

RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Work Plan Addendum No. 17 SWMU 51 RCRA Facility Investigation



Prepared for:

USACE Baltimore District
10 S. Howard St.
Baltimore, MD 21201



Prepared by:

Shaw Environmental, Inc.
2113 Emmorton Park Rd.
Edgewood, MD 21040
Contract No. DACA31-02-0080

Final Document

February 2004

7.

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

Date: March 1, 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 51
Draft revised *Work Plan Addendum 17*
Document submittal and review

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's February, 2004 draft revised *Work Plan Addendum 17* for the investigation of SWMU 51, located at the Radford Army Ammunition Plant (RFAAP). Based upon our review, the draft revised *Work Plan Addendum 17* for the investigation of SWMU 51 is approved. In accordance with Part II. (E) (5) of RFAAP's Corrective Action Permit, the *Work Plan Addendum 17* for SWMU 51 is now considered final. Please forward two copies of the final *Work Plan Addendum 17* to EPA for our files.

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

Sincerely,



Robert Thomson, PE
Federal Facilities

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

7.
McKenna, Jim

From: Parks, Jeffrey [Jeffrey.Parks@shawgrp.com]
Sent: Monday, March 01, 2004 11:36 AM
To: Thomson.Bob@epamail.epa.gov
Cc: John.E.Tesner@nab02.usace.army.mil; Jerome.Redder@ATK.COM;
Jim_McKenna@ATK.COM
Subject: RE: Review of SWMU 58 draft RFI

My apologies to all. I should have clarified in the response to comments that when we made the requested change of samples from stratigraphic characterization samples (51SBC) to chemical characterization samples (51SB); this changed the numbering sequence of the samples (as developed in the WPA). However the location of the samples did not change, and the figure showing the locations of the revised chemical and stratigraphic samples is correct.

Jeff Parks

-----Original Message-----

From: Thomson.Bob@epamail.epa.gov [mailto:Thomson.Bob@epamail.epa.gov]
Sent: Monday, March 01, 2004 10:51 AM
To: Jim_McKenna@ATK.com
Cc: Parks, Jeffrey; Redder, Jerome; 'john e tesner'
Subject: RE: Review of SWMU 58 draft RFI

This is okay...

Rob

Also, just a quick note on SWMU 51, WP Addendum 17. We reviewed the Feb, 2004 draft WP Addendum with the corrected/updated Figure 1-7. The Feb. 2004 draft WP Addendum is okay, and an approval letter will be forthcoming. However, the accompanying Feb. 26, 2004 cover letter mentions the addition of chemical sampling locations (51SBC 10, 51SBC18 and 51SBC16). Please note that these sampling locations are not reflected on the revised Figure 1-7, but not to worry as other samples are. The nomenclature for the sampling locations must have been mixed up with the generation of the revised Figure. However, the correct number of sampling locations is all that matters. Sure had us scratching our heads for a moment.....

Rob

"McKenna, Jim"

<jim.mckenna@us.a To: Bob
Thomson/R3/USEPA/US@EPA
rmy.mil> cc: "Redder,
Jerome" <Jerome.Redder@ATK.COM>, 'john e tesner'
<john.e.tesner@usace.army.mil>, "Parks, Jeffrey N"
<Jeffrey.Parks@shawgrp.com>
03/01/2004 10:35 Subject: RE: Review of
SWMU 58 draft RFI
AM

Rob, Yes there was a response but apparently it did not get attached to
the
12/23/2003 transmittal letter. The responses are in the attached file.
Is
this ok or do you want us to send a hard copy?

Jim McKenna

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

-----Original Message-----

From: Thomson.Bob@epamail.epa.gov [mailto:Thomson.Bob@epamail.epa.gov]
Sent: Monday, March 01, 2004 10:23 AM
To: McKenna, Jim; Redder, Jerome
Cc: John.E.Tesner@nab02.usace.army.mil
Subject: Review of SWMU 58 draft RFI

Hi Folks:

EPA is currently in receipt of the Dec 2003/Jan 2004 version of the
draft RFI for SWUM 58. In reviewing the draft final submittal, we noted
that for all three copies of the draft final report at Region III, there
did not appear to be a response to EPA's September 18, 2003 review

comments. Is there a response to comments out there?

Thanks...Rob Thomson

(See attached file: SWMU 58 RFI RTC attachment.doc)

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February 26, 2004

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

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

Subject: Work Plan Addendum 17, SWMU 51 RCRA Facility Investigation, Final February 2004
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is one certified copy of Work Plan Addendum 17, SWMU 51 RCRA Facility Investigation, Final February 2004 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.

This document has been revised to address the single comment contained in your February 2, 2004 letter as follows:

EPA Comment

Figure 1-7, Proposed Soil Boring Locations, on page 1-18 shows the proposed sampling locations for the site. It is unclear why so few samples are being collected for chemical analysis in the area of the trench, i.e. in the disposal area. It is recommended that at least one additional sample should be collected within the area of the trench (either 51SBC10 or 51SBC18) for chemical analysis. The reliance on geophysical surveys to foster an assumption that the material in the trench disposal area is "homogenous" really has little bearing on determining the nature and extent of contamination in the trench. This is especially true when an assumed homogenous cover, approximately 5-feet thick, is reported to be above the trench area, which could influence any geophysics performed at the site.

RFAAP Response

In order to facilitate approval of Work Plan Addendum (WPA) 17, RFAAP agrees to collect additional soil samples as requested in this comment and in EPA's original comment #12 (USEPA Comments dated 21 November 2003). Additional soil samples will be collected at three locations: two locations inside the trench boundaries, 51SBC10 and 51SBC18; and one location outside the trench area, 51SBC16 (Figure 1-7, WPA 17). Four samples will be collected from each of the borings within the trench area and be analyzed for TCL VOCs, SVOCs, PCBs, PAHs, explosives, TAL inorganics and dioxin/ furans. The surface soil sample at location 51SBC10 will additionally be analyzed for TCL pesticides and herbicides. Three soil samples will be collected from the boring outside the trench area and will be analyzed for TCL VOCs, SVOCs, PAHs, explosives and TAL inorganics. Soil samples will be collected as outlined in WPA 17.

Please coordinate with and provide any questions or comments to myself at (540) 6398266, Jerry Redder of my staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 639-8641.

Sincerely,

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

Enclosure

Page 2

February 26, 2004

Mr. Robert Thomson - EPA

Work Plan Addendum 17, SWMU 51 RCRA Facility Investigation

w/o enclosure

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

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

Coordination:


J. McKenna

Concerning the following:

91

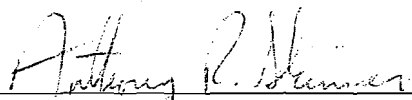
Work Plan Addendum 17
SWMU 51 RCRA Facility Investigation, Final February 2004
Radford Army Ammunition Plant

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

SIGNATURE:

PRINTED NAME:

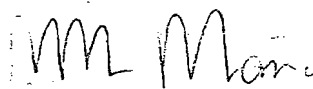
TITLE:


Anthony R. Skinner
LTC, CM, Commanding
Radford AAP

SIGNATURE:

PRINTED NAME:

TITLE:


Anthony Miano
Vice President Operations
Alliant Ammunition and Powder Company, LLC

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

February 2, 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 51
Work Plan Addendum 17
Review of the Army's January 7, 2004 Response to EPA's 11/21/03 review letter

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's January 7, 2004 response to EPA's November 21, 2003 letter concerning the Army's draft *Work Plan Addendum 17* for the investigation of SWMU 51, located at the Radford Army Ammunition Plant (RFAAP). Outlined below, please find EPA's remaining concern based upon the Army's January 7, 2004 response:

- 1) **Figure 1-7, Proposed Soil Boring Locations, on page 1-18** shows the proposed sampling locations for the site. It is unclear why so few samples are being collected for chemical analysis in the area of the trench, i.e. in the disposal area. It is recommended that at least one additional sample should be collected within the area of the trench (either 51SBC10 or 51SBC18) for chemical analysis. The reliance

on geophysical surveys to foster an assumption that the material in the trench disposal area is "homogenous" really has little bearing on determining the nature and extent of contamination in the trench. This is especially true when an assumed homogenous cover, approximately 5-feet thick, is reported to be above the trench area, which could influence any geophysics performed at the site.

This concludes EPA's review of the Army's January 7, 2004 response to EPA's November 21, 2003 letter concerning the Army's draft *Work Plan Addendum 17* for the investigation of SWMU 51, located at the RFAAP. The referenced draft *Work Plan* is disapproved by EPA in its current form, and must be revised to reflect the comment 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, PE
Federal Facilities Branch

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



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 17, SWMU 51 RCRA Facility Investigation, Final December 2003
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is one certified copy of Work Plan Addendum 17, SWMU 51 RCRA Facility Investigation, 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 November 21, 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,


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
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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:

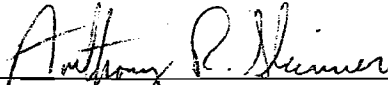

J. McKenna

Concerning the following:

Work Plan Addendum 17
SWMU 51 RCRA Facility Investigation, 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:
PRINTED NAME:
TITLE:



Anthony R. Skinner
LTC, CM, Commanding
Radford AAP

SIGNATURE:
PRINTED NAME:
TITLE:



Anthony Miano
Vice President Operations
Alliant Ammunition and Powder Company, LLC

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Response to USEPA Comments dated 21 November 2003

for

Draft Work Plan Addendum 017

Dated July 2003

General Response

Please note that the plan of action and associated programmatic funding for SWMU 51 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 51 assumes that it is a source that has not released to groundwater, but might require some sort of remedial/removal action. Source removal is the most certain method of achieving regulatory requirements in karst geological settings. Work Plan Addendum 017 (and generally work plan addenda for RFAAP's SWMU's) 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 17 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 51.

EPA Comment 1

Section 1.1, Introduction, page 1-1: The second paragraph states that "there are no records indicating that disposal activities have taken place at SWMU [solid waste management unit] 51 since 1972." However, the first paragraph on page 1-11 states that "the aerial photographic analysis of SWMU 51 indicated that activity was first noted at the site in 1975, where a trench that appeared to be empty was visible in the photograph. By 1981, the trench had been filled and revegetating ground scar was the sole feature that remains." Please revise the WPA to resolve this discrepancy and to retain information that most accurately reflects the operational history of the unit.

RFAAP Response

Text will be revised as follows:

"The Dames and Moore 1992 RFI report stated that an estimated 10 tons of red water ash was reportedly disposed at the site from 1968 to 1972. There are no records available after 1972 regarding activities at SWMU 51; however, aerial photographic analysis indicated that there was an open trench at the site in a 1975 photograph. A 1981 aerial photograph indicated that the trench had been filled and a revegetating ground scar was the major site feature visible."

EPA Comment 2

Section 1.1, Introduction, page 1-1: One of the objectives of the RCRA Facility Investigation (RFI) at SWMU 51 is described as (third bullet) "generate sufficient data to evaluate residual risk ..." emphasis added. The term residual risk is generally used when a site has been remediated to some level (e.g., preliminary remediation goals) and after confirmatory sampling to address risk from the residual contamination not addressed by the remedial action. Based on the information provided in the WPA, it appears no removal action was undertaken at

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SWMU 51. Please revise the WPA to remove the term "residual" from the text or provide data related to previous remedial actions at the site.

RFAAP Response

The term "residual" will be removed from the text as requested.

EPA Comment 3

Page 1-1: Please describe red water and red water ash in the text of the Work Plan.

RFAAP Response

The following text will be added to the WPA:

Red water is a USEPA listed hazardous waste (K047) and is listed solely for reactivity (40 CFR 261.32). During the production and formulation of TNT and TNT containing formulations and products, an alkaline, red colored aqueous waste is generated (red water). This waste stream is composed of TNT purification filtrate, air pollution control scrubber effluent, washwater from cleaning of equipment and facilities, and washwater from product washdown operations.

Red water was concentrated by evaporation and the red water sludge was burned in rotary kilns located in the TNT manufacturing area (USATHAMA, 1976). The ash from the red water sludge burned in the kilns is referred to as red water ash.

Red water and red water ash will be described in Section 1.2.1.2 of the text.

EPA Comment 4

Section 1.2.1.1, Environmental Setting, page 1-5: Under "Geology and Soil," it is stated that "geologic cross sections A-A' and B-B' (Figures 1-3 and 1-4, respectively) are provided to illustrate the subsurface conditions in the vicinity of SWMU 51." It is not clear how the information depicted on these cross sections was obtained or determined. For example, based on the plan view presented on Figure 1-2, there are no monitoring wells or soil borings located along the cross section for SWMU 28. However, this unit is shown on cross section B-B' as having fill material that is approximately 20 feet deep and more than 250 feet wide. As an additional example, only one monitoring well is located on the southeast corner of SWMU 51, and it is not clear how the details provided in cross sections A-A' and B-B' were determined for this unit. Please revise the WPA to clarify how the definitive detailed geologic cross sections were developed and provide any additional borings/monitoring wells that may have been used on the plan view (Figure 1-2) or indicate that such information will be provided in the RFI Report.

RFAAP Response

The text will be clarified. Information for SWMU 28 will be removed from the cross section. The removal of this information should not affect this WPA. Information on SWMU 51 was based on information gathered from the SWMU 51 site specific geophysical surveys, which is why the dashed inferred contact line was used on the figures. A footnote will be added to the figures indicating that information on SWMU 51 presented on the cross sections was inferred from geophysical rather than geological data.

EPA Comment 5

Section 1.2.2, Conceptual Site Model, page 1-11: The exposure pathways presented in Table 1-2 do not consider an adult or child trespasser for surface soil contamination. In addition, only construction workers were considered for the potential future use of groundwater. Since the conceptual site model (CSM) considers both the industrial and residential scenarios, the potential receptors should include adult or child trespasser for surface soil, and adult and children for use of groundwater. Since there are no known restrictions for groundwater use, this is mandatory. Please revise the CSM/potential exposure pathways and receptors accordingly.

RFAAP Response

Adult and child residential receptors for soil will be added to the CSM. This approach will be more conservative than the trespasser scenario. Additionally, a maintenance worker scenario will be added to the CSM. This receptor would be similar to the trespasser receptor; therefore, the trespasser scenario will not be evaluated. Because of the karst geology at RFAAP, groundwater flow is complex. Therefore, groundwater is being addressed separately as part of WPA 009. The RFI will address the completeness of the groundwater pathway.

EPA Comment 6

Section 1.2.2, Conceptual Site Model, page 1-13: The third paragraph on this page indicates that data is insufficient to conclusively state whether the groundwater migration pathway at SWMU 51 is complete and that is considered unknown. In the fourth paragraph it is stated that "groundwater at the site is being addressed in Master Work Plan Addendum 009, Horseshoe Area Groundwater Study (IT, 2002)." As one of the objectives of the RFI is to generate sufficient data to evaluate potential risk on human health and the environment, please clarify where and when this data gap will be filled or include a statement in the WPA that the completeness of the groundwater exposure pathway will be determined before the conduct of risk assessment.

RFAAP Response

As noted, groundwater is being addressed separately in WPA 009. The completeness of the groundwater pathway at SWMU 51 will be assessed in the RFI report with data collected from the sampling strategy as proposed.

EPA Comment 7

Section 1.2.2, Conceptual Site Model, on page 1-13: states that surface water and sediment are considered incomplete pathways because surface water is not present at the site. This pathway is also not identified as a pathway in Table 1-2 on page 1-13. Because contaminated groundwater can discharge to the surface and contaminate surface water and sediment, this pathway may still be complete. This pathway can be addressed as part of the groundwater study mentioned previously in the same section. This issue should be clarified in the text and in Table 1-2.

RFAAP Response

The text will be clarified to indicate that groundwater does not discharge at the site; therefore, the surface water and sediment pathway at the site is not complete. However, contamination of surface water and/or sediment from groundwater discharge offsite will be addressed by the ongoing groundwater study (WPA 009).

EPA Comment 8

Section 1.2.2, Conceptual Site Model, page 1-13: The last paragraph states “air is considered an incomplete pathway because the study area is grass covered and volatilization is not an issue.” Based on the cross sections A-A’ and B-B’, fill material (or potential waste) begins at the surface, and insufficient data exist to determine whether the constituents in the surface and subsurface soil/fill volatilize or not. Therefore, the statement that volatilization is not an issue is not supported by data. If the waste is assumed to contain constituents with propensity to volatilize or to be absorbed in the root/trunk/leaf system of the vegetative cover, then the air pathway will be complete. Please remove this statement and indicate that the air pathway is unknown and will be determined during the RFI. The CSM should be revised accordingly.

RFAAP Response

Because of the type of waste disposed (ash) and the age of the site, volatilization of constituents to the air is not expected. The CSM will be revised to indicate that air is a potential pathway and that the completeness of the pathway is unknown, but will be assessed in the RFI report based on the results of the current sampling strategy. Cross sections A-A’ and B-B’ (Figures 1-3 and 1-4, respectively), will also be revised to indicate that waste in the trench is covered by five feet of soil based on the results of the geophysical surveys.

EPA Comment 9

Table 1.2, Potential Exposure Pathways and Receptors, on page 1-13: does not identify exposure of subsurface soil to terrestrial receptors as a pathway. Depending on the depth analyzed, invertebrates and burrowing mammals can be exposed to subsurface soil. This pathway should be identified in the report.

RFAAP Response

Results of the geophysical surveys indicate a five foot soil cover. To assess potential ecological impacts, surface soil (0-1 ft bgs or 0-2 ft bgs for previous sampling) has been selected for two primary reasons:

1. To maintain consistency with other RFAAP ecological risk assessment documents.
2. To address the most important ecological soil depth exposure interval, as soil depths below two feet would be infrequently contacted.

If results of the stratigraphic profiling indicate that the soil cover is not uniform or that contamination is shallower than the assumed five feet, this potential pathway will be re-evaluated in the RFI report.

EPA Comment 10

Figure 1-2: The estimated groundwater flow direction as depicted on Figure 1-2 is confusing. How about utilizing groundwater table and/or potentiometric surface contours instead.

RFAAP Response

General groundwater flow direction is inferred from monitoring well static water levels and topography. However, because of the karst and fractured bedrock geology, potentiometric maps tend to be inaccurate and unreliable. Because SWMU 51 is topographically elevated, groundwater likely flows in a semi-radial direction to the east. The arrows on Figure 1-2 will be joined by a band to illustrate the perceived direction of groundwater movement.

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EPA Comment 11

Section 1.3, Planned Activities, page 1-14: This section indicates that the selection of the area to be investigated and the soil samples to be collected follows the procedures provided in standard operating procedure (SOP) 30.7. Please revise this section to discuss the sampling methodology or combination of methodologies to be used from among the methods described in the SOP 30.7.

RFAAP Response

The text will be revised to include specifics of the sampling methodologies proposed during investigative sampling activities at SWMU 51.

EPA Comment 12

Figure 1-7, Proposed Soil Boring Locations, on page 1-18: shows the proposed sampling locations for the site. It is unclear why so few samples are being collected for chemical analysis in the area of the trench. For additional characterization for the ecological risk assessment, two additional samples should be collected within the area of the trench (51SBC10 and 51SBC18) for chemical analysis. For more complete coverage of the grid, one additional sample should be collected outside the trench area (51SBC16). This additional analysis is most important for surface soil.

RFAAP Response

As discussed in Section 1.3.1, several geophysical surveys were conducted at SWMU 51 as part of this WPA. The purpose of the geophysical surveys and the stratigraphic profiling of the site is to limit the number of samples necessary to characterize the site. Since the geophysical surveys indicated a fairly homogenous mass in the trench area, the proposed number of trench samples is considered to be sufficient to chemically characterize the trench waste. There are eight proposed surface soil samples in an approximate 20 X 200 foot area (0.09 acres); this would be equivalent to 89 samples on a one acre site, which would appear to be an adequate sampling density. It is unclear how three additional surface soil samples would provide additional critical information to characterize waste buried in a trench.

EPA Comment 13

Section 1.3.2, Proposed Soil Borings, page 1-22: Under "Boring for Physical Analysis" for Atterberg limits American Society of Testing and Materials (ASTM) D4318-00 is specified. ASTM D4318-00 is the standard test methods for liquid limit, plastic limit, and plasticity index of soils. The liquid limit and plastic limit of soils (along with the shrinkage limit [ASTM D4943-02]) are often collectively referred to as the Atterberg limits. Please clarify if testing the soil using ASTM D4943-02 (Standard Test Method for Shrinkage Factors of Soil by the Wax Method) is implied by the use of the term "Atterburg [sic] limits" and/or specify testing of the soil using ASTM D4943-02 to determine shrinkage factors of soil.

The historical standards for measurement of hydraulic conductivity - using a rigid wall, compaction-mold permeameter - are ASTM D5856-95 and ASTM D5856-95(2002). The current active standard is ASTM D5856-95(2002)e1. Please revise this section to correct the reference provided in the text of the WPA for this standard.

21

The current active methods referenced for "soil porosity" determination are ASTM D854-02 and ASTM D2937-00e1, respectively. Please revise the references provided in the WPA.

The above suggested corrections should also be made for Section 2.5.5 (Physical/ Geotechnical Analysis).

RFAAP Response

While the definition of Atterburg limits can include shrinking limits in soil, current usage usually retains the plastic limit, liquid limit, and the plasticity number (or index). The shrinkage limit would be of limited use in the mixed sand, silt, and clay at SWMU 51. Therefore, to remain consistent with previous physical testing of soil at Radford RFAAP Ammunition Plant (RFAAP), ASTM D4318-00 will be performed.

The text will be modified with the current standard for measurement of hydraulic conductivity, ASTM D5856-95(2002)e1.

The text will be modified to show the current soil porosity methods ASTM D854-02 and ASTM D2937-00e1.

EPA Comment 14

Section 1.3.2, Proposed Soil Borings, page 1-22: This section indicates that during soil boring advancement, a portable photoionization detector (PID) will be used for screening volatile organic compounds (VOCs) during the investigation. A PID alone may not detect 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 in surface and subsurface soils were not investigated in the past, it must be ensured that a detector or combination of detectors which will permit the detection of all VOCs will be used during the investigation. The "Monitoring Plan" presented in Section 3.5 should also be revised.

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 51 which is a former red water sludge and ash (explosives production waste) disposal site. 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 will 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 15

Table 1-3, Summary of Proposed RFI Borings, page 1-19: This table indicates that only one boring (51SB3), which is located inside the probable boundaries of the trench, will be used for

physical analysis. It is not clear why physical analysis is confined to only this boring location and how it was determined that this location will yield data representative of the trench. It is recommended that at least one additional location within the trench and another location outside the probable boundaries of the trench be selected for physical analysis. The resulting data will be more representative and will help in comparing the physical parameters of more than one data point. In addition, as stated in the WPA, since "the analyses are intended to enhance the understanding of the physical nature of the soil to provide data necessary for constituent migration modeling, if necessary," vertical variation alone should not be considered sufficient for adequate physical characterization of the soil/fill.

RFAAP Response

The 28 continuous logged borings should provide sufficient field evidence (e.g. color, texture, plasticity, composition) to assess whether site soil conditions are fairly homogeneous throughout the site. The site is approximately 20 X 200 feet. If the lithologic data indicates a wide variety of soil conditions, a second set of samples for physical testing will be collected.

EPA Comment 16

Table 1-4, Proposed Chemical Sampling and Analysis Plan, page 1-20: This table does not list cyanide as one of the analytes. The Radford RFAAP Ammunition Plant (RFAAP) Site Screening Process (SSP) (October 26, 2001) requires that cyanide be included in the analytical suit for all media sampled. Please revise the table to specifically indicate that cyanide will be analyzed for in the samples collected for target analyte list (TAL) inorganic chemicals.

RFAAP Response

Cyanide will be added to the analyte list for TAL inorganic sample locations.

EPA Comment 17

Table 1-4, Proposed Chemical Sampling and Analysis Plan, page 1-21: The "Sample Depth Notes" at the end of this table indicate that the subsurface soil samples collected outside the trench limits will be collected from slightly deeper depth intervals than those collected from within the trench limits. It is not clear why two different depths are implemented for the two areas, and how and when the depths marked with "TBD" will be determined. In addition, since the limits of the trench will be verified by the investigative activities proposed, it is inappropriate at this time to consider that Boring Locations 51SB1, 51SB5, 51SB6, 51SB7, and 51SB8 are outside the trench boundaries. Please revise the WPA to clarify these issues and state that whether a location is in or outside the trench boundaries will be determined after the existing geophysical data are "ground-truthed" to the stratigraphic data generated from the WPA activities.

RFAAP Response

Section 1.3.2, page 1-21, states that "Depths to intermediate samples will be adjusted to account for possible diffusion from the trench area." Sample depths identified as "TBD" will be established by the 28 continuously logged borings advanced at the site. Section 1.3.2 also states that 28 continuously logged borings (to bedrock) will be advanced to "ensure that chemical samples are collected from the proper depths and locations." This plan will ensure that borings 51SB1, 5, 6, 7, and 8 are advanced outside the trench area.

67

Figure 1-7 presents the general conceptual location of sampling locations. Sample locations will be adjusted as additional information is gathered.

EPA Comment 18

Table 1-4, Proposed Chemical Sampling and Analysis Plan, page 1-21: The "Sample Depth Notes" at the end of this table indicate that surface soil samples will be collected at a depth of 0-0.5 feet (ft) below ground surface (bgs) and 0.5-1.0 ft bgs for VOCs. Based on the surface soil sample depths specified above and the definitions provided for the "maximum depth," "within trench," and "beneath trench" for the subsurface soil sample depths, it appears no samples are proposed to be collected from the interval 1.0-5.0 ft bgs. Please revise the WPA to clarify if samples will be collected from 1.0-5.0 ft bgs.

RFAAP Response

Interpretation of the geophysical survey (Section 1.3.1, page 1-15) indicates that trench material starts at approximately five feet bgs. This information would infer that the top five feet of material is cover material and, therefore, it is believed that a surface soil sample would be sufficient to characterize this material. Additionally, Section 1.3.2, states that 28 continuously logged borings (to bedrock) will be conducted to "ensure that chemical samples are collected from the proper depths and locations." These borings will confirm the depth to trench material and should provide information as to the necessary depth for near surface samples. Text will be revised to clarify that sample depths and locations may be revised based on the results of the 28 stratigraphic borings. However, the general plan to collect a surface soil sample, a sample in the trench material, a sample below the trench material, and a sample at the bedrock interface is still considered a valid approach.

EPA Comment 19

Table 2-6, Analyte List, pages 2-15 through 2-22: This table presents the sample quantitation limits and the criteria against which the sample results may be compared. The RFAAP SSP, in Section 3.0, states that "polynuclear aromatic hydrocarbons (PAHs) and pesticides/PCBs [polychlorinated biphenyls] may be analyzed using low detection methods. For example, the National Oceanographic and Atmospheric Administration (NOAA) Status and Trends Methods (USEPA Method No. 1668 [GC/MS], congener standards]; USEPA, 1995d) will be used to meet PCB method detection limits (MDLs) required for the human health and ecological risk screening." The WPA does not list or consider this method for PCBs. Please revise the WPA to ensure that the lowest detection limits possible are proposed and to consider the method suggested in the SSP for PCBs.

In addition, the SSP further states that "an analysis of risk-based concentrations (RBCs) and Biological Technical Assistance Group (BTAG) screening levels relative to analysis reporting limits (RLs) will be conducted as part of Work Plan preparation to ensure that RLs do not exceed screening concentrations (to the greatest extent practicable)." Such analysis is not provided in the WPA, except listing sample quantitation limits and the screening criteria. It is clear from the quantitation limits and criteria listed that for some analytes, the quantitation limits are greater than the corresponding screening criteria (e.g., quantitation limits vs. BTAG values). Please revise the WPA to present this required analysis of RLs versus screening criteria for all the methods proposed.

RFAAP Response

Since the reporting limits are based upon variable sample characteristics that are unknown at this time (i.e., dilutions, sample volumes, percent solids), the quantitation limits (QLs) are used for comparison in the Work Plan. The QLs listed represent the levels of quantitation at 1x dilution, standard sample size, and 100% solids. There may be cases where the screening values cannot be met practically with the given USEPA methodology. Method selection for Work Plan Addendum (WPA) 017 is based upon a variety of factors that include the Quality Assurance Plan (QAP) scope, comparability, sensitivity, economical, and technical factors. USEPA Method 8082 is a GC ECD method for the analysis of the eight standard Aroclors.

Previous PCB analysis has been conducted for soil samples using USEPA SW-846 Method 8082. Analyzing by the same method will provide comparable data. Method 8082 meets the sensitivity requirements listed in the Work Plan scope. The sensitivity (dependent upon matrix characteristics) for Method 8082 includes a method detection limit (MDL) with a range of 0.010 to 0.020 ug/g and a QL with a range of 0.033 to 0.067 ug/g. Both the MDL and QL for Method 8082 meet sensitivity requirements of the cited screening values. The lowest of the screening values for this site is the soil BTAG level of 0.1 ug/g.

WPA 017 will be revised to present an analysis of reporting limits versus screening criteria values for the proposed chemicals/compounds.



REPLY TO
ATTENTION OF

DEPARTMENT OF THE ARMY
U.S. ARMY CENTER FOR HEALTH PROMOTION AND PREVENTIVE MEDICINE
5158 BLACKHAWK ROAD
ABERDEEN PROVING GROUND, MARYLAND 21010-5403

MCHB-TS-REH (40)

25 November 2003

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. 17 SWMU 51 RCRA Facility Investigation.
July, 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) without comment. 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)
IMA, NERO (SFIM-NE-PW-ER)
USACE (CENWO-HX-H)
USAEC (SFIM-AEC-ER)

uf.

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

November 21, 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 51
Review of Army draft *Work Plan Addendum 17*

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's draft *Work Plan Addendum 17* for the investigation of SWMU 51, located at the Radford Army Ammunition Plant (RFAAP). Outlined below, please find EPA's comments based upon that review:

- 1) **Section 1.1, Introduction, page 1-1:** The second paragraph states that "there are no records indicating that disposal activities have taken place at SWMU [solid waste management unit] 51 since 1972." However, the first paragraph on page 1-11 states that "the aerial photographic analysis of SWMU 51 indicated that activity was first noted at the site in 1975, where a trench that appeared to be empty was visible

in the photograph. By 1981, the trench had been filled and revegetating ground scar was the sole feature that remains." Please revise the WPA to resolve this discrepancy and to retain information that most accurately reflects the operational history of the unit.

- 2) **Section 1.1, Introduction, page 1-1:** One of the objectives of the RCRA Facility Investigation (RFI) at SWMU 51 is described as (third bullet) "generate sufficient data to evaluate residual risk ..." emphasis added. The term residual risk is generally used when a site has been remediated to some level (e.g., preliminary remediation goals) and after confirmatory sampling to address risk from the residual contamination not addressed by the remedial action. Based on the information provided in the WPA, it appears no removal action was undertaken at SWMU 51. Please revise the WPA to remove the term "residual" from the text or provide data related to previous remedial actions at the site.
- 3) **Page 1-1** Please describe red water and red water ash in the text of the Work Plan.
- 4) **Section 1.2.1.1, Environmental Setting, page 1-5:** Under "Geology and Soil," it is stated that "geologic cross sections A-A' and B-B' (Figures 1-3 and 1-4, respectively) are provided to illustrate the subsurface conditions in the vicinity of SWMU 51." It is not clear how the information depicted on these cross sections was obtained or determined. For example, based on the plan view presented on Figure 1-2, there are no monitoring wells or soil borings located along the cross section for SWMU 28. However, this unit is shown on cross section B-B' as having fill material that is approximately 20 feet deep and more than 250 feet wide. As an additional example, only one monitoring well is located on the southeast corner of SWMU 51, and it is not clear how the details provided in cross sections A-A' and B-B' were determined for this unit. Please revise the WPA to clarify how the definitive detailed geologic cross sections were developed and provide any additional borings/monitoring wells that may have been used on the plan view (Figure 1-2) or indicate that such information will be provided in the RFI Report.
- 5) **Section 1.2.2, Conceptual Site Model, page 1-11:** The exposure pathways presented in Table 1-2 do not consider an adult or child trespasser for surface soil contamination. In addition, only construction workers were considered for the potential future use of groundwater. Since the conceptual site model (CSM) considers both the industrial and residential scenarios, the potential receptors should include adult or child trespasser for surface soil, and adult and children for use of groundwater. Since there are no known restrictions for groundwater use, this is mandatory. Please revise the CSM/potential exposure pathways and receptors accordingly.
- 6) **Section 1.2.2, Conceptual Site Model, page 1-13:** The third paragraph on this page indicates that data is insufficient to conclusively state whether the groundwater migration pathway at SWMU 51 is complete and that is considered unknown. In the fourth paragraph it is stated that "groundwater at the site is being addressed in Master Work Plan Addendum 009, Horseshoe Area Groundwater Study (IT, 2002)." As one of the objectives of the RFI is to generate sufficient data to evaluate potential risk on human health and the environment, please clarify where and when this data

gap will be filled or include a statement in the WPA that the completeness of the groundwater exposure pathway will be determined before the conduct of risk assessment.

- 7) **Section 1.2.2, Conceptual Site Model, on page 1-13** states that surface water and sediment are considered incomplete pathways because surface water is not present at the site. This pathway is also not identified as a pathway in Table 1-2 on page 1-13. Because contaminated groundwater can discharge to the surface and contaminate surface water and sediment, this pathway may still be complete. This pathway can be addressed as part of the groundwater study mentioned previously in the same section. This issue should be clarified in the text and in Table 1-2.
- 8) **Section 1.2.2, Conceptual Site Model, page 1-13**: The last paragraph states "air is considered an incomplete pathway because the study area is grass covered and volatilization is not an issue." Based on the cross sections A-A' and B-B', fill material (or potential waste) begins at the surface, and insufficient data exist to determine whether the constituents in the surface and subsurface soil/fill volatilize or not. Therefore, the statement that volatilization is not an issue is not supported by data. If the waste is assumed to contain constituents with propensity to volatilize or to be absorbed in the root/trunk/leaf system of the vegetative cover, then the air pathway will be complete. Please remove this statement and indicate that the air pathway is unknown and will be determined during the RFI. The CSM should be revised accordingly.
- 9) **Table 1.2, Potential Exposure Pathways and Receptors, on page 1-13** does not identify exposure of subsurface soil to terrestrial receptors as a pathway. Depending on the depth analyzed, invertebrates and burrowing mammals can be exposed to subsurface soil. This pathway should be identified in the report.
- 10) **Figure 1-2** The estimated groundwater flow direction as depicted on Figure 1-2 is confusing. How about utilizing groundwater table and/or potentiometric surface contours instead.
- 11) **Section 1.3, Planned Activities, page 1-14**: This section indicates that the selection of the area to be investigated and the soil samples to be collected follows the procedures provided in standard operating procedure (SOP) 30.7. Please revise this section to discuss the sampling methodology or combination of methodologies to be used from among the methods described in the SOP 30.7.
- 12) **Figure 1-7, Proposed Soil Boring Locations, on page 1-18** shows the proposed sampling locations for the site. It is unclear why so few samples are being collected for chemical analysis in the area of the trench. For additional characterization for the ecological risk assessment, two additional samples should be collected within the area of the trench (51SBC10 and 51SBC18) for chemical analysis. For more complete coverage of the grid, one additional sample should be collected outside the trench area (51SBC16). This additional analysis is most important for surface soil.

- 13) **Section 1.3.2, Proposed Soil Borings, page 1-22:** Under "**Boring for Physical Analysis**" for Atterberg limits American Society of Testing and Materials (ASTM) D4318-00 is specified. ASTM D4318-00 is the standard test methods for liquid limit, plastic limit, and plasticity index of soils. The liquid limit and plastic limit of soils (along with the shrinkage limit [ASTM D4943-02]) are often collectively referred to as the Atterberg limits. Please clarify if testing the soil using ASTM D4943-02 (Standard Test Method for Shrinkage Factors of Soil by the Wax Method) is implied by the use of the term "Atterburg [*sic*] limits" and/or specify testing of the soil using ASTM D4943-02 to determine shrinkage factors of soil.

The historical standards for measurement of hydraulic conductivity - using a rigid wall, compaction-mold permeameter - are ASTM D5856-95 and ASTM D5856-95(2002). The current active standard is ASTM D5856-95(2002)e1. Please revise this section to correct the reference provided in the text of the WPA for this standard.

The current active methods referenced for "soil porosity" determination are ASTM D854-02 and ASTM D2937-00e1, respectively. Please revise the references provided in the WPA.

The above suggested corrections should also be made for Section 2.5.5 (Physical/Geotechnical Analysis).

- 14) **Section 1.3.2, Proposed Soil Borings, page 1-22:** This section indicates that during soil boring advancement, a portable photoionization detector (PID) will be used for screening volatile organic compounds (VOCs) during the investigation. A PID alone may not detect 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 in surface and subsurface soils were not investigated in the past, it must be ensured that a detector or combination of detectors which will permit the detection of all VOCs will be used during the investigation. The "Monitoring Plan" presented in Section 3.5 should also be revised.

- 15) **Table 1-3, Summary of Proposed RFI Borings, page 1-19:** This table indicates that only one boring (51SB3), which is located inside the probable boundaries of the trench, will be used for physical analysis. It is not clear why physical analysis is confined to only this boring location and how it was determined that this location will yield data representative of the trench. It is recommended that at least one additional location within the trench and another location outside the probable boundaries of the trench be selected for physical analysis. The resulting data will be more representative and will help in comparing the physical parameters of more than one data point. In addition, as stated in the WPA, since "the analyses are intended to enhance the understanding of the physical nature of the soil to provide data necessary for constituent migration modeling, if necessary," vertical variation alone should not be considered sufficient for adequate physical characterization of the soil/fill.

- 16) **Table 1-4, Proposed Chemical Sampling and Analysis Plan, page 1-20:** This table does not list cyanide as one of the analytes. The Radford Army Ammunition Plant (RFAAP) Site Screening Process (SSP) (October 26, 2001) requires that cyanide be included in the analytical suit for all media sampled. Please revise the table to specifically indicate that cyanide will be analyzed for in the samples collected for target analyte list (TAL) inorganic chemicals.
- 17) **Table 1-4, Proposed Chemical Sampling and Analysis Plan, page 1-21:** The "Sample Depth Notes" at the end of this table indicate that the subsurface soil samples collected outside the trench limits will be collected from slightly deeper depth intervals than those collected from within the trench limits. It is not clear why two different depths are implemented for the two areas, and how and when the depths marked with "TBD" will be determined. In addition, since the limits of the trench will be verified by the investigative activities proposed, it is inappropriate at this time to consider that Boring Locations 51SB1, 51SB5, 51SB6, 51SB7, and 51SB8 are outside the trench boundaries. Please revise the WPA to clarify these issues and state that whether a location is in or outside the trench boundaries will be determined after the existing geophysical data are "ground-truthed" to the stratigraphic data generated from the WPA activities.
- 18) **Table 1-4, Proposed Chemical Sampling and Analysis Plan, page 1-21:** The "Sample Depth Notes" at the end of this table indicate that surface soil samples will be collected at a depth of 0-0.5 feet (ft) below ground surface (bgs) and 0.5-1.0 ft bgs for VOCs. Based on the surface soil sample depths specified above and the definitions provided for the "maximum depth," "within trench," and "beneath trench" for the subsurface soil sample depths, it appears no samples are proposed to be collected from the interval 1.0-5.0 ft bgs. Please revise the WPA to clarify if samples will be collected from 1.0-5.0 ft bgs.
- 19) **Table 2-6, Analyte List, pages 2-15 through 2-22 :** This table presents the sample quantitation limits and the criteria against which the sample results may be compared. The RFAAP SSP, in Section 3.0, states that "polynuclear aromatic hydrocarbons (PAHs) and pesticides/PCBs [polychlorinated biphenyls] may be analyzed using low detection methods. For example, the National Oceanographic and Atmospheric Administration (NOAA) Status and Trends Methods (USEPA Method No. 1668 [GC/MS], congener standards]; USEPA, 1995d) will be used to meet PCB method detection limits (MDLs) required for the human health and ecological risk screening." The WPA does not list or consider this method for PCBs. Please revise the WPA to ensure that the lowest detection limits possible are proposed and to consider the method suggested in the SSP for PCBs.

In addition, the SSP further states that "an analysis of risk-based concentrations (RBCs) and Biological Technical Assistance Group (BTAG) screening levels relative to analysis reporting limits (RLs) will be conducted as part of Work Plan preparation to ensure that RLs do not exceed screening concentrations (to the greatest extent practicable)." Such analysis is not provided in the WPA, except listing sample quantitation limits and the screening criteria. It is clear from the quantitation limits and criteria listed that for some analytes, the quantitation limits are greater than the corresponding screening criteria (e.g., quantitation limits vs. BTAG values). Please

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revise the WPA to present this required analysis of RLs versus screening criteria for all the methods proposed.

This concludes EPA's review of the Army's draft *Work Plan Addendum 17* for the investigation of SWMU 51, located at the 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, PE
Federal Facilities Branch

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



COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

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18 November 2003

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

RE: Work Plan Addendum 017 (WPA 17)

Dear Mr. McKenna:

This office has reviewed the referenced draft document and concurs with WPA 17. No revisions to the document are required. Please provide one copy of the **Final** WPA 17 document to this office on CD when completed.

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

Sincerely,

A handwritten signature in cursive script, reading "Mark S. Leeper".

Mark S. Leeper
Remedial Project Manager

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



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

July 18, 2003

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

Subject: Work Plan Addendum 17, SWMU 51 RCRA Facility Investigation, Radford Army Ammunition Plant EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is one certified copy of Work Plan Addendum 17, SWMU 51 RCRA Facility Investigation, 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,

A handwritten signature in black ink, appearing to read "C. A. Jake", written over a horizontal line.

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
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Richmond, VA 23240-0009

Mark Leeper
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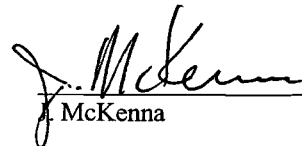
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5158 Blackhawk Road, Attn: MCHB-TS-HER
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10 South Howard Street
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bc: Administrative File
J. McKenna, ACO Staff
Rob Davie-ACO Staff
C. A. Jake
J. J. Redder
Env. File

Coordination:


J. McKenna

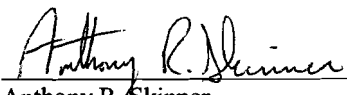
Concerning the following:

671

Work Plan Addendum 17
SWMU 51 RCRA Facility Investigation
Radford Army Ammunition Plant


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Anthony Miano
Vice President Operations
Alliant Ammunition and Powder Company, LLC

68
McKenna, Jim

From: Jenkins, Joanne
Sent: Tuesday, July 08, 2003 8:09 AM
To: McKenna, Jim
Cc: Davie, Robert
Subject: RE: NHPA, Work Plan Addendum 17

Jim,

I checked the locations of Unit 51 with the ICRMP and found that there are no cultural resources identified in that area.

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

-----Original Message-----

From: McKenna, Jim
Sent: Tuesday, July 08, 2003 7:25 AM
To: Jenkins, Joanne
Subject: NHPA, Work Plan Addendum 17

Joanne:

Work Addendum 17 identifies sampling work that will occur at Solid Waste Management Unit 51 in the Horseshoe Area. The WPA has maps that show sampling locations. Need to review for possible interference with historic sites.

Jim

RADFORD ARMY AMMUNITION PLANT, VIRGINIA

Work Plan Addendum No. 17 SWMU 51 RCRA Facility Investigation



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Final Document

February 2004

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LIST OF ABBREVIATIONS AND ACRONYMS

%.....	percent	HAZCOM.....	Hazard Communication
2D-ERI	Two-Dimensional Electrical- Resistivity Imaging	HHRA.....	Human Health Risk Assessment
ANL.....	Argonne National Laboratory	HPLC.....	High Pressure Liquid Chromatography
ASTM.....	American Society of Testing and Materials	HQ	Hazard Quotient
bgs	below ground surface	HRGC/HRMS ..	High-Resolution Gas Chromatography and High- Resolution Mass Spectrometry
BRA.....	Baseline Risk Assessment	HSA.....	Horseshoe Area
BTAG.....	Biological Technical Assistance Group	HSPA.....	Health and Safety Plan Addendum
°C.....	Degrees Celsius	HWMU.....	Hazardous Waste Management Unit
CFR	Code of Federal Regulations	ICP.....	Inductively Coupled Plasma
CLP.....	Contract Laboratory Program	IDM	Investigative-Derived Material
COD	Chemical Oxygen Demand	IT	IT Corporation
CMS	Corrective Measures Study	m.....	meters
CSM	Conceptual Site Model	MDL.....	Method Detection Limit
CVAA.....	Cold Vapor Atomic Absorption	MRL.....	Method Reporting Limit
DAF.....	Dilution Attenuation Factor	MHSP.....	Master Health and Safety Plan
DNT.....	Dinitrotoluene	mL	milliliters
DQO	Data Quality Objective	MQAP	Master Quality Assurance Plan
ECD.....	Electron Capture Detector	MSDS	Material Safety Data Sheet
EM.....	Electromagnetic	msl.....	mean sea level
ERIS	Environmental Restoration Information System	MWP	Master Work Plan
FOL	Field Operations Leader	NG	nitroglycerin
ft	feet	NIST.....	National Institute of Standards and Technology
GC/ECD	Gas Chromatography/Electron Capture Detector	nm.....	nanometers
GC/MS	Gas Chromatography/Mass Spectroscopy	OSHA.....	Occupational Safety and Health Administration
GPS.....	Global Positioning System		

PAH..... Polynuclear Aromatic
Hydrocarbon
PCB Polychlorinated Biphenyl
PETN..... Pentaerythritol Tetranitrate
PID Photoionization Detector
PM..... Project Manager
PPE..... Personal Protective Equipment
and Clothing
ppm..... parts per million
QA Quality Assurance
QA/QC Quality Assurance/Quality
Control
QAPA..... Quality Assurance Plan
Addendum
QC Quality Control
QLs Quantitation Limits
RBC..... Risk-Based Concentration
RCRA..... Resource Conservation and
Recovery Act
RFAAP..... Radford Army Ammunition
Plant
RFI..... RCRA Facility Investigation
RL..... Reporting Limit
Shaw Shaw Environmental, Inc.
SHSO..... Site Health and Safety Officer
SIM..... Selective Ion Monitoring
SLERA Screening Level Ecological
Risk Assessment
SOP..... Standard Operating Procedure
SOQ..... Statement of Qualification
SOW Statement of Work
SSL..... Soil Screening Level
SVOC..... Semivolatile Organic
Compound
SWMU Solid Waste Management Unit
TAL Target Analyte List
TCL Target Compound List
TCLP Toxicity Characteristic
Leachate Procedure
TCLPRL..... Toxicity Characteristic
Leachate Procedure
Regulatory Limit
TIC(s) Tentatively Identified
Compound(s)
TNT Trinitrotoluene
TOC..... Total Organic Carbon
TOX..... Total Organic Halides
TWA..... Time-Weighted Average

USACE..... United States Army Corps of
Engineers
USEPA United States Environmental
Protection Agency
UV Ultraviolet
VDEQ..... Virginia Department of
Environmental Quality
VOC Volatile Organic Compound
WPA..... Work Plan Addendum

EXECUTIVE SUMMARY

Work Plan Addendum (WPA) 17 was developed to address data gaps at Solid Waste Management Unit (SWMU) 51 located in the Horseshoe Area (HSA) of Radford Army Ammunition Plant. SWMU 51 consists of an unlined trench used for the disposal of trinitrotoluene neutralization sludge. The trench has been filled to natural grade and is covered by weeds and grass.

This WPA, through the performance of a Resource Conservation and Recovery Act Facility Investigation (RFI) at SWMU 51, is designed to meet the following project objectives: characterize the vertical and horizontal extent of the trench and the nature and extent of potential contamination on-site; generate sufficient data to evaluate risk through the performance of a Human Health Risk Assessment (HHRA) and a Screening Level Ecological Risk Assessment (SLERA); and, to reach a final decision regarding what remedial action, if any, is needed.

Previous investigations have been conducted as a collective effort at or adjacent to SWMU 51 (SWMUs 28, 51, and 52) and are discussed in this WPA. A data review, including the development of a conceptual site model and a data gap analysis, was performed. Review of the data indicated that there is no existing soil chemical data for SWMU 51, representing a data gap.

To address this data gap, sampling strategies were developed to characterize and delineate SWMU 51. Site-specific sampling location maps and tables indicating sampling locations, depths, and chemical parameters for each sample are presented for SWMU 51. This WPA was designed to provide the rationale for the sample collection strategy and act as a field sampling plan for use while conducting fieldwork activities.

1.0 WORK PLAN ADDENDUM

In accordance with Contract No. DACA31-02-F-0080, Shaw Environmental, Inc. (Shaw) 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) 51, the Trinitrotoluene (TNT) Waste Acid Neutralization Pit, located in the Horseshoe Area (HSA) of Radford Army Ammunition Plant (RFAAP) (**Figure 1-1**). This RFI Work Plan is presented as an addendum [Work Plan Addendum (WPA) No. 17] to, and incorporates by reference, the elements of the RFAAP Master Work Plan (MWP) (URS, 2003).

1.1 INTRODUCTION

SWMU 51 consists of one trench, approximately 20 feet (ft) wide by 200 ft long, located immediately to the southeast and adjacent to SWMU 30 (Closed Asbestos Waste Site) (**Figure 1-2**). SWMU 30 was reportedly used for asbestos disposal and is not part of this unit. SWMU 51 is located approximately 200 ft west of Hazardous Waste Management Unit (HWMU) 16 (Closed Hazardous Waste Landfill) and SWMU 52 (Closed Sanitary Landfill), and 200 ft southwest of SWMU 28 (Closed Sanitary Landfill). The trench has been filled to natural grade with soil and is covered by grass and weeds. A barbed-wire fence surrounds SWMU 51. Separate barbed-wire fencing surrounds the trench areas of SWMU 30.

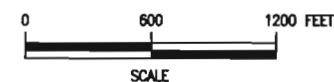
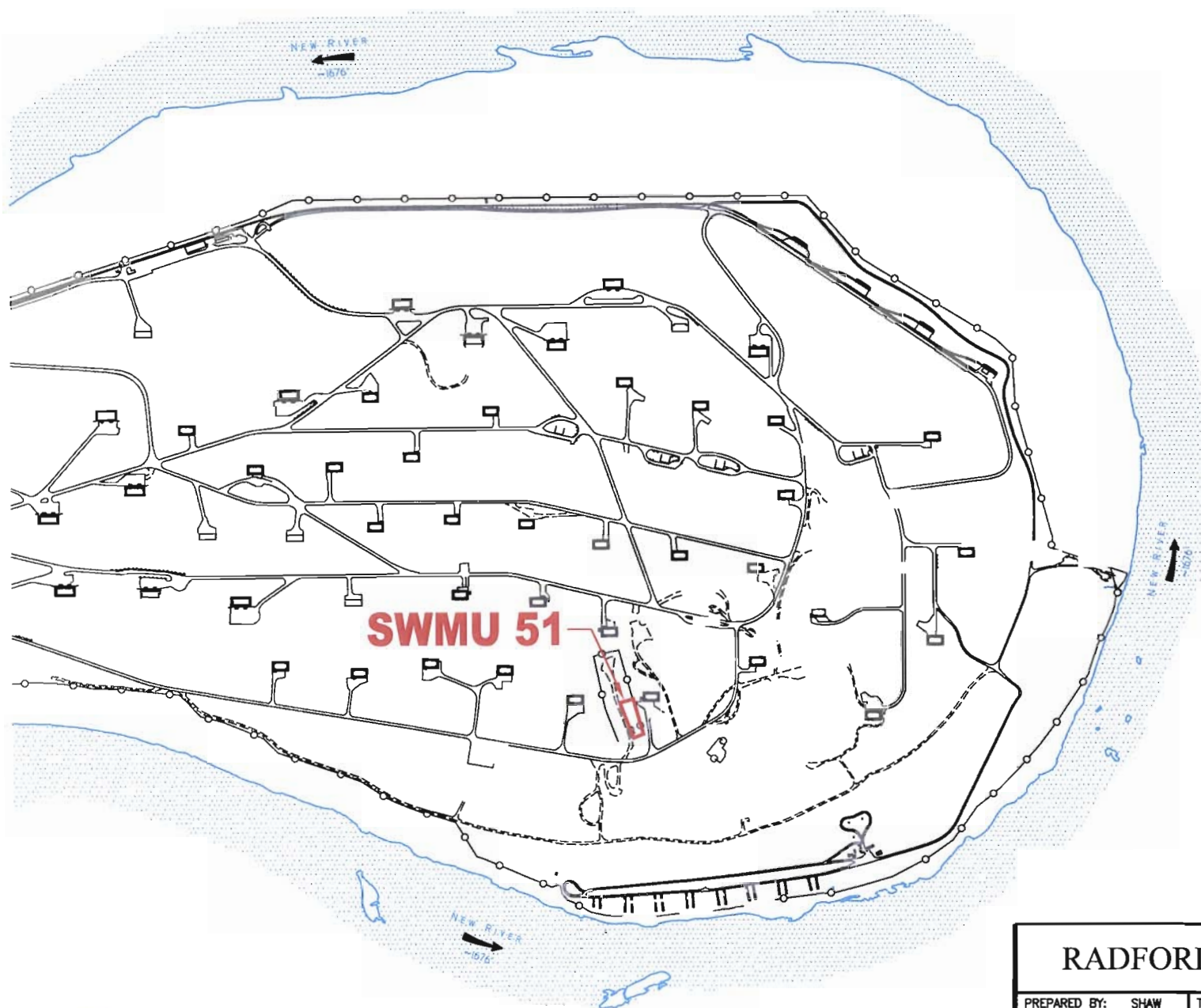
An unknown quantity of TNT neutralization sludge from the treatment of red water was disposed in an unlined trench at SWMU 51 in the 1970's. In addition, the Dames & Moore 1992 RFI Report (Dames & Moore, 1992) stated that an estimated 10 tons of red water ash reportedly was disposed at the site from 1968 to 1972. There are no records after 1972 regarding activities at SWMU 51; however, aerial photographic analysis (USEPA, 1992) indicated that there was an open trench at the site in a 1975 photograph. A 1981 aerial photograph indicated that the trench had been filled and a revegetating ground scar was the major site feature visible (USEPA, 1992).

The project objectives of the RFI at SWMU 51 are:

- Characterize the vertical and horizontal extent of the trench and underlying overburden hydrogeologic units;
- Characterize the nature and extent of possible contamination on-site and possible contaminant sources;
- Generate sufficient data to evaluate risk through comparison to United States Environmental Protection Agency (USEPA) Region III Risk-Based Concentrations (RBCs) (USEPA, 2003), and the background concentration values developed in the Facility-Wide Background Study (IT, 2001a). Ultimately, data will be used to perform a Baseline Risk Assessment (BRA) that is subdivided into a Human Health Risk Assessment (HHRA) and Screening Level Ecological Risk Assessment (SLERA); and,
- Reach a final decision regarding what future action, if any, is needed.

This investigation is structured to fully characterize SWMU 51 and additional investigation is not being considered at this time.

This WPA specifically addresses sections and Standard Operating Procedures (SOPs) contained in the MWP for the investigation at SWMU 51. Relevant SOPs are included in **Appendix A** of this WPA. The MWP will be kept onsite and referenced during field activities.

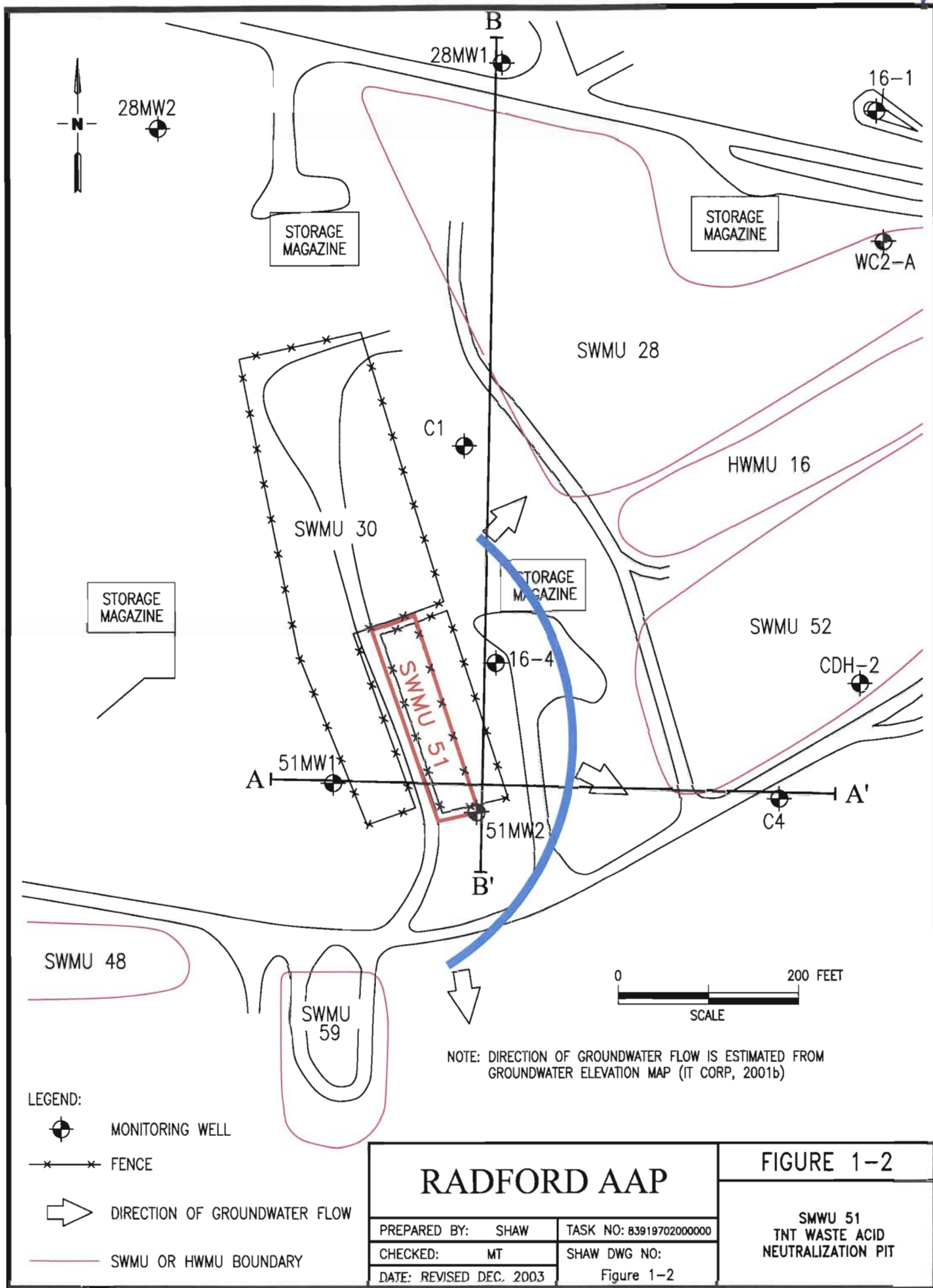


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DATE: REVISED MAY 2003	Figure 1-1

FIGURE 1-1

SITE LOCATION MAP
HORSESHOE AREA
SWMU 51



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DATE: REVISED DEC. 2003	Figure 1-2

FIGURE 1-2

SWMU 51
TNT WASTE ACID
NEUTRALIZATION PIT

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**.

Table 1-1
Applicable MWP Activities and Related SOPs

Subject	MWP Section	Standard Operating Procedures (SOPs) MWP Appendix A and Appendix A of WPA No. 17
Installation Description	2.0	Not Applicable
Environmental Setting	3.0	Not Applicable
Documentation	4.3	10.1 Field Logbook 10.2 Soil 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	70.1 Investigation-Derived Material
Air Monitoring		90.2 Photoionization Detector
Subsurface Investigation	5.2 5.8	20.3 Well and Boring Abandonment 20.11 Drilling Methods and Procedures 30.1 Soil Sampling 30.6 Containerized Material Sampling Strategies 30.7 Sampling Strategies

Changes to the approved WPA will be documented using the Work Plan Revision Form (**Appendix C, Form C-1**). Revisions must be reviewed and approved by the USACE Contracting Officer's Representative 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 (**Appendix C, Form C-2**). The Site Health and Safety Officer (SHSO) will retain this form onsite during investigative activities. Appropriate health and safety precautions must be taken due to the potential handling of hazardous materials, energetics, and/or their degradation compounds.

The investigation program focuses on obtaining the data needed to attain project objectives. The program articulates project objectives, assumptions, and data use specifications. Program elements include:

- **Description of Current Conditions (Section 1.2):** This section includes a site description of SWMU 51 and a discussion of previous SWMU 51 investigations. This section also presents the Conceptual Site Model (CSM) and Data Gap Analysis;
- **Planned Field Activities (Section 1.3):** A site investigation will be performed to collect representative samples from SWMU 51 and achieve project data quality objectives (DQOs). The sampling program presented for this investigation satisfies the DQOs;

- **Quality Assurance/Quality Control (QA/QC) (Section 2.0):** Independent quality control (QC) checks are used to demonstrate investigation and laboratory accuracy, precision, and integrity. The Quality Assurance Plan Addendum (QAPA) provides assurance that data of known and documented quality are generated to allow the Installation to accurately characterize and evaluate SWMU 51 in accordance with the project objectives; and,
- **Health and Safety (Section 3.0):** Site-specific training, work practices and procedures, personal protective equipment and clothing (PPE), and applicable monitoring requirements are presented as the Health and Safety Plan Addendum (HSPA) in *Section 3.0* of this WPA. These requirements provide the procedures for protection of site personnel, including government employees, regulators, contractors, and visitors, who are expected to be involved with site activities.

1.2 DESCRIPTION OF CURRENT CONDITIONS

The following section describes the site background (environmental setting and site history) and the nature and extent of contamination based on previous investigations.

1.2.1 Site Background

1.2.1.1 Environmental Setting

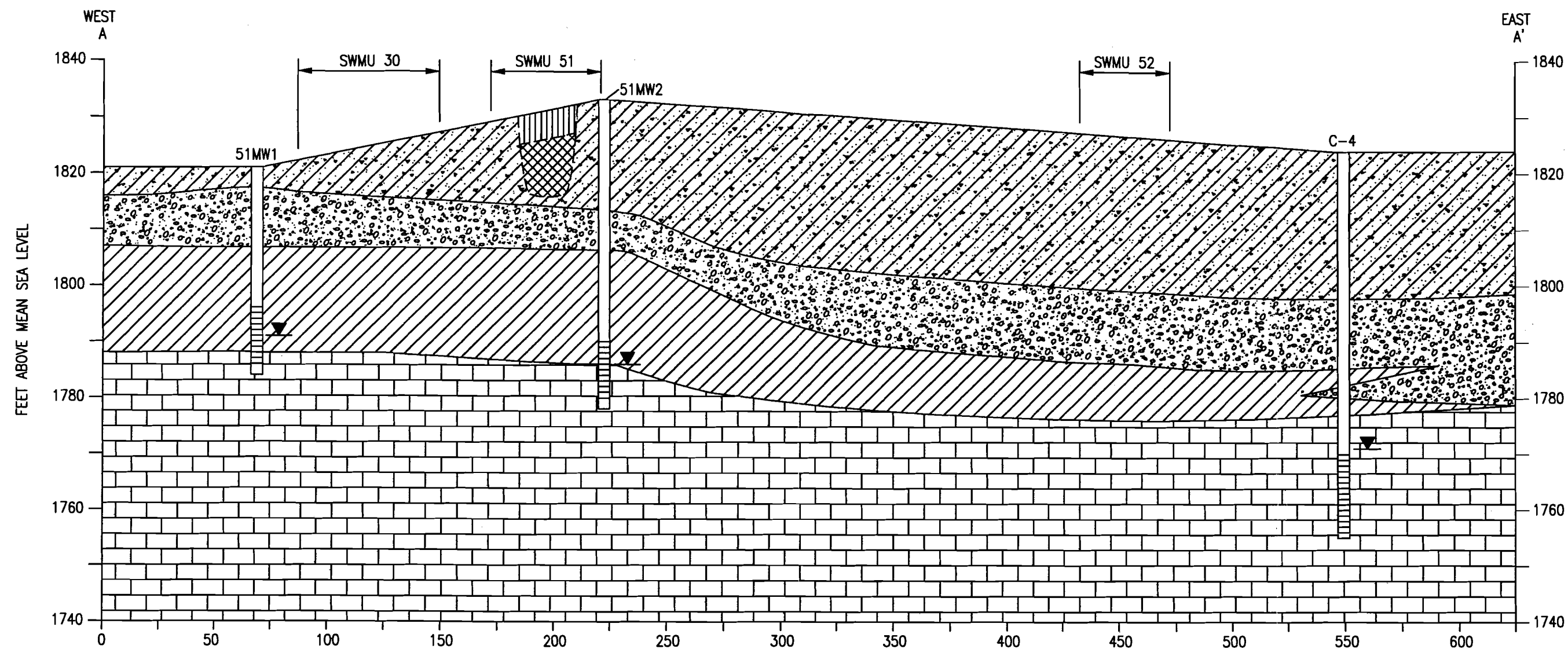
Section 3.0 of the MWP presents information regarding the environmental setting of RFAAP. This section and *Section 1.2.1.3* of this WPA present site-specific information.

Physiography. SWMU 51 is located on a plateau in the southeastern section of the HSA adjacent to HWMU 16 and SWMUs 28, 30, and 52 (**Figure 1-2**). The elevation of the plateau ranges from approximately 1,820 to 1,840 ft mean sea level (msl). The plateau is generally flat to slightly sloping.

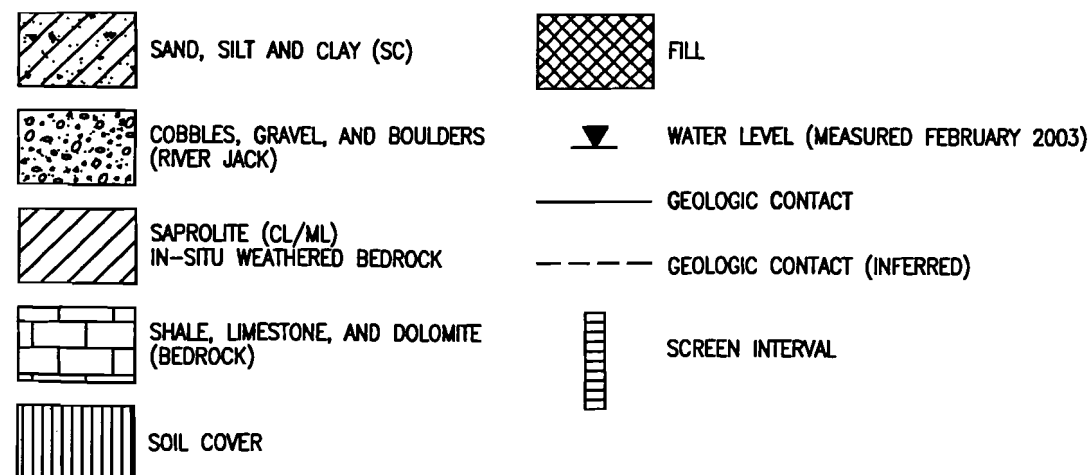
Geology and Soil. A detailed discussion of the geology and soil at RFAAP is presented in *Sections 3.4* through *3.7* of the MWP (URS, 2003), the Facility-Wide Background Study (IT, 2001a), and the Current Conditions Report (IT, 2001b). Geologic cross sections A-A' and B-B' (**Figures 1-3** and **1-4**, respectively) are provided to illustrate the subsurface conditions in the vicinity of SWMU 51. Plan view of the cross sections is presented on **Figure 1-2**.

As shown on **Figures 1-3** and **1-4**, bedrock was encountered at depths between 33 and 47 ft below ground surface (bgs) in monitoring well borings near SWMU 51 (Dames & Moore, 1992). Bedrock consists of the Cambrian-age Elbrook Formation, which is a thickly bedded, blue-gray dolostone interspersed with blue-gray to white limestone. Saprolite, consisting of fine-grained residual deposits and weathered bedrock, described as yellowish-brown, micaceous, clayey silt, overlies bedrock, and ranges from 0 to 25 ft in thickness. Alluvial channel deposits consisting of fine- to coarse-grained, yellowish brown sand and layers of large cobbles (river jack) overlies the saprolite. Paleo-channels, consisting of the alluvial material, are incised into the saprolite so that in places the alluvium rests directly on bedrock. A second alluvial unit consisting of reddish-brown finer-grained terrace and overbank deposits overlies, and is interbedded with, the channel deposits. This unit consists primarily of silty clay and is present from the surface to a depth of approximately 38 feet.

The soil type for the upper unit is the Braddock Loam, which is described as yellowish-brown grading into yellowish-red and red clay extending to a depth of 60 inches or more. Permeability is moderate; natural fertility is low; organic matter content is moderately low. This soil type is acidic or very strongly acidic.

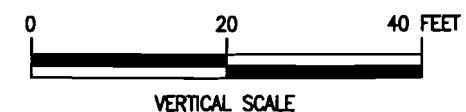
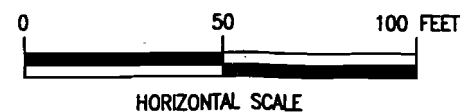


LEGEND



NOTE:

SWMU 51 INFORMATION INFERRED FROM GEOPHYSICAL SURVEYS (SEE SECTION 1.3.1)

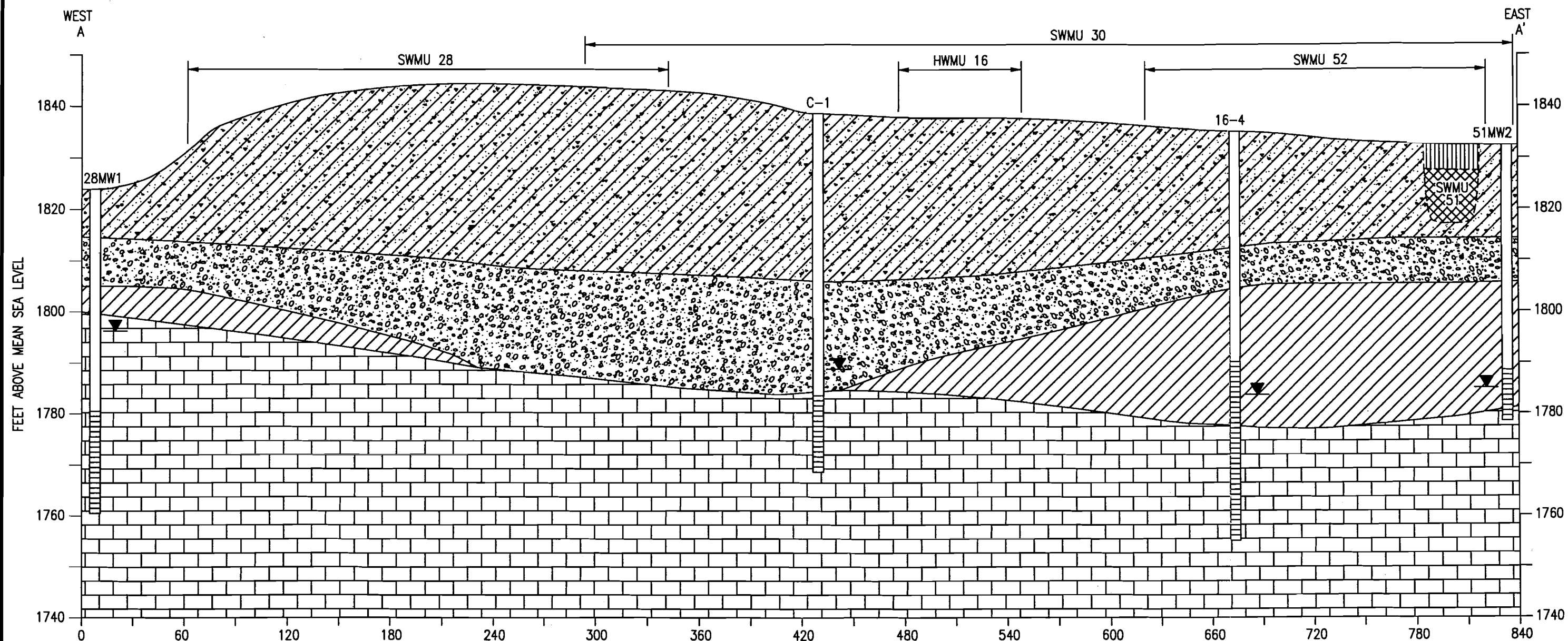


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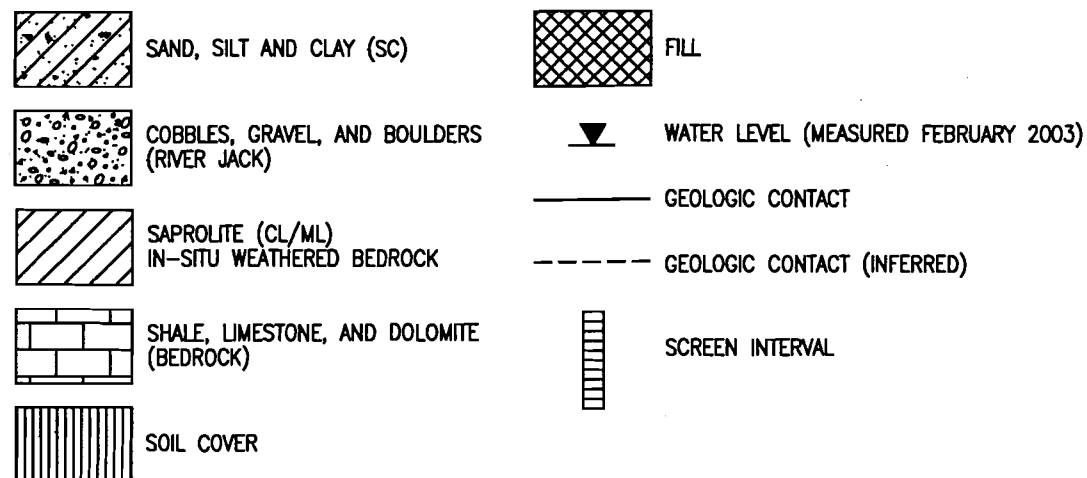
PREPARED BY: SHAW	TASK NO: 63818702000000
CHECKED BY: MT	SHAW DWG NO: Figure 1-3
DATE: REVISED DEC. 2003	

FIGURE 1-3

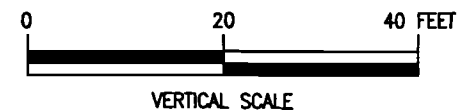
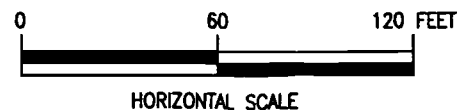
HYDROGEOLOGIC CROSS SECTION A TO A' SWMUs 30, 51, AND 52



LEGEND



NOTE:
SWMU 51 INFORMATION INFERRED FROM GEOPHYSICAL SURVEYS (SEE SECTION 1.3.1)



Source: Dames & Moore, 1992

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Figure 1-4

FIGURE 1-4

HYDROGEOLOGIC CROSS
SECTION B TO B'
SWMUs 28, 51, AND 52

Surface Water. There are no surface water bodies present at the site. Surface water from rain events would be expected to infiltrate into the site soil.

Groundwater. A detailed discussion of regional and RFAAP hydrogeology is presented in Section 3.8 of the MWP (URS, 2003) and the Current Conditions Report (IT, 2001b). Groundwater at SWMU 51 is present in a bedrock aquifer. Boring logs from wells installed in the vicinity of SWMU 51 show that groundwater was first encountered below the bedrock/overburden interface during drilling activities. Water levels rose in the borings after well completion, indicating that the groundwater is present under confining conditions. Groundwater elevations, measured in February 2003, ranged from approximately 32.5 ft bgs in monitoring well 51MW1, to approximately 50.2 ft bgs in monitoring well 51MW2. Other monitoring wells in the vicinity of SWMU 51 are 16-4 and C1. Both wells are screened in bedrock with approximate depths to water of 53 ft bgs and 51.2 ft bgs, respectively. Groundwater is estimated to flow the east and south of SWMU 51 (IT, 2001b).

1.2.1.2 Site History

An unknown quantity of TNT neutralization sludge from the treatment of red water, a waste product generated during the production of TNT, was disposed of in this unlined trench in the 1970s. The sludge contained numerous TNT byproducts including TNT isomers and TNT sodium disulfate. The source of the sludge was from RFAAP Red Water Treatment Plant equalization/neutralization basin (listed as Unit 81a in USEPA, 1987).

Red water is a USEPA listed hazardous waste (K047) and is listed solely for reactivity (40 CFR 261.32). During the production and formulation of TNT and TNT containing formulations and products, an alkaline, red colored aqueous waste is generated (red water). This waste stream is composed of TNT purification filtrate, air pollution control scrubber effluent, washwater from cleaning of equipment and facilities, and washwater from product washdown operations.

In addition to sludge disposal, an estimated 10 tons of red water ash was reportedly disposed of in the trench from 1968 to 1972. During this period, red water was concentrated by evaporation and the sludge was burned in rotary kilns located in the TNT manufacturing area (USATHAMA, 1976). The ash from the red water sludge produced from these kilns (red water ash) was disposed of in SWMUs 41 (Red Water Ash Landfill) and 51.

Red water ash has been described as yellowish-tan in color when dry. When wet, it turns a dark red and generates a dark red leachate. It is corrosive and fine-grained, though it may contain large clinkers (Dames & Moore, 1992).

1.2.1.3 Previous Investigations

RCRA Facility Assessment, USEPA, 1987. An assessment was conducted at the unit to evaluate potential hazardous waste or hazardous constituent releases and implement corrective actions, as necessary. The assessment consisted of a preliminary review and evaluation of available site information, personnel interviews, and a visual inspection of the site. Environmental samples were not collected at SWMU 51 as part of the inspection. The assessment concluded that low levels of dinitrotoluene (DNT) and halomethane groundwater detections in HWMU 16 monitoring wells were indicative of SWMU 51 disposal activities. However, site-specific chemical samples were required in accordance with the RFAAP 1989 RCRA permit.

Installation Assessment, USEPA, 1992. The Environmental Photographic Interpretation Center (EPIC), through the USEPA and U.S. Army Toxic and Hazardous Material Agency (USATHAMA), provided aerial photographic analysis of 42 known SWMUs at RFAAP (USEPA, 1992). Aerial photographs from 1937 through 1986 were analyzed to identify features which may have represented potential groundwater or surface water contamination sources at RFAAP.

The aerial photographic analysis of SWMU 51 indicated that activity was first noted at the site in 1975, where a trench that appeared to be empty was visible in the photograph. By 1981, the trench had been filled and a revegetating ground scar was the sole feature that remained.

RCRA Facility Investigation, Dames & Moore, 1992. Because of the proximate nature and similar disposal methods used at SWMUs 28, 51, and 52, the RFI combined these sites into one study area. Other similar disposal units (HWMU 16 and SWMU 30) were located within the RFI study area, but these sites were not included in the RFAAP 1989 RCRA permit and were not specifically targeted as areas of investigation for the RFI (Dames & Moore, 1992). RFI field activities included the installation and sampling of four monitoring wells (28MW1, 28MW2, 51MW1, and 51MW2) and the sampling of nine existing monitoring wells (16-1, 16-3, 16-4, MW9, C1, C4, CDH-2, WC1-A, and WC2-A). In addition, five representative soil samples were collected from the well borings for physical testing.

Groundwater samples were analyzed for metals, volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), explosives, total organic carbon (TOC), total organic halides (TOX), and pH. Results indicated that one explosive (26DNT), two VOCs (1,1-dichloroethane and methylene chloride), and one SVOC [bis(2-ethylhexyl)phthalate] were present above levels of concern at the time of the investigation in groundwater downgradient of SWMUs 28, 51, and 52. The explosive compound, 26DNT, was attributed to SWMU 51, but 1,1-dichloroethane and methylene chloride appeared to be related to HWMU 16. Because bis(2-ethylhexyl)phthalate was also detected in method blank samples, it was considered a laboratory contaminant and not a site contaminant.

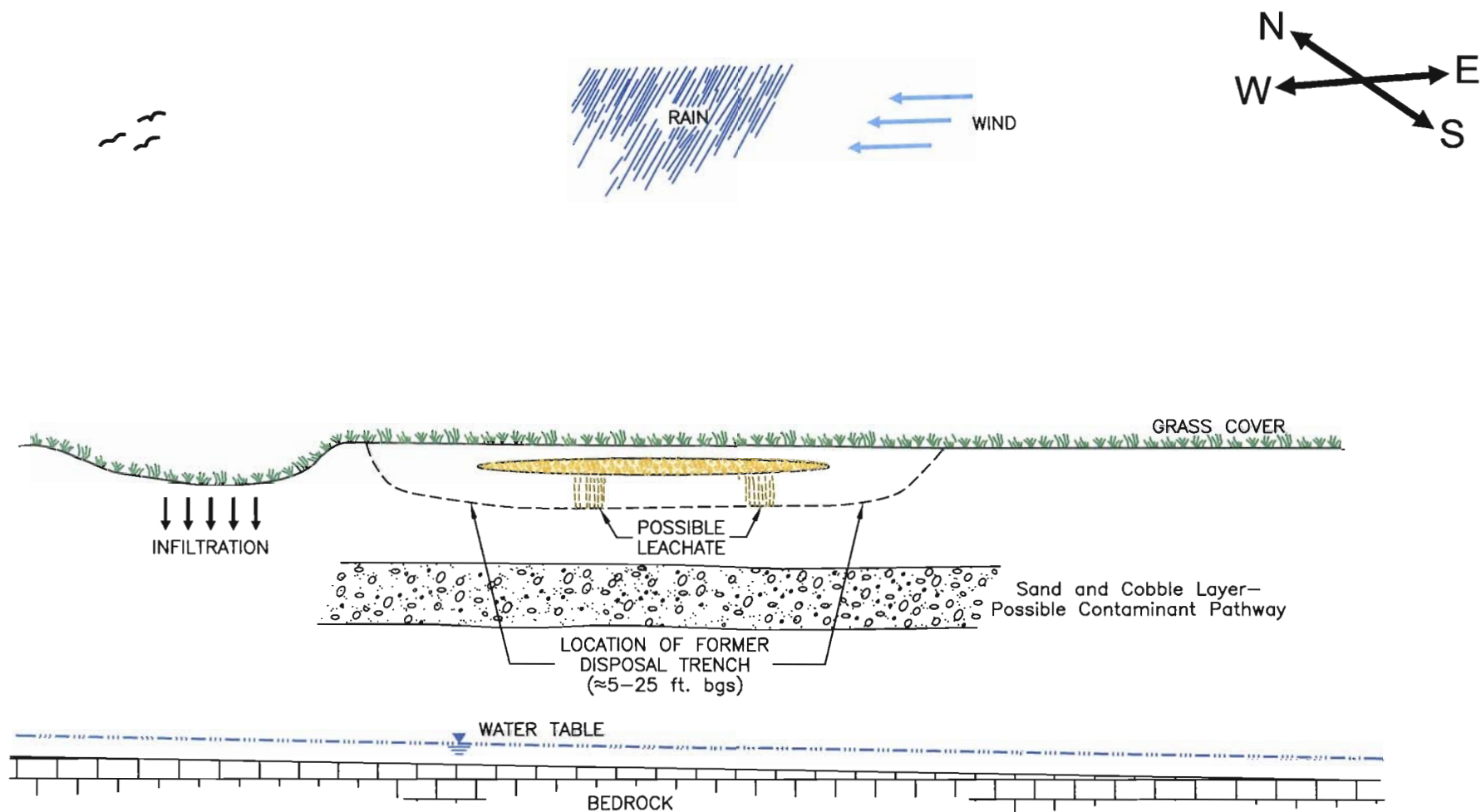
Surface soil samples were not collected for chemical analyses because the waste in each SWMU was buried and covered with clean fill. No subsurface soil samples were collected below the fill material because it was thought that penetration of the landfill would result in the possible release of contaminants.

Based on the investigation results, the RFI recommended a Corrective Measures Study (CMS) for the SWMU 51 study area for the purpose of isolating the waste and preventing leachate generation.

1.2.2 Conceptual Site Model

A conceptual site model for SWMU 51 is shown on **Figure 1-5**. Potentially affected media include air, surface soil, and subsurface soil. Groundwater is being assessed in a separate study (WPA 009) and is not addressed in this CSM. However, the completeness of the groundwater pathway will be assessed in the RFI. The area surrounding the site is relatively flat.

Precipitation is expected to infiltrate into the ground or flow across SWMU 51 to the west toward a low area. Construction workers, maintenance workers, future residential adults and children, and terrestrial biota are considered potential receptors. Although current and future land-use scenarios are limited to industrial operations, both industrial and residential scenarios



"NOT TO SCALE"

NOTE:

SEE TABLE 1–2 FOR ASSOCIATED EXPOSURE PATHWAYS AND POTENTIAL RECEPTORS.

RADFORD AAP

PREPARED BY: SHAW

TASK NO: 83919702000000

CHECKED BY: MT

SHAW DWG NO:

DATE: REVISED JUNE 2003

Figure 1–5

FIGURE 1–5

SWMU 51
CONCEPTUAL
SITE MODEL

will be considered. **Table 1-2** presents the exposure pathways for each receptor. Each media type is described in more detail in the following paragraphs.

Although geophysical surveys indicate that there is a five foot layer of cover soil over the waste trench, the disposal of TNT neutralization sludge and red water ash potentially contaminated both surface and subsurface soil. Human and ecological receptors could be impacted through incidental ingestion and inhalation of soil and dermal absorption through direct contact with impacted soil, or through inhalation of volatiles.

There is a potential for volatilization to the air pathway. Although this is unexpected due to the type of waste disposed (TNT sludge and red water ash), the completeness of the air pathway will be evaluated in the RFI. Surface soil is potentially affected by the disposal of TNT neutralization sludge and red water ash into shallow reaches of the trench. Although the trench was covered to grade with clean fill, not enough information exists to rule out surface soil as a potentially affected medium. Human and ecological receptors could be impacted through incidental ingestion and inhalation of soil and dermal absorption through direct contact with impacted soil.

Subsurface soil is also potentially affected by disposal activities. Construction workers could be negatively impacted through the inhalation of dust during construction activities. Incidental ingestion and dermal absorption may also affect construction workers during construction activities that expose the subsurface soil.

As described in *Section 1.2.1.1*, monitoring well data indicates that groundwater at SWMU 51 is present within a bedrock aquifer, encountered from approximately 32.5 ft bgs, in monitoring well 51MW1, to approximately 50.2 ft bgs in monitoring well 51MW2. As described in *Section 1.2.1.1* and illustrated on the geologic cross sections (**Figures 1-3 and 1-4**) and the CSM (**Figure 1-5**), a layer of sandy gravel with cobbles and boulders (river jack) exists beneath the site. The physical characteristics (e.g., porosity) of this layer may present a possible contaminant transport mechanism for leachate infiltrating through the overlying sand, silt, and clay layer directly beneath SWMU 51. Due to the karst geology at RFAAP, groundwater flow is very complex. Therefore groundwater will be evaluated in a separate study (WPA 009). The completeness of the groundwater migration pathway at SWMU 51 will be evaluated in the RFI.

Surface water and sediment are considered incomplete pathways because surface water is not present at the SWMU and groundwater does not discharge at the site. Surface water and sediment that may be affected by groundwater discharge to the surface offsite will be evaluated in the groundwater study (WPA 009).

1.2.3 Data Gap Analysis

Data are incomplete at SWMU 51 for both physical and chemical parameters. As discussed in *Section 1.2.1.3*, surface or subsurface soil samples have not been collected from the trench for chemical or physical analyses. Therefore, the following analyte classes represent a data gap in the characterization of surface and subsurface soil:

- *Target Compound List (TCL) VOCs;*
- *TCL SVOCs/Polynuclear Aromatic Hydrocarbons (PAHs);*
- *TCL Polychlorinated Biphenyls (PCBs);*
- *Pesticides/herbicides;*

**Table 1-2
Potential Exposure Pathways and Receptors**

Media	Potentially Affected Media	Pathways and Receptors						Comments
		Human			Biota			
		Construction Worker	Maintenance Worker	Residential Adult/Child	Terrestrial	Aquatic	Benthic	
Air	Yes	INH	INH	INH	INH	NA	NA	Completeness of pathway will be assessed during the RFI based on proposed soil sampling.
Surface Water	No	NA	NA	NA	NA	NA	NA	Not present at the site. No groundwater discharge on site. Contamination of surface water and/or sediment from groundwater discharge off site will be addressed by the ongoing groundwater study (WPA 009).
Sediment	No	NA	NA	NA	NA	NA	NA	Not present at the site. No groundwater discharge on site. Contamination of surface water and/or sediment from groundwater discharge off site will be addressed by the ongoing groundwater study (WPA 009).
Surface Soil	Yes	IN, INH, DA	IN, INH, DA	IN, INH, DA	IN, INH, DA	NA	NA	During construction activity, burrowing, future use.
Subsurface Soil	Yes	IN, INH, DA	NA	NA	IN, INH, DA	NA	NA	During construction activity, burrowing.
Groundwater	NA	NA	NA	NA	NA	NA	NA	Groundwater is being addressed separately as part of WPA 009; therefore, groundwater scenarios are not addressed by this CSM. However, the completeness of the groundwater pathway will be addressed in the RFI.

Note: Refer to Figure 1-5 for Conceptual Site Model

Abbreviations: NA = Not Applicable, IN = Ingestion, INH = Inhalation, DA = Dermal Adsorption

- *Explosives;*
- *Target Analyte List (TAL) inorganics (including cyanide);*
- *Dioxins/furans; and,*
- *Physical/geotechnical parameters.*

In addition, the boundaries of the disposal area have not been characterized, and this represents a data gap.

1.3 PLANNED FIELD ACTIVITIES

The SWMU 51 RFI field program is designed to address the data gaps identified in the previous section. Investigative soil samples will be collected following the procedures outlined in SOPs 20.11 (Drilling Methods and Procedures), 30.1 (Soil Sampling), and 30.9 (EnCore Sampling) (found in **Appendix A**). The selection of the area to be investigated and the soil samples to be collected considered the following:

- Evaluation of the potential for migration of constituents through site soil;
- Generation of data that can be used to evaluate risk through a screening comparison to USEPA Region III soil RBCs, the Facility-Wide Background Study (IT, 2001a), and a BRA subdivided into a HHRA and SLERA; and,
- Assessment of the nature of subsurface lithology and the physical characteristics of the disposal trench.

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:

- Geophysical survey to provide subsurface lithology information (completed, refer to *Section 1.3.1*);
- Surface and subsurface soil sampling by direct push technology methods for chemical analysis; and,
- Continuous direct push sampling for stratigraphic characterization

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 USEPA Region III soil RBCs, and performance of a BRA (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 (MHSP). **Table 1-1** identifies the SOPs that will be followed as part of this investigation.

1.3.1 Geophysical Survey

Argonne National Laboratory (ANL) performed a geophysical survey of SWMU 51 during the time period of August through September 2002 to characterize both the lateral and vertical extent of the former trench used for the TNT neutralization sludge disposal (ANL, 2003). Subsurface information obtained by the geophysical surveys was used to develop the CSM and focus the

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proposed sampling activities (discussed in the next section) to assess the nature and extent of TNT neutralized sludge disposed at SWMU 51.

Surface geophysical surveys using two-dimensional resistivity profiling, seismic refraction tomography, and EM-31/34 terrain-conductivity mapping were performed at SWMU 51. Additional seismic velocity measurements were collected in four monitoring wells adjacent to SWMU 51 to help guide the seismic interpretations, and downhole electrical logging was collected by USACE New England District personnel to help validate the resistivity models. The complete draft geophysical report and methods are presented in **Appendix B**.

Geophysical surveys for SWMU 51 consisted of three seismic-refraction profiles, four two-dimensional electrical-resistivity imaging (2D-ERI) profiles, and one electromagnetic (EM) grid (**Appendix B-1, Figure B-1**). Also shown on **Appendix B-1, Figure B-1** are the locations of the main boundary fence for SWMU 30, the interior fence outlining the TNT sludge disposal trench, and the areal coverage provided by the EM grid (~33 ft major survey lines are shown). Two of the profiles (L-2 and L-3) were collected parallel to the long axis of the trench, and the other two profiles (L-1 and L-4) were collected perpendicular to the long axis.

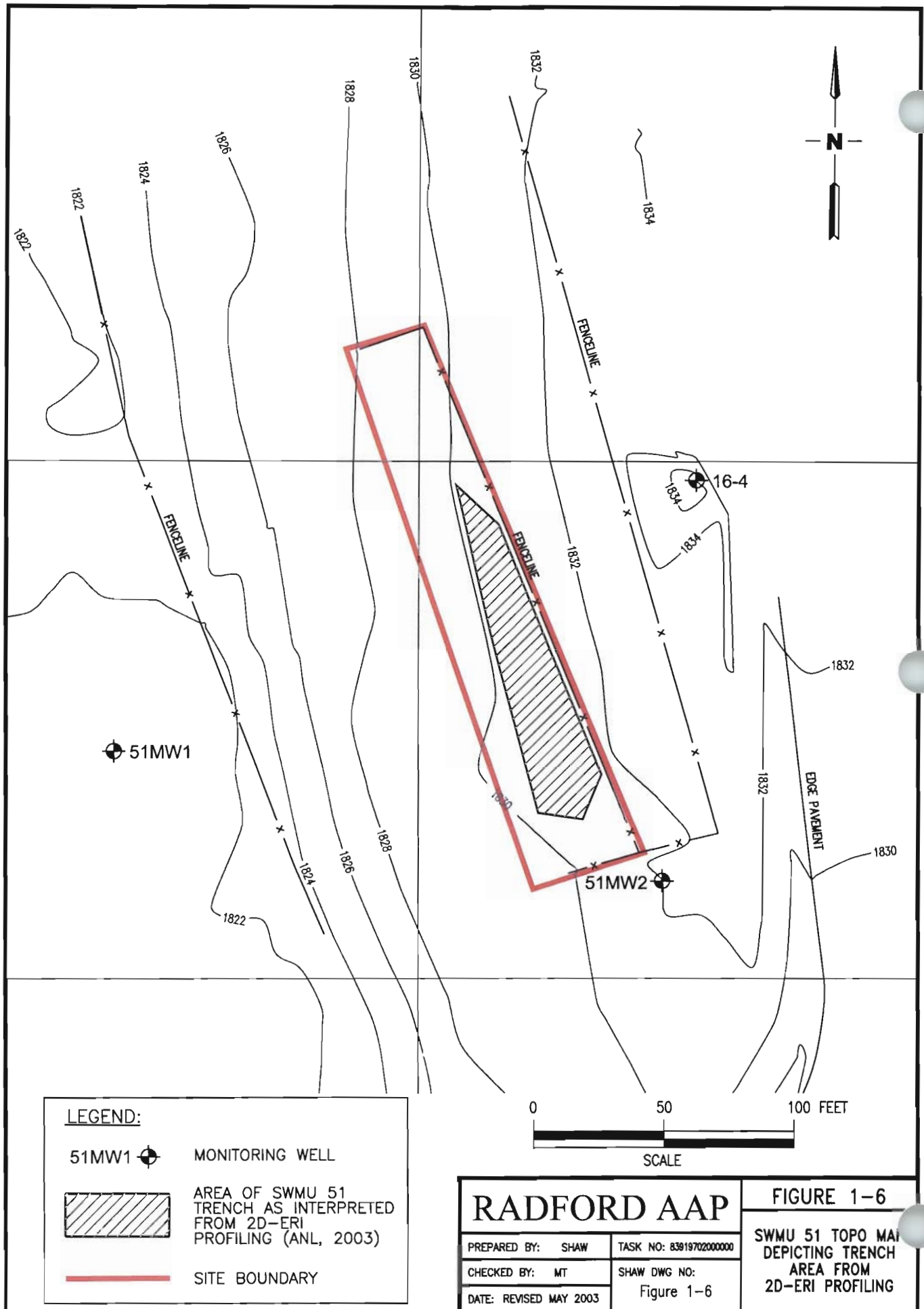
In summary, the seismic refraction tomography profiling, 2D-ERI, and electromagnetic terrain-conductivity surveying were conducted at SWMU 51 in order to delineate the horizontal and vertical boundaries of the disposal trench. The geophysical data suggest that the SWMU 51 related trenching and disposal is contained within the current SWMU 51 fence, and restricted to the southern two-thirds of the fenced area (**Figure 1-6**).

Seismic refraction tomography mapped a low-velocity zone interpreted to be due to the capping or backfilled material, but did not map the base of the trench. Earth-layer models constructed for the profiles indicate an intra-overburden increase in velocity, which occurs near the base of the trenching, and may indicate a maximum boundary for trenching. No significant structural features were indicated for the bedrock, and top-of-bedrock was mapped as a relatively horizontal surface [approximately 1,780-1,782 ft msl or 39-53 ft bgs (observed at monitoring wells 51MW1 and 51MW2, respectively)].

The 2D-ERI profiling modeled a zone of low-resistivity (<80 ohm-m) underlying the SWMU 51 fenced area. The source for the low-resistivity is interpreted to be either the waste or waste byproducts (leachate or leached material). Depth-to-top of this low-resistivity zone ranged from 5-9 ft bgs, and averaged 6-7 ft bgs. Therefore, it is argued that the waste material deposited in the SWMU 51 trench is at least 5 ft bgs.

Depth to the true base of waste is the issue. The resistivity data indicate a range of 15-25 ft bgs for the base, though it is possible that a downward migration of leachate (or leached material) has increased thickness of the low-resistivity zone, thus overstating the thickness of the waste. At best, the base of the low-resistivity zone can serve as an upper boundary for estimating the thickness of the waste material.

Electromagnetic surveys using the EM-31 and EM-34 instruments mapped a zone of increased electrical-conductivity (decreased resistivity) within the southern two-thirds of the SWMU 51 fenced area. A 1-2 mS/m increase was measured by the EM-31, and suggests that the top of the anomalous region must be within the upper 10 ft (~3 meters (m)) of the subsurface. The EM-34 instrument yielded a greater electromagnetic response than the EM-31, indicating that the source of this electrically conductivity zone (low-resistivity) extends below 10 ft (~3 m in depth). The



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anomalous area mapped by the EM-34 is approximately two-thirds that indicated by the 2D-ERI profiles.

The volume of waste is estimated as follows:

- The maximum areal extent of the trench defined by the 2D-ERI data is approximately 2,300 square feet (115 ft x 20 ft). The minimum areal extent can be estimated from the EM-34 conductivity anomaly map, and is 1,800 square feet (90 ft x 20 ft).
- Depth to top of the low-resistivity (electrically conductive) zone ranges from 5-9 ft, and averages 6-7 ft. Depth to bottom ranges from 15-25 ft, with an average of approximately 18 ft. The range in thickness is 6-20 ft, and averages approximately 11 ft.
- Using the average thickness (indicated on the 2D-ERI sections) and the areal extent, a volume range of 19,800 (11 ft x 90 ft x 20 ft) to 25,300 (11 ft x 115 ft x 20 ft) cubic ft or 733 to 937 cubic yards is calculated.

1.3.2 Proposed Soil Borings

Soil borings will be advanced at the SWMU 51 study area; both outside of the probable trench limits and within the probable limits of disposed material. The overall objectives of the investigation are to:

- Characterize material disposed in the trench;
- Evaluate potential chemical impacts of the trench waste material upon site soil;
- Collect soil samples for analysis of physical/geotechnical characteristics; and,
- Ground truth the geophysical data to more accurately assess the dimensions of the trench.

Proposed boring locations are shown on **Figure 1-7**. **Table 1-3** presents a summary of the proposed borings, including the location and purpose of each boring. **Table 1-4** presents the proposed chemical sampling and analysis plan.

Borings for Stratigraphic Characterization

The location and number of borings for stratigraphic characterization is based on the results of the geophysical survey. As presented in **Table 1-3**, borings will be advanced at 25 locations (51SBC1 through 51SBC25) around and through the trench to verify the results of the geophysical survey and for subsurface stratigraphic characterization of the disposal trench and surrounding soil. The borings will be advanced on lines perpendicular to the long axis of the trench. The lines will be spaced approximately 25 feet apart (**Figure 1-7, Lines 2 through 8**). Characterization borings will be advanced prior to the borings proposed for chemical sampling to ensure that chemical samples are collected from the proper depths and locations relative to the trench. Borings for stratigraphic characterization will be advanced to bedrock and continuously logged and interpreted, as outlined in SOP 10.3 (**Appendix A**). Boring locations along each line will be spaced approximately five feet apart. However, as the boundary between native soil and trench material is defined both horizontally and vertically, locations of borings along Lines 2 through 8 may be adjusted to better define the trench boundary. The number of borings, continuously logged to bedrock, when combined with the geophysical data should accurately define the area of the trench both vertically and horizontally.

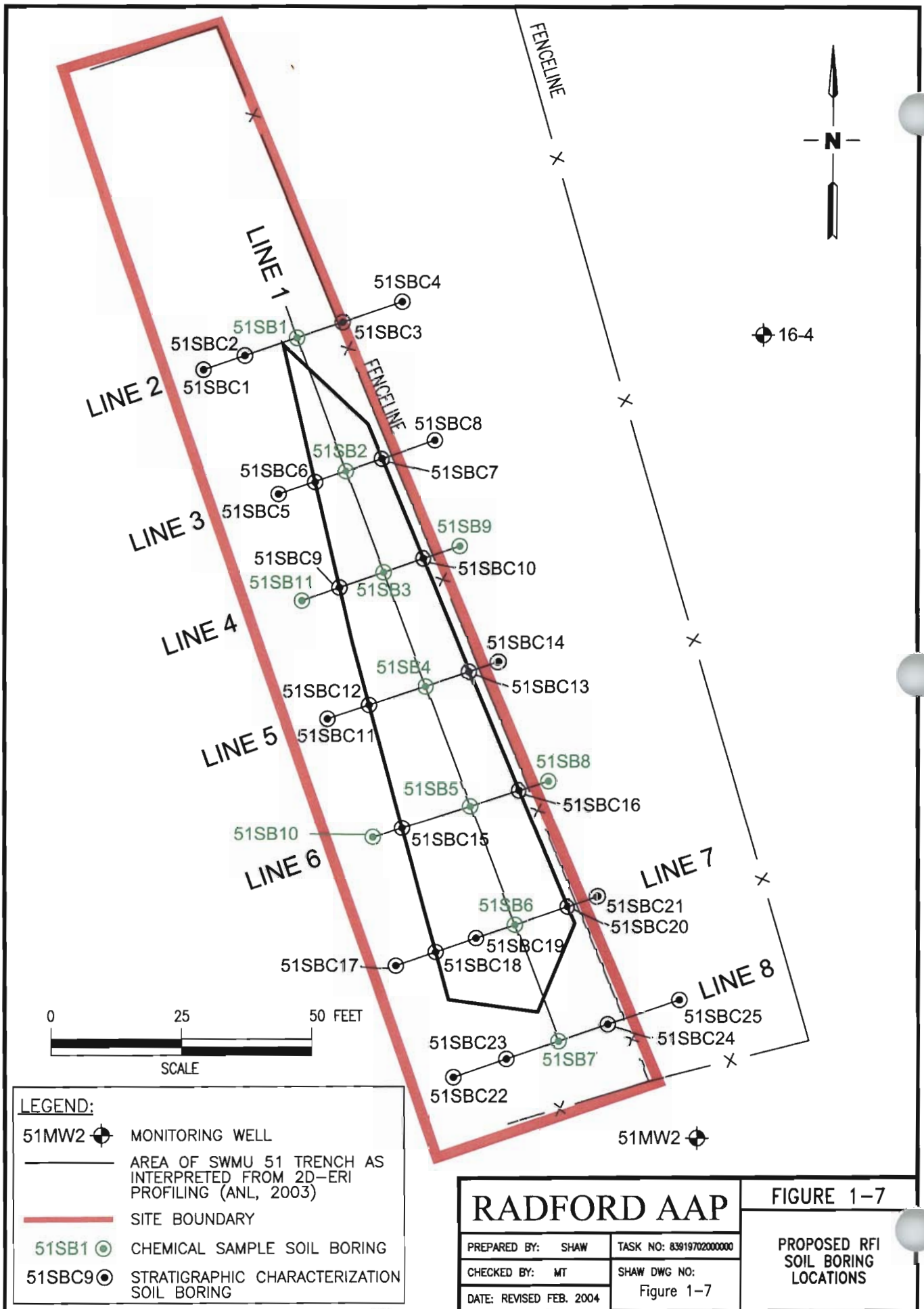


Table 1-3
Summary of Proposed RFI Borings

51SB1 (A,B,C)		✓	✓		✓
51SB2 (A,B,C,D)	✓		✓		✓
51SB3 (A,B,C,D)	✓		✓	✓*	✓
51SB4 (A,B,C,D)	✓		✓		✓
51SB5 (A,B,C,D)	✓		✓		✓
51SB6 (A,B,C,D)	✓		✓		✓
51SB7 (A,B,C)		✓	✓		✓
51SB8 (A,B,C)		✓	✓		✓
51SB9 (A,B,C)		✓	✓		✓
51SB10 (A,B,C)		✓	✓		✓
51SB11 (A,B,C)		✓	✓		✓
51SBC1		✓			✓
51SBC2		✓			✓
51SBC3		✓			✓
51SBC4		✓			✓
51SBC5		✓			✓
51SBC6	✓				✓
51SBC7	✓				✓
51SBC8		✓			✓
51SBC9	✓				✓
51SBC10	✓				✓
51SBC11		✓			✓
51SBC12	✓				✓
51SBC13	✓				✓
51SBC14		✓			✓
51SBC15	✓				✓
51SBC16	✓				✓
51SBC17		✓			✓

Table 1-3 (Continued)
Summary of Proposed RFI Borings

51SBC18	✓				✓
51SBC19	✓				✓
51SBC20	✓				✓
51SBC21		✓			✓
51SBC22		✓			✓
51SBC23		✓			✓
51SBC24		✓			✓
51SBC25		✓			✓

Refer to *Section 2.4.3* of this WPA for a discussion of sample identification derivation.

* If site conditions warrant, additional physical samples will be collected.

Table 1-4
Proposed Chemical Sampling and Analysis Plan

Surface Soil	51SB1A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, explosives, TAL inorganics
	51SB2A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, explosives, TAL inorganics, dioxins/furans
	51SB3A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, explosives, TAL inorganics, dioxins/furans
	51SB4A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, explosives, TAL inorganics, dioxins/furans
	51SB5A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, explosives, TAL inorganics, dioxins/furans
	51SB6A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, pesticides/PCBs, herbicides, explosives, TAL inorganics, dioxins/furans
	51SB7A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB8A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB9A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB10A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB11A	0-0.5 ft bgs	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
Subsurface Soil	51SB1B	TBD*	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB1C	maximum depth	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB2B	within trench	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics, PCBs, dioxins/furans
	51SB2C	beneath trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB2D	maximum depth	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB3B	within trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans

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Table 1-4 (Continued)
Proposed Chemical Sampling and Analysis Plan

Subsurface Soil (Continued)	51SB3C	beneath trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB3D	maximum depth	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB4B	within trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB4C	beneath trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB4D	maximum depth	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB5B	within trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB5C	beneath trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB5D	maximum depth	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB6B	within trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB6C	beneath trench	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB6D	maximum depth	TCL VOCs, SVOCs, PAHs, PCBs, explosives, TAL inorganics, dioxins/furans
	51SB7B	TBD*	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB7C	maximum depth	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB8B	TBD*	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB8C	maximum depth	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB9B	TBD*	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB9C	maximum depth	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB10B	TBD*	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB10C	maximum depth	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB11B	TBD*	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics
	51SB11C	maximum depth	TCL VOCs, SVOCs, PAHs, explosives, TAL inorganics

Sample Depth Notes:

Surface soil samples will be collected at a depth of 0-0.5 ft bgs, below gravel or organic layers, and 0.5-1.0 ft bgs for VOCs.

* TBD = to be determined. Subsurface soil samples collected outside the trench limits will be collected from slightly deeper depth intervals as those collected from within the trench limits to account for possible trench diffusion. These depths will be identified when the trench limits are defined during the continuous logging of stratigraphic borings inside the trench. Maximum depth = sample interval is based upon whether bedrock, the water table, or a depth of 50 ft bgs is encountered first. Within trench = a subsurface soil sample from within the trench waste (estimated depth from 5-25 ft bgs). Sample locations will be based on visual and field screening.

Beneath trench = a subsurface soil sample will be collected immediately below the trench floor.

Analyte Note:

TAL inorganics includes the 23 TAL metals and cyanide.

Borings for Chemical Analysis

As presented in **Table 1-3**, thirty-eight soil samples will be collected from eleven borings (51SB1 through 51SB11) advanced along the long axis of the trench and outside the trench boundary (**Figure 1-7, Lines 1, 4, and 6**) for chemical analysis. For borings advanced outside the trench limits, three samples will be collected from each boring as follows: a sample will be collected at the surface (0-0.5 ft bgs; 0-1 ft bgs for VOCs); at a depth corresponding to slightly below the bottom of the waste; and, at the maximum depth of the boring (50 ft, the water table, or bedrock, whichever is encountered first). For borings advanced in the trench area, four samples will be collected from each boring as follows: a surface soil sample (0-0.5 ft bgs; 0-1 ft bgs for VOCs); a sample from within the waste; a sample from just below the waste; and, a sample at maximum depth of the boring (as described above). If borings advanced through the cover material indicate that the cover is not homogenous, then additional samples will be collected to sufficiently characterize the cover material. The two intermediate depth chemical samples in each boring will be targeted to both the trench waste layer and the sand and cobble layer (illustrated on **Figures 1-3 and 1-4**), as appropriate, based on the stratigraphic characterization borings. Depths to intermediate samples will be adjusted to account for possible diffusion from the trench area. These depths will be identified when the trench limits are defined during the continuous logging of stratigraphic borings inside the trench. Sample locations and depths may be revised based on the results of the 25 stratigraphic borings.

These borings will produce eleven surface soil and 27 subsurface soil samples for chemical analysis (**Table 1-4**). These samples will provide an adequate data set for a nature and extent analysis and risk assessment calculations.

As shown in **Table 1-4**, every sample will be analyzed for TCL VOCs, SVOCs, PAHs, explosives [including nitroglycerin (NG) and pentaerythritol tetranitrate (PETN)], and TAL inorganics. Additionally, six surface soil samples will be collected and analyzed for TCL pesticides/PCBs and herbicides to characterize the site for these parameters. Twenty samples (five surface and fifteen subsurface) will be collected and analyzed for dioxins/furans because of the possibility that burned materials exist within the trench waste. Fifteen subsurface soil samples from the five borings advanced inside the trench will be collected and analyzed for TCL PCBs.

Boring for Physical Analysis

In addition to samples submitted for chemical analysis, up to four soil samples represented by each major change in primary lithology (i.e., clay, silt, sand, and gravel) will be collected for physical and geotechnical properties [*Section 5.8* of the MWP; applicable American Society of Testing and Materials (ASTM)]. Samples will be analyzed for the following parameters in accordance with the QAPA in *Section 2.5.5* of this document:

- Grain size analysis (ASTM D422-98);
- Atterberg limits (ASTM D4318-00);
- Soil moisture content (ASTM D2216-98e1);
- Total organic content (ASTM D2974-00);
- Soil bulk density (ASTM D4253-00);
- Measurement of hydraulic conductivity [ASTM D5856-95(2002)e1];

- col
- Soil porosity (ASTM D854-02 and D2937-00e1); and,
 - pH (ASTM D4972-01).

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

As previously described, soil borings will be advanced to a maximum depth of 50 ft, the water table or bedrock, whichever is encountered first, using direct push technology, consistent with procedures outlined in SOP 20.11 (**Appendix A**). Based on the preliminary geophysical data (ANL, 2003), the depth of trench waste is not anticipated to exceed 25 ft bgs. If probe refusal is encountered at less than 10 ft bgs, the unit will be offset two feet and a boring will be advanced to the point of previous refusal prior to collection of additional samples. Borings will be offset two times prior to relocation. A 4-ft Macro Core device will be used to collect the samples. Lithologic logs will be prepared for each boring location in accordance with the procedures outlined in SOP 10.3 (**Appendix A**). During soil boring advancement, subsurface soil will be screened for the presence of VOCs using a PID, consistent with SOP 90.2 (**Appendix A**).

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration (OSHA) 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 1-5** summarizes the suspected nature (hazardous versus non-hazardous) of the materials that are expected to be produced during investigative activities.

Table 1-5
Handling and Disposal of SWMU 51 Investigation-Derived Materials

Material	Description	Quantity	Concern	Action	Expected Nature of Material
Soil Cuttings	From 36 borings	Approx. two 55-gal. drums	COCs	TCLP metals, TCLP SVOCs, TCLP VOCs, TCLP pesticides, TCLP herbicides, corrosivity as pH, COD, ignitability, and reactivity.	Non-hazardous material. Concentrations are not expected to exceed TCLP or pH limits.
Decontamination Water	Aqueous IDM	Approx. one 55-gal. drum	IDM	TAL inorganics, COD, and pH	Non-hazardous material. Concentrations are not expected to exceed TCLP or pH limits.
PPE	Miscellaneous IDM	Approx. one 55-gal. drum	IDM	--	Non-hazardous material. Will be disposed as IDM.

Notes:

SWMU = Solid Waste Management Unit

Approx. = Approximately

COC = Chemical of Concern

IDM = Investigation-Derived Material

TCLP = Toxicity Characteristic Leachate Procedure

PPE = Personal Protective Equipment and Clothing

SVOC = Semivolatile Organic Compound

VOC = Volatile Organic Compound

Gal. = Gallon

1.3.3 Sample Location Position Information

Sample location coordinates will be obtained using a Trimble Pathfinder Pro XRS Global Positioning System (GPS). The Pathfinder Pro XRS system is capable of obtaining real-time position information with submeter accuracy. Horizontal position information will be recorded in the U.S. State [Virginia (South)] Plane Coordinate System (measured in U.S. survey feet) using the North American Datum of 1983. The vertical control will be measured in feet using the National Geodetic Vertical Datum of 1929. Position information will be entered into the Environmental Restoration Information System (ERIS) database.

2.0 QUALITY ASSURANCE PLAN ADDENDUM

2.1 OBJECTIVE AND SCOPE

This QAPA establishes function-specific responsibilities and authorities for ensured data quality for investigative activities at RFAAP. Specific QC requirements include DQOs, internal QC checks, and analytical procedures during the investigations at SWMU 51 and the HSA. This QAPA is designed to be used in conjunction with the Master Quality Assurance Plan (MQAP) (URS, 2003). 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. 17)
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	20.3, 20.11 30.1, 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	90.2
Data Reduction, Validation, Reporting, and Management	9.0	--
Corrective Action	10.0	--
Quality Assessments	11.0	--

The distribution list for submittals associated with the RFI Program at SWMU 51 is defined in the RCRA Facility Permit (USEPA, 2000a) and is as follows:

At least six copies of draft documents and three copies of the final plans, reports, notifications, or other documents submitted as part of the SWMU 51 RFI are to be submitted to the USEPA Regional Administrator, and shall be sent Certified Mail, Return Receipt Requested, overnight mail, or hand-carried to:

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

In addition, one copy each of such submissions shall be sent to both:

Commonwealth of Virginia
Department of Environmental Quality
Waste Division
P.O. Box 10009
Richmond, VA 23240

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 submission shall be sent to:

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

James McKenna
U.S. Army
Radford Army Ammunition Plant
Route 114, Peppers Ferry Road
Attn: SJMRF-OP-EQ
Radford, Virginia 24143-0002

Dennis Druck
USACHPPM
Attn: MCHB-TS-HER
5158 Blackhawk Road
Aberdeen Proving Ground, Maryland 21010

Tony Perry
U.S. Army Environmental Center
5179 Hoadley Road
Aberdeen Proving Ground, Maryland 21010

2.2 PROJECT ORGANIZATION

2.2.1 Contractor and Subcontractor Responsibilities

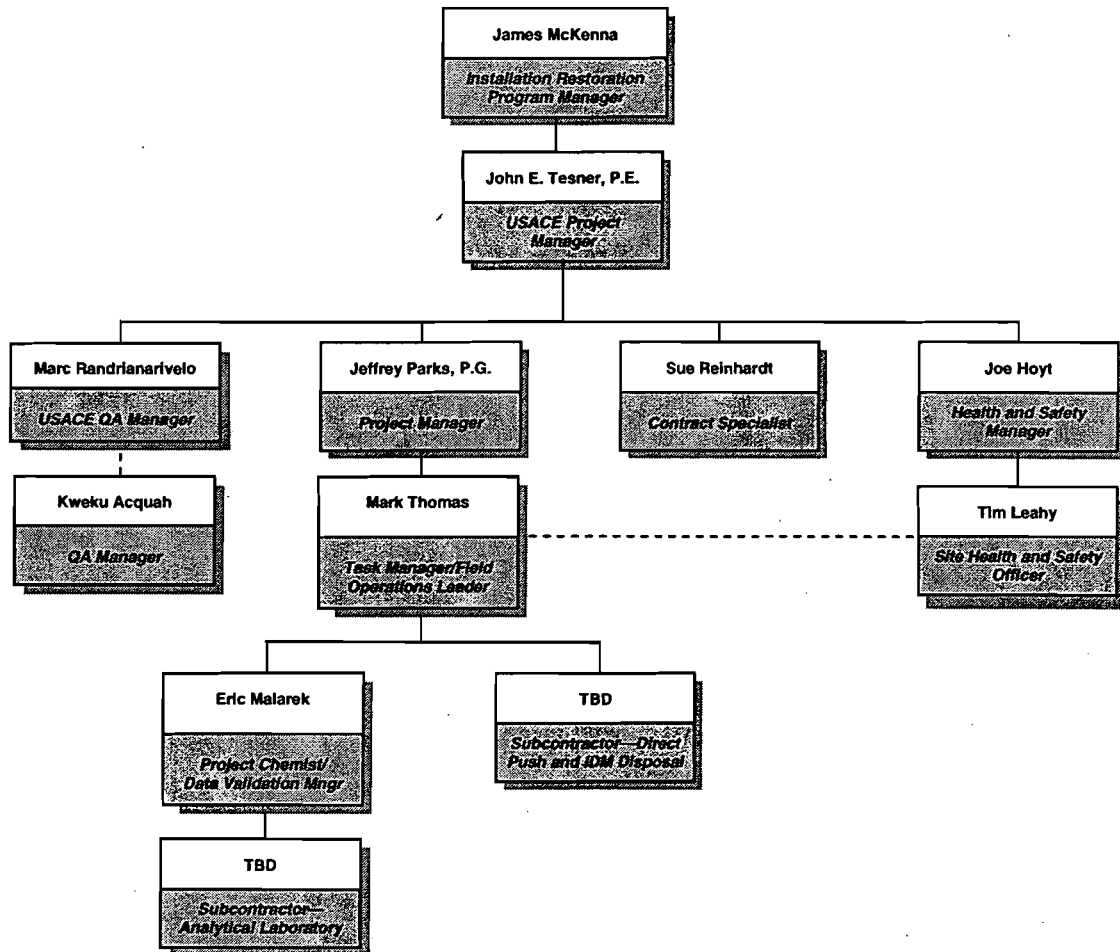
Contractor and subcontractor personnel responsibilities for implementing the technical, quality, and health and safety programs are described in *Section 2.1* of the MQAP. **Figure 2-1** presents the identification and the organization of the project management personnel. Statements of Qualification (SOQs) for subcontractor personnel will be reviewed when subcontractors have been selected.

2.2.2 Key Points of Contact

Table 2-2 provides the names and points of contact for Shaw 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

Figure 2-1
Project Organizational Chart



**Table 2-2
Contractor and Subcontractor Key Points of Contact**

Contractor	Key Point of Contact
Project Manager, Jeffrey Parks e-mail: Jeffrey.Parks@shawgrp.com	Shaw Environmental, Inc. 2113 Emmorton Park Rd Edgewood, MD 21040 Tel (410) 612-6326; Fax (410) 612-6351
Project Contract Specialist, Susan Reinhardt e-mail: Susan.Reinhardt@shawgrp.com	Shaw Environmental, Inc. 2113 Emmorton Park Rd Edgewood, MD 21040 Tel (410) 612-6366; Fax (410) 612-6351
Quality Assurance Manager, Kweku Acquah e-mail: Kweku.Acquah @shawgrp.com	Shaw Environmental, Inc. 2113 Emmorton Park Rd Edgewood, MD 21040 Tel (410) 612-6335; Fax (410) 612-6351
Project Chemist/Data Validation Manager, Eric Malarek e-mail: Eric.Malarek@shawgrp.com	Shaw Environmental, Inc. 2113 Emmorton Park Rd Edgewood, MD 21040 Tel (410) 612-6322; Fax (410) 612-6351
Task Manager and Field Operations Leader, Mark Thomas e-mail: Mark.A.Thomas@shawgrp.com	Shaw Environmental, Inc. 2113 Emmorton Park Rd Edgewood, MD 21040 Tel (410) 612-6375; Fax (410) 612-6351
Health and Safety Manager, Joe Hoyt e-mail: Joseph.Hoyt@shawgrp.com	Shaw Environmental, Inc. 304 Harlow Town Road Louisa, VA 23093 Tel (804) 337-6982; Fax (540) 967-9784
Site Health and Safety Officer, Tim Leahy e-mail: Timothy.Leahy@shawgrp.com	Shaw Environmental, Inc. 2113 Emmorton Park Rd Edgewood, MD 21040 Tel (410) 612-6357; Fax (410) 612-6351
Subcontractor	Key Point of Contact
Analytical Laboratory TBD	TBD
Direct Push and Disposal Management TBD	TBD

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.

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

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The Task Manager is responsible for development of the WPA and technical review of project deliverables. He will coordinate aspects of the RFI and ensure work is performed in accordance with contractor specifications and approved work plans. Additionally, he will ensure that requirements or concerns associated with the project are met and report to the PM.

The QA Manager is responsible for ensuring that QA program is implemented as planned during field activities, data collection, and data validation and review process. The QA manager is responsible for independent peer-review of data validation reports and tabulation to ensure data integrity and validity. In addition, the QA manager is responsible for initiating and conducting system and performance audits to ensure that QA/QC initiatives are met. The QA manager will work closely with the PM and project chemist/data validation manager.

The Project Chemist/Data Validation Manager will ensure that the work performed is in accordance with the MQAP, QAPA, SOPs, and other pertinent analytical procedures. The project chemist/data validation manager will also be responsible for sample tracking, data management, laboratory coordination, data interpretation, and report writing. The project chemist/data validation manager will be responsible for the review, evaluation, and validation of analytical data for the project and will participate in interpreting and presenting the analytical data. This includes reviewing selected field and analytical data to ensure adherence to QA/QC procedures, and approving the quality of data before they are included in the investigation report. The project chemist/data validation manager will be responsible for the validation of the analytical data from the contract laboratory according to the MQAP, QAPA, USACE Shell requirements, USEPA analytical methods performed, and laboratory SOPs. The project chemist/data validation manager is also responsible for the production of a final validation report for the project with a justification for qualifiers applied (if any), while maintaining strict adherence to project schedules.

The Health and Safety Manager will review and internally approve the HSPA, which will be tailored to the specific needs of the project in the task specific addendum. In consultation with the PM, the health and safety manager will ensure that an adequate level of personal protection exists for anticipated potential hazards for field personnel. On-site health and safety will be the responsibility of the SHSO who will work in coordination with the PM and the project health and safety manager.

The Contract Specialist is responsible for tracking funds for labor and materials procurement and oversight of the financial status of the project. Responsibilities include, but are not limited to:

- Preparation of monthly cost reports and invoices;
- Administration of equipment rental, material purchases, and inventory of supplies;
- Administration and negotiation of subcontracts and interaction with the administrative contracting officer and procurement contracting officer on contract and subcontract issues;
- Preparation of project manpower estimates; and,
- Administration of contract documents.

The Analytical Laboratory Project Manager is responsible for the technical quality of the laboratory, adherence to the laboratory QA manual, laboratory personnel management, cost control, and strict adherence to project schedules concerning the analysis for the parameters of interest. The laboratory project manager will ensure the satisfactory analysis of samples and completeness of data documentation according to the analytical statement of work and QAPA. The Shaw project chemist will monitor the laboratory activities.

The Direct Push Subcontractor will be responsible for the technical and QC management of the field drilling, cost control, and strict adherence to project schedules. The overall QC management responsibilities are the satisfactory advancement of each boring with complete data documentation. The Shaw FOL will oversee field activities.

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, 1994a), *USEPA Data Quality Objectives Process for Hazardous Waste Site Investigations EPA QA/G-4HW* (USEPA, 2000b), and the *USACE Shell for Analytical Chemistry Requirements* (USACE, 2001) 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; (2) identification of the primary decision-maker; and, (3) statement of the problem.

(1) *The planning team consists of the RFAAP, USACE, USEPA, Virginia Department of Environmental Quality (VDEQ), the RFAAP Operating Contractor, and Shaw;*

(2) *Relative to the implementation of this WPA, the primary decision-maker is RFAAP, in consultation with USACE, USEPA, VDEQ, and Shaw; and,*

(3) *RFAAP seeks to define the nature and extent of trench waste disposed at SWMU 51 and to describe what risk to human health and the environment exists at SWMU 51.*

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Table 2-3
Summary of Project Data Quality Objectives

DQO Element	Project DQO Summary
Problem Statement	<ul style="list-style-type: none"> • The nature and extent of potential contamination of the trench area at SWMU 51 is currently unknown. • Possible risks to human health and the environment are currently unknown.
Identify Decision/Study Question	<ul style="list-style-type: none"> • Analyze geophysical data of trench area. • Conduct surface/subsurface soil sampling outside and within the trench area to characterize potential impact to surrounding soil. • Collect subsurface soil samples for analysis of physical properties to aid in assessing the nature of possible constituent migration. • Collect samples representative of trench waste.
Decision Inputs	<ul style="list-style-type: none"> • Geophysical Data: Two-dimensional electrical resistivity, seismic refraction profiling tomography, electromagnetic, down-hole logging. • Field investigation data: Soil borings and samples including the depth of trench/waste material from borings. • Chemical analysis: Submit soil samples to USACE-approved off-site analytical laboratory for analyses for TAL inorganics, TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives, dioxins/furans, and physical/geotechnical parameters. For soil waste characterization, TCLP metals, TCLP SVOCs, TCLP VOCs, TCLP pesticides, TCLP herbicides, corrosivity as pH, ignitability, reactivity, and COD will be performed. For aqueous waste characterization, TAL inorganics, COD, and pH will be performed.
Study Boundaries	<ul style="list-style-type: none"> • Physical horizontal boundary of SWMU 51 will be defined within the scope of the RFI by combining geophysical and soil boring information (See Figures 1-1, 1-2, 1-6, and 1-7). • Sample points designed to collect samples representative of fill materials, nearby, and potentially affected soil.
Decision Rule	<ul style="list-style-type: none"> • Comparison to USEPA Region III soil RBCs (USEPA, 2003); as modified for risk screening. • Geophysical data will be calibrated to soil boring data. • Physical and chemical data from soil samples will be used to estimate the extent of trench material.
Tolerable Limits on Decision Errors	<ul style="list-style-type: none"> • Analytical SW-846 Test Methods (USEPA, 1996) reporting limits. USEPA Contract Laboratory Program (CLP)-like raw data package (Level IV) suitable for validation. • Improper estimate of the location of trench material. Additional soil borings may be needed after initial soil borings based on these decision errors.
Optimize the Design for Obtaining Data	<ul style="list-style-type: none"> • Soil borings and soil sampling locations have been placed to provide the most information. • Ground truthing of geophysical data will provide for calibrated geophysical data; a more accurate CSM will be 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) What is the nature and extent of trench waste at SWMU 51? How has the presence of those materials affected human health or the environment based upon comparison of site conditions to levels established in the USEPA Region RBCs?*
- (2) Resultant alternative actions include to assess whether there are significant impacts to human health or the environment:*
 - (2a) Analyze geophysical data in conjunction with soil borings completed within and around the trench area;*
 - (2b) Collect and chemically analyze samples representative of trench waste;*
 - (2c) Collect and chemically analyze surface/subsurface soil samples outside of and beneath the trench area to characterize potential impacts to surrounding soil;*
 - (2d) Collect and chemically analyze surface soil samples; and,*
 - (2e) Collect and analyze subsurface soil samples for physical/geotechnical properties to aid in assessing the nature of possible constituent migration.*

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 (1) identification of the data that will be required to make the decision, (2) determination of the information source, (3) identification of data required for study action levels, and (4) confirmation of appropriate field sampling and analytical methods.

(1) Collection of field soil data from SWMU 51 (See Table 2-3)

- Collect discrete soil samples from the vertical column in each boring advanced within the SWMU 51 area. Continuous intact cores will be collected from each boring for stratigraphic characterization. Boring logs will be developed from information gathered during core collection.

(2) Samples will be analyzed using USEPA SW-846 Update III (USEPA, 1996) and USEPA Method of Chemical Analysis of Water and Wastes (USEPA, 1983) methodologies. Refer to Section 2.5.

(3) The action levels are based upon the USEPA Region III soil RBCs (USEPA, 2003) and Facility-Wide Background Study inorganic screening values (IT, 2001a).

(4) Field sampling will be performed in accordance with the MWP (URS, 2003). Analytical methods are contained in Section 2.5.

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

(1) Physical horizontal boundary of SWMU 51 will be defined within the scope of the RFI by combining geophysical and soil boring information;

(2) Sample points designed to collect samples representative of fill materials, nearby, and potentially affected soil; and,

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(3) Subsurface karst features (pinnacles, floating blocks, etc.) pose a constraint. Boring refusal may encountered on "false bedrock", and appropriate boring offsets should be made if refusal is encountered at significantly shallower depths than anticipated.

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:

- TAL inorganics, TCL VOCs, TCL SVOCs, PAHs, TCL pesticides/PCBs, herbicides, explosives (including NG and PETN), dioxins/furans, pH, TOC; and,
- Depth of trench material from borings.
- For soil waste characterization, TCLP metals, TCLP VOCs, TCLP SVOCs, TCLP pesticides, TCLP herbicides, corrosivity as pH, ignitability, reactivity, and COD will be performed. For aqueous waste characterization, TAL inorganics, COD and pH will be performed.

(2) Action levels include:

- To evaluate the potential risk of exposure to soil at SWMU 51, the discrete soil sampling data will be compared to USEPA Region III soil RBCs (USEPA, 2003);
- At the request of USEPA Region III, a hazard quotient (HQ) of 0.1 or lifetime cancer risk of 1×10^{-5} (whichever occurs at a lower concentration) will be used for risk screening with the RBCs; and,
- The RBCs will be used along with available background data to identify constituent concentrations of potential concern. Constituent concentrations that are above the RBCs will be statistically compared (i.e., mean concentrations) to the Facility-Wide Background Study inorganic screening values (IT, 2001a).

(3) Decision rules include:

- The decision rules are based upon the evaluation of the potential risk of exposure to soil at SWMU 51 against the afore-mentioned parameters and action levels.
 - If the mean constituent concentrations are less than or equal to background [95 percent (%) upper tolerance limits], then it will be considered to be in the range of naturally occurring levels and, thereby, will not present additional risk greater than that from exposure to naturally occurring concentrations in background soil at the Installation.
 - If the mean constituent concentrations are greater than background [95 percent (%) upper tolerance limits], then these concentrations will be evaluated in the RFI contamination and risk assessments.
 - If alternative actions are deemed necessary at SWMU 51, then a CMS for SWMU 51 will be recommended.

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, and (3) potential parameter values and probability tolerance for decision errors.

- (1) *Method detection limits (MDLs) and reporting limits (RLs) are established for each analyte within the suite of parameters sought. MDLs and RLs below the RBCs will ensure the data meets the DQOs. The contract laboratory will provide a CLP-like raw data package (Level IV). The data will be validated in accordance with MQAP requirements (URS, 2003), USACE Shell requirements (USACE, 2001), method-specific criteria from USEPA-SW846, Third Edition, Test Methods for Evaluating Solid Waste, Update III (USEPA, 1996), and laboratory SOPs. The data qualifier scheme will be consistent with USEPA Region III conventions using the USEPA Region III Modifications to National Functional Guidelines for Inorganic Data Review (USEPA, 1993), USEPA Region III Modifications to the National Functional Guidelines for Organic Data Review Multi-media, Multi-concentration (USEPA, 1994b), and the USEPA Region III Dioxin/Furan Data Validation Guidance (USEPA, 1999), as appropriate. The waste characterization sample data will not require USEPA Region III data validation.*
 - (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, including spending unnecessary resources to study further or remediate a site with insignificant risk (Type II, false acceptance). Another potential decision error includes improper estimation of the location of trench material. This decision depends upon the assumption that the field geologist will be able to delineate trench material from in situ soil. Project specific Type I and Type II error rates are 0.05 and 0.2, respectively.*
 - (3) *Information from previous studies and physical features of the areas surrounding SWMU 51 were used to develop a sampling plan design and measurements 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, (3) formulating mathematical expressions to resolve design problems for each alternative, (4) selecting cost-effective data design capable of achieving DQOs, and (5) documentation of operational details and theoretical assumptions.
- (1) *This addendum contains the proposed sampling design program. DQO refinement will be an iterative process throughout the project life cycle.*
 - (2) *Non-statistical sampling procedures are proposed. Biased and judgmental sampling will be performed to verify previous data results and complete site characterization.*
 - (3) *The mathematical equations will be established during the refinement process.*
 - (4) *This addendum contains the proposed sampling design program based on cost and project DQOs.*
 - (5) *Refer to Section 1.3.*

2.4 SAMPLE MANAGEMENT

2.4.1 Number and Type

Table 2-4 includes the estimated number and type of samples proposed during this investigation.

2.4.2 Sample Containers, Preservation, and Holding Times

Parameter, container and preservation requirements, and holding times are presented in Table 2-5.

2.4.3 Sample Identification

The sample identification number will be in a similar manner with past nomenclature at RFAAP. The sample identification will consist of an alphanumeric designation related to the site location, media type, and sequential order according to the sampling event. The sample identification number should not exceed eight characters for subsequent entry into the ERIS. Samples will be coded in the following order to ensure a unique identification.

- **Site Location Code.** The first two characters will be the site location number or code. The identification will include the following:

51 = SWMU 51
TM = Duplicate sample

Table 2-4
Estimated Number and Type of Proposed RFI Samples

Sample Type	Estimated No. of Samples
Physical/Geotechnical	
Surface soil	1
Subsurface soil	3
Total Physical/Geotechnical	4
Chemical	
Surface soil	11
Subsurface soil	27
Total Chemical	38
Trip blank	3
Rinse blank	3
MS	3
MSD	3
Field duplicate	4
Total QC	16
Investigative-Derived Material (aqueous)	1
(solid)	2
Total IDM	3
Total Samples	61

Table 2-5
Parameter, Container, Preservation Requirements, and Holding Times

Parameter	Sample Container*		Preservation Requirement*	Holding Time
	Solid	Aqueous		
Site Characterization				
TCL VOCs	3, 5 gram EnCore sampler, zero headspace	3, 40 mL vials with Teflon septum, zero headspace	Cool: 4 ± 2°C, HCl to pH<2 for aqueous, No Sodium Bisulfate for solids due to sample effervescence	Aqueous: Analysis 14 days Solid: Preparation: 2 days Analysis: 14 days
TCL SVOCs	1, 8 oz, wide mouth glass with Teflon cap	2, 1-L amber glass with Teflon lined cap	Cool: 4 ± 2°C	Aqueous: Extraction: 7 days; Analysis: 40 days Solid: Extraction: 14 days; Analysis: 40 days
TCL Pesticides/PCBs	1, 8 oz, wide mouth glass with Teflon cap	2, 1-L amber glass with Teflon lined cap	Cool: 4 ± 2°C	Aqueous: Extraction: 7 days; Analysis: 40 days Solid: Extraction: 14 days; Analysis: 40 days
Herbicides	1, 8 oz, wide mouth glass with Teflon cap	2, 1-L amber glass with Teflon lined cap	Cool: 4 ± 2°C	Aqueous: Extraction: 7 days; Analysis: 40 days Solid: Extraction: 14 days; Analysis: 40 days
Explosives	1, 8 oz, wide mouth glass with Teflon cap	2, 1-L amber glass with Teflon lined cap	Cool: 4 ± 2°C	Aqueous: Extraction: 7 days; Analysis: 40 days Solid: Extraction: 14 days; Analysis: 40 days
Polynuclear Aromatic Hydrocarbons	1, 8 oz, wide mouth glass with Teflon cap	2, 1-L amber glass with Teflon lined cap	Cool: 4 ± 2°C	Aqueous: Extraction: 7 days; Analysis: 40 days Solid: Extraction: 14 days; Analysis: 40 days
Dioxins/furans	1, 8 oz, wide mouth glass with Teflon cap	2, 1-L amber glass with Teflon lined cap	Cool: 4 ± 2°C	Aqueous: Extraction: 30 days; Analysis: 45 days Solid: Extraction: 30 days; Analysis: 45 days
TAL Inorganics	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L polyethylene	Cool: 4 ± 2°C, HNO ₃ to pH<2 for aqueous	Metals: 180 days Mercury: 28 days
pH	1, 4 oz, wide mouth glass with Teflon cap	1, 250 mL glass or HDPE	Cool: 4 ± 2°C	ASAP
Grain Size	3, 8 oz, wide mouth glass with Teflon cap	NA	Cool: 4 ± 2°C	None
Total Organic Carbon	1, 4 oz, wide mouth glass with Teflon septum, zero headspace	3, 40 mL vials with Teflon septum, zero headspace	Cool: 4 ± 2°C, HCl or H ₂ SO ₄ to pH<2 for aqueous	28 days

*Parameters with same preservation requirements may be combined at laboratory's discretion.

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Table 2-5 (Continued)
Parameter, Container, Preservation Requirements, and Holding Times

Parameter	Sample Container*		Preservation Requirement*	Holding Time
	Solid	Aqueous		
Waste Characterization				
TCLP VOCs	1, 4 oz, wide mouth glass with Teflon septum, zero headspace	3, 40 mL vials with Teflon septum, zero headspace	Cool: 4 ± 2°C	TCLP Extraction: 14 days; Sample Analysis: 14 days
TCLP SVOCs	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L glass or HDPE	Cool: 4 ± 2°C	TCLP Extraction: 14 days So; 7 days Aq Extraction : 7 days Sample Analysis: 40 days
TCLP Pesticides	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L glass or HDPE	Cool: 4 ± 2°C	TCLP Extraction: 14 days So; 7 days Aq Extraction : 7 days Sample Analysis: 40 days
TCLP Metals	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L glass or HDPE	Cool: 4 ± 2°C	TCLP Extraction: 180 days ICP; Mercury : 28 days Sample Analysis: 180 days ICP Mercury : 28 days
Ignitability	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L glass or HDPE	Cool: 4 ± 2°C	28 days
Reactive Sulfide	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L glass or HDPE	Cool: 4 ± 2°C	7 days
Reactive Cyanide	1, 8 oz, wide mouth glass with Teflon cap	1, 1-L glass or HDPE	Cool: 4 ± 2°C	14 days
Corrosivity as pH	1, 8 oz, wide mouth glass with Teflon cap	1, 250 mL glass or HDPE	Cool: 4 ± 2°C	ASAP
Chemical Oxygen Demand	1, 8 oz, wide mouth glass with Teflon cap	1, 250 mL glass	Cool: 4 ± 2°C, HCl or H ₂ SO ₄ to pH<2 for aqueous	28 days

*Parameters with same preservation requirements may be combined at laboratory's discretion.

Legend:

ASAP = As Soon As Possible
 NA = Not Applicable
 PCB = Polychlorinated Biphenyl
 TAL = Target Analyte List
 TCL = Target Compound List
 TCLP = Toxicity Characteristic Leachate Procedure
 SVOC = Semivolatile Organic Compound
 VOC = Volatile Organic Compound

- **Sample/Media Type.** The second two characters will be the sample/media type. Sample types will be designated by the following codes:

DW = IDM
 SB = Soil Boring (chemical analysis)
 SBC = Soil Boring (stratigraphic analysis)

- **Sampling Location Number.** The next one or two characters will be the number of the sampling location (e.g., 1, 2, 3,..., 9, 10, 11,...).
- **Sample Depth.** At sites where there are several samples to be collected at different depths, the sequential collection order will be followed by a letter in alphabetic order indicating shallow to deep depths (e.g., A, B, C,...), where A would be the shallow sample.
- **Duplicate.** Duplicate samples will be identified with a "TM" prefix preceding the sample/media type. A record of the samples that correspond to the duplicates will be kept in the field logbook.

Sample Identification Examples:

1. The first shallow soil sample for chemical analysis at location 5 at SWMU 51 collected at a point would be identified as 51SB1A. The field duplicate for the same sample would be TMSB1A.
 2. The second soil sample depth collected for chemical analysis at soil boring location 5 at SWMU 51 would be identified as 51SB1B. The duplicate for the same sample would be TMSB1B.
 3. The first shallow soil sample for stratigraphic analysis at location 5 at SWMU 51 collected at a point would be identified as 51SBC1A.
- **Quality Control Samples.** QC samples will be identified by date (mo,day,yr), followed by QC sample type, and sequential order number at one digit. The QC sample types include:

R = Rinse Blank T = Trip Blank

For example, the second rinse blank collected on 07 July 2003, would be identified as 070703R2.

2.5 ANALYTICAL PROCEDURES

2.5.1 Laboratory Procedures for Chemical Analyses

A USACE-approved laboratory will perform RFI analytical activities. Analytical compound lists and quantitation limits (QLs) are provided in **Table 2-6**. The methods listed are in accordance with USEPA Office of Solid Waste and Emergency Response Test Methods for Evaluating Solid Waste Physical/Chemical Methods (SW-846), Update III, December, 1996. The analyses include TAL inorganics, TCL VOCs, TCL SVOCs, explosives (including NG and PETN), PAHs, TCL pesticides/PCBs, herbicides, dioxins/furans, pH, and TOC.

Analytical QLs were compared to screening levels to ensure that they do not exceed the screening levels listed in **Table 2-6**. During the planning stage, the QLs are used for comparison rather than method reporting limits (MRLs) or method detection limits (MDLs) because MRLs are sample specific and take into account characteristics such as dilutions, sample volumes, and percent moistures which are unknown prior to sampling and analysis. The laboratory will be required to perform and report MDLs for each sample and analysis. These limits are specific to the laboratory, instrumentation, and methodology and are updated at least annually. The MDLs represent the lowest level the laboratory can detect a constituent at a 99% confidence for a specific compound. If a compound is detected >MDL and <MRL, it is treated as estimated "J". The QLs listed in **Table 2-6** are conservative limits and, although some exceedances of the screening levels are indicated, this does not necessarily indicate that the method will not detect the compound at, or below, the screening level.

Although some QLs are above the screening levels for certain compounds because the values cannot be met practically with the given USEPA methodology, the best available methods were selected to attain screening level requirements. Economical, technical, comparability, and sensitivity factors were considered during the method selection process for this WPA. The MRLs and MDLs will be compared to screening levels during the data analysis stage in the RFI.

Table 2-6
Analyte List

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)				Background
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:		Soil (mg/kg)
												Acute	Chronic	Water & Organisms	Organisms Only	
TAL Metals																
Aluminum	N	200	20	50	3,700	7,800	100,000	NA	25	1	NA	750	87	NA	NA	40,041
Antimony	N	5	0.5	6	1.5	3.1	41	13	30	0.48	150	NA	NA	14	4,300	NA
Arsenic	C	3	0.5	10	0.04	0.43	1.9	0.026	48	328	8.2	340	150	0.018	0.14	15.8
Barium	N	20	2	2,000	260	550	7,200	2,100	10,000	440	NA	NA	NA	1,000	NA	209
Beryllium	N	2	0.2	4	7.3	16	200	1,200	5.3	0.02	NA	NA	NA	NA	NA	1.02
Cadmium	N	2	0.1	5	1.8	3.9	51	27	0.53	3	1.2	4.3	2.2	NA	NA	0.69
Calcium	NA	100	10	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	N	10	1	100	11	23	310	42	2	0.02	81	16	11	NA	NA	65.3
Cobalt	N	50	5	NA	73	160	2,000	NA	35,000	0.1	NA	NA	NA	NA	NA	72.3
Copper	N	20	2	1,000	150	310	4,100	11,000	6.5	15	34	13	9	1,300	NA	53.5
Iron	N	50	5	300	2,200	2,300	31,000	NA	320	3,260	NA	NA	1,000	300	NA	50,962
Lead	NA	2	0.3	15	NA	400	750	400	3.2	2	46.7	65	2.5	NA	NA	26.8
Magnesium	NA	100	10	NA	NA	NA	NA	NA	NA	4,400	NA	NA	NA	NA	NA	NA
Manganese	N	10	1	50	73	160	2,000	950	14,500	330	NA	NA	NA	50	100	2,543
Mercury	N	0.1	0.05	2	1.1	2.3	31	NA	0.012	0.058	0.15	1.4	0.77	0.05	0.051	0.13
Nickel	N	40	4	NA	73	160	2,000	NA	160	2	20.9	470	52	610	4,600	62.8
Potassium	NA	3,000	300	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	N	5	1	50	18	39	510	19	5	1.8	NA	NA	5	170	11,000	NA
Silver	N	10	1	100	18	39	510	31	0.0001	0.0000098	1	3.4	NA	NA	NA	NA
Sodium	NA	200	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Thallium	N	2	0.3	2	0.26	0.55	7.2	3.6	40	0.001	NA	NA	NA	1.7	6.3	2.11
Vanadium	N	50	5	NA	1.1	2.3	31	220	10,000	0.5	NA	NA	NA	NA	NA	108
Zinc	N	20	2	5,000	1,100	2,300	31,000	14,000	30	10	150	120	120	9,100	69,000	202
Inorganic																
Cyanide	N	10	0.4	200	73	160	4,100	150	5.2	0.005	NA	22	5.2	700	220,000	NA
Perchlorate	NA	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
pH	NA	±0.1	±0.1	6.5-8.5	NA	NA	NA	NA	NA	NA	NA	NA	6.5-9	5-9	NA	NA
Organic																
Total Organic Carbon	NA	1,000	1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total Organic Halides	NA	175	1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Explosives																
Cyclotrimethylene-trinitramine (RDX)	C	0.26	0.2	NA	0.61	5.8	26	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cyclotetramethylene-tetranitramine (HMX)	N	0.26	2.1	NA	180	390	5,100	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,3-Dinitrobenzene	N	0.13	0.1	NA	0.37	0.78	10	0.037	1,200	NA	NA	NA	NA	NA	NA	NA

**Table 2-6
Analyte List (Continued)**

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
Explosives (continued)															
2,4-Dinitrotoluene	N	0.13	0.2	NA	7.3	16	200	0.57	230	NA	NA	NA	NA	0.11	9.1
2,6-Dinitrotoluene	N	0.26	0.2	NA	3.7	7.8	100	0.25	230	NA	NA	NA	NA	NA	NA
Dinitrotoluene Mix	C	0.39	0.2	NA	0.09	0.94	4.2	NA	230	NA	NA	NA	NA	NA	NA
Nitrobenzene	N	0.26	0.2	NA	0.35	3.9	51	0.023	27,000	NA	NA	NA	NA	17	1,900
Nitroglycerin	C	0.97	0.3	NA	4.8	46	200	NA	NA	NA	NA	NA	NA	NA	NA
PETN	NA	0.97	0.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TETRYL	N	0.26	0.2	NA	37	78	1,000	NA	NA	NA	NA	NA	NA	NA	NA
1,3,5-Trinitrobenzene	N	0.13	0.1	NA	110	230	3,100	NA	NA	NA	NA	NA	NA	NA	NA
2,4,6-Trinitrotoluene	C!	0.26	0.2	NA	1.83	3.9	51	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitrotoluene	C	0.52	0.4	NA	0.046	2.8	12	NA	NA	NA	NA	NA	NA	NA	NA
3-Nitrotoluene	C	0.52	0.4	NA	12	160	2,000	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitrotoluene	C	0.52	0.4	NA	0.62	38	170	NA	NA	NA	NA	NA	NA	NA	NA
4-Amino-2,6-dinitrotoluene	N	0.26	0.2	NA	0.73	1.6	20	NA	NA	NA	NA	NA	NA	NA	NA
2-Amino-4,6-dinitrotoluene	N	0.26	0.2	NA	0.73	1.6	20	NA	NA	NA	NA	NA	NA	NA	NA
TCL SVOCs															
1,2-Dichlorobenzene	N	5	0.170	600	27	700	9,200	0.46	763	0.1	0.035	NA	NA	2,700	17,000
1,2,4-Trichlorobenzene	N	5	0.170	70	0.72	78	1,000	7.5	50	0.1	0.040	NA	NA	260	940
1,3-Dichlorobenzene	N	5	0.170	NA	18	230	3,100	2.9	763	NA	NA	NA	NA	400	2,600
1,4-Dichlorobenzene	C	5	0.170	75	0.47	27	120	0.0071	763	0.1	0.11	NA	NA	400	2,600
2-Chloronaphthalene	N	5	0.170	NA	49	630	8,200	32	NA	NA	NA	NA	NA	1,700	4,300
2-Chlorophenol	N	5	0.170	NA	3	39	510	NA	970	0.1	NA	NA	NA	120	400
2-Methylnaphthalene	N	5	0.170	NA	12	160	2,000	22	NA	NA	0.07	NA	NA	NA	NA
2-Methylphenol	N	5	0.170	NA	180	390	5,100	NA	NA	0.1	0.063	NA	NA	NA	NA
2-Nitroaniline	N	5	0.170	NA	11	23	310	NA	NA	NA	NA	NA	NA	NA	NA
2-Nitrophenol	NA	5	0.170	NA	NA	NA	NA	NA	150	0.1	NA	NA	NA	NA	NA
2,4-Dichlorophenol	N	5	0.170	NA	11	23	310	1.2	365	0.1	NA	NA	NA	93	790
2,4-Dimethylphenol	N	5	0.170	NA	73	160	2,000	6.7	2,120	0.1	0.029	NA	NA	540	2,300
2,4-Dinitrophenol	N	25	0.830	NA	7.3	16	200	NA	150	0.1	NA	NA	NA	70	14,000
2,4-Dinitrotoluene	N	5	0.170	NA	7.3	16	200	0.57	230	NA	NA	NA	NA	0.11	9.1
2,4,5-Trichlorophenol	N	5	0.170	NA	370	780	10,000	NA	63	0.1	NA	NA	NA	2,600	9,800
2,4,6-Trichlorophenol	C	5	0.170	NA	6.1	58	260	NA	970	0.1	NA	NA	NA	2.1	6.5
2,6-Dinitrotoluene	N	5	0.170	NA	3.7	7.8	100	0.25	230	NA	NA	NA	NA	NA	NA
3-Nitroaniline	C!	5	0.170	NA	3.3	2.3	140	NA	NA	NA	NA	NA	NA	NA	NA
3,3'-Dichlorobenzidine	C	5	0.170	NA	0.15	1.4	6.4	0.0049	NA	NA	NA	NA	NA	0.04	0.077
4-Bromophenylphenylether	NA	5	0.170	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloro-3-methylphenol	NA	5	0.170	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Chloroaniline	N	5	0.170	NA	15	31	410	0.97	NA	NA	NA	NA	NA	NA	NA

Table 2-6
Analyte List (Continued)

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
TCL SVOCs (continued)															
4-Chlorophenylphenylether	NA	5	0.170	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3+4-Methylphenol	N	5	0.170	NA	18	39	510	NA	NA	0.1	0.67	NA	NA	NA	NA
4-Nitroaniline	C!	5	0.170	NA	3.3	23.5	140	NA	NA	NA	NA	NA	NA	NA	NA
4-Nitrophenol	N	25	0.830	NA	29	63	820	1.7	150	0.1	NA	NA	NA	NA	NA
4,6-Dinitro-2-methylphenol	N	25	0.830	1.6	0.37	0.78	10	NA	NA	NA	NA	NA	NA	13.4	765
Acenaphthylene	NA	5	0.170	NA	NA	NA	NA	NA	NA	0.1	0.044	NA	NA	NA	NA
Acenaphthene	N	5	0.170	NA	37	470	6,100	100	520	0.1	0.016	NA	NA	1,200	2,700
Anthracene	N	5	0.170	NA	180	2,300	31,000	470	0.1	0.1	0.853	NA	NA	9,600	110,000
Benz[a]anthracene	C	5	0.170	NA	0.092	0.87	3.9	1.5	6.3	0.1	0.261	NA	NA	0.0044	0.049
Benzo[b]fluoranthene	C	5	0.170	NA	0.092	0.87	3.9	4.5	NA	0.1	3.20	NA	NA	0.0044	0.049
Benzo[a]pyrene	C	5	0.170	0.2	0.0092	0.087	0.39	0.37	NA	0.1	0.430	NA	NA	0.0044	0.049
Benzo[g,h,i]perylene	N	5	0.170	NA	18	230	3,100	680	NA	0.1	0.670	NA	NA	NA	NA
Benzo[k]fluoranthene	C	5	0.170	NA	0.92	8.7	39	45	NA	0.1	NA	NA	NA	0.0044	0.049
Benzoic acid	N	25	0.170	NA	15,000	31,000	410,000	NA	NA	NA	NA	NA	NA	NA	NA
Benzyl alcohol	N	5	0.170	NA	1,100	2,300	31,000	88	460,000	NA	NA	NA	NA	NA	NA
Bis(2-chloroethoxy)methane	NA	5	0.170	NA	NA	NA	NA	NA	11,000	NA	NA	NA	NA	NA	NA
Bis(2-chloroethyl)ether	C	5	0.170	NA	0.0096	0.58	2.6	0.00004	NA	NA	NA	NA	NA	0.031	1.4
Bis(2-chloroisopropyl)ether	C	5	0.170	NA	0.26	9.1	41	0.0017	NA	NA	NA	NA	NA	1,400	170,000
Bis(2-ethylhexyl)phthalate	C	5	0.170	6	4.8	46	200	2,900	30	NA	1.30	NA	NA	1.8	5.9
Butylbenzylphthalate	N	5	0.170	NA	730	1,600	20,000	17,000	3	NA	0.063	NA	NA	3,000	5,200
Carbazole	C	5	0.170	NA	3.3	32	140	0.47	NA	NA	NA	NA	NA	NA	NA
Chrysene	C	5	0.170	NA	9.2	87	390	150	NA	0.1	0.384	NA	NA	0.0044	0.049
Di-n-butylphthalate	N	5	0.170	NA	370	780	10,000	5,000	0.3	NA	1.40	NA	NA	2,700	12,000
Di-n-octylphthalate	N	5	0.170	NA	150	310	4,100	490,000	0.3	NA	6.20	NA	NA	NA	NA
Dibenz[a,h]anthracene	C	5	0.170	NA	0.0092	0.087	0.39	1.4	NA	0.1	0.063	NA	NA	0.0044	0.049
Dibenzofuran	N	5	0.170	NA	1.2	16	200	3.8	NA	NA	NA	NA	NA	NA	NA
Diethylphthalate	N	5	0.170	NA	2,900	6,300	82,000	450	3	NA	0.20	NA	NA	23,000	120,000
Dimethylphthalate	N	5	0.170	NA	37,000	78,000	1,000,000	NA	3	NA	0.07	NA	NA	313,000	2,900,000
Fluoranthene	N	5	0.170	NA	150	310	4,100	6,300	3,980	0.1	0.600	NA	NA	300	370
Fluorene	N	5	0.170	NA	24	310	4,100	140	430	0.1	0.019	NA	NA	1,300	14,000
Hexachlorobenzene	C	5	0.170	1	0.042	0.4	1.8	0.052	3.68	NA	0.022	NA	NA	0.00075	0.00077
Hexachlorobutadiene	C!	5	0.170	NA	0.73	1.6	37	1.8	9.3	NA	0.011	NA	NA	0.44	50
Hexachlorocyclopentadiene	N	5	0.170	50	22	47	610	1,800	5.2	NA	NA	NA	NA	240	17,000
Hexachloroethane	C!	5	0.170	NA	3.65	7.8	200	0.36	540	NA	NA	NA	NA	1.9	8.9
Indeno[1,2,3-cd]pyrene	C	5	0.170	NA	0.092	0.87	3.9	13	NA	0.1	0.600	NA	NA	0.0044	0.049
Isophorone	C	5	0.170	NA	70	670	3,000	0.41	117,000	NA	NA	NA	NA	36	2,600

**Table 2-6
Analyte List (Continued)**

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
TCL SVOCs (continued)															
N-Nitrosodi- <i>n</i> -propylamine	C	5	0.170	NA	0.0096	0.091	0.41	0.000047	NA	NA	NA	NA	NA	0.005	1.4
N-Nitrosodiphenylamine	C	5	0.170	NA	14	130	580	0.76	5,850	NA	0.028	NA	NA	5	16
Naphthalene	N	5	0.170	NA	0.65	160	2,000	0.15	100	0.1	0.160	NA	NA	NA	NA
Nitrobenzene	N	5	0.170	NA	0.35	3.9	51	0.023	27,000	NA	NA	NA	NA	17	1,900
Pentachlorophenol	C	25	0.830	1	0.56	5.3	24	NA	13	0.1	0.36	19	15	0.28	8.2
Phenanthrene	N	5	0.170	NA	18	230	3,100	680	6.3	0.1	0.240	NA	NA	NA	NA
Phenol	N	5	0.170	NA	1,100	2,300	31,000	67	79	0.1	0.42	NA	NA	21,000	4,600,000
Pyrene	N	5	0.170	NA	18	230	3,100	680	NA	0.1	0.665	NA	NA	960	11,000
Pyridine	N	5	0.170	NA	3.7	7.8	100	NA	NA	NA	NA	NA	NA	NA	NA
Dioxins/Furans															
2,3,7,8-TCDD	C	0.00001	0.000001	0.00003	0.00000045	0.0000043	0.000019	0.0000086	0.00001	0.010	NA	NA	NA	0.000000013	0.000000014
1,2,3,7,8-PeCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8-HxCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,6,7,8-HxCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8,9-HxCDD	C	0.00001	0.000001	NA	0.000011	0.0001	0.00046	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,7,8-TCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8-PeCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4,7,8-PeCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8-HxCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,6,7,8-HxCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,3,4,6,7,8-HxCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8,9-HxCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8,9-HpCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
OCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total TCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PeCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total HxCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total HpCDD	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total TCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total PeCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total HxCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Total HpCDF	NA	0.00001	0.000001	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
PAHs															
Acenaphthylene	N	0.05	0.0017	NA	18	230	3,100	680	NA	0.1	0.044	NA	NA	NA	NA
Acenaphthene	N	0.05	0.0017	NA	37	470	6,100	100	520	0.1	0.016	NA	NA	1,200	2,700
Anthracene	N	0.05	0.0017	NA	180	2,300	31,000	470	0.1	0.1	0.853	NA	NA	9,600	110,000

Table 2-6
Analyte List (Continued)

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
PAHs (continued)															
Benz[a]anthracene	C	0.05	0.0017	NA	0.092	0.87	3.9	1.5	6.3	0.1	0.261	NA	NA	0.0044	0.049
Benzo[b]fluoranthene	C	0.05	0.0017	NA	0.092	0.87	3.9	4.5	NA	0.1	3.20	NA	NA	0.0044	0.049
Benzo[a]pyrene	C	0.05	0.0017	0.2	0.0092	0.087	0.39	0.37	NA	0.1	0.430	NA	NA	0.0044	0.049
Benzo[g,h,i] perylene	N	0.05	0.0017	NA	18	230	3,100	680	NA	0.1	0.670	NA	NA	NA	NA
Benzo[k]fluoranthene	C	0.05	0.0017	NA	0.92	8.7	39	45	NA	0.1	NA	NA	NA	0.0044	0.049
Chrysene	C	0.05	0.0017	NA	9.2	87	390	150	NA	0.1	0.384	NA	NA	0.0044	0.049
Dibenz[a,h]anthracene	C	0.05	0.0017	NA	0.0092	0.087	0.39	1.4	NA	0.1	0.063	NA	NA	0.0044	0.049
Fluoranthene	N	0.05	0.0017	NA	150	310	4,100	6,300	3,980	0.1	0.600	NA	NA	300	370
Fluorene	N	0.05	0.0017	NA	24	310	4,100	140	430	0.1	0.019	NA	NA	1,300	14,000
Indeno[1,2,3-cd]pyrene	C	0.05	0.0017	NA	0.092	0.87	3.9	13	NA	0.1	0.600	NA	NA	0.0044	0.049
2-Methylnaphthalene	N	0.05	0.0017	NA	12	160	2,000	22	NA	NA	0.07	NA	NA	NA	NA
Naphthalene	N	0.05	0.0017	NA	0.65	160	2,000	0.15	100	0.1	0.160	NA	NA	NA	NA
Phenanthrene	N	0.05	0.0017	NA	18	230	3,100	680	6.3	0.1	0.240	NA	NA	NA	NA
Pyrene	N	0.05	0.0017	NA	18	230	3,100	680	NA	0.1	0.665	NA	NA	960	11,000
TCL VOCs															
Acetone	N	5	0.005	NA	550	7,000	92,000	2.2	9,000,000	NA	NA	NA	NA	NA	NA
Benzene	C	1	0.005	5	0.34	12	52	0.0019	5,300	0.1	NA	NA	NA	1.2	71
Bromochloromethane	NA	1	0.005	NA	NA	NA	NA	NA	11,000	3,000	NA	NA	NA	NA	NA
Bromodichloromethane	C	1	0.005	80	0.17	10	46	0.0011	11,000	450	NA	NA	NA	0.56	46
Bromoform	C	1	0.005	80	8.5	81	360	0.067	NA	NA	NA	NA	NA	4.3	360
Bromomethane	N	1	0.005	NA	0.85	11	140	0.041	NA	NA	NA	NA	NA	48	4,000
2-Butanone	N	5	0.005	NA	700	4,700	61,000	2.9	3,220,000	NA	NA	NA	NA	NA	NA
Carbon disulfide	N	1	0.005	NA	100	780	10,000	19	2	NA	NA	NA	NA	NA	NA
Carbon tetrachloride	C	1	0.005	5	0.16	4.9	22	0.0021	35,200	0.3	NA	NA	NA	0.25	4.4
Chlorobenzene	N	1	0.005	100	11	160	2,000	0.8	50	0.1	NA	NA	NA	680	21,000
Chloroethane	C	1	0.005	NA	3.6	220	990	0.019	NA	NA	NA	NA	NA	NA	NA
Chloroform	C	1	0.005	80	0.15	78	1,000	0.00091	1,240	0.3	NA	NA	NA	5.7	470
Chloromethane	N	1	0.005	NA	19	NA	NA	0.93	NA	NA	NA	NA	NA	NA	NA
Dibromochloromethane	C	1	0.005	80	0.13	7.6	34	0.00083	11,000	NA	NA	NA	NA	0.41	34
1,1-Dichloroethane	N	1	0.005	NA	80	780	10,000	4.5	160,000	0.3	NA	NA	NA	NA	NA
1,2-Dichloroethane	C	1	0.005	5	0.12	7	31	0.001	20,000	870	NA	NA	NA	0.38	99
1,1-Dichloroethene	N	1	0.005	7	35	390	5,100	2.9	11,600	NA	NA	NA	NA	0.057	3.2
cis-1,2-Dichloroethene	N	1	0.005	70	6.1	78	1,000	0.35	11,600	0.3	NA	NA	NA	NA	NA
trans-1,2-Dichloroethene	N	1	0.005	100	12	160	2,000	0.82	11,600	0.3	NA	NA	NA	700	140,000
1,2-Dichloropropane	C	1	0.005	5	0.16	9.4	42	0.0021	NA	NA	NA	NA	NA	0.52	39
cis-1,3-Dichloropropene	C	1	0.005	NA	0.44	6.4	29	0.0031	244	0.3	NA	NA	NA	10	1,700
trans-1,3-Dichloropropene	C	1	0.005	NA	0.44	6.4	29	0.0031	244	0.3	NA	NA	NA	10	1,700

**Table 2-6
Analyte List (Continued)**

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
TCL VOCs (continued)															
Ethylbenzene	N	1	0.005	700	130	780	10,000	15	32,000	0.1	0.010	NA	NA	3,100	29,000
2-Hexanone	N	5	0.005	NA	150	310	4,100	NA	428,000	NA	NA	NA	NA	NA	NA
4-Methyl-2-pentanone	N	5	0.005	NA	630	NA	NA	5.9	460,000	100	NA	NA	NA	NA	NA
Methylene chloride	C	1	0.005	5	4.1	85	380	0.019	11,000	0.3	NA	NA	NA	4.7	1,600
Styrene	N	1	0.005	100	160	1,600	20,000	57	NA	0.1	NA	NA	NA	NA	NA
1,1,2,2-Tetrachloroethane	C	1	0.005	NA	0.053	3.2	14	0.00068	2,400	0.3	NA	NA	NA	0.17	11
Tetrachloroethene	C	1	0.005	5	0.53	32	140	0.024	840	0.3	0.057	NA	NA	0.8	8.85
Toluene	N	1	0.005	1,000	75	1,600	20,000	8.8	17,000	0.1	NA	NA	NA	6,800	200,000
1,1,1-Trichloroethane	N	1	0.005	200	320	2,200	29,000	60	9,400	0.3	0.031	NA	NA	NA	NA
1,1,2-Trichloroethane	C	1	0.005	5	0.19	11	50	0.00078	9,400	0.3	0.031	NA	NA	0.6	42
Trichloroethene	C	1	0.005	5	0.026	1.6	7.2	0.00026	21,900	0.3	NA	NA	NA	2.7	81
Vinyl chloride	C	1	0.005	2	0.015	0.09	4.0	0.00033	11,600	0.3	NA	NA	NA	2	525
m- & p-Xylene	N	2	0.01	10,000	21	1,600	200,000	3.0	6,000	0.1	0.040	NA	NA	NA	NA
o-Xylene	N	1	0.005	10,000	21	1,600	200,000	3.0	6,000	0.1	0.040	NA	NA	NA	NA
Xylene (total)	N	2	0.005	10,000	21	1,600	200,000	3.0	6,000	0.1	0.040	NA	NA	NA	NA
TCL Pesticides															
Aldrin	C	0.050	0.00067	NA	0.0039	0.038	0.17	0.0077	3.0	0.10	NA	3	NA	0.00013	0.00014
Alpha-BHC	C	0.050	0.00067	NA	0.011	0.10	0.45	0.0004	NA	NA	NA	NA	NA	0.0039	0.013
beta-BHC	C	0.050	0.00067	NA	0.037	0.35	1.6	0.002	NA	NA	NA	NA	NA	0.014	0.046
delta-BHC	NA	0.050	0.00067	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Gamma-BHC (Lindane)	C	0.050	0.00067	0.2	0.052	0.49	2.2	0.006	0.08	0.10	NA	0.95	NA	0.019	0.063
alpha-Chlordane	C	0.050	0.00067	2	0.19	1.8	8.2	0.092	0.0043	0.10	NA	2.4	0.0043	0.0021	0.0022
gamma-Chlordane	C	0.050	0.00067	2	0.19	1.8	8.2	0.092	0.0043	0.10	NA	2.4	0.0043	0.0021	0.0022
Dieldrin	C	0.10	0.00067	NA	0.0042	0.040	0.18	0.0022	0.0019	0.10	16	0.24	0.056	0.00014	0.00014
4,4'-DDD	C	0.10	0.00067	NA	0.28	2.7	12	11	0.60	0.10	2.2	NA	NA	0.00083	0.00084
4,4'-DDE	C	0.10	0.00067	NA	0.20	1.9	8.4	35	1050	0.10	1.58	NA	NA	0.00059	0.00059
4,4'-DDT	C	0.10	0.00067	NA	0.20	1.9	8.4	1.2	0.001	0.10	NA	1.1	0.001	0.00059	0.00059
Endosulfan I	N	0.050	0.00067	NA	22	47	610	20	0.056	NA	NA	0.22	0.056	110	240
Endosulfan II	N	0.10	0.00067	NA	22	47	610	20	0.056	NA	NA	0.22	0.056	110	240
Endosulfan sulfate	NA	0.10	0.00067	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	110	240
Endrin	N	0.10	0.00067	2	1.1	2.30	31	5.4	0.0023	0.10	NA	0.086	0.036	0.76	0.81
Endrin aldehyde	NA	0.10	0.00067	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.76	0.81
Endrin ketone	NA	0.10	0.00067	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor	C	0.050	0.00067	0.4	0.015	0.14	0.64	0.84	0.0038	NA	NA	0.52	0.0038	0.00021	0.00021
Heptachlor epoxide	C	0.050	0.00067	0.2	0.0074	0.070	0.31	0.025	0.0038	0.10	NA	0.52	0.0038	0.001	0.00011
Methoxychlor	N	0.50	0.00067	40	18	39	510	310	0.03	0.10	NA	NA	0.03	100	NA
Toxaphene	C	3.0	0.033	3.0	0.061	0.58	2.6	0.63	0.0002	NA	NA	0.73	0.0002	0.00073	0.00075

Table 2-6
Analyte List (Continued)

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
TCL PCBs															
Aroclor-1016	C!	1	0.033	0.5	0.255	0.55	14.3	4.2	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Aroclor-1221	C	2	0.067	0.5	0.033	0.32	1.4	NA	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Aroclor-1232	C	1	0.033	0.5	0.033	0.32	1.4	NA	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Aroclor-1242	C	1	0.033	0.5	0.033	0.32	1.4	NA	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Aroclor-1248	C	1	0.033	0.5	0.033	0.32	1.4	NA	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Aroclor-1254	C!	1	0.033	0.5	0.033	0.16	1.4	1.1	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Aroclor-1260	C	1	0.033	0.5	0.033	0.32	1.4	NA	0.014	0.1	0.022	NA	0.014	0.00017	0.00017
Herbicides															
2,4-D	N	0.5	0.020	70	37	78	1,000	9	NA	NA	NA	NA	NA	100	NA
2,4-DB	N	2	0.100	NA	29	63	820	NA	NA	NA	NA	NA	NA	NA	NA
2,4,5-TP (Silvex)	N	0.1	0.010	50	29	63	820	21	NA	NA	NA	NA	NA	10	NA
2,4,5-T	N	0.1	0.010	NA	37	78	1,000	2	NA	NA	NA	NA	NA	NA	NA
Dalapon	N	2	0.100	200	110	230	3,100	7.1	NA	NA	NA	NA	NA	NA	NA
Dicamba	N	0.5	0.020	NA	110	230	3,100	4.5	NA	NA	NA	NA	NA	NA	NA
Dichloroprop	NA	0.5	0.020	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dinoseb	N	0.5	0.020	7.0	3.7	7.8	100	0.17	NA	NA	NA	NA	NA	NA	NA
MCPA	N	125	10	NA	1.8	3.9	51	NA	NA	NA	NA	NA	NA	NA	NA
MCPP	N	125	10	NA	3.7	7.8	100	NA	NA	NA	NA	NA	NA	NA	NA
Waste Characterization															
TCLPRL (µg/L)															
TCLP SVOCs															
1,4-Dichlorobenzene	NA	100	NA	7,500,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2-Methylphenol (o-cresol)	NA	100	NA	200,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4-Dinitrotoluene	NA	100	NA	130	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
3-Methylphenol (o-cresol)	NA	100	NA	200,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4-Methylphenol (o-cresol)	NA	100	NA	200,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobenzene	NA	100	NA	130	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachlorobutadiene	NA	100	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Hexachloroethane	NA	100	NA	3,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Nitrobenzene	NA	100	NA	2,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pentachlorophenol	NA	250	NA	100,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Pyridine	NA	100	NA	5,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,5-Trichlorophenol	NA	250	NA	400,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
2,4,6-Trichlorophenol	NA	100	NA	2,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TCLP VOCs															
Benzene	NA	10	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Carbon tetrachloride	NA	10	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chlorobenzene	NA	10	NA	100,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chloroform	NA	10	NA	6,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,2-Dichloroethane	NA	10	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1,1-Dichloroethene	NA	10	NA	700	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 2-6
Analyte List (Continued)

Parameter	Effect	Quantitation Limits		Drinking Water MCLs (µg/L)	Tap Water RBCs (µg/L)	Region III Soil Risk Based Concentration October 2003		SSL Transfers Soil to Groundwater (DAF 20) (mg/kg)	Region III BTAG Screening Levels			USEPA Water Quality Criteria (µg/L)			
		Aqueous (µg/L)	Soil (mg/kg)			Residential (mg/kg)	Industrial (mg/kg)		Aqueous (µg/L)	Soil (mg/kg)	Sediment (mg/kg)	Freshwater		Human Health Risk for Consumption of:	
												Acute	Chronic	Water & Organisms	Organisms Only
TCLP VOCs (continued)															
Methyl ethyl ketone	NA	10	NA	200,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Tetrachloroethene	NA	10	NA	700	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Trichloroethene	NA	10	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Vinyl Chloride	NA	10	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TCLP Pesticides															
Chlordane	NA	0.05	NA	30	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Endrin	NA	0.10	NA	20	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
gamma-BHC (Lindane)	NA	0.05	NA	400	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor	NA	0.05	NA	8.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Heptachlor epoxide	NA	0.05	NA	8.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Methoxychlor	NA	5.0	NA	10,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Toxaphene	NA	3.0	NA	500	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TCLP Metals															
Arsenic	C	100	NA	5,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Barium	N	2000	NA	100,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cadmium	N	50	NA	1,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	N	100	NA	5,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lead	NA	30	NA	5,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mercury	NA	2	NA	200	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Selenium	NA	50	NA	1,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Silver	NA	100	NA	5,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Miscellaneous															
Ignitability	NA	±1°F	NA	140°F	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Corrosivity as Ph	NA	±1 Units	NA	<2 or >12	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Reactive Cyanide	NA	5 mg/kg	NA	250 mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Reactive Sulfide	NA	20 mg/kg	NA	500 mg/kg	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Chemical Oxygen Demand (COD)	NA	3,000	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

NOTES: (1) Referenced RBCs and soil screening levels (SSLs) are from the USEPA Region III RBC table dated 10/15/03. (2) Referenced MCLs are from USEPA 40 CFR 141 and 142. (3) Referenced Biological Technical Assistance Group (BTAG) values are from the USEPA Region III BTAG Screening Levels table dated 8/9/95. (4) Referenced TCLP regulatory limits (TCLPRLs) are from USEPA 40 CFR 261.4. (5) The RBC levels for noncarcinogenic chemicals are presented with a hazard quotient of 0.1 to allow for cumulative effects, multiple contaminated media, and multiple routes of exposure. (6) The SSLs for soil to groundwater migration contains a default value of 20 for the dilution attenuation factor (DAF). (7) Lead values were provided by USEPA Region III. (7) The RBC for pyrene has been substituted for acenaphthylene, benzo(g,h,i)perylene, and phenanthrene.

NA = not applicable.

Bold border indicates that the screening levels cannot be met. However, the QLs are conservative limits and, although some exceedances of the screening levels are indicated, this does not necessarily indicate that the method will not detect the compound at, or below, the screening level. Although some QLs are above the screening levels for certain compounds because the values cannot be met practically with the given USEPA methodology, the best available methods were selected to attain screening level requirements.

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For soil waste characterization, Toxicity Characteristic Leachate Procedure (TCLP) metals, TCLP SVOCs, TCLP VOCs, TCLP pesticides, TCLP herbicides, ignitability, corrosivity as pH, reactivity, and chemical oxygen demand (COD) will be performed. For aqueous waste characterization, TAL inorganics, COD and pH will be performed. The following sections briefly describe the analytical methodologies to be used in the RFI.

2.5.2 Inorganics

TAL inorganics. TAL inorganics are analyzed using a combination of the following methodologies: inductively coupled plasma (ICP), ICP/mass spectroscopy (MS), and cold vapor atomic absorption (CVAA). Trace metals are analyzed using USEPA SW-846 Methods 3015A/6010B and 3010A(Mod.)/6020 for aqueous samples and 3050B (Mod.)/6020 and 3051A/6010B for solid samples. The modifications to the preparatory methods for the ICP/MS analysis includes the use of a hot block digestion step. USEPA SW-846 does not have a specific method for hot block digestion for method 6020. The lab uses the hot block digestion in order to get lower detection limits as well as reducing contamination issues that occur from hot plate and microwave digestion procedures. The ICP method involves the simultaneous or sequential multi-element assessment of trace elements in solution. The basis of the method is the measurement of atomic emission by optical spectrometry. Samples are nebulized and the aerosol that was produced was transported to the plasma torch where excitation occurs. Characteristic atomic-line emission spectra are produced by a radio-frequency ICP. A background correction technique is utilized to compensate for variable background contribution for the assessment of trace elements.

Mercury. Mercury will be analyzed using CVAA according to USEPA SW-846 Method 7470A for aqueous samples and Method 7471A for solid samples. A sample aliquot is initially digested with nitric acid to free combined mercury. The mercury is then reduced to its elemental state and aerated from the solution into a closed system. The mercury vapor is passed through a cell positioned in the path of the mercury light source and the measured abundance is proportional to the concentration of mercury in the sample.

2.5.3 Organics

TCL VOCs. Samples will be analyzed for TCL VOCs using USEPA SW-846 Method 5030B/8260B for aqueous samples and USEPA SW-846 5035B/8260B for solid matrices using purge and trap technology. Soil samples will be collected using an EnCore sampling device and subsequently sent to the laboratory for analysis. No sodium bisulfate will be added to the soils due to the possibility of effervescence and ketone formation. An inert gas is bubbled through a mixture of reagent water and 5 gram soil sample in a specifically designed purging chamber at 40 degrees Celsius (°C) or through a 25 milliliters (mL) aqueous sample contained at ambient temperature. The vapor is swept through a sorbent column where the purgeable compounds were trapped. After purging was completed for both solid and aqueous samples, the sorbent column was heated and backflushed with the inert gas to desorb the purgeable compounds onto a gas chromatograph programmed to separate the purgeable compounds, which are then detected with a mass spectrometer. The gas chromatography/mass spectroscopy (GC/MS) instrument is calibrated for a series of target analytes using chemical standards of known concentration and purity. Quantification of these target analytes is performed against specific internal standards as identified in the respective method. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time and mass spectra.

Chromatographic peaks in volatile/semivolatile fractions analyses that are not target analytes, surrogates, or internal standards are potential Tentatively Identified Compounds (TICs). TICs must be qualitatively identified by a National Institute of Standards and Technology (NIST) mass spectral library search and the identification assessed by the data reviewer. For each sample, the laboratory conducts a mass spectral search of the NIST library and report the possible identity for the 10 VOC and/or 20 SVOC largest fraction peaks that are not surrogates, internal standards, or target compounds, but that have an area or height greater than 10 percent of the area or height of the nearest internal standard. TICs do not provide a quantified value, however, they do indicate the presence of samples where extensive organic contamination may exist and will be used to indicate samples with high organic contamination.

TCL SVOCs. Samples will be analyzed for TCL SVOCs using USEPA SW-846 Method 8270C. Solid samples will be extracted using soxhlet according to USEPA SW-846 Method 3550C and aqueous samples will be extracted using a continuous liquid-liquid extraction technique according to USEPA SW-846 Method 3510C. The extract is injected into a gas chromatograph programmed to separate the compounds, which are then detected with a mass spectrometer. The GC/MS instrument is calibrated for a series of target analytes using chemical standards of known concentration and purity. Quantification of these target analytes is performed against specific internal standards as identified in the respective method. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time and mass spectra. The top 10 TICs will be reported for SVOCs and used as an indicator for samples with high organic matrices.

PAHs. Samples will be analyzed for PAHs using USEPA SW-846 Method 8270C selective ion monitoring (SIM) procedures. The use of USEPA SW-846 Method 8270C SIM is employed for PAH analysis to achieve lower quantitation and detection limits in order to meet screening criteria. GC/MS methodology also provides a confirmatory mass spectroscopy step. Solid samples will be extracted using soxhlet according to USEPA SW-846 Method 3550C and aqueous samples will be extracted using a continuous liquid-liquid extraction technique according to USEPA SW-846 Method 3510C. The extract is injected into a gas chromatograph programmed to separate the compounds, which are then detected with a mass spectrometer. The GC/MS instrument is calibrated for a series of target analytes using chemical standards of known concentration and purity. Quantification of these target analytes is performed against specific internal standards as identified in the respective method. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time and mass spectra.

Explosives. Samples will be analyzed for explosives using USEPA SW-846 Method 8330A. 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 undissolved 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. The concentrated extract is diluted with reagent grade water, and an aliquot is separated on a C-18 reverse phase column. The wavelength is set at 254 nanometers (nm) and confirmed on a cyanide reverse column. Solid samples are extracted using acetonitrile in an ultrasonic bath, then filtered and chromatographed similarly to aqueous samples. Identification of these target analytes is based on a comparison of the analyte to the

chemical standards used during calibration based on the analyte's retention time using primary and secondary columns.

NG/PETN. Samples will be analyzed for NG/PETN using USEPA SW-846 Method 8332. Solid samples will be extracted with acetonitrile in an ultrasonic bath, then filtered and mixed with a calcium chloride solution. Aqueous samples are extracted according to USEPA SW-846 Method 8330, using a double salting-out procedure with acetonitrile. The extract is mixed with calcium chloride just prior to analysis. The concentration is quantified using an isocratic high pressure liquid chromatography (HPLC) system equipped with a column heater and ultraviolet (UV) detector. Sample concentrations are confirmed on dissimilar columns. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time using primary and secondary columns.

TCL Pesticides/PCBs. Samples will be analyzed for TCL pesticides and PCBs using USEPA SW-846 Methods 8081A and 8082, respectively. Aqueous and solid samples will be prepared for analysis using extraction techniques. Solid samples will be extracted using soxhlet method USEPA SW-846 Method 3540C for samples. Aqueous samples will be extracted using a continuous liquid-liquid extraction technique by USEPA SW-846 Method 3520C. The extract will be injected into a gas chromatograph programmed to separate the compounds, which are then detected with an electron capture detector (ECD). Sulfur cleanups will be employed to aid in the quantification based upon the matrix interferences. Sample concentrations are confirmed on dissimilar columns. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time using primary and secondary columns.

Herbicides. Samples will be analyzed for herbicides according to USEPA SW-846 Method 8151A. Aqueous samples are extracted with diethyl ether and then esterified with either diazomethane or pentafluorobenzyl bromide. The derivatives are identified by gas chromatography with an electron capture detector (GC/ECD). The results are reported as acid equivalents. Sample concentrations are confirmed on dissimilar columns. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time using primary and secondary columns.

Dioxins/furans. Samples will be analyzed for dioxins/furans using USEPA SW-846 Method 8290. The analytical method used for the analysis of approximately 17 dioxins and furans calls for the use of high-resolution gas chromatography and high-resolution mass spectrometry (HRGC/HRMS) on purified sample extracts. This method is specific for the analysis of 2,3,7,8-tetrachlorinated dibenzofuran (2,3,7,8-TCDD), substituted penta, hexa, hepta, and octachlorinated dibenzo-*p*-dioxins and dibenzofurans in water, soil, and waste samples of various media. Measurements of toxicity are required for the analysis. Identification of these target analytes is based on a comparison of the analyte to the chemical standards used during calibration based on the analyte's retention time using primary and secondary columns.

2.5.4 Waste Characterization

TCLP Extraction. Samples for disposal will undergo TCLP extraction by USEPA SW-846 Method 1311. Samples are separated by phase, particle size reduced (for solids), and extracted for 18 hours in an extraction fluid. The final liquid extract is separated from the solid material and combined with the initial liquid phase (if applicable). The sample TCLP extract is then treated as an aqueous sample for analysis of metals, VOC, SVOCs, pesticides, and herbicides following the analytical procedures in *Section 2.5.3*.

Corrosivity as pH. Corrosivity as pH will be analyzed using USEPA SW-846 Method 9040B for aqueous samples and Method 9045C for solid samples. A sample pH is directly measured electrometrically using either a glass electrode in combination with a reference potential or a combination electrode. For solids, samples are mixed 1:1 with reagent water prior to measurement.

Chemical oxygen demand. COD will be analyzed using USEPA Method of Chemical Analysis of Water and Wastes Method 410.4 (USEPA, 1983). A sample is heated under acidic conditions at a slow, constant rate in an oven or block digester in the presence of dichromate at 150°C for two hours. The COD is measured at 600 nm spectrophotometrically.

Reactivity. Reactivity comprises of reactive sulfide and reactive cyanide. Reactive sulfide is analyzed in aqueous and solid samples using USEPA SW-846 Method Chapter 7.3.4. This procedure is a colorimetric determination. Sulfide reacts with dimethyl-p-phenylenediamine in the presence of ferric chloride to produce methylene blue. Reactive cyanide is analyzed in aqueous and solid samples using USEPA SW-846 Method Chapter 7.3.3.

Ignitability. Ignitability is analyzed using USEPA SW-846 Method 1010A for aqueous samples and USEPA SW-846 Method 1030 for solid samples. A 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 ignited the vapor above the sample.

2.5.5 Physical/Geotechnical Analysis

As discussed in *Section 1.3.2*, four soil samples will be collected for analysis of physical/geotechnical parameters. Analysis will be conducted by a USACE-approved laboratory. The following physical/geotechnical analyses are proposed:

- Grain-size analysis (ASTM D422-98);
- Atterberg limits (ASTM D4318-00);
- Soil moisture content (ASTM D2216-98e1);
- Total organic content (ASTM D2974-00);
- Soil bulk density (ASTM D4253-00);
- Measurement of hydraulic conductivity [ASTM D5856-95(2002)e1];
- Soil porosity (ASTM D854-02 and D 2937-00e1); and,
- pH (ASTM D4972-01).

2.6 INTERNAL QUALITY CONTROL CHECKS

Internal QC components that will be used by Shaw during operations at RFAAP are presented in *Section 8.0* of the MQAP. The internal quality components include the field QC samples and the laboratory QC elements to be followed.

2.6.1 Field Quality Control Elements

Rinse blanks, trip blanks, and field duplicates will be collected during the acquisition of environmental samples at RFAAP. **Table 2-7** 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 2-8**.

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Table 2-7
Field Quality Control Samples

Control	Purpose of Sample	Collection Frequency
Duplicate Sample	Ensure precision in sample homogeneity during collection and analysis	1 per 10 (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 (5%) of field samples per matrix per equipment type
Temperature Blank	Verify sample cooler temperature during transport	1 temperature blank per cooler
Trip Blank	Assess whether cross-contamination occurs during shipment or storage with aqueous VOC samples	1 trip blank per cooler containing aqueous VOC samples

Table 2-8
Field Quality Control Elements Acceptance Criteria

Item	DQO	Parameter	Frequency of Association	Criteria Requirement
Field Duplicate	P	Inorganics	1 per 10 samples per matrix	RPD \leq 20% Aqueous; difference \pm RL* RPD \leq 35% Solid; difference \pm 2xRL*
		Organics	1 per 10 samples per matrix	RPD \leq 50% Aqueous; difference \pm RL* RPD \leq 100% Solid; difference \pm 2xRL*
Trip Blank	A, R	VOCs in water	1 per cooler with aqueous VOCs	No target analytes above MDL; 5% of decision limit
Rinse Blank	A, R	Every	1 per 20 samples per matrix per equipment type	No target analytes above MDL; 5% of decision limit
Chain-of-Custody Forms	R	Every	Every sample	Filled out correctly to include signatures; no missing or incorrect information.
Field Logbook	R	Every	Every sample	Filled out correctly to include analytical parameters; map file data; and applicable coding information.
Field Instrument Calibration Logs	A	Every	Every measurement	Measurements must have associated calibration reference

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

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

2.6.2 Laboratory Quality Control Elements

The laboratory QC elements are summarized in **Table 2-9**. Specific laboratory analytical goals and corrective actions are summarized in **Tables 2-10 through 2-16** for the parameters specified in *Section 2.5*.

Table 2-9
Analytical Quality Control Elements of a Quality Assurance Program

Item	DQO	Parameter	Frequency of Association	Criteria Requirement
Analytical Method	C	Every	Each analysis	Method analysis based on USEPA methods as defined in <i>Section 2.5</i> .
Chemical Data Packages	A, P, C	Every	Each lot/batch	Pass peer review and formal QA/QC check.
Laboratory Chain of Custody	R	Every	Each sample container	No deficiencies
Laboratory System Controls	A, R	Every	During laboratory operations	Custody of sample within laboratory fully accounted for and documented
Holding Time	A, P, R	Every	Each analysis	No deficiencies (USEPA Region III Modifications)
Method Blanks	A	Every	Each lot/batch	No target analytes detected in the method blanks or <5% of the LOC.
Matrix Spikes and Duplicates	A, P	Every	Each lot/batch	Must meet USEPA criteria as defined in Tables 2-10 to 2-16 .
Surrogates	A	Organics	Organic fractions, including QC samples	Required to meet the stricter of the USEPA criteria.
Serial dilution	A	Metals	Each lot/batch	Must meet USEPA criteria as defined in Table 2-13 .

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

Table 2-10
Quality Control Method Criteria for Volatile Organic Compounds by USEPA SW-846 8260B

Procedure	Frequency	Acceptance Criteria			Corrective Action
Initial Calibration 5-pt curve	Set-up, major maintenance, and quarterly	RRF > 0.1 for SPCCs chloromethane, 1,1-dichloroethane, and bromoform RRF > 0.3 for SPCCs 1,1,2,2-tetrachloroethane and chlorobenzene RRF > 0.05 for the other target compounds (see Table 2-6) RSD ≤ 30% for CCCs response factors RSD ≤ 15% for the other target compounds (see Table 2-6) If linear regression is used $r > 0.990$ ICV: %Rec. = 80-120%			If RSD of the average RRF for calibration check compounds > 30%, the initial calibration must be repeated. Data reviewer should review and judge the target compounds against the acceptance criteria.
Continuing calibration check	Every 12 hours	RRF > 0.1 for SPCCs chloromethane, 1,1-dichloroethane, bromoform RRF > 0.3 for SPCCs 1,1,2,2-tetrachloroethane and chlorobenzene RRF > 0.05 for the other target compound (see Table 2-6) %D ≤ 20% for every target compound (see Table 2-6)			Samples cannot begin until this criterion is met. Data reviewer should review and judge the target compounds against the acceptance criteria.
Method blanks	Every 12 hours	< MDL; No target analytes below 5% of the decision limit, 5% of the sample concentrations, or the MDL, whichever is higher.			Document source of contamination.
Tuning BFB	Prior to calibration	Must meet tuning criteria.			Re-tune, re-calibrated.
LCS	Every batch	<u>Standards</u> Every target compound (see Table 2-6)	<u>Solid</u> <u>%Rec.</u> 75-125% (60-140% for sporadic marginal failures - 3 allowed)	<u>Aqueous</u> <u>%Rec.</u> 80-120% (60-140% for sporadic marginal failures - 3 allowed)	Qualify associated data biased high or biased low as appropriate.
Internal Standards	Every sample	<u>Standards</u> Bromochloromethane 1,4-difluorobenzene chlorobenzene	<u>Criteria</u> Retention time ±30 seconds of last CC Area changes by a factor of two (-50% to +100%)		Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with standards outside criteria.
Surrogate	Every sample	<u>Standards</u> 4-bromofluorobenzene 1,2-dichloroethane-d ₄ toluene-d ₈	<u>Solid</u> 75-125% 75-125% 75-125%	<u>Aqueous</u> 80-120% 80-120% 80-120%	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> Every target compound (see Table 2-6)	<u>Solid</u> <u>%Rec.</u> <u>%RPD</u> 70-130% ≤30 (60-140% ≤40% for sporadic marginal failures - 3 allowed)	<u>Aqueous</u> <u>%Rec.</u> <u>%RPD</u> 70-130% ≤30 (60-140% ≤40% for sporadic marginal failures - 3 allowed)	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.

Sources: (USEPA, 1996); (USACE, 2001, Appendix I)

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Table 2-11

Quality Control Method Criteria for Semivolatile Organic Compounds and Polynuclear Aromatic Hydrocarbons by USEPA SW-846 8270C and SW-846 8270C SIM

Procedure	Frequency	Acceptance Criteria			Corrective Action
Initial calibration curve (5-pt curve)	Set-up, major maintenance	RRF > 0.05 for every target compound; RSD ≤30% for CCC compounds. RSD ≤15% for the other target compounds. If linear regression is used $r \leq 0.990$ ICV: %Rec. = 70-130%			Must meet criteria prior to sample analysis. Data reviewer should review and judge the target compounds against the acceptance criteria.
Continuing calibration standard	12 hours	RRF > 0.05 for every target compound. The percent difference must be ≤20% for response factors from initial calibration.			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.
Internal standards	Every sample	Retention time ±30 seconds of last CC Area changes by a factor of two (-50% to +100%)			Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with standards outside criteria.
Tuning DFTPP	12 hours	Must meet tuning criteria.			Re-tune, re-calibrate.
Method blanks	Per extraction batch	< MDLs; No target analytes below 5% of the decision limit, 5% of the sample concentrations, or the MDL, whichever is higher.			Document source of contamination.
LCS	Every batch	Standards Every target compound (see Table 2-6)	Aqueous (%Rec.) 60-120% (~15 analytes) 45-135% (~30 analytes) 20-150% (~15 analytes) (15-150% ≤50% for sporadic marginal failures - 5 allowed)	Solid (%Rec.) 60-120% (~20 analytes) 45-135% (~25 analytes) 30-150% (~15 analytes) (20-150% ≤60% for sporadic marginal failures - 5 allowed)	Qualify associated data biased high or biased low as appropriate.
Surrogate spikes	Every sample	Standards nitrobenzene-d5 2-fluorobiphenyl p-terphenyl-d14 phenol-d5 2-fluoropropenol-d6 2,4,6-tribromophenol 2-chlorophenol 1,2-dichlorobenzene	Aqueous (%Rec.) 45-135% 45-135% 45-135% 35-140% 35-140% 35-140% 35-140% 45-135%	Solid (%Rec.) 45-135% 45-135% 45-135% 35-140% 35-140% 35-140% 35-140% 45-135%	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-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 Every target compound (see Table 2-6)	Aqueous %Rec. %RPD 45-135% ≤50 (15-150% ≤50% for sporadic marginal failures - 5 allowed)	Solid %Rec. %RPD 45-135% ≤60 (20-150% ≤60% for sporadic marginal failures - 5 allowed)	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.

Sources: (USEPA, 1996); (USACE, 2001, Appendix I)

Table 2-12
Quality Control Method Criteria for Explosives by USEPA SW-846 8330 and 8332

Procedure	Frequency	Acceptance Criteria			Corrective Action
Initial calibration curve 5-pt curve	Set-up, major maintenance	%RSD<20% of the response factor from the initial curve for every target compound. If linear regression is used $r \geq 0.990$ ICV %Rec. = 85-115%			Must meet criteria prior to sample analysis
Continuing calibration standard	Daily	%D recovery $\pm 15\%$ of the response factor from the initial curve for every target compound.			If criteria are not met, re-analyze the daily standard. If the daily standard fails a second time, perform a new initial curve.
Independent reference standard (LCS)	1 per batch	<u>Standards</u> Every target compound (see Table 2-6)	<u>Aqueous</u> 60-120% (40-150% for sporadic marginal failures - 2 allowed)	<u>Solid</u> 60-120% (40-150% for sporadic marginal failures - 2 allowed)	Qualify associated data biased high or biased low as appropriate.
Instrument Blank	12 hours, after analytical run and highly contaminated samples.	< MDL; No target analytes below 5% of the decision limit, 5% of the sample concentrations, or the MDL, whichever is higher.			Demonstrated "clean." Affected sample will be re-analyzed.
Method blanks	Per extraction batch	< MDL; No target analytes below 5% of the decision limit, 5% of the sample concentrations, or the MDL, whichever is higher.			Identify source of contamination. Take appropriate action and document. If preparation is in error, re-prep sample. If samples cannot be re-prepared, qualify the sample. Document actions taken.
Surrogate spikes	Every sample	<u>Standards</u> 4-nitroaniline	<u>Aqueous</u> <u>%Rec.</u> 50-150%	<u>Solid</u> <u>%Rec.</u> 50-150%	Examine each QC element (LCS, MB, ICV, CCV, etc.). If surrogate is out for the QC samples, check quantitation, then re-analyze (if still out of control). If QC passes, qualify samples after checking preparation steps. 2. If re-analysis of original extracts is out of control, re-extract and re-analyze samples. Follow step 1. If still out of control or samples cannot be re-extracted, qualify data.
Matrix spike and duplicate samples	1 per 20 samples per matrix	<u>Standards</u> Every target compound (see Table 2-6)	<u>Aqueous</u> <u>%Rec.</u> <u>RPD</u> 50-140% ≤ 50 (40-150% for sporadic marginal failures - 2 allowed)	<u>Solid</u> <u>%Rec.</u> <u>RPD</u> 50-140% ≤ 50 (40-150% for sporadic marginal failures - 2 allowed)	Investigate to identify cause and document actions taken; data are acceptable. Data reviewer may use the MS and MSD results in conjunction with other QC sample results to assess the need for some qualification of the data.
Target Analyte Confirmation	Every detect	RPD $\leq 40\%$			Qualify data as appropriate.

Sources: (USEPA, 1996); (USACE, 2001, Appendix I)

Table 2-13
Quality Control Method Criteria for Metals by USEPA SW-846 6020/6010B/7470A/7471A

Procedure	Frequency of QC Procedure	Acceptance Criteria	Corrective Action
Initial calibration curve (3-pt curve Hg) (1-pt curve low level ICP)	Daily or major maintenance, instrument modification, replacement of the torch, replacement of the mirror	$r > 0.995$ for each element r: linear correlation coefficient Low level check std. $\pm 20\%$ recovery ICV 90-110% recovery If MSA performed, $r > 0.995$	If $r < 0.995$ for an element, the standards for that element must be prepared again and/or the lower/upper range standard must be used.
Continuing calibration verification (CCV)	Every 10 samples or 2 per 8 hr and end of run.	Recovery $\pm 10\%$ of true value for ICP Recovery $\pm 20\%$ of true value for Hg	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.
Highest mixed standard	Before sample analysis	Recovery $\pm 5\%$ of true value for ICP Not applicable for Hg	If criteria are not met, reanalyze the daily standards. If the daily standard fails a second time, initial calibration must be repeated.
Interference check standard (ICS)	Beginning and end of each sample analytical run or 2 per 8 hr.	Recovery $\pm 20\%$ of true value for ICP Not applicable for Hg	Terminate the analysis, correct the problem, re-calibrate, re-verify the calibration, and reanalyze the samples.
Initial and continuing calibration blank (ICB/CCB)	Every 10 samples, end of analytical run	Concentration $< 3 \times$ s of the background mean (ICP). $< \text{MDL}$; No target analytes below 5% of the decision limit, 5% of the sample concentrations, or the MDL, whichever is higher.	If the average is not within criteria, terminate the analysis, correct the problem, re-calibrate, and reanalyze each sample analyzed since the last acceptable CCB.
Serial Dilution (ICP)	1 per 20 samples per matrix for samples $> 10 \times \text{IDL}$	Difference between diluted and undiluted sample $< 10\%$ for ICP Not applicable for Hg	Chemical or physical interference should be suspected. Investigate to identify cause.
Preparation/method blank	1 per batch per matrix	$< \text{MDL}$; No target analytes below 5% of the decision limit, 5% of the sample concentrations, whichever is higher.	Documented source of contamination.
Laboratory Control Sample	1 per 20 samples	80-120% (for sporadic marginal failure: 60-140% - 2 allowed)	Qualify associated data biased high or biased low as appropriate.
Matrix spike and duplicate and sample duplicate	1 per 20 samples per matrix	$75\% \leq \% \text{Rec.} \leq 125\%$; $\% \text{RPD} < 25\%$; If spike(s) outside of limits, analyze PDS. PDS limits are 75-125% for 6010B $80\% \leq \% \text{Rec.} \leq 120\%$; $\% \text{RPD} < 20\%$ for 7000 methods. PDS limits are 85-115% for 7000 methods.	If matrix spike recovery does not meet criteria (except Ag), a post digestion spike is required for each method except GFAA. Qualify results in accordance with Regional criteria.

Sources: (USEPA, 1996); (USACE, 2001, Appendix I)

Table 2-14
Quality Control Method Criteria for Dioxins/Furans by USEPA SW-846 8290

Procedure	Frequency	Acceptance Criteria			Corrective Action
Initial calibration curve (5-pt curve)	Set-up, major maintenance	%RSD $\pm 20\%$ for unlabeled standard compounds %RSD $\pm 30\%$ for labeled reference compounds Isotopic ratio must be within the established control limits. The signal to noise ratio must be ≥ 2.5 for each selected ion current profile.			Must meet criteria prior to sample analysis. Data reviewer should review and judge the target compounds against the acceptance criteria.
Continuing calibration standard	12 hours	The percent difference must be $\pm 20\%$ for each standard unlabeled compounds and $\pm 30\%$ for reference labeled compounds. Signal to noise ratio of 10:1 for each selected ion profile.			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.
Internal standards	Every sample	Retention time ± 30 seconds of last CC Area changes by a factor of two (-50% to $+100\%$) 40-135% recovery			Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with standards outside criteria.
Tuning PFK	12 hours	Must meet tuning criteria with resolving power of ≥ 10000 (10% valley).			Re-tune, re-calibrate.
Method/preparation blanks	Per extraction batch	< MDL; No target analytes.			Document source of contamination.
LCS	Every batch	40-135% recovery			Qualify associated data biased high or biased low as appropriate.
Surrogate spikes	Every sample	40-135% recovery			Investigate to identify cause and document actions taken; data are acceptable.
Matrix spike and duplicate	1 per 20 samples per matrix	<u>Standards</u> Every target compound (see Table 2-6)	<u>Aqueous</u> %Rec. %RPD 40-135% ≤ 50	<u>Solid</u> %Rec. %RPD 40-135% ≤ 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.

Sources: (USEPA, 1996); (USACE, 2001, Appendix I)

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Table 2-15
Quality Control Method Criteria for TCL Pesticides and PCBs by USEPA SW-846 8081A and 8082

Procedure	Frequency of QC Procedure	Acceptance Criteria			Corrective Action
Initial calibration curve Single/multi-component (5pt)	Set-up, major maintenance	%RSD < 20% of the response factor from the initial curve. Lab may use first or higher order regression fit ($r \geq 0.99$) if %RSD > 20%. ICV % Rec.: 85-115%			Must meet criteria prior to sample analysis
Continuing calibration standard	12 hours or every 20 samples	%D recovery $\pm 15\%$ of the response factor from the initial curve for every single peak compound.			If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated.
Independent reference standard (LCS)	Per batch	<u>Standards</u> Every target compound (see Table 2-6)	<u>Aqueous % Rec.</u> 50-130% (30-150% for sporadic marginal failures - 2 allowed)	<u>Solid % Rec.</u> 50-130% (30-150% for sporadic marginal failures - 2 allowed)	Initiate investigation and document actions taken.
Endrin/4,4-DDT Breakdown	Per batch	endrin/4,4-DDT degradation $\leq 15\%$. combined endrin/4,4-DDT degradation $\leq 30\%$.			If criterion is not met, system must be deactivated and the affected sample reanalyzed if endrin or 4,4-DDT or their degradation products are detected in the samples.
Instrument blank	12 hours, after analytical run and highly contaminated samples.	< MDL; No target analytes below 5% of the decision limit, 5% of the sample concentrations, whichever is higher.			Demonstrated "clean". Affected sample will be reanalyzed.
Method blanks	Per extraction batch	< MDL; No target analytes below 5% of the decision limit, 5% of the sample concentrations, whichever is higher.			Document source of contamination.
Surrogate spikes	Every sample	<u>Surrogate</u> Dibutylchloredate 2,4,5,6-Tetrachloro m-xylene	<u>Aqueous %Rec.</u> 40-140 40-140	<u>Solid %Rec.</u> 40-140 40-140	Investigate to assess cause, correct the problem, and document actions taken; re-extract and re-analyze sample. If still out, qualify.
Matrix spike and duplicate	1 per 20 samples per matrix	<u>Standards</u> Every target compound (see Table 2-6)	<u>Aqueous %Rec. %RPD</u> 40-140% ≤ 50 (30-150% (60% for sporadic marginal failures - 2 allowed))	<u>Solid %Rec. %RPD</u> 40-140% ≤ 50 (30-150% $\leq 60\%$ for sporadic marginal failures - 2 allowed)	Data reviewer may use the MS and MSD results in conjunction with other QC sample results to assess the need for some qualification of the data. Specific method cleanups may be used to eliminate or minimize sample matrix effects.
Target Analyte Confirmation	Every detect	RPD $\leq 40\%$			Qualify data as appropriate.

Sources: (USEPA, 1996); (USACE, 2001, Appendix I)

Table 2-16
Quality Control Method Criteria for Herbicides by USEPA SW-846 8151A

Procedure	Frequency of QC Procedure	Acceptance Criteria			Corrective Action
Initial calibration curve 5-pt curve	Set-up, major maintenance	%RSD<20% of the response factor from the initial curve for every compound. Lab may use first or higher order regression fit ($r \geq 0.99$) if %RSD > 20%.			Must meet criteria prior to sample analysis
Continuing calibration (calibration check)	Daily	%D recovery \pm 15% of the response factor from the initial curve for every target compound.			If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated.
Independent reference standard (LCS)	Every batch	Standards Every target compound (see Table 2-6)	Aqueous % Rec. 70-130%	Solid % Rec. 70-130%	%Rec. are outside criteria, sample batch should be re-calibrated and re-analyzed. If still outside criteria, qualify associated data biased high or biased low as appropriate.
Method/preparation blanks	1 per batch	< MDL; No target analytes below 5% of the decision limit, 5% of the sample concentrations, whichever is higher.			Document source of contamination.
Surrogate spikes	Every sample	Standards 2,4-dichlorophenyl-acetic acid (DCAA)	Aqueous %Rec. 70-130%	Solid %Rec. 70-130%	Investigate to assess cause, correct the problem, and document actions taken; re-extract and re-analyze sample. If still out, qualify.
Matrix spike and duplicate	1 per 20 samples per matrix	Standards Every target compound (see Table 2-6)	Aqueous %Rec. %RPD 50-150% ≤ 25	Solid %Rec. %RPD 50-150% ≤ 35	Data reviewer may use the MS and MSD results in conjunction with other QC sample results to assess the need for some qualification of the data. Specific method cleanups may be used to eliminate or minimize sample matrix effects.
Target Analyte Confirmation	Every detect	RPD $\leq 40\%$			Qualify data as appropriate.

Sources: (USEPA, 1996); (USACE, 2001, Appendix D)

2.7 DATA COLLECTION AND VALIDATION

Analysis will be conducted by a USACE-certified analytical laboratory. Level IV CLP-like raw data will be provided along with the Form 1s for data validation. Data validation will be conducted and documented based upon the quality assurance project plan requirements, MQAP (Section 9.5) requirements, USACE Shell requirements (USACE, 2001), USEPA methodology requirements, and USEPA Region III guidance, as applicable. Data qualifications will follow the *USEPA Region III Modifications to the National Functional Guidelines for Organic Data Review Multi-media, Multi-concentration* (USEPA, 1994b) and *USEPA Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (USEPA, 1993), and the *USEPA Region III Dioxin/Furan Data Validation Guidance* (USEPA, 1999), as appropriate. Verification for organic data will be performed at USEPA Region III level M3 and the verification for inorganic data will be performed at USEPA Region III level IM2. The waste characterization sample data will not require USEPA Region III data validation. The project QA Manager/Data Validation Manager will oversee the performance of data validation functions.

Shaw will direct the overall data management. Data activity for the sampling program will be divided between Shaw and DataChem Laboratories, Inc. 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 Shaw for evaluation and interpretation. Data generated will be assessed for accuracy, precision, comparability, representativeness, completeness, and sensitivity.

3.0 HEALTH AND SAFETY PLAN ADDENDUM

3.1 OBJECTIVE AND SCOPE

This site-specific HSPA was developed to provide the requirements for protection of site personnel including government employees, Shaw, regulators, subcontractors, and visitors, who are expected to be involved with soil boring advancement/sampling at SWMU 51.

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 Volume III of the MWP, as shown in Table 3-1.

Table 3-1
Health and Safety Issues Discussed in the MWP

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

Shaw and subcontractor personnel performing field activities 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 51 and must be amended if conditions change. A copy of this HSPA will be available at each work site.

3.2 TRAINING PLAN

Training will be used to review important topics outlined in this addendum and to inform Shaw personnel and subcontractor personnel of the hazards and control techniques associated with SWMU 51.

3.2.1 Project-Specific Hazard Analysis

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

Physical hazards.

- Heat/cold stress- refer to *Sections 3.2.1* and *3.2.2* of the MHSP;
- Manual lifting- refer to *Section 3.2.4* of the MHSP; and,

- Slips, trips, and falls- refer to *Section 6.1.1* of the MHSP.

Biological hazards. Refer to *Section 3.3* of the MHSP.

- Insect bites and stings;
- Tick bites;
- Snake bites; and,
- Plants.

Chemical hazards.

- Chemicals of concern in site-specific media.

3.2.2 Hearing Conservation Training

Site personnel involved in heavy equipment operation in addition to other operations involving exposure to noise levels exceeding 85 dBA 8-hour time-weighted average (TWA), shall be trained according to 29 Code of Federal Regulations (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.

3.2.3 Hazard Communication Training

In order to comply with the requirements of the OSHA Hazard Communication (HAZCOM) Standard, 29 CFR 1910.1200, Shaw will have a written HAZCOM program in place. The written HAZCOM program addresses training (including potential safety and health effects from exposure), labeling, current inventory of hazardous chemicals on 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 Shaw's HAZCOM program will be maintained onsite for the duration of the project, and later incorporated in the employees' personal training file.

3.2.4 Confined Space Entry Training

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

3.2.5 Daily Safety Meetings

Each day before starting investigative activities, contractor and subcontractor personnel will be given a safety briefing by the SHSO. This briefing will identify the anticipated site activities and the potential hazards that may be encountered during that day's activities.

The safety briefing may also be used to review use of safety equipment, emergency medical procedures, emergency notification signals, accident prevention, and relevant sections of the work plan. As needed, these topics will be reviewed daily to ensure that site operations are conducted in a safe manner. A daily debriefing will also be held, if needed. Records of safety meetings documenting the date, attendees, and discussion topics covered will be maintained.

3.3 SITE SAFETY AND CONTROL

Site safety is the responsibility of site personnel. Personnel onsite will be required to follow safe work practices contained in this section, and immediately notify the SHSO of conditions that do not comply with the MHSP. These provisions are intended to be the minimum safe practices that site personnel will follow.

3.4 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

PPE will be required during fieldwork. The minimum and initial level of PPE for these activities will be Modified Level D, consisting of steel-toed boots, nitrile/latex gloves, safety glasses, and a hard hat. An organic vapor level between 1 and 5 parts per million (ppm) above background, as measured by a PID, will cause the level of PPE to be upgraded to Level C. 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, personnel working onsite will be required to participate in Shaw's written 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.

3.5 MONITORING PLAN

During sampling activities, the SHSO will monitor the site initially and continuously for potentially hazardous airborne contaminants using a PID, which will be used to detect organic vapors. The PID will be calibrated in accordance with the manufacturer's calibration instructions. Draeger tubes may be used to monitor for specific contaminants based on the readings from the other instruments, as appropriate. The action levels for volatile organics at sustained concentrations in the breathing zone are as follows:

<u>PID Readings</u>	<u>Action</u>
Background to (background + 1 ppm)	Continue work, monitor
(Background + 1 ppm) to (background + 5 ppm)	Upgrade to Level C PPE
>(Background + 5 ppm)	Stop work, investigate

3.6 EMERGENCY RESPONSE PLAN

Emergency response will follow the protocols set forth in the 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

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 <i>Safety, Security and Environmental Rules for Contractors and Subcontractors</i> (ATK, 2000).	

4.0 REFERENCES

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- IT Corporation (IT), 2002. *Radford Army Ammunition Plant, Master Work Plan Addendum 009*. Draft Final document. February 2002. Delivery Order No. 0008, Contract No. DACA31-94-D-0064.
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- U.S. Environmental Protection Agency (USEPA), 1992. *Installation Assessment: Radford Army Ammunition Plant, Radford, Virginia*. U.S. Environmental Protection Agency, Office of Research and Development. TS-PIC-92372. June 1992.
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- U.S. Environmental Protection Agency (USEPA), 1994a. *Guidance for the Data Quality Objectives Process*. EPA/600/R-96/055. September.
- U.S. Environmental Protection Agency (USEPA), Region III. 1994b. *Region III Modifications to the National Functional Guidelines for Organic Data Review Multi-media, Multi-concentration*.
- U.S. Environmental Protection Agency (USEPA), 1996. *Test Methods for Evaluating Solid Waste Physical/Chemical Methods, Update III*. December.

- U.S. Environmental Protection Agency (USEPA), 1999. *USEPA Region III Dioxin/Furan Data Validation Guidance*. March 1999.
- U.S. Environmental Protection Agency (USEPA), 2000a. *Permit for Corrective Action and Waste Minimization*: Pursuant to the Resource Conservation and Recovery Act as Amended by the Hazardous and Solid Waste Amendment of 1984, Radford Army Ammunition Plant, Radford, Virginia. VA1210020730.
- U.S. Environmental Protection Agency (USEPA), 2000b. *Data Quality Objectives Process for Hazardous Waste Investigations*, EPA QA/G-4HW. January.
- U.S. Environmental Protection Agency (USEPA), 2003. *USEPA Region III Risk-Based Concentration Table*. October 2003.

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Appendix A

Standard Operating Procedures

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**Standard Operating Procedures
Referenced in WPA No. 17**

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 Form
20.0	SUBSURFACE INVESTIGATION
20.3	Well and Boring Abandonment
20.11	Drilling Methods and Procedures
30.0	SAMPLING
30.1	Soil Sampling
30.6	Containerized Material
30.7	Sampling Strategies
30.9	Collection of Soil Samples by USEPA SW 846 Method 5035- Using Disposable EnCore Samplers
50.0	SAMPLE MANAGEMENT
50.1	Sample Labels
50.2	Sample Packaging
70.0	INVESTIGATIVE-DERIVED WASTE
70.1	Investigative-Derived Waste
80.0	DECONTAMINATION
80.1	Decontamination
90.0	AIR MONITORING EQUIPMENT
90.2	Photoionization Detector (Microtip HL-200)

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 "RFT" (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:

$$1 \text{ EV} = [\pi R_w^2 h_w + 0.30p(R_s^2 - R_w^2)h_s] * (0.0043)$$

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

$$0.0043 = \text{gal/in}^3$$

and filter pack porosity is assumed as 30%, or

$$\text{Volume in casing} = (0.0043 \text{ gal/in}^3)(p)(12 \text{ in/ft})(R_c^2)(W_h)$$

Where:

R_c = radius of casing in inches, and
 W_h = water column height in feet

$$\text{Vol. in sandpack} = (0.0043 \text{ gal/in}^3)(p)(12 \text{ in/ft})(R_b^2 - R_c^2)(W_h)(0.30)$$

(if W_h is less than the length of the sandpack), or

$$\text{Vol. in sandpack} = (0.0043 \text{ gal/in}^3)(p)(12 \text{ in/ft})(R_b^2 - R_c^2)(Sh)(0.30)$$

(if W_h is greater than the length of the sandpack).

where:

R_b = 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;

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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.

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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 _____

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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 _____

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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 _____			

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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- μ m).

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

G = gravel
S = sand

Modifying Symbols

W = well graded
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 IDENTIFICATION

If one-half or more of the material will pass a No. 200 sieve (75 μ m), 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 dilatancy, 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:

<u>Description</u>	<u>Criteria</u>
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:

<u>Description</u>	<u>Criteria</u>
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:

<u>Blow Count</u>	<u>Relative Density for Sand</u>
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:

<u>Blow Count</u>	<u>Consistency for Clays</u>	<u>Description</u>
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:

<u>Modifiers</u>	<u>Descriptions</u>
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:

<u>Description</u>	<u>Criteria</u>
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:

<u>Description</u>	<u>Criteria</u>
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 be 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:

$$RQD = [\Sigma \text{ length of intact core pieces} > 100 \text{ mm (4-inches)}] \times 100\% / \text{total core length.}$$

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:

<u>AEG Fracturing</u>	<u>Spacing</u>
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:

<u>Hardness</u>	<u>Criteria</u>
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 stains 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

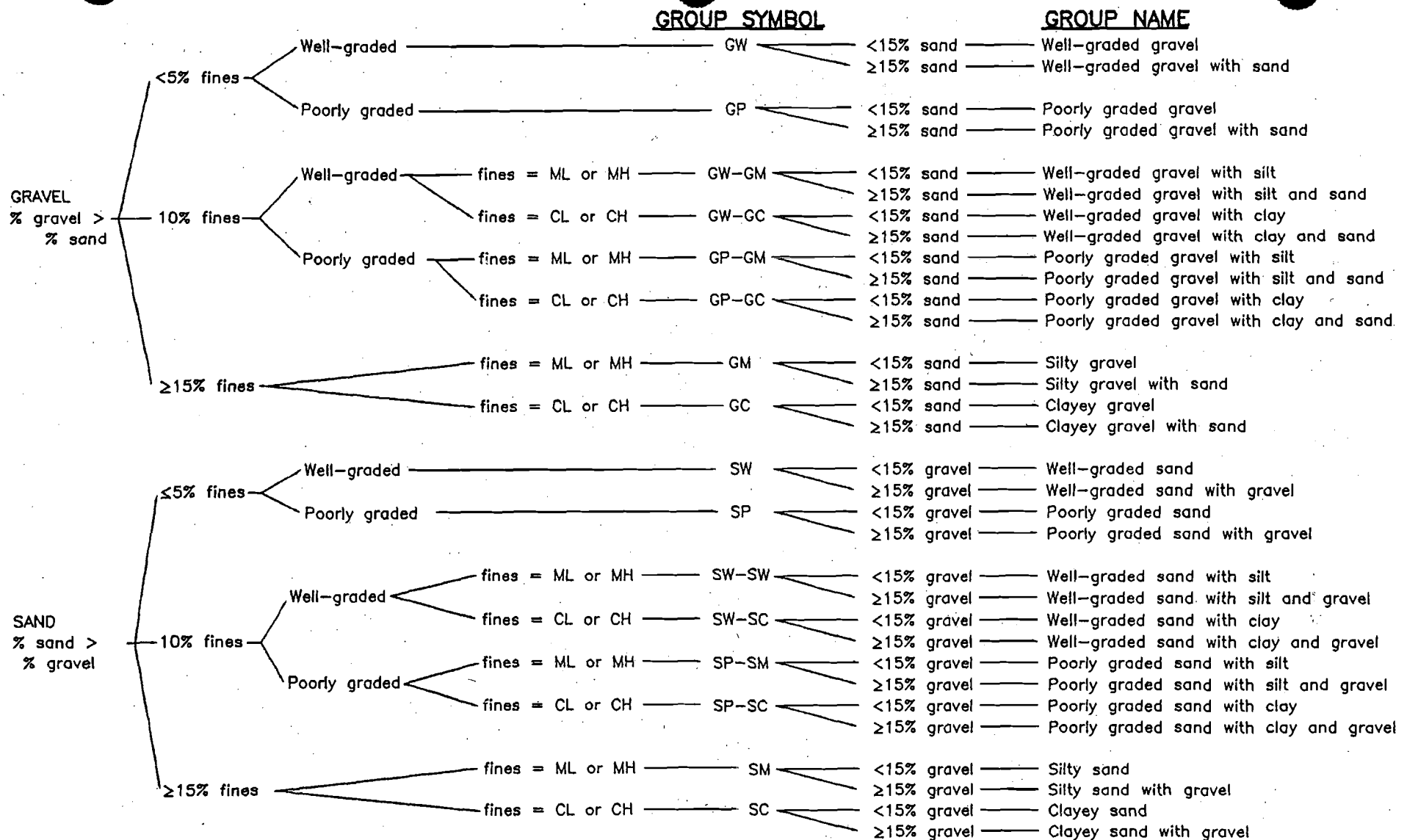
Not applicable.

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%.

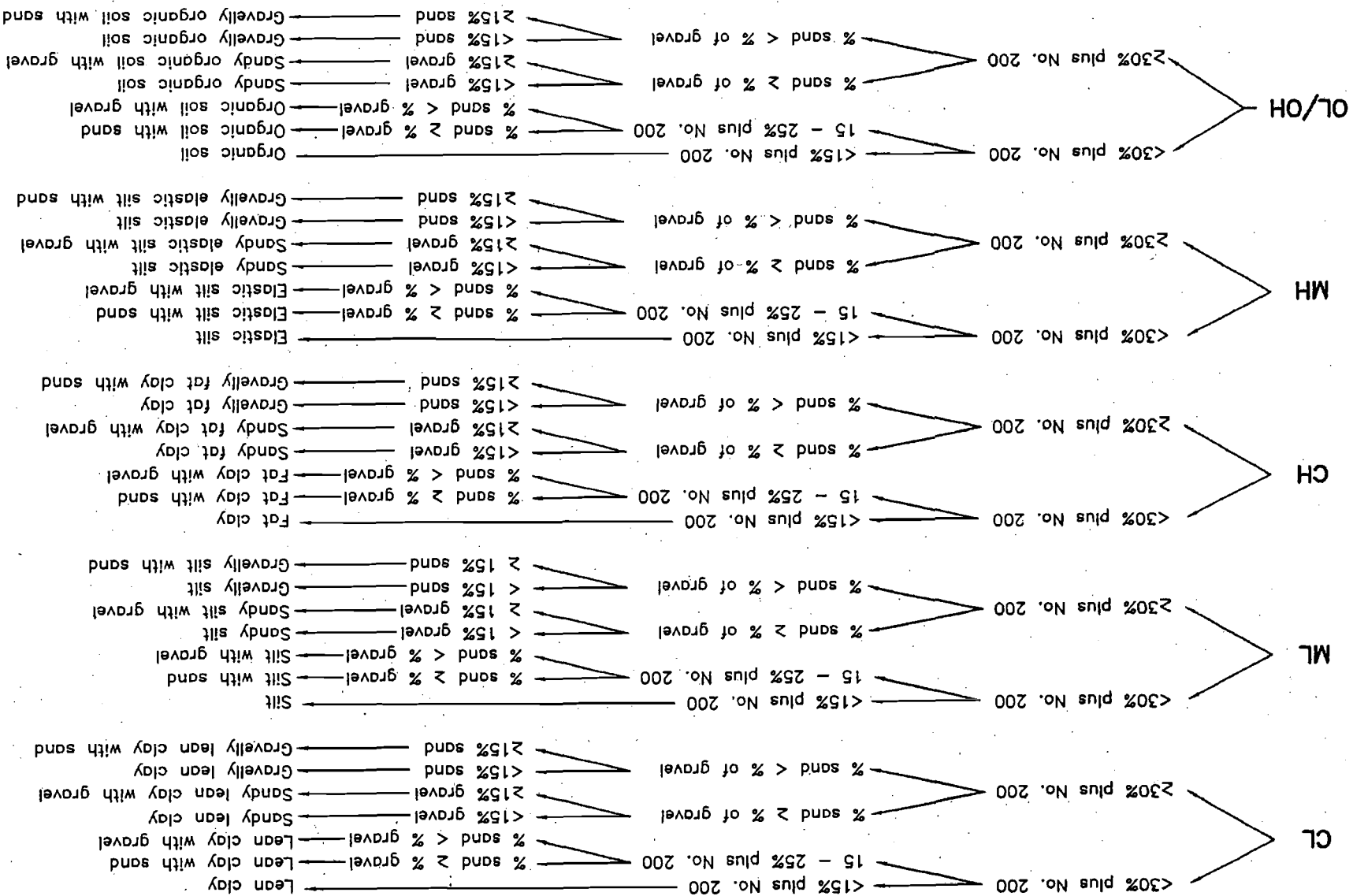
RFAAP MASTER WORK PLAN		FIGURE 10.03a
		FLOW CHART FOR IDENTIFYING COARSE-GRAINED SOILS
Date: 06/13/01	Prepared By: URS Corp./DAT	
Scale: NO SCALE	File Name: P:\...Figure XXX.x..	

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NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES,

GROUPE

GROUP NAME



MASTER WORK PLAN

RFAP

Date:

06/13/01

Scale: NO SCALE

File Name:

Prepared By: URS Corp./DRT

P:\..Figure XXXx.

FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS

FIGURE 10.03b

STANDARD OPERATING PROCEDURE 10.4

CHAIN-OF-CUSTODY FORM

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for use of the chain-of-custody form. An example is provided as part of this SOP. Other formats with similar levels of detail are acceptable.

2.0 MATERIALS

- Chain-of-custody form; and
- Indelible ink pen.

3.0 PROCEDURE

1. Record the project name and number.
2. Record the project contact's name and phone number.
3. Print sampler's names in "Samplers" block.
4. Enter the Field Sample No.
5. Record the sampling dates for all samples.
6. List the sampling times (military format) for all samples.
7. Indicate, "grab" or "composite" sample with an "X."
8. Record matrix (e.g., aqueous, soil).
9. List the analyses/container volume across top.
10. Enter the total number of containers per Field Sample No. in the "Subtotal" column.
11. Enter total number of containers submitted per analysis requested.
12. State the carrier service and airbill number, analytical laboratory, and custody seal numbers.
13. List any comments or special requests in the "Remarks" section.
14. Sign, date, and time the "Relinquished By" section when the cooler is relinquished to the next party.
15. Upon completion of the form, retain the shipper copy and place the forms and the other copies in a zip seal bag to protect from moisture. Affix the zip seal bag to the inside lid of the sample cooler to be sent to the designated laboratory.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

USEPA. 1990. *Sampler's Guide to the Contract Laboratory Program*. EPA/540/P-90/006, Directive 9240.0-06, Office of Emergency and Remedial Response, Washington, DC, December 1990.

USEPA. 1991. *User's Guide to the Contract Laboratory Program*. EPA/540/O-91/002, Directive 9240.0-01D, Office of Emergency and Remedial Response, January 1991.

USEPA. 1998. *EPA Requirements for Quality Assurance Project Plans*. EPA/600/R-98/018, QA/R5, Final, Office of Research and Development, Washington, D.C.

FIGURE 10.4-a
EXAMPLE CHAIN-OF-CUSTODY FORM

Project Number		Project Name			Matrix	A N A L Y S E S								S u b t o t a l	LAB:	
Project Contact (Name and Phone Number)															AIRBILL No:	
Samplers:															Courier:	
Field Sample No.	Date (MM-DD-YY)	Time	C o m p	G r a b											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								

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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 20.11 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.

- (2)
- 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 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 additional 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 sampler 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 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.

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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.

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- 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 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 30.6 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 heterogeneous 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 semi-circular 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.

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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 O-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. ***Push*** cap over flat area of ridge ***and twist*** 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.

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9. The disposable sampler should collect approximately 5 grams of soil (not necessary to weigh in the field). After a sample has been collected and capped, tear off the identification tag found at the bottom of the label on the aluminized bag. This tag is added to the sampler on the cap used to seal the sampler.
 10. Place the sampler back in the aluminized bag and seal the top (a zip-lock seal). Make sure all the appropriate information is on the label. Record the sampler ID number on the chain-of-custody. Make sure each sampler and 125-mL container is labeled with the same location identification. The sampler should be placed inside the plastic zip-lock bags.
 11. Place the 125-mL wide mouth jars in the cooler with the sampler on top. These should be sandwiched between bags of ice to maintain the correct temperature. If sent with the jars and samplers, a temperature bottle (used to evaluate the temperature on receipt) should be placed in the middle of the jars. The sample temperature should be 4°C during shipment.
 12. Ship the samples so that they will be received within 24 hours of sampling. The laboratory must receive the sampler within 40 hours of the collection so that they can be correctly preserved.

3.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

1. All data must be documented on chain-of-custody forms, field data sheets and in the field logbook.
2. An equipment blank is a QA/QC sample that will determine potential contamination from sampling equipment used to collect and transfer samples from the point of collection to the sample container. An equipment blank is performed by pouring demonstrated analyte free water from one sample container, over a sampler, and into a separate set of identical sample containers. The equipment blank is optional when sampling with the methanol preservation technique. It may be required on a site-specific basis if elevated analytical results are suspected to be due to cross contamination from sampling equipment.
3. A trip blank is a QA/QC sample, which will determine additional sources of contamination that may potentially influence the samples. The sources of the contamination may be from the laboratory, sample containers, or during shipment. The laboratory prepares a trip blank at the same time and in the same manner as the sample containers. The trip blank must accompany the sample containers to the field and back to the laboratory along with the collected samples for analysis. It must remain sealed at all times until it is analyzed at the laboratory. The frequency of collection for the trip blank must be at a rate of one per sample shipment.

3.5 LIMITATIONS IN SAMPLING

This sampling protocol will not be applicable to all solid environmental matrices, such as those that cannot be cored including non-cohesive granular material, gravel, or hard dry clay. In this case, the procedure for collecting VOC samples using Methanol Preservation should be used (see SOP 30.8).

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

- En Novative Technologies, Inc. 2000. Users Manual for En Core® Sampler. February 2001.
- USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans*. EM 200-1-3, 1 February.
- USEPA. 1997. *Test Methods for Evaluating Solid Waste, Volume IB: Laboratory Manual Physical/Chemical Methods*, Third Edition, (as updated through update IIIA). Office of Solid Waste and Emergency Response, Washington, DC.

STANDARD OPERATING PROCEDURE 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.

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.

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**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] [HNO₃] [NaOH] [H₂SO₄]
SAMPLER: _____

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 3x4 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.

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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 DIUF 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.

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STANDARD OPERATING PROCEDURE 90.2 PHOTOIONIZATION DETECTOR (MICROTIP HL-200)

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with the photoionization detector (Microtip HL-200). The photoionization detector (PID) uses an ultraviolet-emitting lamp designed to detect, measure, and display the total concentration of airborne ionizable gases and vapors. This information is used to determine control measures such as protection and action levels.

Use of brand names in this SOP is in no way intended as endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc., are acceptable. If alternate equipment is to be used, the contractor shall provide applicable and comparable SOPs for its maintenance and calibration.

2.0 MATERIALS

- Microtip;
- Battery pack;
- Calibration gas (100 ppm isobutylene);
- Tedlar bag;
- Tygon tubing;
- Regulator;
- Calibration logbook; and
- Field logbook.

3.0 PROCEDURE

3.1 GENERAL

1. Turn the instrument on by pressing the back of the power switch located on the handle of the Microtip.
2. The message "Warming up now, please wait" will be displayed for up to 3 min. After normal display appears, the Microtip is ready for calibration.
3. Fill a Tedlar bag with the desired calibration gas (usually 100 ppm isobutylene).
4. Press SETUP button and select the desired Cal Memory using the arrow keys (normally set to 200 ppm). Press EXIT button to leave setup function.
5. Press CAL button and expose Microtip to Zero Gas. (Usually clean outdoor air will be suitable. If any doubt exists as to the cleanliness of the background air, a commercial source of zero gas should be used.).

6. The Microtip then asks for the Span Gas concentration. Enter the known span gas concentration and then connect the Tedlar bag containing the Span Gas.
7. Press Enter, and the Microtip sets its sensitivity. Once the display reverts to normal the Microtip is calibrated and ready for use. Remove the Span Gas from the inlet probe. The instrument should be calibrated at least once a day.

3.2 BATTERY CHARGING

1. Ensure Microtip is off.
2. Set the voltage selector switch on the bottom of the battery charger to the appropriate AC line voltage.
3. Press the release button on the bottom of the Microtip and remove the battery pack by sliding it backwards.
4. Plug charger into the battery pack and then into an AC outlet and allow the battery to charge for at least 8 hours.
5. After charging, remove the charger, first from the outlet then from the battery pack, and slide the battery pack back onto the Microtip.

4.0 PRECAUTIONS

- Microtip does not carry an Intrinsic Safety Rating and must not be used in a hazardous location where flammable concentrations of gases or vapors are constantly present.
- All calibration, maintenance, and servicing of this device, including battery charging, must be performed in a safe area away from hazardous locations.
- Do not open or mutilate battery cells.
- Do not defeat proper polarity orientation between the battery pack and battery charger.
- Substitution of components may affect safety rating.

NOTE: The span gas concentration is dependent upon both the concentration of the span gas used and the rating of the UV lamp in the Microtip at time of calibration. If using 100-ppm isobutylene and the standard 10.6 eV lamp, the span gas concentration will be 56 ppm.

5.0 REFERENCE

Microtip HL-200 User's Manual. February 1990.

yes

Appendix B Geophysical Survey

This Appendix Contains:

Appendix B-1 Geophysical Report

Appendix B-2 Geophysical Methods

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Appendix B-1

Geophysical Report

B.1 INTRODUCTION

SWMU 51 is located in the southeast section of the Horseshoe Area and adjacent to SWMU 30. Background information indicates that the site consists of a 20x200-ft trench that has been filled to grade, and is weed and grass covered. An unknown quantity of TNT neutralization sludge from the treatment of red water was disposed in this unlined trench in the 1970's, and an estimated 10 tons of red water ash was reportedly disposed in the trench from 1968 to 1972 (Dames & Moore, 1992). The trench is reported to be centrally located between two-adjacent trenches that are part of SWMU 30.

Surface geophysical surveys using two-dimensional resistivity profiling, seismic refraction tomography, and EM-31/34 terrain-conductivity mapping were performed at SWMU 51 during the time period of August through September 2002. Additional downhole seismic velocity measurements were collected in four monitoring wells adjacent SWMU 51 to help guide the seismic interpretations, and downhole electrical logging was collected by USACE New England District personnel to help constrain the resistivity models.

B.2 OBJECTIVE

The primary objective of the SWMU 51 surveys was to provide both the lateral and vertical extent of the former trench used for the TNT neutralization sludge disposal. Information obtained by the geophysical surveys will be used to develop the CSM and focus the proposed sampling activities to assess the nature and extent of TNT neutralized sludge disposed at SWMU 51.

B.3 TECHNICAL APPROACH

Site conditions are critical in assessing what geophysical techniques are appropriate for an investigation. SWMU 51 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 landfill areas, the overburden may contain a considerable thickness (>10-ft) of red water ash, as well as other debris associated with dump activities.

Two-dimensional electrical resistivity imaging (2D-ERI), seismic refraction profiling/tomography, 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. **Appendix B-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 by void and 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, though the presence of an electrically conductive pore-fluid, or a significant clay fraction, could alternately yield lower-resistivities than expected. Air-filled fractures and voids would likely increase the electrical resistivity.

The trench work within the overburden sediment is expected to produce a zone of slightly lower seismic-velocity and lower electrical resistivity. In addition, the presence of waste material and degradation products may also lower the electrical response in the vicinity of the trench. Metallic debris deposited within the trench will also have a significant electromagnetic response during the EM surveys.

B.4 GEOPHYSICAL SURVEYS

Geophysical surveys for SWMU 51 consisted of 3 seismic-refraction profiles, 4 two-dimensional resistivity (2D-ERI) profiles, and one EM grid (**Figure B-1**). Also shown on Figure 1 are the locations of the main boundary fence for SWMU 30, the interior fence outlining the TNT sludge disposal trench, and the areal coverage provided by the EM grid (~33 ft major survey lines are shown). Two of the profiles (L-2 and L-3) were collected parallel to the long axis of the trench, and the other two profiles (L-1 and L-4) were collected perpendicular to the long axis.

B.4.1 Geophysical Profiling (Seismic and Resistivity)

Both seismic and two-dimensional resistivity data (2D-ERI) were collected along profiles L-1, L-2, and L-4, and only a resistivity survey was conducted along Profile L-3. Each profile was extended beyond the fence boundaries in order to verify whether or not the fenced area truly marks the limits of the TNT sludge disposal trench. Profile L-4 was also extended further to the west and outside the limits SWMU 30 fence to allow contrasting presumed natural conditions with the geophysical response within SWMUs 30 and 51.

Resistivity data were collected using both Schlumberger and dipole-dipole array surveys (see **Appendix B-2** for further explanation). Use of both 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.

The seismic data were processed using both refractor-layer (earth-layer) and tomographic models. Earth-layer models provide discreet boundaries between horizontal zones (layers) of different seismic velocity, and are limited to a single velocity per model layer. Tomographic models do not have this restriction, and attempt to show both horizontal and vertical changes in velocity. The tomographic cross-section was developed using several different velocity models including the earth-layer solution. Modeling generally resolved into similar solutions, of which one is shown for each profile.

The resistivity and seismic 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 same color-contour scheme is used throughout for all four profiles to allow a direct comparison of anomaly magnitudes. For each profile, three model panels are shown, with the upper two panels representing the dipole-dipole and Schlumberger array results, and the bottom panel the seismic refraction results. The seismic model for Profile L-2 is used as comparison with the resistivity data collected on Profile L-3. Also shown on each panel, are the intersecting points of cross-lines, the refractor-layer seismic model (orange trace lines), and the relative position of the SWMU 51 fence (magenta rectangle near ground surface labeled as the "SWMU 51 fenced area").

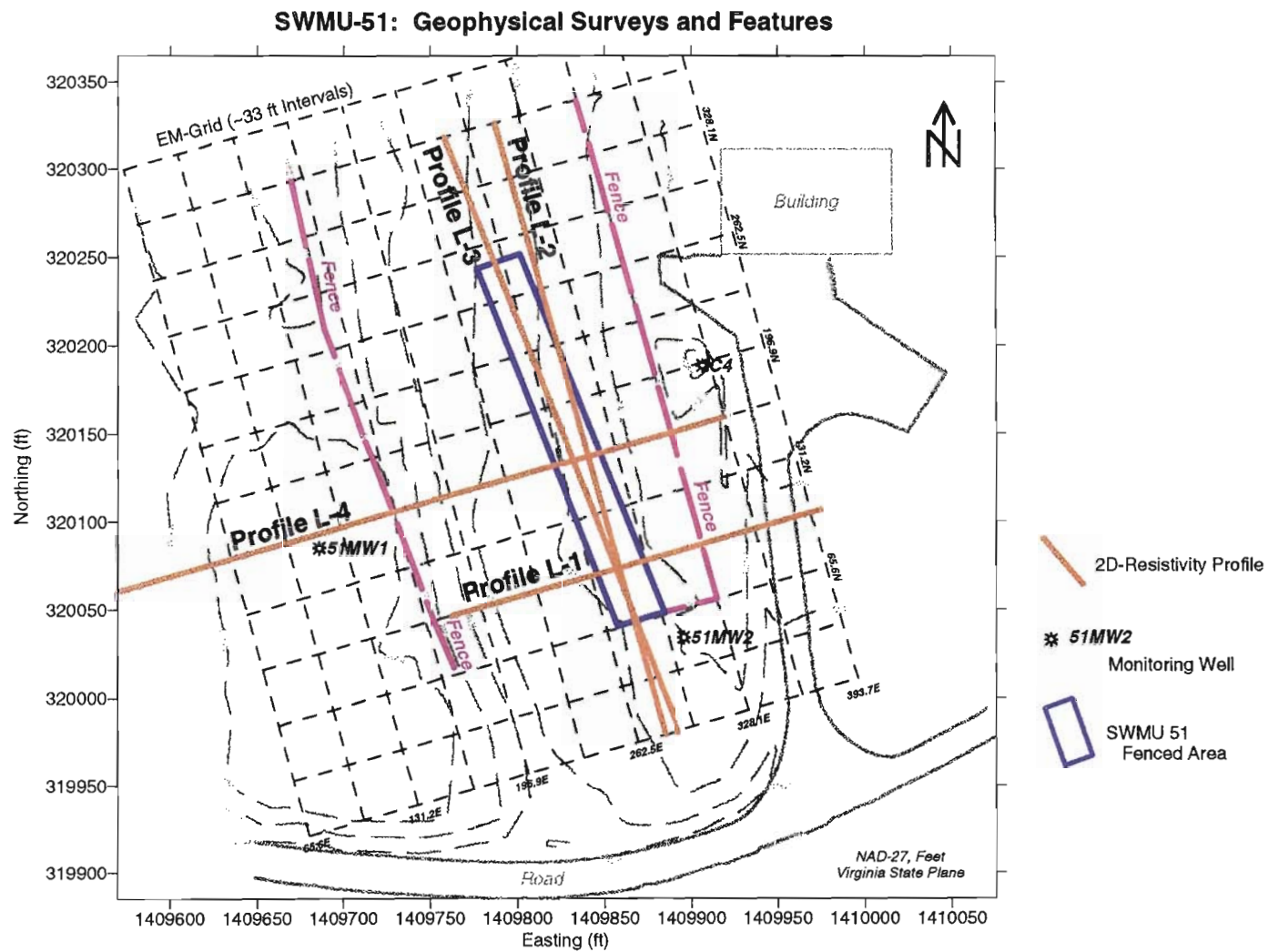


Figure B-1. Base Map for SWMU 51.

Profile L-1

Profile L-1 was acquired along a WSW-ENE transect near the southern end of the SWMU 51 area, along a line perpendicular to the long axis of the TNT trench (**Figure B-1**). Both 2D-ERI and seismic surveys were collected on this profile. The resistivity survey used an electrode spacing of 6.56 ft (2 m) and a total of 28 electrodes, and the seismic profile used a single array of 48 geophones spaced at a 3.28 ft (1 m) interval. The resulting geophysical models are shown in **Figure B-2**.

A distinct zone of low-resistivity (<80 ohm-m) is present on the 2D-ERI models (upper 2 panels) of **Figure B-2**. The lateral extent of this low-resistivity zone coincides roughly with the area bounded by the SWMU 51 fence (264X to 292X on the profile). Low-resistivities within this zone are tentatively interpreted as waste and/or waste byproduct resulting from activities at SWMU 51. Depth to top of this low-resistivity zone ranges from 5 to 7 ft below ground surface (bgs), with the shallower depth-to-top near the western and eastern edges of this feature. The base of the low-resistivity occurs at approximately 16 ft bgs, giving 9-11 ft in total thickness.

Material of higher resistivity caps the low-resistivity zone, and is interpreted to correlate with the blocky (cobbles) rubble observed on the ground surface during data collection. Note also that a zone of low-to-moderate resistivity (100-300 ohm-m) occurs in the upper 10 ft of the subsurface in the approximate position of one of the SWMU 30 trenches (profile coordinates 212-250X).

The short length of the resistivity profile was not able to resolve the overburden-bedrock interface. The bedrock surface is approximately 1,780 ft in elevation near well 51MW2, and ~1,782 ft beneath well 51MW1.

A three-layer solution was used to construct the earth-layer model for Profile L-1 using seismic velocities of 400, 700, and 2,000 m/s. The tomographic solution yielded a slightly different set of average velocities (550, 970, 1,550 m/s) for the same range of depths on the earth layer model.

The uppermost refractor surface indicates a broader area of lower velocity material than that indicated by the SWMU 51 fenced area (and corresponding resistivity anomaly). This surface deepens to approximately 15 ft bgs immediately west of the SWMU 51 fence. The tomography model also depicts a zone of low seismic velocity (stippled pattern of velocity less than 450 m/s). The low-velocity zone, however, is much broader than the resistivity anomaly (and location marked by the fence), and extends in depth to approximately the top of the low-resistivity anomaly (base of cap material). The most likely interpretation is that this low-velocity zone is a result of backfilling and capping, and not representative of the waste material within the trench.

The lowermost refractor surface likely corresponds to an interface above the bedrock surface. Note that well 51MW2 (50 ft to the south) places the bedrock approximately 8-to-10 ft deeper than this refractor. The highest velocities observed on tomographic model for Profile L-1 are significantly lower (1,800 m/s versus 2,400-2,700 m/s) than seismic velocities observed for the bedrock on the other three profiles.

Profile L-2

Profile L-2 was collected along a transect sub-parallel to the long axis of the SWMU 51 fenced area, along the 278E axis line of the EM grid (**Figure B-1**). Both 2D-ERI and seismic

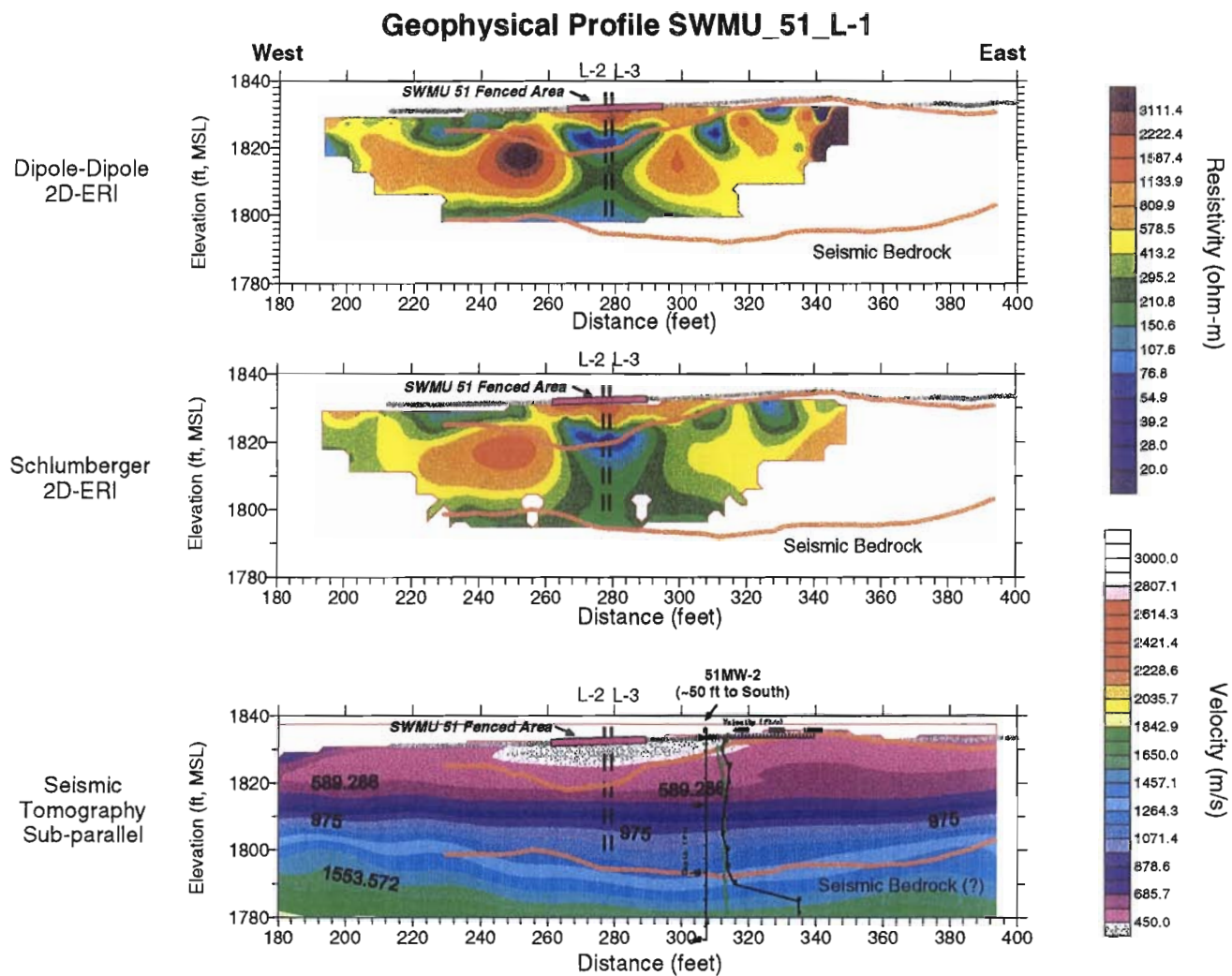


Figure B-2. Geophysical Results for Profile L-1

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data were collected. The resistivity survey used an electrode spacing of 13.12 ft (4 m) and a total of 28 electrodes. The seismic profile used two adjacent spreads of 48 geophones spaced at a 3.28 ft (1 m) interval. The resulting geophysical models are shown in **Figure B-3**.

Both resistivity models (upper two panels, **Figure B-3**) show a zone of low-resistivity (<80 ohm-m) extending from 100X to 205X. The electrical response of this zone is interpreted to be caused by the waste and/or waste byproduct based on its position relative to the SWMU 51 fence area (note that Profile L-2 exits the fence enclosure approximately three-quarters the length of the N-S fence length) and similarity to responses observed on the other three profiles. The top of this feature ranges from 6-9 ft bgs and the base from 16 to 21 ft bgs, with a general deepening towards the north. The Schlumberger model (middle panel) does not provide a sharp boundary for the base of this anomaly, but instead models a zone of intermediate resistivity (100-300 ohm-m) immediately beneath the suspected location of the trench.

A three-layer model was used to construct the earth-layer solution for Profile L-2. Layer velocities are higher than that indicated for L-1, and are (top to bottom) 521, 1,046, and 3,035 m/s. The resulting tomographic solution yielded overburden velocities consistent with the earth-layer model, but with a lower bedrock velocity (2,421 m/s).

The uppermost refractor surface exhibits a slight depression in the vicinity of the trench, but the tomographic solution models this interface as a horizontal surface. A distinct zone of low velocity (<450 m/s, stippled area), with a thickness of 5-6 ft, is modeled over the southern two-thirds of the resistivity defined trench location. The upper refractor surface appears to approximate the base of the low-resistivity anomaly within the central part of the profile (150X), but is more likely corresponding to natural changes in subsurface conditions. As with the L-1 Profile, the L-2 seismic data cannot be used to resolve the waste thickness within the SWMU 51 trench.

The top of bedrock, as defined by the earth-layer model, is interpreted as a relatively flat surface ranging approximately 55-60 ft in depth, and with a slight rise to 50 ft bgs near profile coordinate 80X. The corresponding tomographic model images the bedrock as a horizontal surface at approximately 60 ft in depth. A slight decrease in velocity is observed in the bedrock between profile coordinates 50X and 90X.

Profile L-3

Profile L-3 was collected along the long axis of the SWMU 51 fenced area, extending approximately 66 ft to the south of the fenced area and 70 ft to the north. Only resistivity data were collected using 56 electrodes at a spacing of 6.56 ft (2m), which provided a line length of 360.9 ft (110 m). It was hoped that the finer electrode spacing and co-linearity with the trench's long axis would yield a better definition of the trench boundaries. The resulting dipole-dipole and Schlumberger array models are shown in **Figure B-4** (upper two panels), and the seismic model results for Profile L-2 (lower panel) are shown for comparison.

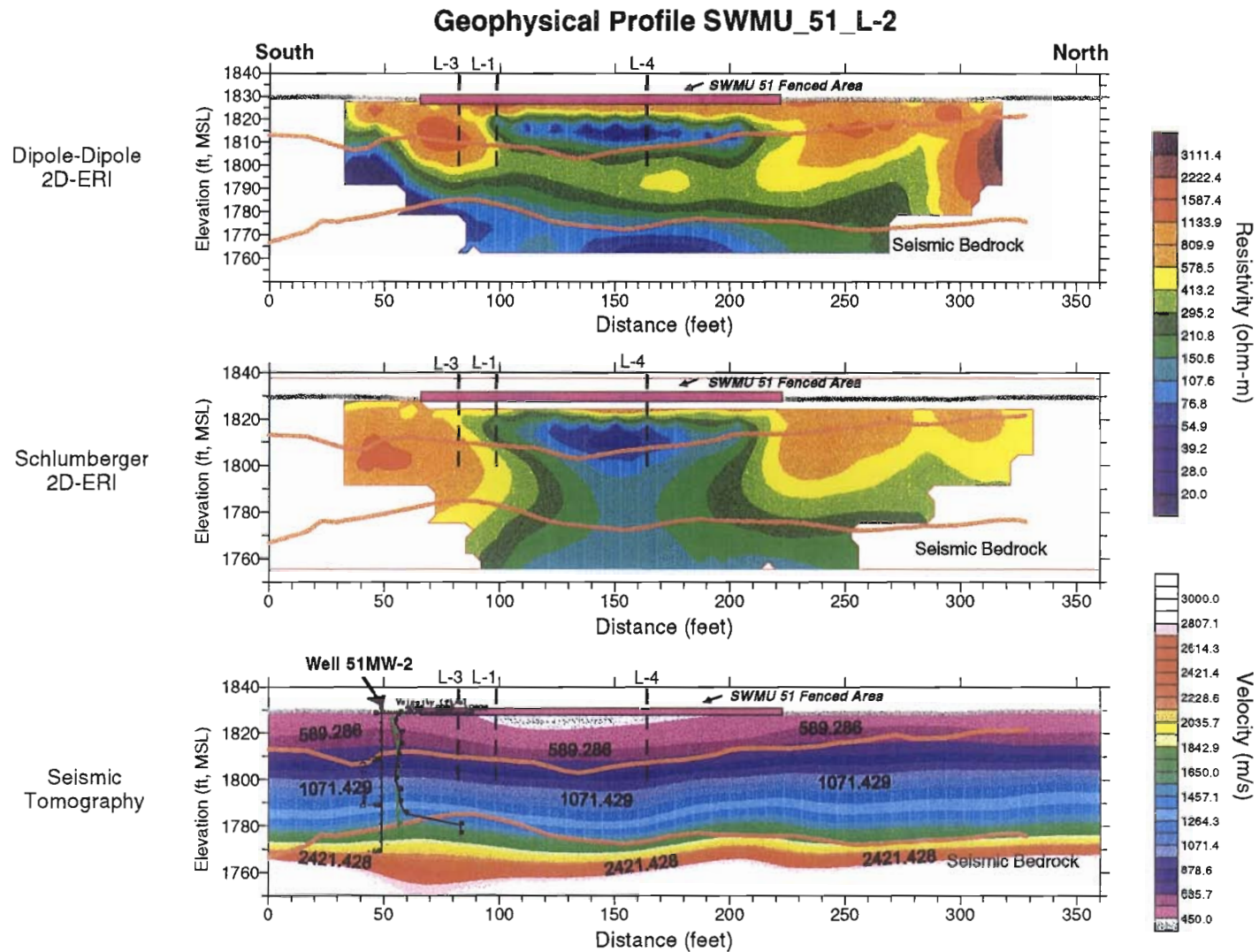


Figure B-3. Geophysical Results for Profile L-2

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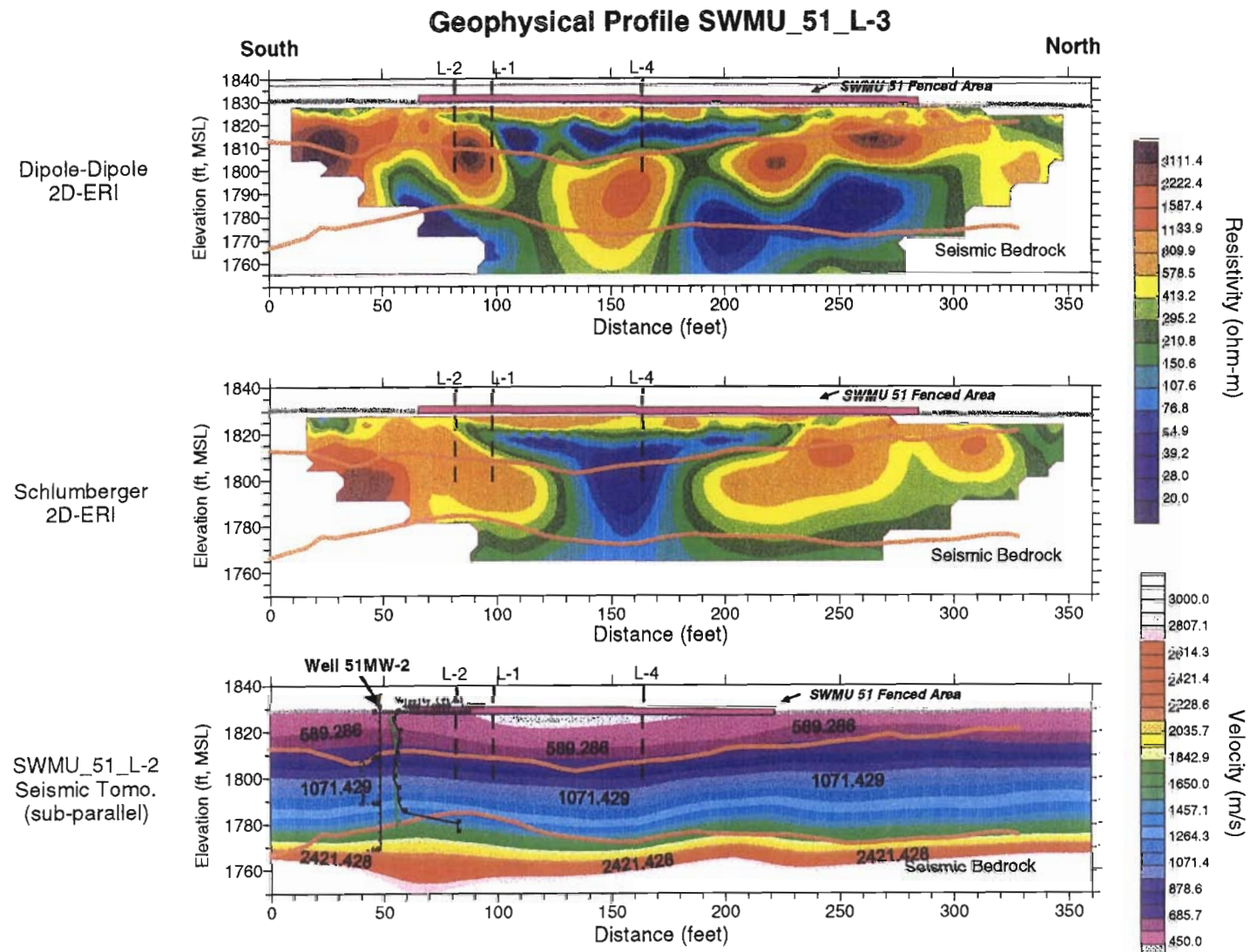


Figure B-4. Geophysical Results for Profile L-3

The resistivity models depict a zone of low-resistivity (<80 ohm-m) between profile coordinates 90X to 225X, with a depth to top ranging from 7-to-9 ft bgs and depth-to-base from 15-to-25 ft (average is approximately 18 ft bgs). Following interpretations for Profiles L-1 and L-2, this low-resistivity zone is probably the electrical response of the waste and/or waste byproduct. The dipole-dipole model indicates less lateral continuity in the trench, exhibiting a break in the low-resistivity near profile coordinate 120X. This low-resistivity zone extends to its greatest depth immediately adjacent to this break. The Schlumberger model does not resolve the base of this anomaly in the central part of the profile, although the upper refractor of the L-2 seismic model appears to mimic the base of the low-resistivity zone.

Other zones of low-resistivity are modeled by the dipole-dipole data near the southern end and northern third of the SWMU 51 fenced area. The Schlumberger model does not image these same features suggesting that they are most likely modeling artifacts.

Profile L-4

Profile L-4 was collected on a line perpendicular to the long axis of the trench along EM grid axis 164N. The profile was extended to the west so that well 51MW1 could be used to help guide the interpretation, and so the electrical and seismic character of the "undisturbed" area west of SWMU 30 could be used as a contrast. The resistivity data were collected with 56 electrodes at a spacing of 6.56 ft (2 m), providing a profile length of approximately 360 ft. Two adjacent spreads of 48 geophones, spaced at 3.28 ft (1m) intervals, were used for seismic data collection. The resulting geophysical models are shown in **Figure B-5**.

A distinct, low-resistivity anomaly (<80 ohm-m) is centered beneath the SWMU 51 fenced area, located between profile coordinates 265X and 280X. The depth-to-top of this anomaly is approximately 7 ft, and the depth-to-bottom, though not fully resolved, is estimated at approximately 20 ft. This depth estimate is based on the Schlumberger model at the point where the upper seismic refractor crosses the base of the low-resistivity anomaly. Note that unlike the results for the other three profiles, the dipole-dipole array did not resolve the base of the low-resistivity zone.

Two other zones of low-resistivity are present at depth to the west of the SWMU 51 fenced area. The zone of low-resistivity occurring between coordinates 170X and 200X is interpreted to correlate with the SWMU 30 trenches. The source for the furthest west zone of low-resistivity is not known, but may be due to the general decrease in resistivity observed near the overburden-bedrock interface.

The seismic model for Profile L-4 (bottom panel **Figure B-5**) shows a relatively flat bedrock surface, and a broad area of lower velocity underlying SWMU 30 and SWMU 51. A three-layer solution was required for the earth-layer model, using velocities of 500, 800, and 2,550 m/s. The tomographic model yielded similar velocities (550, 878, and 2,421 m/s) for equivalent depth ranges. A zone of low-velocity (<450 m/s) is modeled by the tomographic solution as a broad swale underlying the SWMU 51 fenced area. The base of this low-velocity zone corresponds with the top of the low-resistivity anomaly, suggesting that this is related to the cap and/or backfill material.

B.4.2 EM-31 and EM-34 Conductivity Surveys

Electromagnetic (EM) surveys were performed in the grid area shown on **Figure B-1** with the objective of mapping the lateral extent of the SWMU 51 trench, and to determine

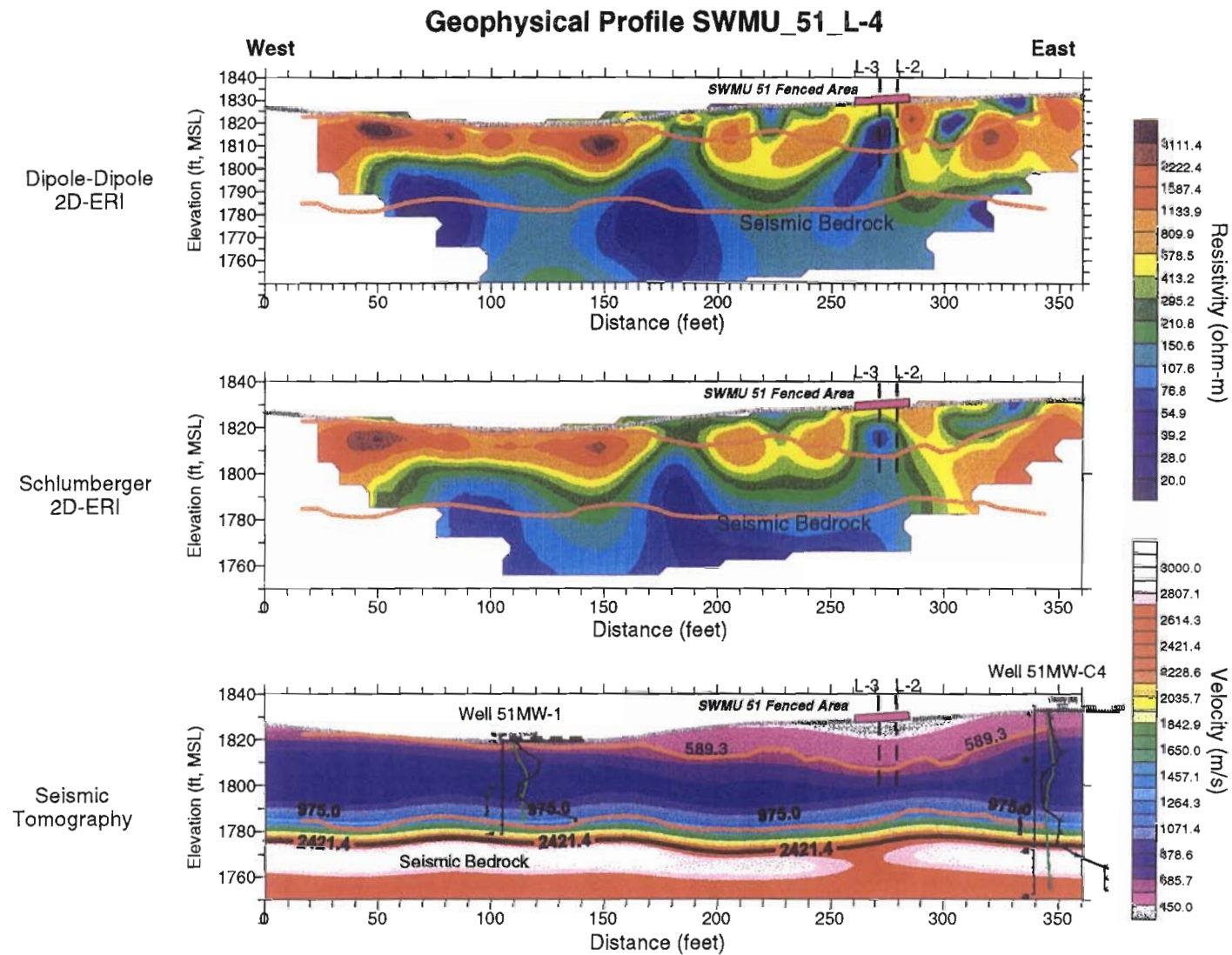


Figure B-5. Geophysical Results for Profile L-4

whether a significant quantity of metallic debris has been buried. It was expected that the activities involved in the construction of and disposal within the trench would alter the subsurface electrical properties, yielding a distinguishable anomalous area associated with the trench. Prior to performing the surveys, the barbed wire fence enclosure surrounding SWMU 51 was removed to the extent practicable, with only the corner fence posts and possibly some rusted fencing material within the vegetation at the site remaining in place.

Both the EM-31 and EM-34 terrain-conductivity meters were used to collect EM measurements at SWMU 51 (see **Appendix B-2** for a further description). EM-31 measurements were collected along profiles spaced at 8 ft (2.5 m) in the approximate north-south direction and along profiles spaced at 33 ft (10 m) in the approximate east-west direction. Both quad-phase (electrical-conductivity) and inphase (percent metals) data were collected with the EM-31. EM-34 surveys were collected along profiles spaced at 33 ft (10 m) in the approximate north-south direction, and along 66 ft (20 m) spaced profiles in the approximate east-west direction (except for profiles along 164E and 328.1E, which were excluded to reduce interference from the SWMU 30 fence lines). The EM-34 collects only quad-phase (electrical conductivity) data.

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 the upper 10 ft (3 m) of subsurface material, with the peak response occurring in the 1.6 to 8.2 ft (0.5-2.5 m) depth range. The EM-34 meter was operated in the horizontal dipole mode using a coil spacing of 66 ft (20 m), which resulted in 80% of the response (also peak response) coming from the upper 33 ft (10 m) of subsurface material.

Figure B-6 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 4 geophysical profiles are shown as heavy brown lines, and the interpreted area of the trench (from 2D ERI profiles) as a crosshatched region. Site features including roads, fences, wells, and ground-surface topography are also shown. Some of the EM-31 data were not included in construction of the map due to their proximity to the fence lines. Natural or background conditions are inferred on **Figure B-6** for the western side of the grid (west of the fence line) where conductivity values range from 5-to-7 mS/m.

The high conductivity anomalies (>12 mS/m) located to the west of Profile L-3, and north of Profile L-1 (grid area: 99N-to-396N; 164E-to-260E), are most likely related to one or more of the SWMU 30 disposal trenches. Another zone of high conductivity parallels the easternmost fence line, and may be related to another SWMU 30 trench. Profile data collected within 10 ft of this easternmost fence were excluded from the plot, and thus the observed anomalous character cannot fully be due to the fence. Note that the original description of SWMU 51 cites that the neutralization sludge trench lies between two adjacent SWMU 30 trenches, supporting this interpretation of the EM-31 plot.

Inspection of the EM-31 anomaly map reveals a slight increase in conductivity within the southern two-thirds of the SWMU 51 fenced area. This increase, related to changes in electrical properties within the upper 10 ft (3 m) at the site, is approximately 1-2 mS/m higher than background levels, and is roughly coincident with the trench area defined by the resistivity profiles. All four resistivity profiles indicate an electrically conductive zone from 5-9 ft bgs, which is near the practicable depth limits of the EM-31 instrument.

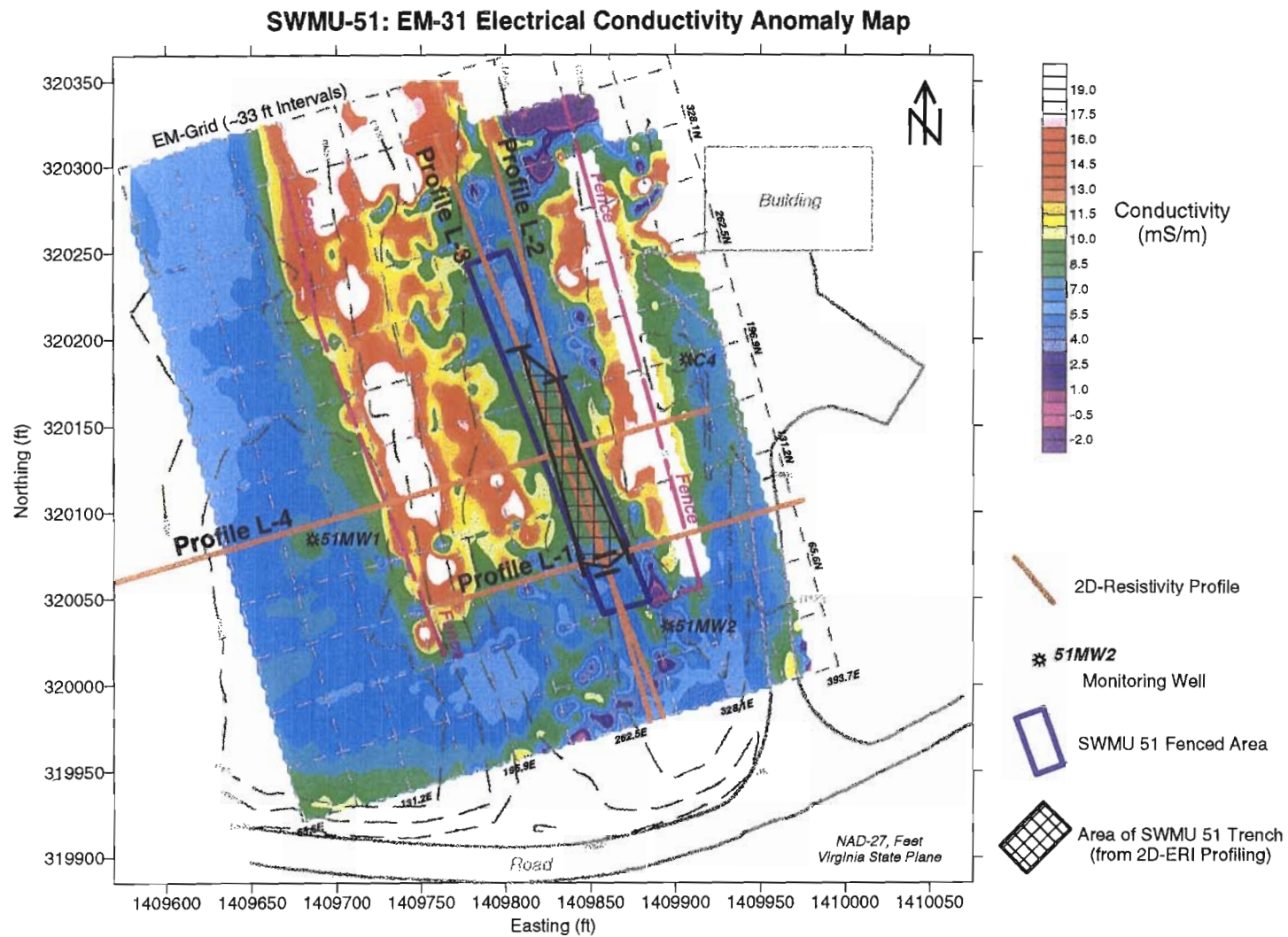


Figure B-6. EM-31 Conductivity Anomaly Map

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In-phase (metals) data were collected concurrently with the EM-31 conductivity data, and the resulting anomaly map is shown in **Figure B-7**. No metal response is indicated in the areas west, south, and east of the SWMU 30 fence (outer fence lines). No metal (other than a couple fence posts at the inner fence corners) was detected within the fenced boundary of SWMU 51 (blue outlined rectangle). Metal related anomalies associated with other site activities were detected to the west, north, and east of SWMU 51 corresponding with anomalous areas shown on the conductivity plot (**Figure B-6**).

The EM-34 conductivity anomaly map is shown in **Figure B-8** using the same color scale as that used in **Figure B-6** (EM-31 conductivity). The relatively higher "background" conductivity (8-10 mS/m vs. 5-7 mS/m) is interpreted to result from the EM-34 sampling to a greater depth, and thus including presumably wetter soils in the measurement (depth to bedrock is great enough to have little impact on the EM measurements).

An area of increase in conductivity (~4 mS/m) is observed within the southern two-thirds of the SWMU 51 fenced area. This relative high area is in the approximate location as a conductivity increase observed in the EM-31 data, though of greater relative magnitude. Therefore, it is likely that the conductive material (possibly the waste itself or leached material) delineated by the EM surveys extend to depths greater than 10 ft (~3 m). The north-south extent of this anomaly is less than the areal coverage indicated by the 2D-ERI profiles (crosshatched polygon). Other areas of high-conductivity, the grid area between 164E-260E, 99N-230N, and those north of grid 250N are most likely related to the trenches of SWMU 30.

B.5 SUMMARY

Seismic refraction profiling, two-dimensional electrical-resistivity imaging (2D-ERI), and electromagnetic terrain-conductivity surveying were conducted at SWMU 51 in order to delineate the boundaries of the disposal trench. The geophysical data suggest that the SWMU 51 related trenching and disposal is contained within the current SWMU 51 fence, and restricted to the southern two-thirds of the fenced area.

Seismic refraction tomography mapped a low-velocity zone interpreted to be due to the capping or backfilled material, but did not map the base of the trench. Earth-layer models constructed for the profiles indicate an intra-overburden increase in velocity, which occurs near the base of the trenching, and may indicate a maximum boundary for trenching. No significant structural features were indicated for the bedrock, and top-of-bedrock was mapped as a relatively horizontal surface.

2D-ERI profiling modeled a zone of low-resistivity (<80 ohm-m) underlying the SWMU 51 fenced area. The source for the low-resistivity is interpreted to be either the waste or waste byproducts (leachate or leached material). Depth-to-top of this low-resistivity zone ranged from 5-9 ft bgs, and averaged 6-7 ft bgs. Therefore it is argued that the waste material deposited in the SWMU 51 trench is at least 5 ft bgs.

Depth to the true base of waste is the issue. The resistivity data indicate a range of 15-to-25 ft bgs for the base, though it is possible that a downward migration of leachate (or leached material) has increased thickness of the low-resistivity zone, thus overstating the thickness of the waste. At best, the base of the low-resistivity zone can serve as an upper boundary for estimating the thickness of the waste material.

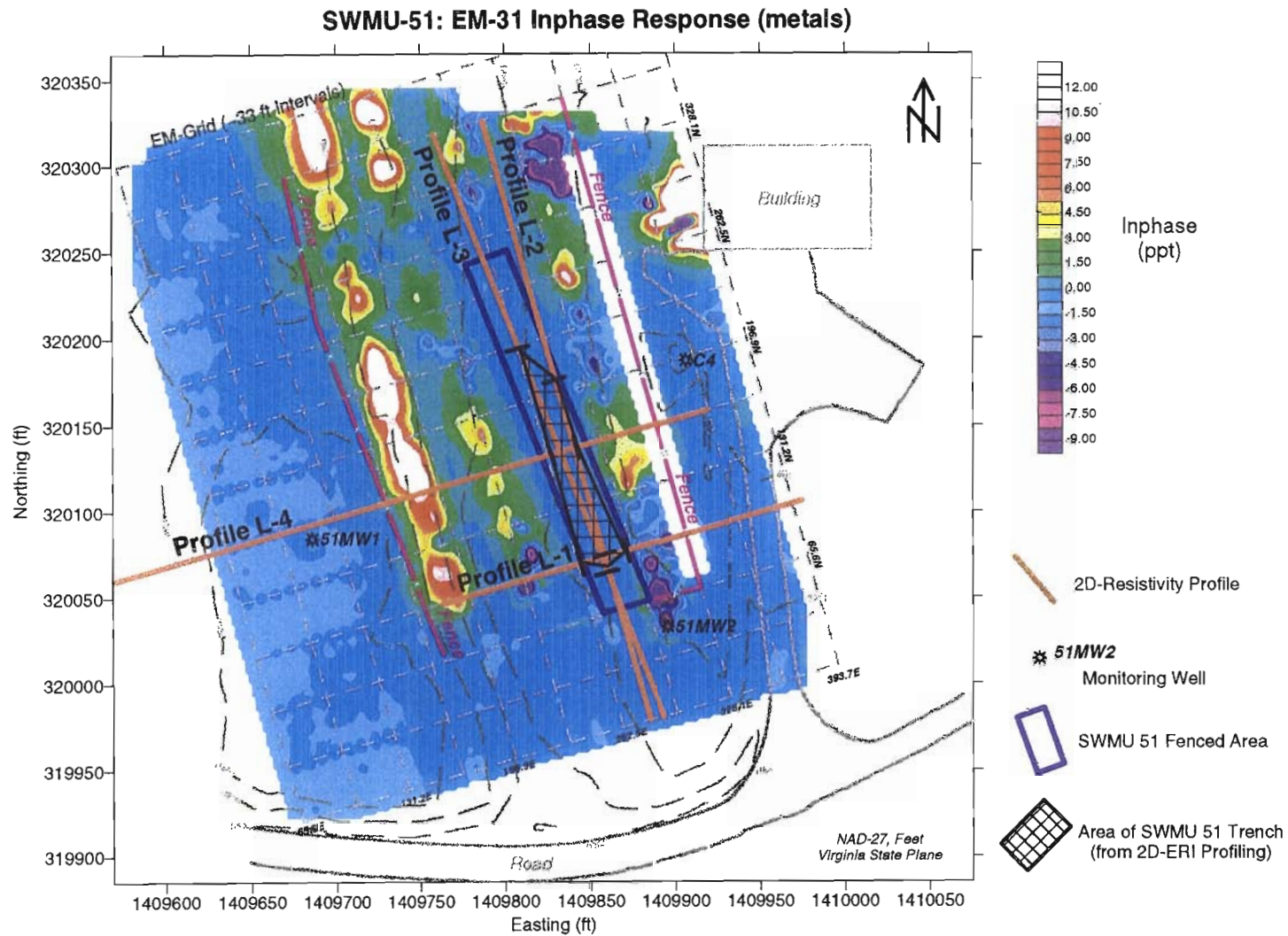


Figure B-7. EM-31 Inphase Response (Metals) Anomaly Map

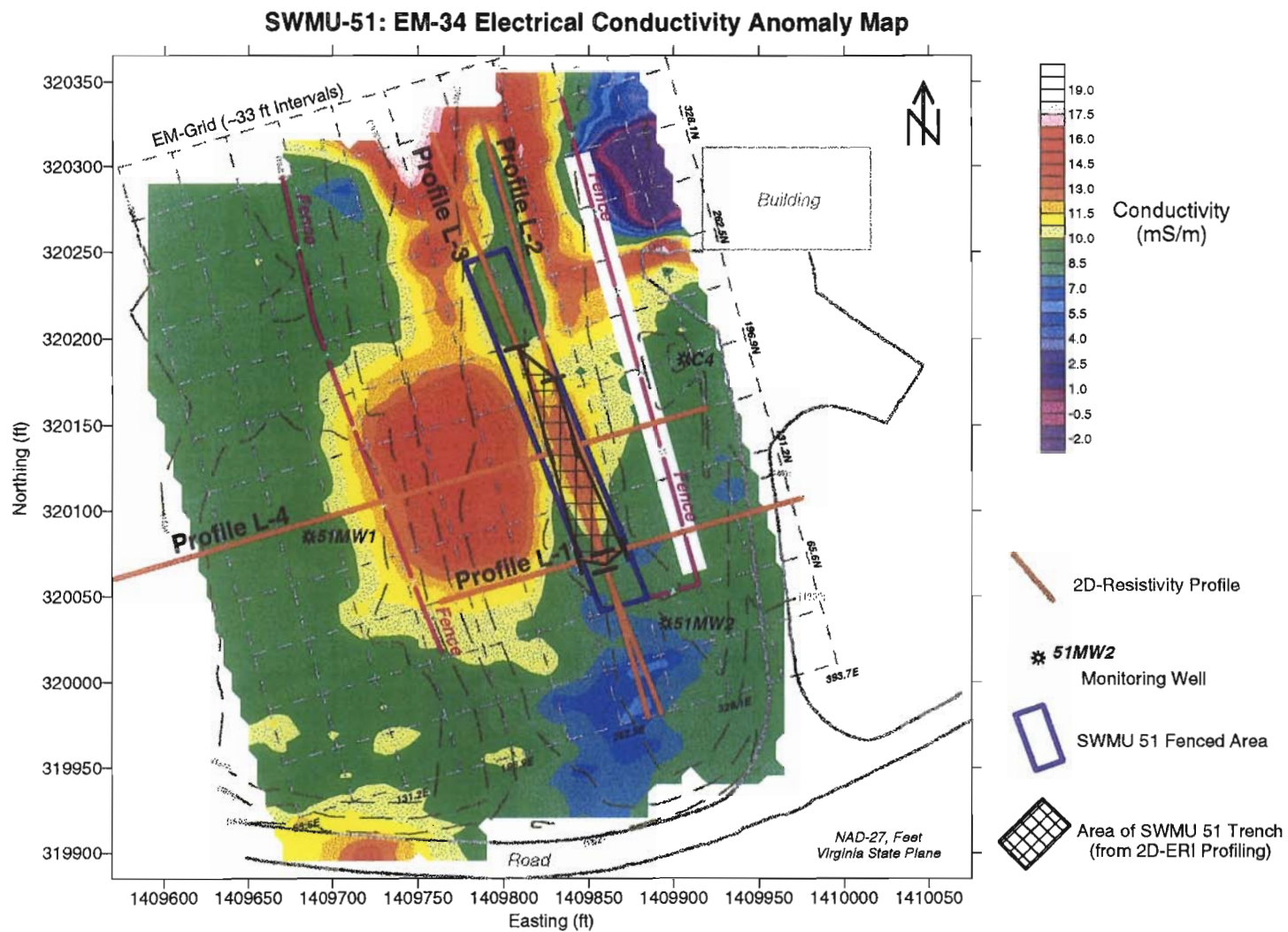


Figure B-8. EM-34 Conductivity Anomaly Map

Electromagnetic surveys using the EM-31 and EM-34 instruments mapped a zone of increased electrical-conductivity (decreased resistivity) within the southern two-thirds of the SWMU-51 fenced area. A 1-2 mS/m increase was measured by the EM-31, and suggests that the top of the anomalous region must be within the upper 10 ft (3 m) of the subsurface. The EM-34 instrument yielded a greater electromagnetic response than the EM-31, indicating that the source of this electrically conductivity zone (low-resistivity) extends below 10 ft (~3 m in depth). The anomalous area mapped by the EM-34 is approximately two-thirds that indicated by the 2D-ERI profiles.

The volume of waste is estimated as follows:

- The maximum areal extent of the trench defined by the 2D-ERI data is approximately 2,300 square feet (115 ft x 20 ft). The minimum areal extent can be estimated from the EM-34 conductivity anomaly map, and is 1,800 square feet (90 ft x 20 ft).
- Depth to top of the low-resistivity (electrically conductive) zone ranges from 5-9 ft, and averages 6-7 ft. Depth to bottom ranges from 15-25 ft, with an average of approximately 18 ft. The range in thickness is 6-20 ft, and averages approximately 11 ft.
- Using the average thickness (indicated on the 2D-ERI sections) and the areal extent, a volume range of 19,800 (11 ft x 90 ft x 20 ft) to 25,300 (11 ft x 115 ft x 20 ft) cubic ft or 733 to 937 cubic yards is calculated.

Appendix B-2

Geophysical Methods

GEOPHYSICAL METHODS

2D Electrical Resistivity Imaging

Two-dimensional electrical resistivity imaging (2D-ERI) measures horizontal and vertical variations in the electrical-resistance of the subsurface. For RFAAP, 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. The trench work within the overburden sediment is expected to produce a zone of lower electrical resistivity. In addition, the presence of waste material and degradation products may also lower the electrical response in the vicinity of the trench.

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. Resistivity, an intrinsic property of the earth, is then calculated using the measured voltage, the electric current strength, and a geometric factor for the electrode array. The calculated resistivity value is actually an "apparent-resistivity" because it includes the resistances of all 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 determine 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 have impacted the data set.

Apparent-resistivity pseudosections are converted, through a process termed inversion, into an electrical-resistivity cross-section showing true earth-layer 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 (EM-31 and EM-34) are used to measure the electrical conductivity of the near surface, and can also 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 determines the depth of penetration. **Table B-1** lists the depth of investigation for different coil orientations and separations for the Geonics EM-31 and EM-34 meters. 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.

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Table B-1
Effective Penetration Depth of the EM-31 and EM-34 Instruments

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 all 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.

Geonics EM-34. The EM-34 is a two-person operable instrument that can measure terrain conductivities to depths of 150-ft (Geonics, 1991). Data were collected at approximately 1 sample per two-feet, and fiducial marker points are recorded at 20-to-50-ft intervals to help mitigate measurement point location errors due to uneven walking speeds. A Polycorder data logger is used to record the line geometry and profile data, which are 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 are planned as processing outputs from the refraction profiling. The commercially available SeisOpt2D code will be 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) is used to record the travel-time of the first returning seismic signal. This information is plotted on a time-distance graph; for the case of plane layer geometry, the time-distance plot will show 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 (EWG) or a 16-lb. sledgehammer were used as the energy source. Geophones (seismic-receivers) were spaced at a 3.28-ft (1-m) 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 consists 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 either the SeisOpt2D code available from Optim Software, or the GeoCT-II code from GeoTomo.

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

The SeisOpt2D software achieves a globally optimized, velocity model using only first arrival travel time data and array geometry as input. SeisOpt2D requires no prior assumptions of subsurface structure, or any other subjective data, as input. A controlled Monte-Carlo inversion method is employed where the derived models are conditionally accepted or rejected based on a probability criterion. The criterion allows the algorithm to escape from non-unique, local, travel time minima to achieve a unique, globally optimized model of subsurface velocity structure. The algorithm makes no assumptions on the orientation of the subsurface velocity gradient, and can therefore reveal vertical structures and strong lateral gradients, if present.

The GeoCT-II inversion code also uses the geometry and first-arrival information as a starting point to apply a nonlinear continuum inversion in order to achieve a velocity-depth model. This package also allows providing a priori constraints such as known velocities from downhole surveys, and using earth-layer models as starting points.

Vertical Seismic Profiling

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

0.1 ms interval (10,000 samples per second), which is required so that very small changes in arrival time (up to 0.2 milli-seconds) can be detected. The small arrival time changes are due to the presence of fast-velocity limestones and dolomites and correspond to a seismic wave traveling from 10,000 to 25,000-ft/s (yields arrival-time changes of 0.2 to 0.5 milliseconds over a 5 foot interval).

Data processing consisted of the following:

- Pick first arrival energy for the downhole and reference geophones;
- Sort the arrival-time data by depth point;
- Compute and apply shot-timing corrections using the arrival time picks obtained from the reference geophones;
- Compute the average velocity to a receiver station using the straight-line distance from the shot to the receiver and the corrected arrival time;
- Convert to vertical travel-time using the depth point for the receiver and the computed average velocities; and
- Compute 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 are correlated with the lithologic information and other available borehole geophysical data.

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Appendix C
Forms

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Form C-1
Revision Form
Work Plan—Quality Assurance Plan—Health and Safety Plan Addendum No. 17

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 ____

Location: Horseshoe Area, SWMU 51

Site Personnel:

Date _____

