
<tr><td>6</td><td>M+2/M+2</td><td>1.24</td><td>1.05 – 1.43</td></tr>
<tr><td>(13)C-HxCDF</td><td>M/M+2</td><td>0.51</td><td>0.43 – 0.59</td></tr>
<tr><td>(13)C-HpCDF</td><td>M/M+2</td><td>0.44</td><td>0.37 – 0.51</td></tr>
<tr><td>7</td><td>M+2/M+4</td><td>1.04</td><td>0.88 – 1.20</td></tr>
<tr><td>8</td><td>M+2</td><td>0.89</td><td>0.76 – 1.02</td></tr>
<tr><td>Continuing calibration standard</td><td>Prior and closing every 12 hours</td><td colspan="4">%D ±20% for standard compounds, or mean with no individual >25%.
%D ±30% for reference compounds, or mean with no individual >35%.
The signal to noise ratio must be ≥10.
Isotopic ratio must be within the preceding established control limits.</td><td>If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, calibration must be repeated. Data reviewer should review and judge the target compounds against the acceptance criteria.</td></tr>
<tr><td>Internal standards</td><td>Every sample</td><td colspan="4">% recovery between 40-135%</td><td>Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with standards outside criteria.</td></tr>
<tr><td>Method blanks</td><td>Per extraction batch</td><td colspan="4">No target analytes detected greater than the RL.</td><td>Document source of contamination.</td></tr>
<tr><td>LCS</td><td>Every batch</td><td colspan="2"><u>Standards</u>
Full compliment target list.</td><td colspan="2">±20% for standard compounds.
±30% for reference compounds.</td><td>Recoveries indicating a low bias require a re-extraction/reanalysis. Qualify associated data biased high or biased low as appropriate.</td></tr>
<tr><td>Surrogate Spike or Recovery Standard</td><td>Every sample</td><td colspan="4">% recovery between 40-135%</td><td>Investigate to identify cause and document actions taken; data are acceptable.</td></tr>
<tr><td>Matrix spike and duplicate</td><td>1 per 20 samples per matrix</td><td colspan="2"><u>Standards</u>
Full compliment target list.</td><td colspan="2">±20% for standard compounds.
±30% for reference compounds.
RPD ≤ 25%</td><td>If results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.</td></tr>
</table>

Table 2-25

Quality Control Method Criteria for Perchlorate by USEPA Method of Chemical Analysis for Water and Wastes 314.0

Procedure	**Frequency of QC Procedure**	**Acceptance Criteria**	**Corrective Action**
Initial calibration curve 5-pt curve	Major maintenance, instrument modification, per manufacturer's specifications	r > 0.99	If outside criteria, the standards must be reanalyzed until correlation passes. Must meet criteria prior to sample analysis.
Matrix Conductivity Threshold (MCT)	Prior to sample analysis	Conductivity of the matrix < MCT. Perchlorate recovery ± 20%. Perchlorate retention time shift from mid-point of initial calibration < 5%.	Sample must be pretreated.
Instrument Performance Check Standard	Start of each sequence	Must have a conductance within ± 10% of MCT.	
Initial calibration verification	1 per batch	Recovery ±10% of true value.	If outside criteria, the standard must be reanalyzed. Must meet criteria prior to sample analysis.
Continuing calibration verification (CCV)	Every 10 samples, end of analytical run	Recovery ±15% of true value.	Reanalyze CCV. If the CCV fails second time, the analysis must be terminated, the problem corrected, the instrument re-calibrated, and the calibration re-verified prior to continuing sample analyses.
Continuing calibration blank (CCB)	Every 10 samples, end of analytical run	Not detected greater than the RL.	If not within criteria, terminate the analysis, correct the problem, re-calibrate, and reanalyze each sample analyzed since the last acceptable CCB.
Method blank	1 per 20 samples or batch	Not detected greater than the RL.	Re-prep and analyze whole batch after source of contamination is found and eliminated.
Laboratory Control Sample	1 per 20 samples	85-115%.	Recoveries indicating a low bias require a re-extraction/reanalysis. Qualify associated data biased high or biased low as appropriate.
Matrix spike and duplicate	1 per 20 samples per batch	% recovery - 80-120%. RPD ≥ 15%.	If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic.

2.7 DATA COLLECTION AND VALIDATION

Non-CLP SW-846 Test Methods are proposed for analytical work for these WPA and analyses will be conducted by a USACE-validated analytical laboratory. Level IV CLP-like raw data will be provided along with the Form 1. Additional discussion as to the laboratory deliverables may be found in Section 9.8.3 of the MQAP. Data will be made available to the USEPA upon request and presented in the Soil Sampling Investigation Report.

Data validation will be conducted on 100% of the data and documented based on the MQAP Section 9.5, USEPA SW-846 Test Method criteria, the USACE Shell Document - Appendix I to the Engineer Manual 200-1-3 (USACE 1994), and USEPA Region III guidance. Data qualifiers will follow the USEPA Region III Modifications to the USEPA National Functional Guidelines for Evaluating Inorganic Analysis and USEPA Region III Modifications to the USEPA National Functional Guidelines for Organic Data Review Multi-media, Multi-concentration (OLM01.0-OLM01.9). Verification for organic data will be performed at level M3 and the verification for inorganic data will be performed at level IM2.

Manual data validation will be conducted by an independent, third party data validator not directly associated with the field-sampling program. Mr. John Kearns, Quality Assurance Manager, will oversee the performance of data validation functions. Data validation will be performed by knowledgeable and experienced individuals who can best perform evaluations within the necessary validation components. The data validator's qualifications will include experience with each of the elements required for the data verification and validation including ensuring that the measuring system meets the user's needs, assigning qualifiers to individual data values, assessing the relevancy of performance criteria, and concluding that data can proceed to quality assessment and reporting.

URS will direct the overall data management. Data management activities for the sampling program will be divided between URS and TriMatrix Laboratories (Paradigm Analytical Laboratories for dioxin/furan analyses). Each firm has the equipment needed to perform the required data management functions. The laboratory will perform data entry and manipulation operations associated with the analysis of raw analytical data and provisions of chemical analysis results by sampling location. These data will be transmitted to URS for evaluation and interpretation. In addition, URS will review boring logs and sample location maps.

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3.0 HEALTH AND SAFETY PLAN ADDENDUM

3.1 INTRODUCTION

This site-specific HSPA was developed to provide the requirements for protection of site personnel, including government employees, URS personnel, regulators, subcontractors, and visitors, that are expected to be involved with soil boring advancement/sampling at SWMU 41.

This HSPA addresses project-specific hazards, which include physical hazards, biological hazards, and chemical hazards, as identified in Section 3.2.2, below.

This addendum addresses site-specific training, PPE, and air monitoring requirements. General health and safety issues that are also applicable to this scope of work are addressed in Master Health and Safety Plan (MHSP), as shown in Table 3-1.

Table 3-1
Health and Safety Issues Discussed in the MHSP
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Health and Safety Issue	Section in MHSP
Site Safety and Health Documentation	1.4
Safety Statement	1.5
Health and Safety Personnel and Responsibilities	2.1
Hazard Assessment and Hazard Control	3.0
Training Plan	4.0
Medical Surveillance Plan	5.0
Site Safety and Control	6.0
PPE	7.0
Personnel and Equipment Decontamination	8.0
Monitoring Plan	9.0
Emergency Response and Contingency Plan	10.0

URS, subcontractor personnel, and site visitors will read this HSPA and will be required to follow its protocols as minimum standards. This HSPA is written for the site-specific conditions at SWMU 41 and must be amended if conditions change. A copy of this HSPA will be available at each work site.

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.

3.2 TRAINING PLAN

Training will be used to review important topics outlined in this addendum and to inform URS personnel and subcontractor personnel of the hazards and control techniques associated with facility-wide conditions.

Site personnel will be informed of the specific PPE that will be worn during field activities. This includes, at a minimum, steel-toed boots, safety glasses with side shields, gloves, and hardhat. Each field person will also have a respirator on the site, in the event that an emergency occurs and a respirator is necessary for site evacuation, or if the use of a respirator is necessary based on air monitoring results. Prior to initiation of fieldwork, the staff will be required to review the manual *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2000). Additional training, which will be conducted during daily safety “tailgate” meetings, will include emergency and evacuation procedures, general safety rules, and use of automobiles. Written documentation of safety briefings will be kept on the site.

3.2.1 Hazard Information Training

Hazard information training will be presented to URS and subcontractor personnel to provide a description of the Hazardous, Toxic, and Radioactive Waste (HTRW) with the potential to be found at SWMU 41. Training will also be provided on the potential biological, chemical, and physical hazards to be found at the Installation. The URS SHSO will conduct this training based on information provided by the operating contractor.

3.2.2 Project-Specific Hazard Analysis

The following hazards must be recognized and controlled during applicable investigative activities:

(1) Physical Hazards

- Cold stress – refer to Section 3.2.2 of the MHSP;
- Falls, open excavation, confined-space entry;
- Noise from heavy equipment;
- Cuts, abrasions, and lacerations;
- Manual lifting – refer to Section 3.2.4 of the MHSP;
- Slips, trips and falls associated with walking through heavily vegetated areas – refer to Section 6.1.1 of the MHSP;
- Heavy equipment – refer to Section 6.1.2.1 of the MHSP; and
- Main Manufacturing Area – overhead power lines.

(2) Biological Hazards (refer to Section 3.3 of the MHSP)

- Insect bites and stings;

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- Tick bites;
- Snake, rodent, or other animal bites; and
- Dangerous plants.

(3) Chemical Hazards

- Potential exposure to toxic chemicals; and
- Potential exposure to dangerous fumes in case of a nearby release or spill of acids, resulting in the creation of a fume cloud.

3.2.3 Hearing Conservation Training

Site personnel involved in heavy equipment operation in addition to other operations involving exposure to noise levels exceeding 85 decibels on the A-weighted scale Decibels on the A-Weighted Scale (dBA) eight-hour time-weighted average (TWA) shall be trained according to 29 CFR 1910.95. This training shall address the effects of noise on hearing, the purpose, advantages, disadvantages, and selection of hearing protection devices, and the purpose and explanation of Audiometric test procedures.

3.2.4 Hazard Communication Training

In order to comply with the requirements of the Occupational Safety and Health Administration (OSHA) Hazard Communication (HAZCOM) Standard, 29 CFR 1910.1200, URS will have a written HAZCOM Program in place. The written hazard communication program addresses training (including potential safety and health effects from exposure), labeling, current inventory of hazardous chemicals on the site, and the location and use of Material Safety Data Sheets (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 shall be scheduled and presented. HAZCOM training shall be documented by the SHSO using a HAZCOM Employee Training Record. This documentation and the URS HAZCOM Program will be maintained on the site for the duration of the project, and later incorporated in the employees' personal training file.

3.2.5 Confined Space Entry Training

Confined space entry training will not be required for fieldwork, as there will be no confined spaces entered during this investigation.

3.3 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

The minimum and initial level of PPE for these activities will be Level D. The initial selection of PPE is 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 upon 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 decisions on which protective level is most appropriate will be made by the SHSO.

In accordance with 29 CFR 1910.134, URS personnel working on the site will be required to participate in the written URS respiratory protection program. Personnel slated for fieldwork will have a qualitative fit test performed at least once per year or more frequently as required by law. Site personnel will be trained on the use, limitations, maintenance, inspection, and cleaning of respirators.

3.4 MONITORING PLAN

During sampling activities, the SHSO will monitor the site initially and periodically for potentially hazardous airborne constituents or physical hazards. The SHSO will use a PID to detect volatile organic vapors. SOP 90.1 describes the calibration of the PID that the SHSO will conduct daily. The action levels for volatile organic compounds at sustained concentrations in the breathing zone are as follows:

PID Readings	Action
Background plus 5 ppm	Investigate
Five ppm to 25 ppm	Upgrade to Level C (full face air-purifying respirator with organic vapor/acid gas cartridges), and investigate
Greater than 25 ppm	Suspend work, depart area, and investigate
ppm = Parts Per Million	

3.5 EMERGENCY RESPONSE PLAN

Emergency response will follow the protocols set fort in MHSP, Section 10.0. Table 3-2 presents the current emergency telephone numbers applicable to activities performed at RFAAP.

Table 3-2
Emergency Telephone Numbers
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

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) 731-2000 - General Telephone Number
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
Christiansburg, VA 24073

Take Route 114 toward Radford to first traffic light. Take US Route 11 South and go across the bridge over the New River. Turn left after crossing the bridge and go to Virginia Route 177 South and turn right. Proceed on VA 177 South and cross over Interstate 81. New River Valley Medical Center is on the left.

** These telephone numbers are referenced from *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2000).

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4.0 REFERENCES

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APPENDIX A

Standard Operating Procedures

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Standard Operating Procedures

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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
20.7	Resistivity and Electromagnetic Induction Surveys
20.8	Magnetic and Metal Detection Surveys
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
30.6	Containerized Material
30.7	Sampling Strategies
30.9	Collection of Soil Samples By USEPA SW-846 Method 5035 Using Disposable Samplers
40.0	**FIELD EVALUATION**
40.1	Multiparameter Water Quality Monitoring Instrument
40.2	Water Level and Well-Depth Measurements
40.3	Slug Tests
50.0	**SAMPLE MANAGEMENT**
50.1	Sample Labels
50.2	Sample Packaging
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)

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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).*

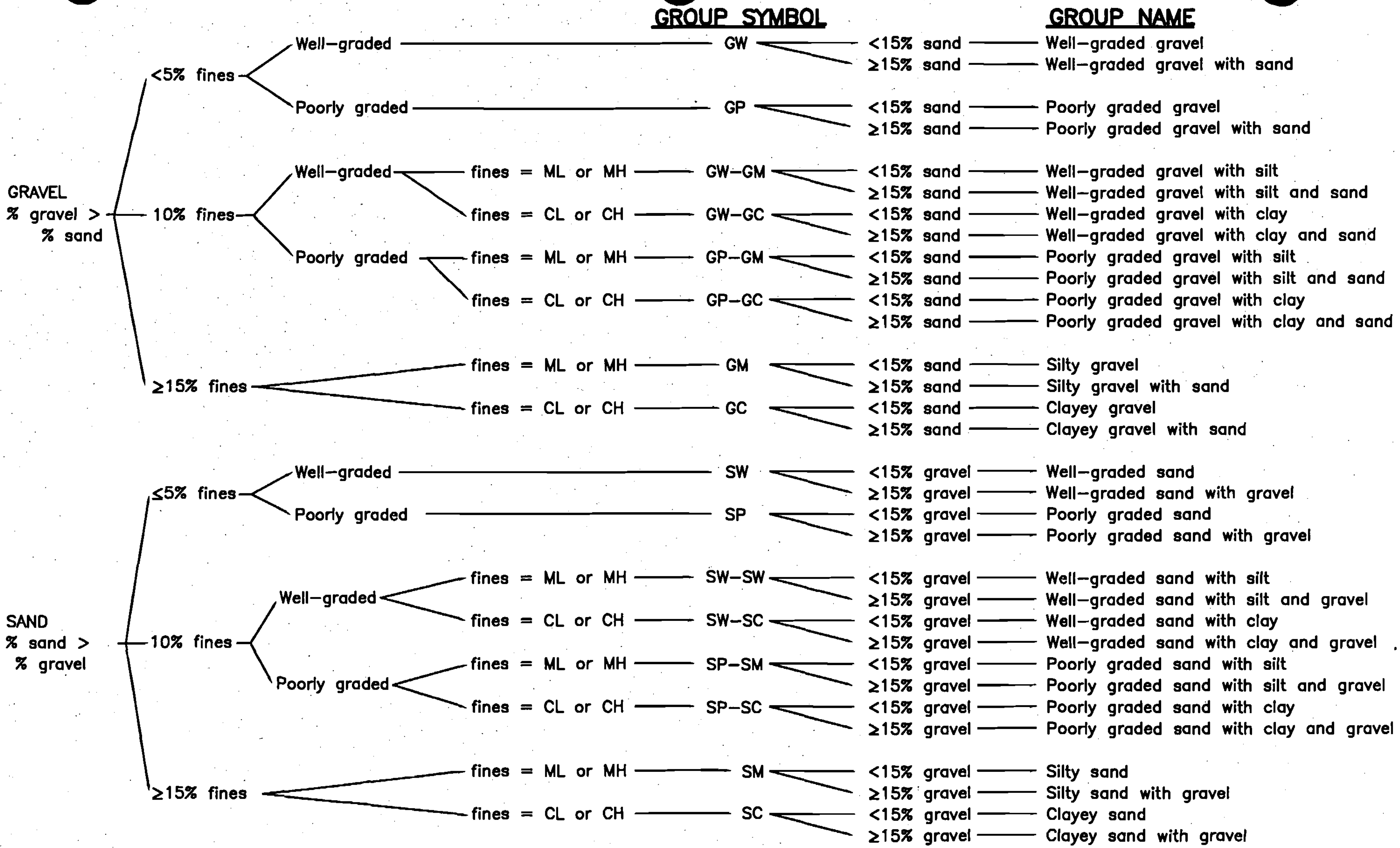
ASTM Standard D 5434-93. 1993. *Guide for Field Logging of Subsurface Explorations of Soil and Rock.*

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*

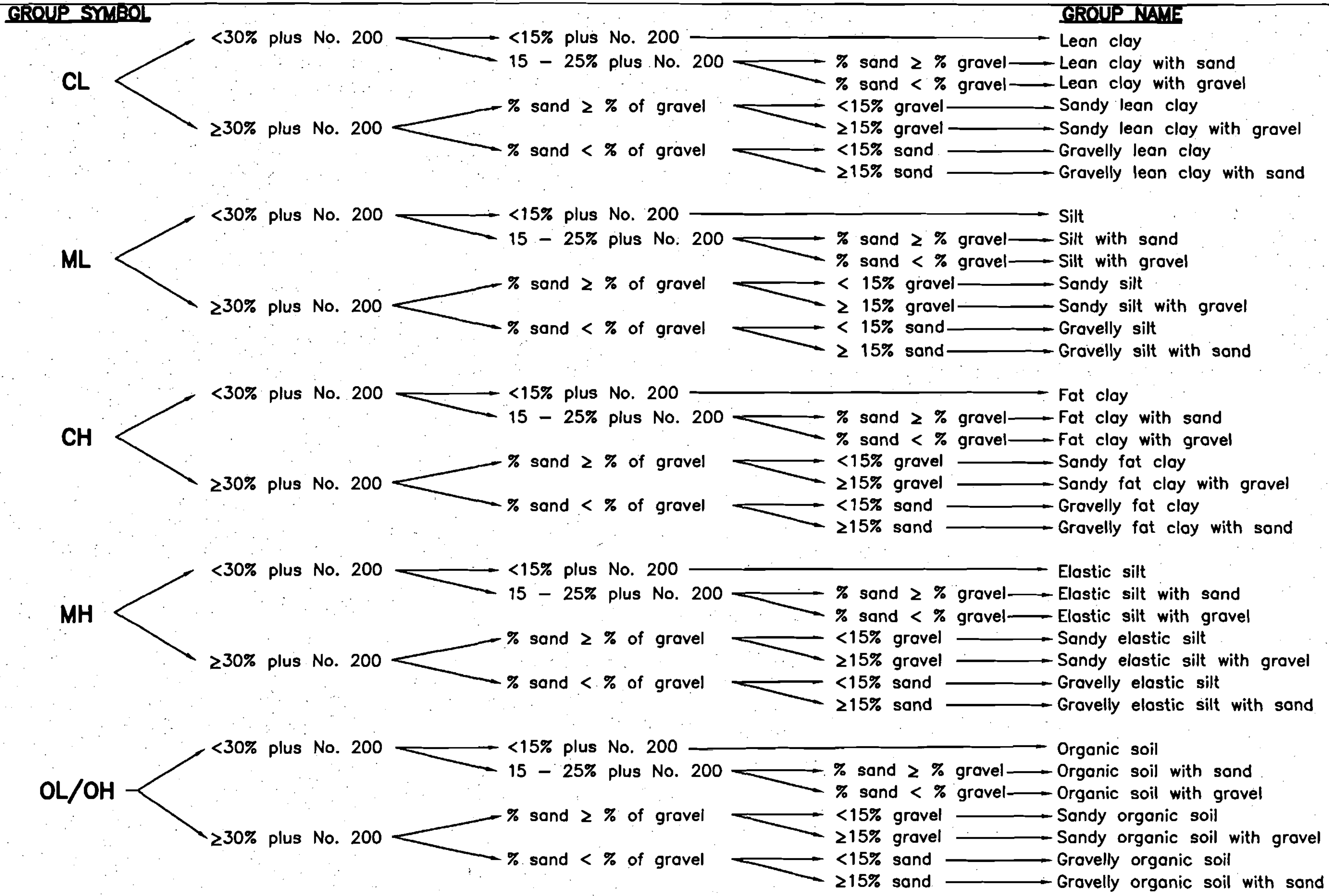
Prepared By: *URS Corp./DRT*

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%.

SOURCE: A 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 10.03b

FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS

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	ANALYSES									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______________________________________

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

- Appoint an excavation competent person;
- Conduct daily inspections of excavation and surrounding area;
- Excavation entry is prohibited without approval of the excavation competent person;
- Protect employees in excavations deeper than four feet by means of properly designed protective systems;
- Protective systems must comply with 29 CFR 1926 Subpart P Appendices B, D, and E;
- Excavations will be clearly identified and barricaded to keep unauthorized individuals out.

5.0 REFERENCE

USEPA. 1987. *A Compendium of Superfund Field Operations Methods*. December.

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.

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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.*

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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 30.6
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 30.9
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.

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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 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.

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PHOTO 1: SWMU 41 Burial Area, Facing North-Northeast, Monitoring Well Number 2 Visible Near Trees in Upper Right

PHOTO 2: SWMU 41 Burial Area, Facing South-Southwest, Monitoring Well Number 2 Bollards Visible Near Trees in Upper Left of Photograph

PHOTO 3: SWMU 41 Burial Area, Facing North

PHOTO 4: SWMU 41 Upgradient of Burial Area, Facing West

2N

PHOTO 5: SWMU 41 Lagoon Area, Facing Northeast – Site topographic survey benchmark pin located in base of pole selected in photo. TNT wastewater treatment equalization basin in left foreground.

PHOTO 6: SWMU 41 Lagoon Area, Facing Northeast

PHOTO 7: SWMU 41, Downgradient of Lagoon Area, Facing East Toward Stroubles Creek

PHOTO 8: SWMU 41, Downgradient of Lagoon Area facing north-northeast

APPENDIX C

V1 BORING LOGS

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BORING 41MW1

Surface Elevation: 0
Location: Radford AAP, Virginia
Start: 08:15 on 10-8-91
Finish: 10:45 on 10-10-91

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
0	SPT	1	19		10			CL	REDDISH BROWN (5YR 4/4) SILTY CLAY, STIFF, LITTLE YELLOW AND OLIVE MOTTLING, DRY
									GRADING DARK BROWN (7.5YR 3/3)
									BECOMING SLIGHTLY PLASTIC, TRACE MEDIUM SAND, SLIGHTLY MOIST
5	SPT	2	10		5				SLIGHTLY GRAVELLY
10									GRADING SOFTER
	SPT	3	63		79				GRAVEL SEAM 11.0-12.0 FEET
									BLACK SILT, SOFT, AND LIGHT BROWN SILT WITH REDDISH YELLOW MOTTLING OVERLAYING BEDROCK AT 13.0 FEET
								LS DLST	LIMESTONE/DOLOSTONE, LIGHT GRAY TO BLUISH BLACK, HARD, WELL CEMENTED, MODERATELY TO HIGHLY FRACTURED, WITH CALCITE INFILLING RUST COLORED STAINING FOUND AT MOST FRACTURES
15									
20	NX			1	100	85			GRADES TO LIGHT GRAY (N/7), HARD
									ZONE OF MORE FRACTURES, THICKER CALCITE VEINS, SOME SAND AND CLAY FILLED PARTINGS
									BECOMES DARK GRAY TO BLUISH BLACK, WITH ABUNDANT CALCITE FILLED CRACKS.
25	NX			2	98	100			RUST COLORED STAINING, LESS FREQUENT TRACE PYRITE AT 24.0 FEET
									LESS FRACTURED, CALCITE VEINS BECOME PITTED AND VUGGY
30	NX			3	100	27			
									GRAYISH BROWN (2.5Y 5/2) HIGHLY WEATHERED AND FRACTURED ZONE FROM 32.0 TO 35.0 FEET SOME FRACTURES STAINED STRONG BROWN (7.5YR 5/6) GRAY (N/5)
35	NX			4	100	50			
	NX			5	82	96			CONTINUED GRAY, HARD, WITH HEALED CRACKS AND FRACTURES
40									

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW1 (Cont'd)

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %
40						
45	NX			6	80	90
50	NX			7	90	93
55	NX			8	100	57
60	NX			9	100	98
65	NX			10	100	83
70	NX			11	100	88
75	NX			12	96	100
	NX			13	100	90
80						

Sample Interval

Symbols

LS
DLST

Description

GRADES TO 10YR 4/3 DARK BROWN WITH VARYING SHADES OF GRAY, WITH ABUNDANT CALCITE CRYSTALS, SLIGHT PITTING

BECOMING LESS FRACTURED, WITH FRACTURES OCCURRING ALONG CALCITE VEINS, WHERE MINERAL STAINING IS EVIDENT (YELLOWISH BROWN AND BLACK)

SAME LIMESTONE/DOLOSTONE WITH FEW FRACTURES AND YELLOWISH RED STAINING AT FRACTURES

SOME LIGHT OLIVE SHADING

BECOMES PITTED, CALCITE MORE OBUNDANT, THIN SEAMS OF MORE WEATHERED LIMESTONE INTERBEDDED WITH THE HARDER DOLOSTONE/LIMESTONE
PITTING ENDS 62.9 FEET WHERE BECOMES HARDER

BECOMING DARKER, FEW FRACTURES

GRADING DARKER TO DARK BLUISH GRAY (5B 4/1), WITH FEW FRACTURES AND CALCITE-HOLED CRACKS HEALED CRACKS SHOW SLIGHT SIGNS OF WEATHERING

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW1 (Cont'd)

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
80							▮	☐	WITH SLIGHT ORANGE-YELLOW STAINING
									BORING TERMINATED AT A DEPTH OF 81.5 FEET
85									

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW2

Surface Elevation: 0
Location: Radford AAP, Virginia
Start: 10:25 on 9-4-91
Finish: 15:30 on 9-6-91

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval
0	SPT	1	13		60		
5	SPT	2	17		30		
10	SPT	3	11		45		
15	SPT	4	11		65		
20	SPT	5	49		90		
25	SPT	6	42		0		
	SPT	7			35		
30							
35							
40							

Symbols	Description
CL	BROWN (7.5YR 5/4) SILTY SANDY CLAY WITH PEA GRAVEL, SLIGHTLY PLASTIC, SLIGHTLY MOIST, MEDIUM STIFF PLASTICITY INCREASING, SAND CONTENT DECREASING OCCASIONAL GRAVEL ZONES CLAY BECOMING MOIST OCCASIONAL SILTY ZONES GRAVEL DECREASING
CL	STRONG BROWN (7.5YR 4/6) HIGHLY PLASTIC CLAY, SMALL BLACK SPECKS, TRACE SAND, NO GRAVELS, VERY STIFF OCCASIONAL GRAVELS OR COBBLES
$\frac{\text{LS}}{\text{DLST}}$	YELLOWISH BROWN (5YR 4/4) SILTY CLAY, WITH SOME REDDISH BROWN MOTTLING, OVERLYING BEDROCK BLUE-GRAY LIMESTONE/DOLOSTONE, DRY, HARD

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW2 (Cont'd)

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
40									
								LS DLST	BLUE GRAY LIMESTONE/DOLOSTONE, HARD
45									
50									
55									
									BLUE-GRAY LIMESTONE/DOLOSTONE, HARD
60									
									BLUE-GRAY LIMESTONE/DOLOSTONE, HARD, DRY
65									
70									
									BLUE-GRAY LIMESTONE/DOLOSTONE, HARD, DRY
75									
80									

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW2 (Cont'd)

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
80									
85									BLUE-GRAY LIMESTONE/DOLOSTONE, HARD, DRY
90									
95									BECOMING SOFTER GRAY, CLAYEY LIMESTONE/DOLOSTONE
100								LS/DLST	GRAY, CLAYEY, SOFT LIMESTONE/DOLOSTONE
105									
110									
115									ROCK GETTING SOFTER, CUTTINGS SLIGHTLY MOIST
120									

PLATE
LOG OF BORING

BORING 41MW2 (Cont'd)

308

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
120								LS/DLST	CUTTINGS MOIST, SOFT, LIGHT GRAY CLAYEY LIMESTONE/DOLOSTONE
125									BORING TERMINATED AT A DEPTH OF 125.0 FEET

PLATE
LOG OF BORING

BORING 41MW3

Surface Elevation: 0
Location: Radford AAP, Virginia
Start: 07:30 on 10-17-91
Finish: 14:00 on 10-17-91

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %
0	SPT	1	35		65	
5	SPT	2	22		65	
10	SPT	3	18		95	
15	SPT	4	103		45	
20	SPT	5	82		80	
25	SPT	6	35		80	
30	SPT	7	50/0		100	
35	NX			1	95	66
40						

Symbols	Description
ML	STRONG BROWN (7.5YR 4/6) CLAYEY SILT WITH SOME GRAVELS, WITH REDDISH BROWN AND VERY PALE BROWN MOTTLING
CL	DARK YELLOWISH BROWN (10YR 4/4) SANDY CLAY, HIGHLY PLASTIC WITH OCCASIONAL GRAVELLY ZONES BECOMES STRONG BROWN (7.5YR 5/6) MORE GRAVELS VERY GRAVELLY 14–19 FEET, WITH CLAY
ML	PALE OLIVE (5YR 6/3) AND OLIVE YELLOW (2.5Y 6/6) SILT, HARD, DRY, FRIABLE, SLIGHTLY GRAVELLY, WITH SOME BLACK STAINING OCCASIONAL THIN SILTSTONE SEAMS (OLIVE GRAY) GRADES TO LIGHT YELLOWISH BROWN (2.5Y 6/4) WITH OLIVE AND GRAY MOTTLING
CL	STRONG BROWN (7.5YR 5/6) CLAY, SOFT, MOIST, STICKY, HIGHLY PLASTIC
SH	DARK GREENISH GRAY (5BG 4/1) SHALE, WITH ABUNDANT CALCITE VEINS, NO APPARENT BEDDING, YELLOW STAINING AT FRACTURES BECOMES HIGHLY WEATHERED YELLOWISH BROWN WITH INCREASED CLAY OCCASIONAL LAYERS OF SILTSTONE AND PITTED LIMESTONE

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW3 (Cont'd)

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
40							■	SH	LESS WEATHERED DARK GREENISH GRAY SHALE WITH CALCITE VEINS
	NX			2	88	45	■		WITH HIGHLY WEATHERED AND CLAYEY ZONES
							■	DLST	BECOMES PITTED AND SLIGHTLY VUGGY CLAYEY DOLOSTONE, GRAY (N/5) WITH THIN LIMESTONE SEAMS, HIGHLY WEATHERED, SANDY
45							■		
	NX			3	100	78	■		BLUISH GRAY, HIGHLY CRACKED AND RECEMENTED WITH SOME REDDISH BROWN STAINING
50							□		CONTINUED HIGHLY WEATHERED
							□		WET
55							□		BROWN (10YR 5/3) DOLOSTONE, WET, MUDDY
							□		SOFT, MUDDY
60							□		
									BOREHOLE TERMINATED AT A DEPTH OF 62.0 FEET
65									

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW3A

Surface Elevation: 0
Location: Radford AAP, Virginia
Start: 07:30 on 10-15-91
Finish: 09:15 on 10-15-91

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
0	SPT	1	43		45			CL	STRONG BROWN (7.5YR 4/6) SILTY CLAY, SLIGHT PLASTICITY, SLIGHTLY MOIST, WITH YELLOW (10YR 4/6) MOTTLING
									PLASTICITY INCREASING
5	SPT	2	17		90				BECOMES GRAVELLY AND SANDY AT 6.5 FEET, MOIST, MEDIUM STIFF, WITH SOME LIGHT OLIVE BROWN MOTTLING
									OLIVE BROWN (2.5Y 4/3) SANDY CLAY, MOIST; PLASTIC, WITH GRAVEL
10	SPT	3	13		25				
15	SPT	4	10		65			CL	
20	SPT	5	100/4		30				ENCOUNTER WOOD PIECES AT 20.5 FEET
25	SPT	6	100/5		100				SLIGHT BLACK MOTTLING
									BOREHOLE TERMINATED AT A DEPTH OF 27.0 FEET
30									

PLATE
LOG OF BORING

BORING 41MW3B

Surface Elevation: 0
Location: Radford AAP, Virginia
Start: 12:07 on 10-15-91
Finish: 12:40 on 10-16-91

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %
0	SPT	1	35		65	
5	SPT	2	22		65	
10	SPT	3	18		95	
15	SPT	4	103		45	
20	SPT	5	82		80	
25	SPT	6	35		80	
30	SPT	7	50/0		100	
35	NX			1	95	66
40						

Symbols	Description
ML	STRONG BROWN (7.5YR 4/6) CLAYEY SILT WITH SOME GRAVELS, WITH REDDISH BROWN AND VERY PALE BROWN MOTTLING
CL	DARK YELLOWISH BROWN (10YR 4/4) SANDY CLAY, HIGHLY PLASTIC WITH OCCASIONAL GRAVELLY ZONES BECOMES STRONG BROWN (7.5YR 5/6) MORE GRAVELS VERY GRAVELLY 14–19 FEET, WITH CLAY
ML	PALE OLIVE (5YR 6/3) AND OLIVE YELLOW (2.5Y 6/6) SILT, HARD, DRY, FRIABLE, SLIGHTLY GRAVELLY, WITH SOME BLACK STAINING OCCASIONAL THIN SILTSTONE SEAMS (OLIVE GRAY) GRADES TO LIGHT YELLOWISH BROWN (2.5Y 6/4) WITH OLIVE AND GRAY MOTTLING
CL	STRONG BROWN (7.5YR 5/6) CLAY, SOFT, MOIST, STICKY, HIGHLY PLASTIC
SH	DARK GREENISH GRAY (5BG 4/1) SHALE, WITH ABUNDANT CALCITE VEINS, NO APPARENT BEDDING, YELLOW STAINING AT FRACTURES BECOMES HIGHLY WEATHERED YELLOWISH BROWN WITH INCREASED CLAY OCCASIONAL LAYERS OF SILTSTONE AND PITTED LIMESTONE

PLATE
LOG OF BORING

Dames & Moore

BORING 41MW3B (Cont'd)

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval	Symbols	Description
40								SH	LESS WEATHERED DARK GREENISH GRAY SHALE WITH CALCITE VEINS
	NX			2	88	45			WITH HIGHLY WEATHERED AND CLAYEY ZONES
								DLST	BECOMES PITTED AND SLIGHTLY VUGGY CLAYEY DOLOSTONE, GRAY (N/5) WITH THIN LIMESTONE SEAMS, HIGHLY WEATHERED, SANDY
45									
	NX			3	100	78			BLUISH GRAY, HIGHLY CRACKED AND RECEMENTED WITH SOME REDDISH BROWN STAINING
50									CONTINUED HIGHLY WEATHERED
55									

BOREHOLE TERMINATED AT A DEPTH OF 55.0 FEET

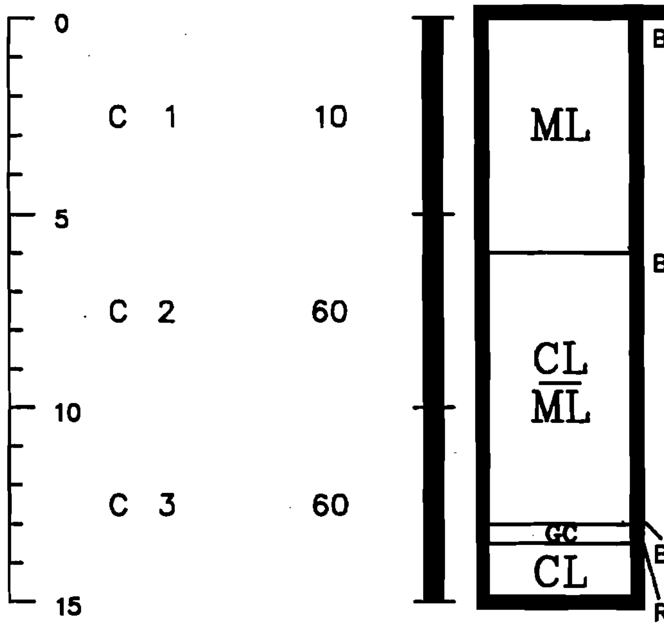
PLATE
LOG OF BORING

207

BORING 41SB1

Surface Elevation: 1730.0 Feet, MSL
Location: Radford AAP, Virginia
Start: 15:09 on 10-25-91
Finish: 15:45 on 10-25-91

Depth (Feet)	Sampling Method	Sample No.	Blows/Foot	Core Run No.	% Recovery	RQD %	Sample Interval
	C	1			10		
	C	2			60		
	C	3			60		



Description

BROWN (7.5YR 5/4) SANDY SILT, MOIST, FILL MATERIAL

BLACK (10YR 2/1) CLAY AND SILT, VERY MOIST,
PROBABLY RED WATER ASH WASTE

CHEMICAL SAMPLE COLLECTED 8.0-10.0 FEET

BECOMES INTERBEDDED WITH YELLOWISH RED (5YR 5/6) SILTY CLAY FROM 12.0 TO 13.0 FEET, VERY MOIST

BLUISH GRAY (5B 5/1) LIMESTONE AND DOLOMITE GRAVEL FROM 13.0-13.4 FEET

REDDISH YELLOW SILTY CLAY WITH BLACK MINERAL INCLUSIONS

CHEMICAL SAMPLE COLLECTED 14.0-15.0 FEET

BELOW 15.0 FEET IS CLEAN SOIL

BOREHOLE TERMINATED AT A DEPTH OF 15.0 FEET

PLATE
LOG OF BORING

Dames & Moore

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APPENDIX D
ARGONNE NATIONAL LABORATORY
DRAFT GEOPHYSICAL SURVEYS – SWMU 41

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APPENDIX D.1: Geophysical Report

1. INTRODUCTION

SWMU 41 is located in the southeast section of the Main Manufacturing Area at Radford Army Ammunition Plant (RFAAP) and consists of two non-contiguous areas, an unlined lagoon (Area A) and a burial area (Area B). The lagoon is approximately 50x70-ft in size and the burial area is approximately 100x150-ft in size. The lagoon received ash material as well as runoff from washing trucks used to haul red water ash. The burial area is described as being lined with a clay soil and was used for the disposal of red water ash from approximately 1967 to 1971.

Argonne National Laboratory (ANL) performed surface geophysical surveys using two-dimensional resistivity profiling, seismic refraction tomography, and EM-31 electrical-conductivity mapping on the burial area of SWMU 41 during August through September 2002. Field inspection of the SWMU 41 lagoon (Area A) indicated that geophysical surveys were not necessary due to the obvious surface expression of this feature. ANL also performed vertical seismic profiles in the three monitoring wells adjacent to SWMU 41 to help guide the seismic interpretations. USACE collected downhole electrical and natural-gamma logs to help constrain the resistivity models.

2. OBJECTIVE

The SWMU 41 surveys were conducted in order to delineate potential burial locations within the burial area (Area A) of SWMU 41. Information obtained by the geophysical surveys was used in developing plans for follow-on focused studies relative to potential constituents in soil.

3. TECHNICAL APPROACH

Site conditions, intrusive sampling and remediation goals are critical in determining what geophysical techniques are appropriate for an investigation. RFAAP is underlain by carbonate rock (limestone and dolomite) that in places is structurally complex (folded and faulted) and contains clastic interbeds and tectonic breccias. Overburden sediments range from 0 to 60+ feet in thickness, and in the burial area, a clay liner may be present as well as an unspecified amount of red water ash.

Geophysical investigations provide subsurface geologic information using non-intrusive techniques, the data from which can often times are interpreted in more than one way. Therefore, the use of two or more geophysical methods, plus the integration of available geotechnical information, allows for a more constrained interpretation of the geophysical data.

Two-dimensional electrical resistivity imaging (2D-ERI), seismic refraction profiling/tomography, and electromagnetic (EM) terrain-conductivity mapping are applicable techniques that can map changes in the electrical (2D-ERI and EM) and acoustic (seismic) characteristics of the underlying soil and rock. These techniques provide complementary information about the subsurface, which can provide a more definitive interpretation of subsurface anomalies over that obtained using the techniques individually. Appendix D.2 describes in more detail the theory and operation of these methods.

In general, the underlying rock should have a higher seismic-velocity than the overburden sediment, and should be readily distinguishable on the resulting tomographic sections. A decrease in seismic velocity will occur where the rock is fractured (weak zones), less competent, or dominated solution cavity development.

The electrical response of the rock is more complex and depends on the type of strata present and the electrical properties of the pore fluid. Higher electrical-resistivity should occur if carbonate rock is present. Alternatively, the presence of an electrically conductive pore-fluid, or a significant clay fraction, could yield lower-resistivities than expected. Air-filled fractures and voids would likely increase the electrical resistivity.

The disruption of the overburden sediment by activities associated with the burial area is expected to produce a zone of slightly lower seismic-velocity and lower electrical resistivity. In addition, the presence of buried material and degradation products may also lower the electrical response. Metallic debris at the site will also have a significant electromagnetic response during the EM surveys.

Prior to performing the geophysical surveys, a local grid system (geophysical grid) was established which covered the SWMU 41 area. URS Corporation used a Virginia Licensed Surveyor to locate the geophysical grid onto the reference frame established for the "RAAP Project Site Map, dated 8/19/92." GPS measurements were also collected by ANL staff at selected points within the geophysical grid, along the geophysical profiles, and at the 3 monitoring wells adjacent SWMU 41. The GPS used was a Trimble Pro XRS receiver with integrated, real-time differential correction provided by the Omnistar service, and is reported to have sub-meter accuracy. The GPS measured positions were converted into the NAD-83, Virginia State Plane (Zone 4502), US Survey Feet reference frame using Pathfinder Office Pro software (Trimble) and the USACE Corpscon program.

Comparison of the GPS positions with the RAAP Project Map locations indicated that the GPS points needed to be shifted approximately 2756 ft to the east, and around 1362 ft to the south in order to match the base map prepared for SWMU 41. Consistent scaling, such as that used for the SWMU 40/71 site, could not be used to rectify both coordinate frames, nor was it clear what actual reference-frame is being used for the site. Thus to accommodate site reporting and cleanup activities, locations given in this report conform with the horizontal datum established with the 1992 RAAP Project Site Map.

4. Geophysical Surveys

Geophysical surveys collected at the SWMU 41 burial area consisted of an EM-31 survey, two seismic refraction profiles, and 2 two-dimensional resistivity (2D-ERI) profiles (see Figure D.1). The EM-31 survey was added to the scope of work to help better guide the location of the 2D-ERI profiles. Vertical seismic profiling was also conducted in the three wells adjacent to SWMU 41 (41MW1, 41MW2, and 41MW3) in order to provide velocity measurements used for the seismic-modeling. Downhole electrical and natural-gamma logging conducted by USACE staff was used to help constrain the geophysical models.

EM-31 Terrain Conductivity Survey

Electromagnetic (EM) surveys were performed in the grid area shown on Figure D.1 with the objective of mapping likely disposal sites within the southern part of SWMU 41. It was expected that the activities involved in the construction of and disposal within the trench would alter the subsurface electrical properties. EM-31 measurements were collected along profiles spaced at 8 ft intervals in the approximate northeast-southwest direction and along profiles spaced at 16 ft in the approximate northwest-southeast direction. Quadrature-phase data were collected with the EM-31 for the SWMU 41 survey. EM measurements reflect a weighted average with greater weight given to shallower depths. The EM-31 was operated in the vertical dipole mode and 80% of the measured response correlates with material within the upper 10 ft of the subsurface, with the peak response occurring in the 1.6 to 8.2 ft depth range. The in-phase response of the EM-31, which indicates relative subsurface metal content, malfunctioned during the SWMU 41 survey.

Figure D.2 shows the conductivity anomaly map constructed from the EM-31 survey. Red-to-white colors indicate areas of relatively higher electrical conductivity, whereas blue-to-magenta colors areas of lower conductivity. The locations of the seismic and resistivity profiles are also shown in Figure D.2, as are the positions of the 3 monitoring wells and the ground-surface topography. Natural or background conditions are not inferred on Figure D.2 due to the limited area covered by the survey. A total range in electrical-conductivity of approximately 160 mS/m was measured at SWMU 41.

Two anomalies of relatively higher electrical conductivity are observed in the south central and southeast part of the map. The first anomaly is elongated along a rough NNW-SSE axis, and is approximately 120 ft in length and 20-30 ft in width. The second zone is approximately 30 ft in diameter. Based on the EM-31 conductivity data, this is likely the location of the 1967-1971 disposal area(s). The two anomalous areas may in fact be contiguous, separated by fill material of a different electrical signature. The larger area to the north, represented by the darker blue colors on Figure D.2, is not thought to be buried material. The gradational decrease in conductivity toward the edges of the site probably represents changes in the thickness and character of the overburden material, although it is possible that burial material is present at depths greater than that measured by the EM-31 (i.e. greater than ~10ft).

Seismic Surveys

Two seismic refraction profiles, 41-Seis-L1 and 41-Seis-L2, and three vertical seismic profiles were collected at SWMU 41 (see Figure D.1). A geophone spacing of 3 ft was used and shot points were spaced at approximately 16 ft intervals. Profile 41-Seis-L1 is approximately 330 ft in length, and 41-Seis-L2 160 ft in length. Profile 41-Seis-L1 is oriented parallel to the long axis of the burial area, and 41-Seis-L2 is roughly perpendicular to this axis. Vertical seismic profiles used a geophone spacing of 5 ft, and surveyed wells 41MW1, 41MW2, and 41MW3.

Figure D.3 shows the results for the three vertical seismic profiles collected at SWMU 41, which are used to provide in situ velocity measurements of the underlying soil and rock Data collection and processing steps are outlined in Appendix D.2. Survey results at SWMU 41 indicate that that the limestone and dolostone units should have seismic velocities of about 8500 ft/s (2600 m/s) or greater. Overburden units are observed to range in velocity from 1500 ft/s (450m/s) to 5500 ft/s (1500m/s).

Figure D.4 shows the seismic modeling results for profiles 41-Seis-L1 (top panel) and 41-Seis-L2 (bottom panel). The profiles were processed using both refractor-layer (earth-layer) and tomographic models as described in Appendix D.2. Results are presented as color-contoured cross-sectional models with magenta-to-blue colors representing lower values, and red-to-white colors higher values. The earth-layer interfaces are shown as dark gray trace lines labeled as "SIPT Refractor", and also shown are the vertical seismic profiling results for wells 41MW1 and 41MW2 with their relative positions projected onto Profile 41-Seis-L1. Note that Well 41MW1 is approximately 60 ft distant from the profile, and 41MW2 about 40 ft.

Profile 41-Seis-L1 (top panel, Figure D.4) shows the bedrock surface dipping to the NW, dropping to approximately 60 ft below ground surface (bgs) at the NW end. Note that bedrock was observed on the access road to the NW of the profile (~20 ft lower in elevation), which requires the bedrock surface to begin sloping up to NW, beyond the end of the profile. Weathered rock was observed at the surface at the SE end of the profile. Here the model predicts upwards of 5 ft to top-of-competent-rock. The velocities obtained from tomographic modeling are consistent with results from the vertical seismic profiling. Two gentle sags are modeled on the bedrock surface centered at profile coordinates 100X and 235X. A zone of slightly lower bedrock velocity (11,000 ft/s versus 13,000 ft/s) is modeled beneath the sag from about 55X to 115X. Seismic velocities within the overburden do not appear to have discerned anomalous areas associated with disposal activities.

Profile 41-Seis-L2 (bottom panel, Figure D.4) models the top-of-rock at a depth consistent with that predicted by Profile 41-Seis-L1. The bedrock surface appears to rise towards the southwest to approximately 20 ft bgs. Bedrock velocities for 41-Seis-L2 are generally lower than observed for 41-Seis-L1, though this may be an artifact due to the short profile length versus bedrock depth, which limits the subsurface coverage. Obvious velocity anomalies are not present within the overburden along the seismic profiles to pinpoint possible disposal activities.

Resistivity Profiling

Two-dimensional resistivity data (2D-ERI) were collected along profiles 41-Resist-L1 and 41-Resist-L2 (see Figure D.1). These profiles were oriented to target the high electrical-conductivity feature observed in the EM-31 data (Figure D.2). Profile 41-Resist-L1 used 54 electrodes spaced at 6.5 ft intervals, providing a profile length of approximately 347 ft. Space constraints limited Profile 41-Resist-L2 to about 180 ft of lateral coverage, which required the 56 electrodes to be spaced at 3 ft intervals. Both Schlumberger and dipole-dipole arrays were used to collect the resistivity profiles (see Appendix D.2 for further explanation). Use of these array types allows discerning whether observed anomalies are modeling or data collection artifacts, and more credence is given to the results where models constructed from both array types show similar features.

Presented in Figure D.5 are the dipole-dipole results, which are shown as color-contoured cross-sectional models with magenta-to-blue colors representing lower values, and red-to-white colors higher values. Also shown are vertical seismic profiling results obtained in Well 41MW1, which is plotted at the approximate position of the perpendicular from each line to the well. Note that Well 41MW-1 is approximately 40 ft from either profile.

Profile 41-Resist-L1 (top panel, Figure D.5) maps an approximately 30 ft thick, and laterally continuous, zone of higher resistivity (>500 ohm-m) in the central to southeastern part of the profile (from 100X to 300X). The depth to top of this zone is consistent with where the seismic data indicates competent rock. Note that the bottom of this zone roughly coincides with a zone of lower velocity on the vertical seismic profile.

The high-resistivity zone becomes laterally discontinuous to the northwest suggesting the presence of either a lithologic break or a zone of weaker rock. Comparison with seismic velocities obtained for profile 41-Seis-L2 (bottom panel, Figure D.4), which crosses 41-Resist-L1 at approximately 45X, also indicates the presence of weaker rock. The seismic model, however, predicts a lower bedrock elevation (1760 ft) than does the resistivity model (1770-1775 ft).

An approximately 6-10ft thick zone of low-resistivity (<10 ohm-m) is modeled between coordinates 110X and 290X on Profile 41-Resist-L1. This low-resistivity roughly coincides with the extent of electrically conductive zones (area of low-resistivity) mapped by the EM-31 survey. The 2D-ERI data indicates a maximum burial depth of approximately 10-12 ft bgs if the low-resistivity zone truly represents buried material. This area of low-resistivity may extend to greater depths to the northwest to approximately 50X on the profile.

Profile 41-Resist-L2 (bottom panel, Figure D.5) produced a similar model as that shown for 41-Resist-L1. The profile was oriented through the long axis of the EM conductivity anomaly (Figure D.2) in order to provide a depth estimate to the base of this feature. The low resistivity zone is about 10 ft in thickness, and extends approximately the same breadth as the EM anomaly (120 ft, from 25X to 155X).

5.0 Summary

Electromagnetic terrain-conductivity surveying, seismic refraction profiling, and two-dimensional electrical-resistivity imaging (2D-ERI) were conducted at SWMU 41 burial area in order to locate potential zones of buried material.

Electromagnetic surveys using the EM-31 instrument mapped a zone of increased electrical-conductivity within the south central and southeastern part of the survey area. These zones are interpreted as the area of the former burial area. The EM data indicates a limited area of disposal (Figure D.2), but does not rule out the area to the northwest due to greater depth to rock indicated by the seismic survey (Figure D.4).

Seismic refraction mapped the bedrock as a surface sloping towards the North and Northwest, with a slight decrease in velocity in the 50X to 115X on 41-Seis-L1, which is also observed on Profile 41-Seis-L2. This velocity change indicates rather tenuously a lithologic or structural break (consistent with a weaker bedrock zone modeled by 2D-ERI model for Profile 41-Resist-L1). Other significant structural features were not indicated for the bedrock.

2D-ERI profiling modeled a zone of extremely low-resistivity (<10 ohm-m) underlying the upper 10 ft of the ground surface. The spatial extent of these low-resistivity zones is consistent with the conductivity anomalies mapped by the EM-31. The 2D-ERI data suggests a limited depth of burial (<15 ft bgs).

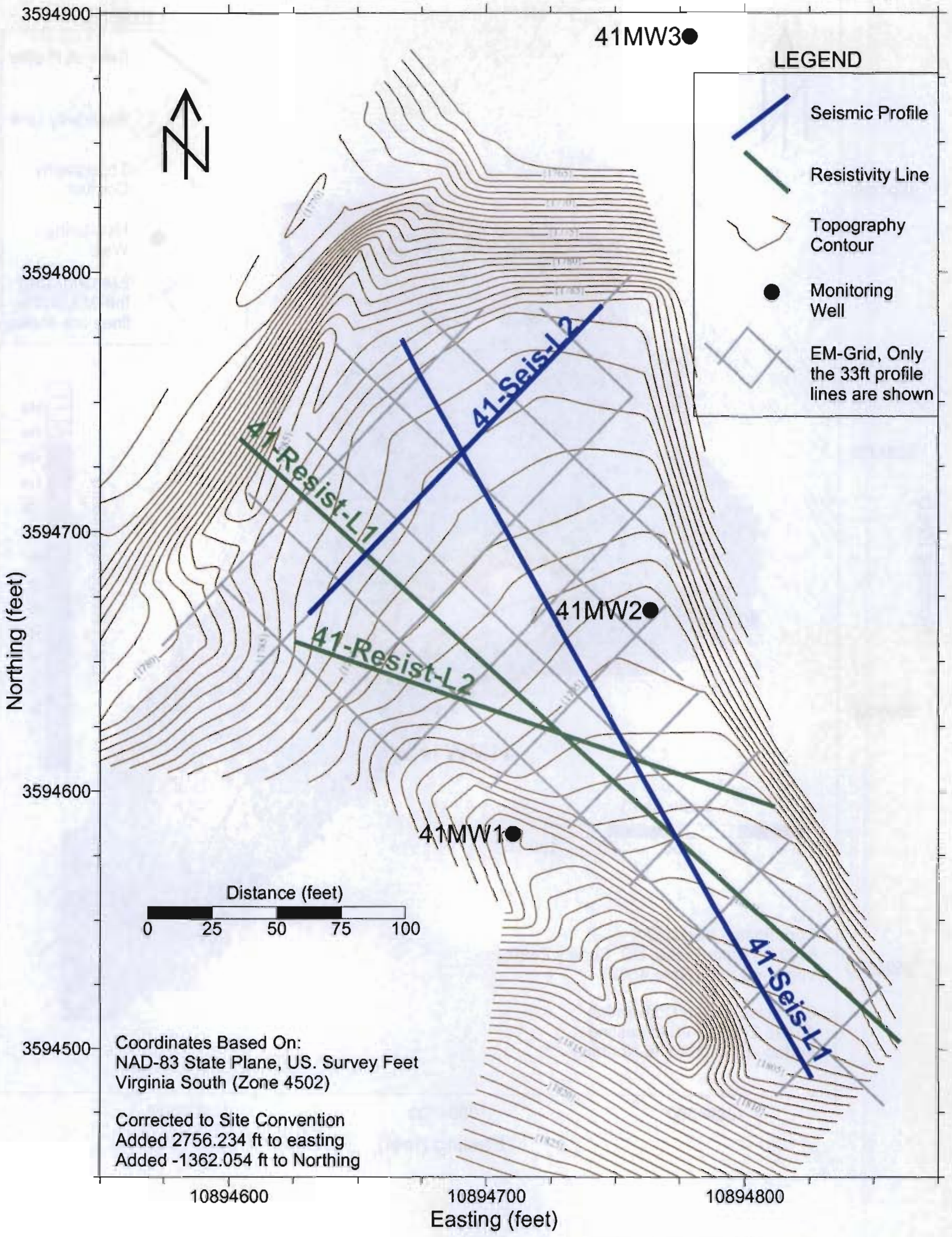

Figure D.1 SWMU 41 Base Map (Area A)

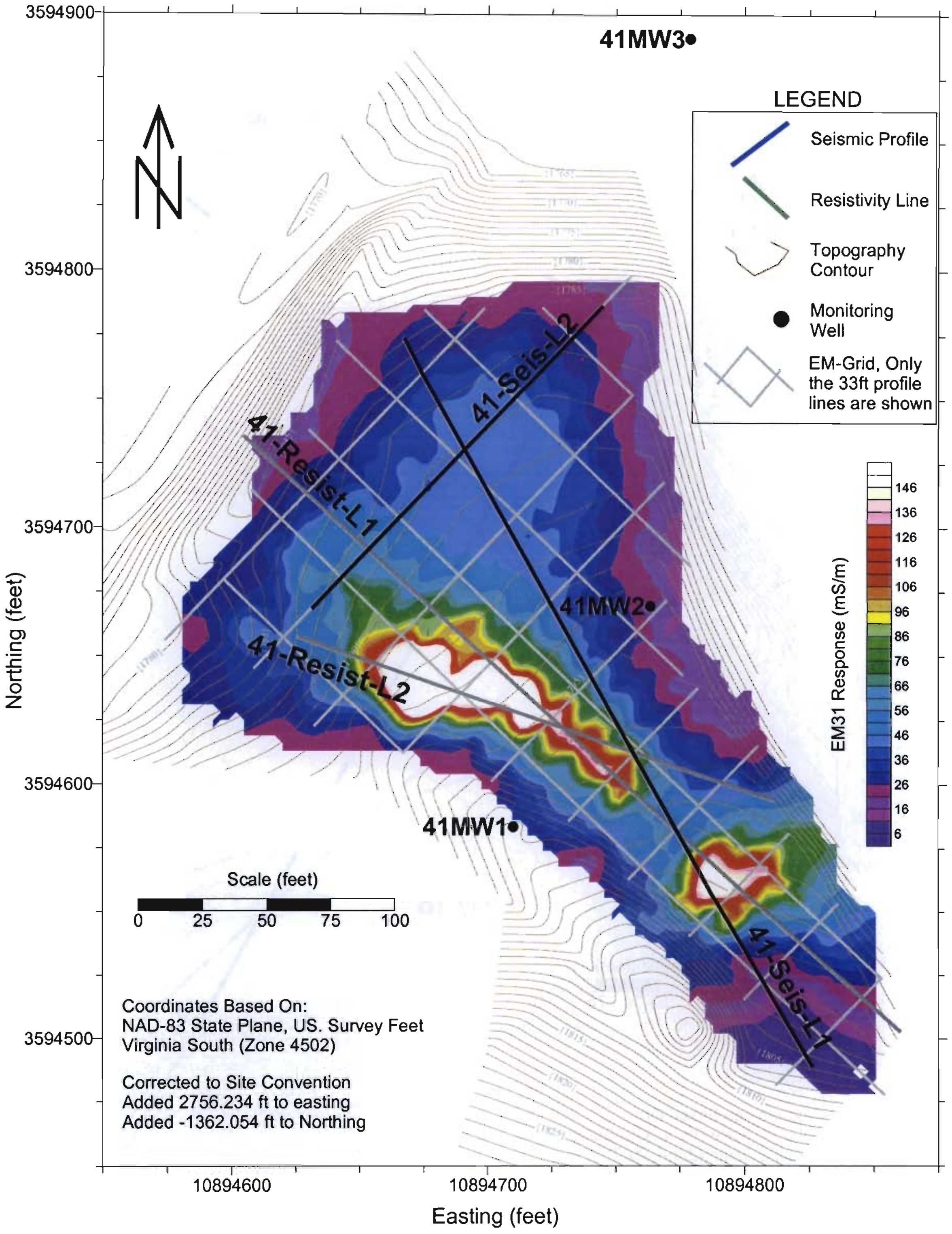

Figure D.2 EM-31 Conductivity Anomaly Map

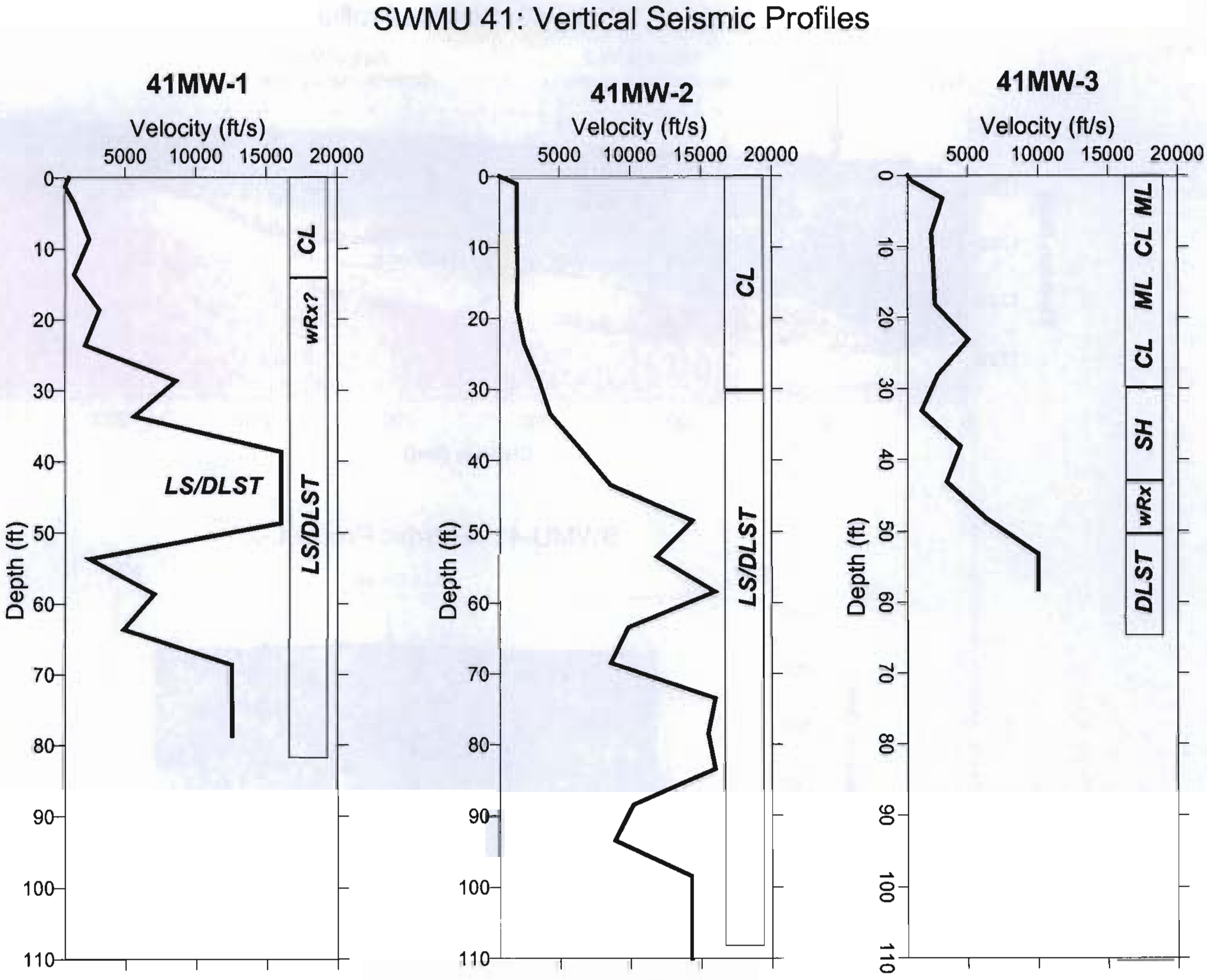

Figure D.3 Vertical Seismic Profiling at SWMU 41

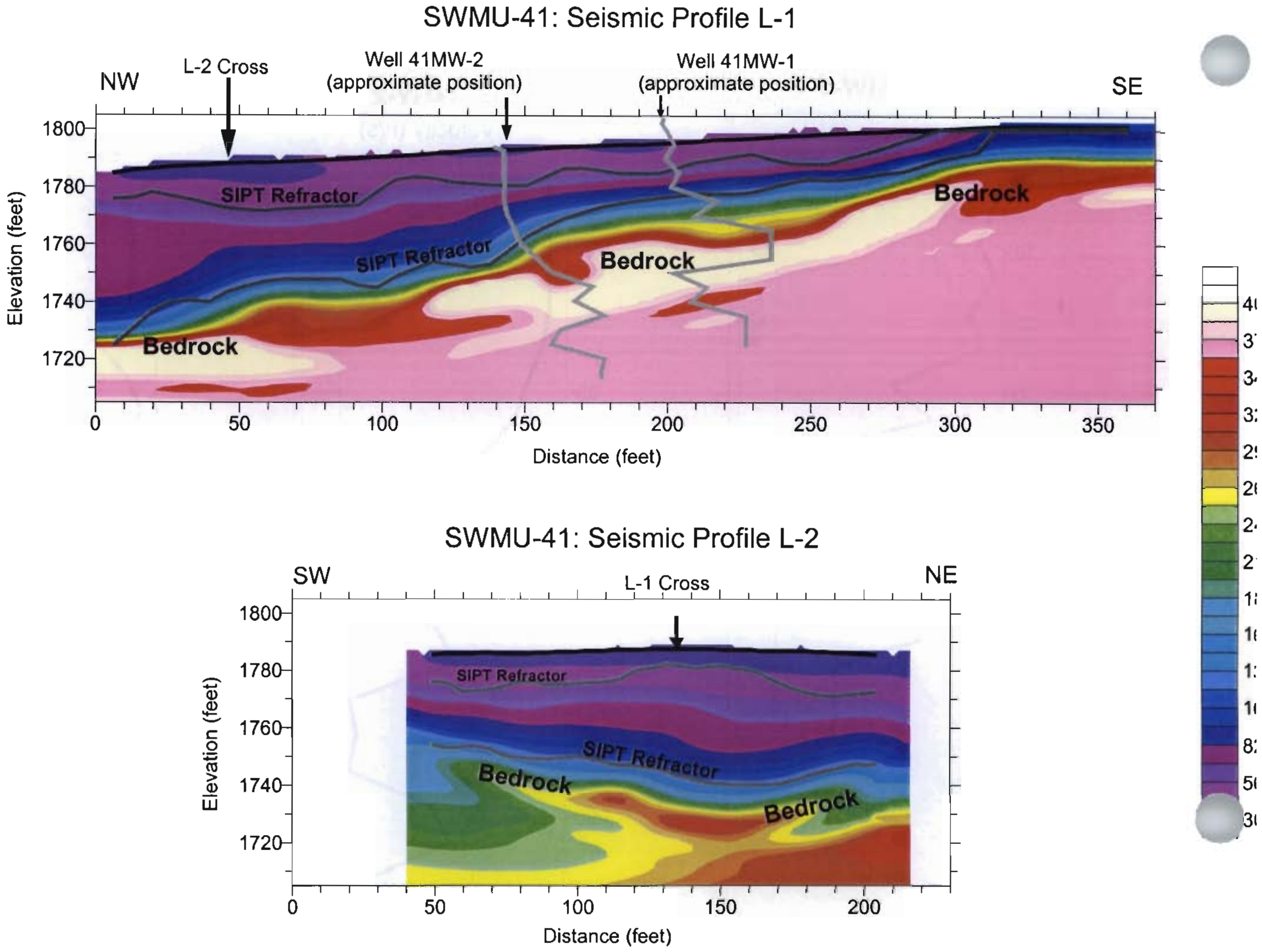

Figure D.4 Seismic Refraction Profiling Results

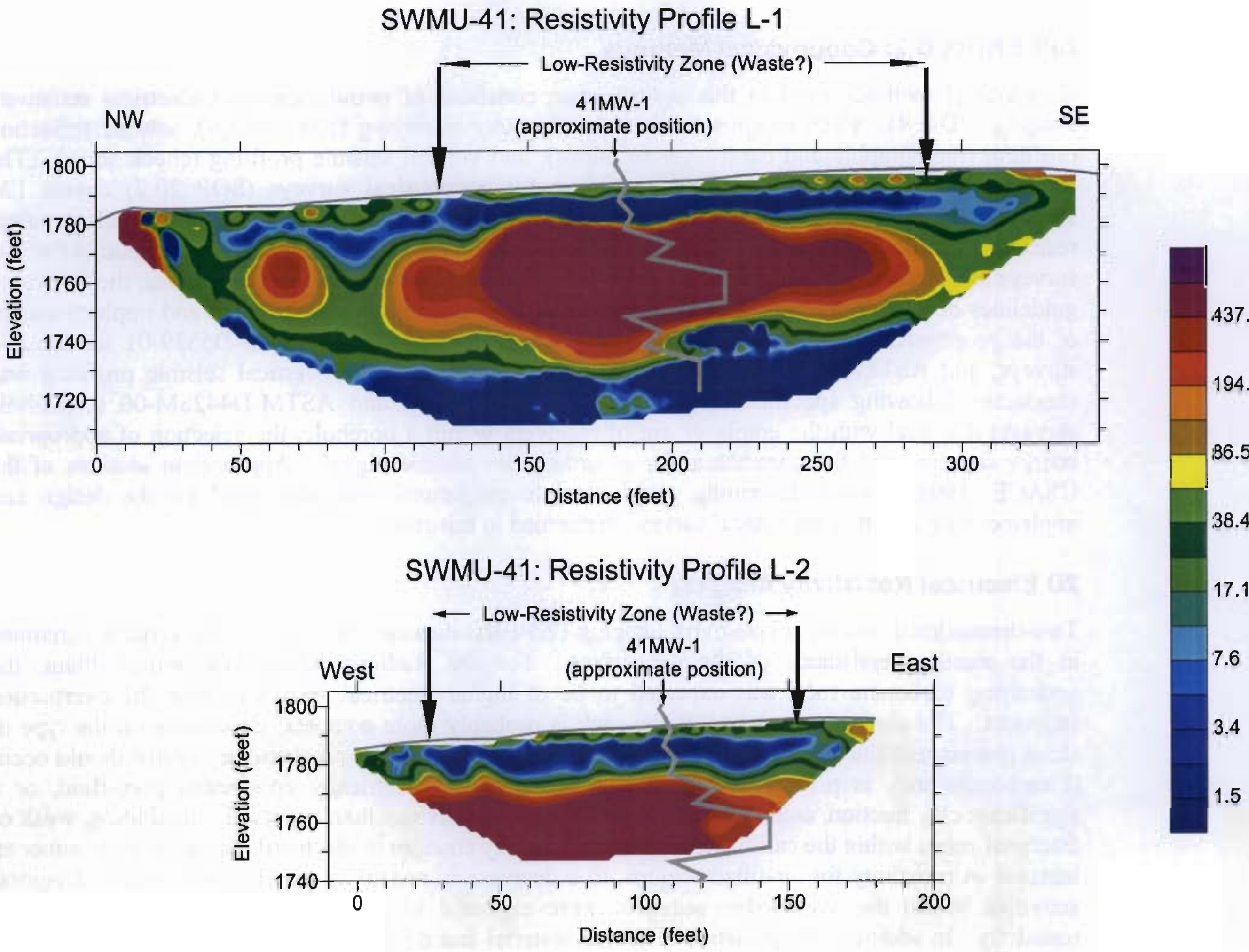

Figure D.5. 2D-ERI Model Results for SWMU 41

APPENDIX D.2: Geophysical Methods

Geophysical methods used in this investigation consisted of two-dimensional electrical resistivity imaging (2D-ERI), electromagnetic terrain-conductivity surveying (EM surveys), seismic refraction profiling (tomographic and earth-layer solutions), and vertical seismic profiling (check shots). The Radford specific standard operating procedure for geophysical surveys (SOP 20.7) covers EM surveys, and provides guidelines for vertical electrical sounding (VES) and horizontal electrical resistivity profiling, but does not cover the full two-dimensional resistivity and seismic refraction surveys used for this investigation. In order to meet data quality and project objectives, the following guidelines developed through ASTM International were used in the construction and implementation of the geophysical surveys; ASTM-D6431-99 for 2D-ERI profiling, ASTM-D5539-01 for the EM surveys, and ASTM-D5777-00 for the seismic-refraction surveys. Vertical seismic profiling was conducted following specific sections of ASTM-D65777-00 and ASTM-D4428M-00 (cross-hole surveys) that deal with the emplacement of receivers within a borehole, the selection of appropriate energy sources, and the parameters for recording the seismic signal. Appropriate sections of the USACE (1995) manual describing geophysical investigations were also used for the design and implementation of the geophysical surveys performed in this study.

2D Electrical Resistivity Imaging

Two-dimensional electrical resistivity imaging (2D-ERI) measures horizontal and vertical variations in the electrical-resistance of the subsurface. For the Radford Army Ammunition Plant, the underlying carbonate rock was expected to be of higher-electrical resistivity than the overburden sediment. The electrical response of the rock is probably more complex, depending on the type of strata present and the electrical properties of the pore fluid. Higher electrical-resistivity should occur if carbonate rock is present, though the presence of an electrically conductive pore-fluid, or a significant clay fraction, could alternately yield lower-resistivities than expected. In addition, weak or fractured zones within the carbonate rock should display changes in electrical character, from either an increase in resistivity for air-filled regions, to a decrease in resistivity for clayey intervals. Disposal activities within the overburden sediment were expected to produce a zone of lower electrical resistivity. In addition, the presence of buried material and degradation products may also lower the electrical response.

The Advanced Geosciences, Inc. (AGI) Sting/Swift™ system is an automatic multi-electrode system and earth resistivity meter that acquires data by passing an electric current between two electrodes and measuring the potential difference (voltage) between two separate electrodes. The measured voltage is a factor of the resistance of the earth material and the geometry of the electrode array (e.g. dipole-dipole, Schlumberger). Resistivity, an intrinsic property of the earth, is then calculated using the measured voltage, the amperage, and a geometric factor for the electrode array. The calculated resistivity value is actually an "apparent-resistivity" because it includes the resistances of the material that the electrical current passes through. A modeling procedure is then used to convert the measured apparent-resistivity data into earth-layer resistivity sections.

The electrodes used to measure the voltage difference are arranged in various geometries called arrays, and the calculated apparent-resistivity value is interpreted to represent a depth point at the center of an individual array. Depth of measurement is related to width of electrode separation, with greater electrode separation resulting in greater depths of penetration. Classically, two different techniques are used to assess the electrical resistivity of earth materials. In vertical electrical sounding (VES), electrodes are expanded about the center of an array to generate a layered electrical section at a single point (vertical profile). The lateral profiling technique uses an array with a fixed electrode separation, which is marched along a line to image lateral variations at a constant depth.

Two-dimensional electrical-resistivity imaging (2D-ERI) combines VES and lateral profiling into a single survey without the time-consuming process of constantly moving electrodes and reconnecting cables. In 2D-ERI a single cable connects a linear array of electrodes, which are turned on and off using a preprogrammed sequence via a controller box. The raw apparent-resistivity data are typically displayed as a pseudosection where the lateral position of the measurement point is placed at the center of the corresponding electrode array, and the depth of the measurement increases with increasing electrode spacing. Apparent-resistivity pseudosections are useful for performing quality-control checks and for examining whether manmade objects (e.g. buried utilities) have impacted the data set.

Apparent-resistivity pseudosections are converted, through a process termed inversion, into an electrical-resistivity cross-section showing true subsurface resistivities. RES2DINV (Loke, 1996), a commercially available program, was used to perform the two-dimensional inversion modeling. During the inversion, the subsurface is divided into a number of blocks equal to or less than the number of measurement points. A smoothness-constrained, least-squares inversion routine is used to estimate the resistivity value of each block, and finite-element or finite-difference forward modeling is used to calculate the resulting pseudosection. The model is iteratively corrected until an apparent-resistivity pseudosection calculated from the model converges with the measured apparent-resistivity pseudosection. A root-mean-square (RMS) error calculation of the difference between the two apparent-resistivity pseudosections is used as a measure of the degree of fit for the model. Maximum convergence often occurs within 3 to 5 iterations, after which RMS values do not change significantly and the model may start to become unstable.

Electromagnetic Terrain-Conductivity Surveying

Electromagnetic-induction instruments are used to measure the electrical conductivity of the near surface, and can be used to locate buried metallic objects. A transmitter coil is used to induce an electrical current into the ground, and the receiver coil measures the strength of the secondary magnetic field generated by these currents. Two components of the secondary magnetic field are recorded: 1) the quadrature-phase component which is used to measure the ground conductivity, and 2) the inphase component which is used for metallic detection due to its extreme sensitivity to large metallic objects (Geonics Ltd., 1991). The electrical conductivity of the ground is nearly linearly proportional to strength of the quadrature-phase component and is given in units of milli-siemens per meter (mS/m). The inphase measurement is the ratio of the secondary magnetic field to the primary field, and is expressed in parts per thousands (ppt).

The coils can be oriented in either a vertical dipole or horizontal dipole configuration. For the vertical dipole case, the axes of the coils are oriented perpendicular to the ground surface, and for the horizontal dipole, the axes are parallel to the ground surface. For both cases, the coils are maintained in a coplanar state. The vertical dipole orientation is generally preferred over the horizontal dipole because it provides for a greater investigative depth and is less sensitive to near surface variations.

The separation between the transmitter and receiver coils is the primary component that assesses the depth of penetration. Table A-1 lists the depth of investigation for different coil orientations and separations for the Geonics EM-31 and EM-34 instruments. The "Practical Depth" is roughly the depth at which 80% of the instrument response has occurred, and the "Effective Depth Range" is the where the instrument's overall response is the greatest. Thus, layers within the "Effective Depth Range" contribute most to the measured conductivity. The bolded numbers are for configurations used in this study.

Table D- 1. Effective penetration depth of the EM-31 and EM-34 Instruments (bold items indicate methods used in this report)

Instrument	Coil Orientation	Practical Depth	Effective Depth Range
EM-31 (3.3 m)	Horizontal Dipole	5.5 ft (1.7 m)	0-5.5 ft (0-1.7 m)
	Vertical Dipole	10 ft (3 m)	1.6-8.2 ft (0.5-2.5 m)
EM-34 (20 m)	Horizontal Dipole	33 ft (10 m)	0-33 ft (0-10 m)
	Vertical Dipole	59 ft (18 m)	10-49 ft (3-15 m)

Conductivity values obtained in EM surveying represent weighted mean values of the layer conductivities from the ground surface to the maximum depth that is sensed by the EM instrument (McNeill, 1980). If the underlying rock or sediment is uniform, the measured conductivity value will be the true conductivity. The amount of contribution to the measured conductivity from a single layer depends on its conductivity, depth, and thickness. In general, deeper layers contribute less to the final value than do near-surface layers, as do layers outside the effective depth range.

Geonics EM-31

The EM-31 transmitter and receiver coils are housed in a 3.5m long sensor boom, and a single person can operate the instrument (Geonics, 1991). A nominal depth of investigation of 18-ft (5.5-m) is realized when measurements are made using the vertical-dipole mode. Measurements are collected at ½ second intervals, and the quadrature and inphase components are collected simultaneously. This allows discrimination between anomalies sourced by buried metallic objects from those that are either lithologically or hydrologically controlled. Additional information consisting of the profile position, starting, and ending points, as well as fiducial mark locations along the profile, were recorded with an OMNI 720 data logger (Polycorder). This information is then downloaded to a personal computer for processing and display.

Seismic Refraction Tomography

Seismic refraction provides acoustic velocity and layer depth information (Redpath, 1973). The refraction method generally depends on an increase in seismic-wave velocity (speed of sound through earth material) with depth, though the newer tomographic codes presently available have the capability of handling a velocity inversion (zones of lower seismic velocity underlying zones of higher velocity). Both a tomographic model and an earth-layer (refractor) cross-section were implemented as processing outputs from the refraction profiling. The commercially available GeoCT-II code was used to construct the tomographic model, and the SIPT software package was used to generate the earth-layer cross-section.

In the refraction method, the seismic energy (or wave) bends (refracts) at interfaces between layers of different velocities. In the special case where the seismic wave has been refracted parallel to the interface, the seismic energy travels along this interface, generating a head wave that returns to the surface. A linear array of acoustic receivers (geophones) was used to record the travel-time of the first returning seismic signal. This information was plotted on a time-distance graph; for the case of plane layer geometry, the time-distance plot showed distinct linear segments for each layer where the inverse of the slope of a segment is equivalent to the apparent seismic velocity for a particular layer.

A multi-channel, engineering seismograph was used to record the seismic refraction information, and either a 500-lb weight drop elastic wave generator (EWG) or a 16-lb. sledgehammer were used as the energy source. Geophones (seismic-receivers) were spaced at a 3 ft interval during surveying. Shot points were acquired at every fifth geophone position, which allows input to the tomographic modeling software.

The processing sequence for the refraction data consisted of:

- Picking first arrival times of return energy for each shot;
- Assigning the array-geometric to the first arrival data;
- Inverting the first-arrival information for velocity and depth using the SIPT algorithm (delay-time method); and
- Constructing a tomographic model of the first-arrival information using the GeoCT-II code from GeoTomo LLC.

The SIPT method took advantage of the reverse-spread geometry and far offset shot points of the survey to compute depths to interfaces below each geophone. The algorithm employed the delay-time method of Pakiser and Black (1957) to calculate depth and position of refraction horizons. The generated refraction model was further refined using a ray-tracing algorithm which overcomes difficulties associated with dipping or undulating horizons.

The GeoCT-II software used a nonlinear, wave front migration technique to generate the velocity-depth cross-section. The shot-receiver geometries, measured first-arrival time information, and a starting velocity model were used in the geophysical inversion. Other a priori constraints such as known velocities from borehole logging and vertical seismic profiling can be used to help guide the inversion. Because a starting model is required by GeoCT-II, the robustness of the solution must be tested using a suite of starting models.

For the RFAAP processing, starting models ranged from simple two-layer cases to vertical velocity gradients, and to the more complex SIPT solution. Different model outputs from GeoCT-II were compared in order to discern where possible modeling artifacts occur. The resulting velocity-depth cross-sections, regardless of the starting model, appeared to converge to the solutions presented in the report (based on the SIPT solution as starting model).

Vertical Seismic Profiling

Vertical seismic profiles (check shots) were used to measure the in-situ velocity of the sediment and rock penetrated by wells at the site. These data provided confirmatory velocity information for the refraction models. The general configuration for recording the downhole seismic data consisted of a three-component geophone, implementing 40Hz receiver elements. The downhole geophone was moved in 5-ft increments within the borehole (5-ft receiver spacing). A sledgehammer was used as the energy source, and is placed at offsets up to 15-ft from the borehole. Three additional geophones were placed on the surface at offsets up to 20-ft from the borehole, and were required to resolve shot-timing variations that occur when using impact sources.

The velocity of the earth material and the type of well construction used governed the placement of the sledgehammer source, vertical spacing of the downhole receiver, and the sampling rate. The objective was to record a seismic signal that has been transmitted through the earth, and not along the borehole wall or borehole casing. This required offsetting the shot point from 5 to 15 ft from the borehole so that the velocity of the near surface material (upper 30 ft) could be measured.

The vertical spacing used was primarily dependent on expected velocities within the subsurface and the recording limitations afforded by the seismic gear. Data recorded at the 0.1 ms interval (10,000 samples per second) used for RFAAP allowed discerning arrival time changes as small as 0.2 ms (twice the sampling interval). Given an expected velocity range of 10,000 to 25,000 ft/s, the 5 ft spacing used yielded theoretical arrival time changes from 0.2 to 0.5 ms.

Data processing consisted of the following:

- Picked first arrival energy for the downhole and reference geophones;
- Sorted the arrival-time data by depth point;

- Computed and applied shot-timing corrections using the arrival time picks obtained from the reference geophones;
- Computed the average velocity to a receiver station using the straight-line distance from the shot to the receiver and the corrected arrival time;
- Converted to vertical travel-time using the depth point for the receiver and the computed average velocities; and
- Computed interval velocities using least squares line-fitting algorithm to estimate the slope (inverse of velocity) between measurement points. The least-squares operator has the advantage of smoothing over small time-picking errors.
- Where available, the data were correlated with the lithologic information and other available borehole geophysical data.

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APPENDIX E

FORMS

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Form E-1
Work Plan Revision Form
Work Plan – Quality Assurance Plan – Health and Safety Plan – Addendum No. 18
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

SITE DESIGNATION / LOCATION:

Radford Army Ammunition Plant
Radford, VA

SUBJECT:

Section: ______________________________

Addendum: ____________________________

Version: ______________________________

Effective Date: _________________________

Approved by:
Field Operations Leader

____

Date: ________________________________

Concurrence:
Project Manager

____

Date ________________________________

Sheet _____ of _____

Form E-2
Worker Acknowledgement Form
SWMU 41 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Document: Master Work Plan/QAP/HSP and Work Plan Addendum No. 18

Version: Final

Project: Radford Army Ammunition Plant

Location: Red Water Ash Burial Ground, SWMU 41

Prior to the initiation of field activities, I have been given an opportunity to read and question the contents of this Master Work Plan/QAP/HSP, this Site-Specific Addendum, and approved revisions through the number listed above. With my signature, I certify that I have read, understood, and agree to comply with the information and directions set forth in these plans. I further certify that I am in full compliance with 20 Code of Federal Regulations (CFR) 1910.120 concerning training and medical monitoring requirements.

Site Personnel:

Name (please print)	**Signature**	**Date**