RAAP050506\65007

DELIVERY ORDER NO. 0027
ENVIRONMENTAL SERVICES
PROGRAM SUPPORT
CONTRACT DACA31-00-D-0011

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

WORK PLAN
ADDENDUM NO. 13
RCRA Facility Investigation at Solid Waste Management Unit 54

FINAL DOCUMENT

September 2002

PREPARED BY:

URS

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

ATK
ALLIANT TECHSYSTEMS

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

December 6, 2002

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

Subject: Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, Final September 2002
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Based upon your October 10, 2002 approval letter for the subject work plan, enclosed are three report covers for "Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, Final September 2002". Report covers will be sent under separate cover to the Virginia Department of Environmental Quality (VDEQ), U.S. Army Environmental Center, U.S. Army Center for Health Promotion and Preventive Medicine.

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

Sincerely,

C. A. Jake

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

Enclosure

w/o enclosure

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

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

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

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

02-815-170
JMcKenna/JJRedder

3

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

Katie Watson
Engineering & Environment, Inc.
4428 Northgate Drive
Knoxville, TN 37938

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

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

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

Coordination: J. McKenna
J. McKenna

02-815-170
JMcKenna/JJRedder

5

Concerning: Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, Final September 2002

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: Brian A. Butler
TITLE: LTC, CM, Commanding
Radford AAP

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

COMMONWEALTH *of* VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

W. Tayloe Murphy, Jr.
Secretary of Natural Resources

Street address: 629 East Main Street, Richmond, Virginia 23219
Mailing address: P.O. Box 10009, Richmond, Virginia 23240
Fax (804) 698-4500 TDD (804) 698-4021
www.deq.state.va.us

Robert G. Burnley
Director

(804) 698-4000
1-800-592-5482

5 November 2002

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

RE: Addendum's 13 & 14 September 2002

Dear Mr. McKenna:

This office has reviewed the referenced draft document and concurs with Addendum's 13 & 14. No revisions to the document are required. Please provide this office a copy of the final document when it is completed.

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

Sincerely,

Mark S. Leeper
RPM

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

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

9

Date: October 10, 2002

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 54
Work Plan Addendum 13
Document submittal and review

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's September, 2002 *Work Plan Addendum 13* for the investigation of SWMU 54, located at the Radford Army Ammunition Plant (RFAAP). Based upon our review, *Work Plan Addendum 13* is approved. In accordance with Part II. (E)(5)of RFAAP's Corrective Action Permit, *Work Plan Addendum 13* is now considered final.

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

Sincerely,

Robert Thomson

Robert Thomson, PE
Federal Facilities Branch

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

13

ALLIANT TECHSYSTEMS

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

September 11, 2002

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

Subject: Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, September 2002
Work Plan Addendum 14 RCRA Facility Investigation at Solid Waste Management Unit 40/71, September 2002
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is a certified copy of "Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, September 2002" and a certified copy of "Work Plan Addendum 14 RCRA Facility Investigation at Solid Waste Management Unit 40/71, September 2002". Your two additional copies and copies to Virginia Department of Environmental Quality (VDEQ), U.S. Army Operations Support Command, U.S. Army Environmental Center, U.S. Army Center for Health Promotion and Preventive Medicine will be sent under separate cover.

These work plans have been revised per our conference call of August 22, 2002 and are considered final. Upon your concurrence new report covers will be sent. Also enclosed are responses to EPA comments of July 22 and 25, 2002 and VDEQ comments of June 3, 2002.

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

Sincerely,

C. A. Jake

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

Enclosure

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

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

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

02-815-129
JMcKenna/JJRedder

Kenneth G. Barnes
U.S. Army Operations Support Command
Environmental Restoration Division
1 Rock Island Arsenal, Attn: AMSOS-ISR
Rock Island, IL 61299-5500

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

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

w/o enclosure
Russell Fish, P.E., EPA Region III

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

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

Coordination: J. McKenna
J. McKenna

02-815-129
JMcKenna/JJRedder

Concerning: Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, September 2002 and Work Plan Addendum 14 RCRA Facility Investigation at Solid Waste Management Unit 40/71, September 2002

[illegible]rtify 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: Brian A. Butler
TITLE: LTC, CM, Commanding
Radford AAP

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

02-815-129
JMcKenna/JJRedder

Response to Comments
Draft RCRA Facility Investigation
Work Plan Addendum 13, SWMU 54
Radford Army Ammunition Plant
Radford, Virginia

Comments from USEPA correspondence dated 22 July 2002

GENERAL COMMENTS

1. **Conceptual Site Models**: The conceptual site model does not include a residential receptor for the risk assessment. Even though it is unlikely that a clean-up would be based upon a residential risk scenario at the Radford AAP, it is still necessary and proper to determine what risk would be posed under such a scenario. This is especially true for a determination of "clean closure", where waste is not left in-place at a site. Without including the residential risk scenario, the Army will be defaulting to a non-clean closure scenario, leaving waste "in-place", which would require long-term monitoring, maintenance, and 5-year reviews. This automatic default is not acceptable to EPA. Therefore, the residential risk scenario should be included in the conceptual site model.

> **RESPONSE:** Text has been added to the fifth paragraph of Section 1.2.4, Conceptual Site Model, stating that, "Although current and future land-use scenarios are limited to industrial operations, both industrial and residential scenarios will be considered."

SPECIFIC COMMENTS

2. **Section 1.2.3.4, Supplemental RFI Report, SWMU 54 - 1998, page 1-39**: The third paragraph of this subsection states that data generated by Millennium Science and Engineering (MSE, 1998) "should not be relied upon as a definitive data." However, Table 1-3 indicates, under "Data Usability," that the soil data can be used as definitive data for constituents of potential concern (COPC) identification and for site characterization, and that the groundwater data can be used as definitive data for COPC identification. In addition, since the MSE report did not provide the depths of samples and the discussion of the surface and subsurface soil samples in *Work Plan Addendum 13* is based on assumptions, the usability of the MSE data for site characterization appears to be inappropriate. Please revise the *Work Plan Addendum 13* (WPA) to resolve this discrepancy and discuss the usability of the MSE data for the RCRA Facility Investigation (RFI).

> **RESPONSE:** Section 1.2.3.4, 3rd Paragraph, Last Line was revised to: "Data generated by MSE (1998) can be used for site screening purposes (including

identification of COPCs) and should not be relied upon as definitive data for characterization purposes."

3. <u>**Section 1.2.3.5, Correspondence August 20, 1999, Subject SWMU 54 Interim Action, pages 1-46 through 1-79**</u>: The sixth paragraph on page 1-66 states that analytical results for two backfill material samples identified as 54BF1 and 54BF2 are summarized in Appendix B. Appendix B does not contain the referenced information. Please provide the referenced data in the WPA.

> **RESPONSE:** The referenced data has been provided in Appendix B, Soil Composite Data, Parallax (2000).

3.a <u>**The seventh paragraph on page 1-66**</u> indicates that for excavated and backfilled cells, data for 2,4,6-TNT were adjusted to zero. Please explain why the data for 2,4,6-TNT in the backfilled cells were adjusted to zero.

> **RESPONSE:** For values that were reported as non-detect, TNT has been adjusted to zero (as opposed to using the MDL or ½ of the MDL) for the presentation of the estimated post-excavation isoconcentration map of Area A.

3.b <u>**The fourth paragraph on page 1-77**</u> states that groundwater results are summarized in Table 1-5. Table 1-5 summarizes soil results. Please provide the referenced summary data in the WPA.

> **RESPONSE:** The paragraph should refer the reader to Table 1-4 not 1-5. This has been corrected in the report and other references have been checked for accuracy.

4. <u>**Section 1.2.4, Conceptual Site Model, page 1-82**</u>: This section states that surface water and sediment are not considered in the conceptual site model (CSM) "because there are no surface water bodies in the SWMU 54 area." Surface water and sediment should not be ruled out from the CSM because the New River is located just 150 feet east of SWMU 54, and surface runoff and groundwater from SWMU 54 area discharge to the New River. In addition, the data presented in the WPA do not conclusively rule out that SWMU 54 had impacted the New River because the limits of constituent migration are currently unknown. Please revise the WPA to include surface water and sediment in the CSM.

> **RESPONSE:** A site-specific CSM has been developed for SWMU 54 to assess potential contaminant sources, exposure pathways, and human and ecological receptors (Figure 1-49). Potentially affected media include surface soil, subsurface soil, and groundwater. The SWMU 54 area is relatively level and precipitation is expected to infiltrate into the ground. A topographic high running parallel to the river and the roadbed on the southern perimeter of the site effectively capture surface runoff and eliminate the possibility of sheet flow reaching the New River. Sufficient data do not exist to establish the existence or

absence of a complete pathway resulting from site groundwater discharge to the New River and the possible resultant pathway to surface water and sediment (via ingestion, inhalation, and/or dermal contact). The results of the investigative activities from the WPA are anticipated to facilitate the definition of the limits of constituent migration in groundwater. The completeness of the surface water and sediment migration pathways at SWMU 54 is considered unknown. Once the constituent migration limits have been assessed, the completeness of the surface water and sediment pathways will be examined

5. **Section 1.2.5, Data Gap Analysis, pages 1-82 through 1-86**: Perchlorate should be identified as a data gap in this section.

RESPONSE: Perchlorate has been identified in the SWMU 54 RFI Work Plan as a data gap.

6. **Section 1.2.5, Data Gap Analysis**: A data gap that is not identified is that no ERA has been performed. Because no ERA has been performed, potential threats to ecological receptors have yet to be identified. This data gap should be discussed, and an ERA performed for the SWMU. The Planned Field Activities (Section 1.3) should state that to fulfill this data gap, an ecological risk assessment would be performed.

RESPONSE: The results of a Baseline Risk Assessment (including an ecological risk screening) have been identified as a data gap in the WPA.

7. **Section 1.3, Planned Field Activities, page 1-86**: The third bullet on this page states that the data will be used to evaluate the leaching of contaminants from soil to the groundwater and the fate and transport of contaminants in groundwater. This evaluation must also determine if the migration pathway to the New River from groundwater is complete. If the pathway is found to be complete, sediment sampling in the New River is recommended.

RESPONSE: The RFI Work Plan Addendum has been modified to state that the collected data will also be utilized to assess whether the migration pathway to the New River from groundwater is complete.

8. **Section 2.0, Quality Assurance Plan Addendum, pages 2-1 through 2-28**: Tables 2-5 through 2-11 provide a summary of analyte method detection limits, reporting limits and screening criteria for all the analytes proposed but perchlorate. Please provide similar data for perchlorate as appropriate.

RESPONSE:

Similar data is provided for perchlorate in Table 2-11 including analyte method detection limits, reporting limits, and screening criteria.

Draft Comments from VDEQ received via e-mail attachment 3 June 2002

1. **Page 1-4,** MWP is not referenced.

   Response: The Master Work Plan is referenced at the end of paragraph 1 on page 1-1. The acronym will be defined again on page 1-4. It is also included in the References section of the WPA (Section 4.0).

2. **Figure 1-3,** is the thin lined section, near the ground water symbol and "New River", a different formation?

   Response: The incorrect fill was designated in the CADD drawing for this area of Figure 1-3. Figure 1-3 has been revised to include the correct fill in this location.

3. **Table 1-4,** what does the dashed box represent?

   Response: The dashed box represents an exceedance of the lead informal action level. The symbol for this was omitted from the Table 1-4 legend. The legend has been corrected.

4. **Figures 1-8 – 1-11,** there are some borings that have no values.

   Response: The samples collected from soil borings advanced during the Parson's 1996 study did not include shallow soil samples for 54SB9 and 54SB15. Therefore, no values are reported for these locations for shallow soils.

5. **Page 1-46, Ground water, 54MW4 was sampled along with 54MW1. The results from the sampling event indicate that there were hits in 54MW1 and 54MW4 is not mentioned. Does this mean there were no hits in 54MW4?**

   Response: Yes.

6. **Page 1-77, last paragraph,** tetrachloroethene should not be excluded from the COPCs from area B.

   Response: The single detection of tetrachloroethene (2 ug/l) was j-flagged as an estimated value between the Method Detection Limit and the Reporting Limit. The Tap Water RBC for tetrachloroethene is currently 1.1 ug/l and the MCL is 5 ug/l. Previous sampling of groundwater with analysis for volatile organic compounds (VOCs) has not detected tetrachloroethene at concentrations above RBCs in Area B at SWMU 54. It is recommended that tetrachloroethene continue to be excluded as a COPC in Area B.

7. **Table 1-10 page 1,** please explain the rationale of why there will be no soil samples collected above the water table for 17A – 38B.

> **Response:** Previous analytical results for these locations have been assessed and were found to be usable for characterization purposes. Further sampling appears unnecessary in these locations.

8. **Figure 1-51,** it may be advantageous to collect a soil sample in the northwest section near the SWMU boundary.

> **Response:** This area of the site was assessed and samples were allocated to grids to assure the Data Quality Objectives are met. The northern site boundary was conservatively approximated, but previous sampling and remedial activities strongly indicate that the impacted portion of Area A is along its southern boundary. This was the rationale for surrounding this area with samples. To ensure that impacted soil did not extend to the northern portion of Area A, 54SB17, 54SB19, and 54SB22 are proposed and considered sufficient. It is recommended that the current sampling plan remain unchanged.

9. **Figure 1-54,** it may be advantageous to collect additional soil samples in the southwest areas where the lead levels are greater than 1000 ppm.

> **Response:** This area of the site was assessed and samples were allocated to grids to assure the Data Quality Objectives are met. The grid sizing is relatively small (40 feet by 40 feet) and hence the area of potential lead levels exceeding 1000ppm is small. This area appears to be well bounded both by the proposed sampling locations 54SB41, 54SB42, and 54SB51; and by areas of previous excavation (shown in green shading on the figure). It is recommended that the current sampling plan remain unchanged.

10. **Table 1.7:** The RBC for pyrene can be used as a substitute for acenapthylene, benzo(ghi)perylene and phenanthrene.

> **Response:** The comment has been incorporated into the Final Work Plan Addendum.

11. **Page 1-77,** last paragraph, last line. J-flagged values should not be disqualified as COPCs at this early stage of assessment.

> **Response:** Please see response to Comment 6.

Response to Comments
Draft RCRA Facility Investigation
Work Plan Addendum 14
SWMU 40/71
Radford Army Ammunition Plant
Radford, Virginia

Comments from USEPA correspondence dated 25 July 2002
GENERAL COMMENTS

1. **Conceptual Site Models**: The conceptual site model does not include a residential receptor for the risk assessment. Even though it is unlikely that a clean-up would be based upon a residential risk scenario at the Radford AAP, it is still necessary and proper to determine what risk would be posed under such a scenario. This is especially true for a determination of "clean closure", where waste is not left in-place at a site. Without including the residential risk scenario, the Army will be defaulting to a non-clean closure scenario, leaving waste "in-place", which would require long-term monitoring, maintenance, and 5-year reviews. This automatic default is not acceptable to EPA. Therefore, the residential risk scenario should be included in the conceptual site models for SWMUs 40 & 71.

   Response: Text has been added to Section 1.2.4, Conceptual Site Model, stating that, "Although current and future land-use scenarios are limited to industrial operations, both industrial and residential scenarios will be considered."

SPECIFIC COMMENTS

2. **Section 1.2.4, Conceptual Site Model**, states that "based on previous investigations, groundwater is not present in overburden soils in the immediate vicinity of SWMU 40/71 to depths of at least 160 feet bgs [below ground surface] ...Groundwater is therefore, not considered a migration pathway at SWMU 40/71." This conclusion is not supported by the current investigative data. Groundwater was found in Well 40MW3, which is located in the vicinity of SWMU 40/71 and is screened from 97 to 117 feet bgs. All the other attempts in finding groundwater were abandoned at depths much less than the 160 feet bgs, except at borehole 40MW1A. Therefore, it is inaccurate to state that groundwater is not present to depths of at least 160 feet bgs. In addition, previous investigations (Dames & Moore, 1992; Engineering Science, 1994; Parsons 1996) have concluded that groundwater from the vicinity of SWMU 40/71 may be drained by solution-enhanced epikarstic features in the bedrock. Thus, the potential leachate as depicted in Figure 1-13 (Site Conceptual Model) can be drained by the "bedding-parallel solution features" and "fracture-type solution features," thereby impacting the groundwater. Because of the complexity of the site hydrogeology, previous investigations do not appear to be sufficient grounds for the conclusions reached in the Work Plan Addendum 14 (WPA). Revise the WPA to propose further investigation of the groundwater and include groundwater in the Conceptual Site Model (CSM).

Response: The WPA will be revised to indicate that it is unknown whether the groundwater exposure pathway is complete. The current groundwater study in the "Horseshoe" area is scheduled for expansion into the Main Manufacturing Area (MMA) in fiscal year 2006. The expanded study area includes SWMU 40/71. This study is a result of discussions/decisions coordinated with the USEPA and VDEQ at the Installation Action Plan Workshop in May 2001.

3. **Section 1.2.5, Data Gap Analysis**, presents information on data gaps that have been identified. A data gap that is not identified is that no ERA has been performed. Because no ERA has been performed, potential threats to ecological receptors have yet to be identified. This data gap should be discussed in this section.

   Response: The results of a Baseline Risk Assessment (including an ecological risk screening) have been identified as a data gap in the WPA.

4. Although the WPA explains that 40MW2 and 40MW4 were constructed as groundwater monitoring wells, the depths at which these "wells" were completed makes them unlikely to intercept any possible high water table. For example, borehole 40MW4 was advanced to 90 feet bgs and no water was encountered. However, a groundwater monitoring well was constructed to approximately 69 ft bgs to "intercept any possible high water table at a future date." This assumes that a water table rise of over 21 feet is expected, since water was not encountered at 90 feet bgs. Revise the WPA to remove references to groundwater monitoring wells 40MW2 and 40MW4 and associated legends from all the figures, because 40MW2 and 40MW4 are not groundwater monitoring wells.

   Response: Figure 1-15, Proposed Sampling Locations, has been modified to remove the legend reference to "monitoring wells" and changed to "Dry Hole" and the symbol in the legend and on the figure have been changed to be different from those used for monitoring wells. The names of the Dry Holes have been retained as 40MW2 and 40MW4.

5. **Section 1.2.4, Conceptual Site Model, page 1-21:** The first paragraph of this section states that "based on current data available for the site, migration pathways of constituents from SWMU 40/71 likely include surface water (limited however, to during rainfall events), leaching of constituents into subsurface soils, and wind-borne dispersion of accumulated soil in the northern scarp area." However, subsequent discussions in paragraphs 1 and 2 dismiss the potential migration pathways for surface water and wind-born dispersion for both SWMUs 40 and 71. Revise the WPA to resolve these discrepancies. In addition, include the potential migration pathway for wind-borne dispersion in the CSM as the area proximal to the northern scarp shows possible wind-borne dispersion of soil particulates.

   Response: The Conceptual Site Model developed as part of the Work Plan Addendum was modified to clearly state which migration and exposure pathways are complete, incomplete, or unknown. Current conditions at the site do not support the conclusion that wind-borne dispersion of accumulated soil occurs at SWMU 40/71 and therefore, this pathway has been identified as incomplete. Storm water on the site does not appear to enter surface water bodies and therefore, the surface water migration pathway has also been identified as incomplete.

6. **<u>Section 1.3.2, Soil Borings, pages 1-33 through 1-35</u>:** The fifth bullet on page 1-34 indicates that Boring 71SB11 is proposed in the Flash-Burn Area. However, Figure 1-15 identifies the boring as 71SB1 and 71SB11 as a surficial soil sampling location. Please resolve this discrepancy between the text and the figure.

   Response: Figure 1-15 was corrected to show boring 71SB11 correctly.

   <u>The second paragraph on page 1-35 references Section 6.4</u> of the Master Work Plan (MWP) for the analysis of physical and geotechnical properties of soils. This information is not provided in the referenced section of the MWP. Please provide the correct reference for the information.

   Response: The reference to Section 6.4 has been corrected to Section 5.8.

7. **<u>Section 1.3.3.2, Cindered Area, page 1-36:</u>** This section identifies the two surface soil-sampling locations proposed for the Cindered Area as 40SS4 and 40SS5. However, Figure 1-15 identifies the surface soil sampling locations as 40554 and 40555. Please revise the text or the figure to use a consistent sample location designation.

   Response: The two surface soil-sampling locations have been corrected to refer to 40SS4 and 40SS5.

8. **<u>Table 1-6, Handling and Disposal of Non-hazardous Materials</u>:** This table does not appear to include soils to be stockpiled from the geophysical anomaly excavation (see Section 1.3.1). Please revise this table or the text of Section 1.3.1 to discuss how the soils stockpiled from the pit excavation will be managed and disposed. Also, correct the following in Table 1-6:

   - The title of the table should read "Handling and Disposal of Investigation-Derived Materials." Whether the materials are hazardous or non-hazardous will be determined after the actions specified in column six of the table are conducted.

   - The last column, second row, should read "soil" instead of "sediment."

   Response: The table has been modified to discuss how the soils stockpiled from the test pit excavation will be managed. The title of the table has been modified and the word sediment has been changed to soil.

9. **<u>Table 2-4, Summary: Proposed Sample Identification and Depths</u>:** The depths specified in this table for various sample locations do not match those discussed in Section 1.3 (Planned Field Activities). For example, for the surficial soil sampling the table indicates that samples will be collected from 0-6 inches. However, the text in Section 1.3.3 indicates that a sample will be collected from 0-6 inches bgs and another sample will be collected from

6-12 inches bgs. Revise table to reflect the discussions provided in Section 1.3. Also, define "intermediate depth" in Table 2-4.

Response: Fourteen soil borings will be advanced and surface, intermediate, and base of overburden samples will be collected from these soil borings (three depths except where fill materials are encountered, and then 4 depths if encountered). Soil boring surface samples will be collected from 0-6 inches except for volatiles that will be sampled from 6-12 inches. The table has been revised to reflect the discussions provided in Section 1.3.

10. **APPENDIX A, STANDARD OPERATING PROCEDURES, Standard Operating Procedure 20.4, Test Pits**: Section 4.0 of this standard operating procedure (SOP) references the site-specific health safety plan for precautions during test pit excavation and backfill. This referenced information is not provided in the site-specific health and safety plan (Section 2.0). Please provide the referenced information either in this SOP or the Health and Safety Plan Addendum.

Response: Please note that WPA Section 3.0 contains the site-specific health and safety plan. WPA Section 3.2.2, Project-specific Hazard Analysis outlines site-specific hazards, including those that may be encountered during Test Pit excavation, such as falls, noise from heavy equipment, and overhead power lines.

Draft Comments from VDEQ received via e-mail attachment 3 June 2002

1. Page 1-34, Section Soil Borings, second bullet, what if the boundaries of the landfill are not found with the projected three borings?

Response: This will be further assessed in the field at the time of investigation but it appears that the boundaries of the fill material have been well characterized by the results of the geophysical investigation and an examination of aerial photographs.

2. Page 1-36, Section 1.3.3.3, surficial soil sampling is collected from 0-6 inches, however, samples 71ss11,12,13 are proposed to be collected at 6-12 inches. Will surface soil be collected in the "surface material" sample? Moreover, Table 2-4 lists the three sample locations as 0-6 inches.

Response: Surface soil samples will be collected from 0-6 inches for all analyte suites except for volatiles, which will be sampled from 6-12 inches. The text in Section 1.3.3, Surficial Soil Sampling, and Table 2-4 has been revised to clarify the specification of surface soil sampling depths.

3. Tables 2.7 and 2.8. The RBC for pyrene may be used as a substitute for acenapthylene, benzo(ghi)perylene, and phenanthrene.

Response: The comment will be incorporated into the revised WPA.

4. Table 2-9. The RBC for Endrin may be used as a substitute for endrin sulfate, endrin ketone, and endrin aldehyde. The RBC for endosulfan I may be used for endosulfan II, and the RBC for alpha BHC may be used for delta BHC.

> **Response:** The comment will be incorporated into the revised WPA.

5. Tables 2-11 and 2-12. RBCs for tap water are listed in these tables; however, there is no mention of groundwater samples in the planned field activities or proposed sampling locations (Section 1.0). According to Figure 1-13 and the text in section 1.0, leaching of contaminants into groundwater appears to be a possible route of exposure and should be investigated. Figure 1-14 does not include groundwater as an exposure pathway.

> **Response:** The WPA will be revised to indicate that is unknown whether the groundwater exposure pathway is complete. The current groundwater study in the "Horseshoe" area is scheduled for expansion into the Main Manufacturing Area (MMA) in fiscal year 2006. The expanded study area includes SWMU 40/71. This study is a result of discussions/decisions coordinated with the USEPA and VDEQ at the Installation Action Plan Workshop in May 2001. Inclusion of the tap water RBCs in Tables 2-11 and 2-12 is strictly for reference and document completeness.

39

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

received 6 August 2002

July 22, 2002

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 54
Work Plan Addendum 13
Document submittal and review

Dear Mr. McKenna and Ms. Jake:

The U.S. Environmental Protection Agency (EPA) has reviewed the Army's draft *Work Plan Addendum 13* for the investigation of SWMU 54, located at the Radford Army Ammunition Plant (RFAAP). Outlined below, please find EPA's comments based upon that review:

GENERAL COMMENTS

1. **Conceptual Site Models**: The conceptual site model does not include a residential receptor for the risk assessment. Even

W

though it is unlikely that a clean-up would be based upon a residential risk scenario at the Radford AAP, it is still necessary and proper to determine what risk would be posed under such a scenario. This is especially true for a determination of ``clean closure'', where waste is not left in-place at a site. Without including the residential risk scenario, the Army will be defaulting to a non-clean closure scenario, leaving waste ``in-place", which would require long-term monitoring, maintenance, and 5-year reviews. This automatic default is not acceptable to EPA. Therefore, the residential risk scenario should be included in the conceptual site model.

SPECIFIC COMMENTS

2. **Section 1.2.3.4, Supplemental RFI Report, SWMU 54 - 1998, page 1-39:** The third paragraph of this subsection states that data generated by Millennium Science and Engineering (MSE, 1998) "should not be relied upon as a definitive data." However, Table 1-3 indicates, under "Data Usability", that the soil data can be used as definitive data for constituents of potential concern (COPC) identification and for site characterization, and that the groundwater data can be used as definitive data for COPC identification. In addition, since the MSE report did not provide the depths of samples and the discussion of the surface and subsurface soil samples in *Work Plan Addendum 13* is based on assumptions, the usability of the MSE data for site characterization appears to be inappropriate. Please revise the *Work Plan Addendum 13* (WPA) to resolve this discrepancy and discuss the usability of the MSE data for the RCRA Facility Investigation (RFI).

3. **Section 1.2.3.5, Correspondence August 20, 1999, Subject SWMU 54 Interim Action, pages 1-46 through 1-79:** The sixth paragraph on page 1-66 states that analytical results for two backfill material samples identified as 54BF1 and 54BF2 are summarized in Appendix B. Appendix B does not contain the referenced information. Please provide the referenced data in the WPA.

   The seventh paragraph on page 1-66 indicates that for excavated and backfilled cells, data for 2,4,6-TNT were adjusted to zero. Please explain why the data for 2,4,6-TNT in the backfilled cells were adjusted to zero.

   The fourth paragraph on page 1-77 states that groundwater results are summarized in Table 1-5. Table 1-5 summarizes soil results. Please provide the referenced summary data in the WPA.

4. **Section 1.2.4, Conceptual Site Model, page 1-82:** This section states that surface water and sediment are not considered in the conceptual site model (CSM) "because there are no surface water bodies in the SWMU 54 area." Surface water and sediment should not be ruled out from the CSM because the New River is located just 150 feet east of SWMU 54, and surface runoff and groundwater from SWMU 54 area discharge to the New River. In addition, the data presented in the WPA do not conclusively rule out that SWMU 54 had impacted the New River because the limits of constituent migration are currently unknown. Please revise the WPA to include surface water and sediment in the CSM.

5. **Section 1.2.5, Data Gap Analysis, pages 1-82 through 1-86:** Perchlorate should be identified as a data gap in this section.

6. **Section 1.2.5, Data Gap Analysis:** A data gap that is not identified is that no ERA has been performed. Because no ERA has been performed, potential threats to ecological receptors have yet to be identified. This data gap should be discussed, and an ERA performed for the SWMU. The Planned Field Activities (Section 1.3) should state that to fulfill this data gap, an ecological risk assessment will be performed.

7. **Section 1.3, Planned Field Activities, page 1-86:** The third bullet on this page states that the data will be used to evaluate the leaching of contaminants from soil to the groundwater and the fate and transport of contaminants in groundwater. This evaluation must also determine if the migration pathway to the New River from groundwater is complete. If the pathway is found to be complete, sediment sampling in the New River is recommended.

8. **Section 2.0, Quality Assurance Plan Addendum, pages 2-1 through 2-28:** Tables 2-5 through 2-11 provide a summary of analyte method detection limits, reporting limits and screening criteria for all the analytes proposed but perchlorate. Please provide similar data for perchlorate as appropriate.

This concludes EPA's review of the Army's draft *Work Plan Addendum 13 for* the investigation of SWMU 54 located at the RFAAP. The referenced draft *Work Plan Addendum 13 is* disapproved by EPA in its current form, and it 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 above document and submit a revised copy to EPA for review within 60 days of the receipt of EPA comments. Part II, Section E.4.f. of the Permit allows for an additional 20 days for issuing the revised document to EPA, provided that timely notice is given, i.e. within 10 days. Additional time extensions can be requested under Part II, Section F. of the permit.

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

Sincerely,

Robert Thomson

Robert Thomson, PE
Federal Facilities Branch

cc: Russell Fish, EPA
Mark Leeper, VDEQ

47

McKenna, Jim

From: Leeper,Mark [msleeper@deq.state.va.us]
ent: Monday, June 03, 2002 12:27 PM
To: McKenna, Jim
Cc: Thomson. Bob (E-mail)

raft Comments for RI.doc

Hey Jim,

Enclosed are the comments for Addendum 13 & 14. Please let me know if you have any questions.

Thanks,

<<Draft Comments for RI.doc>>

****

Mark S. Leeper
Remedial Project Manager
Federal Facilities Restoration Program
Virginia Department of Environmental Quality
804.698.4308 W
04.698.4383 F

****

49

Draft Comments for Addendum 14

1. Page 1-34, Section Soil Borings, second bullet, what if the boundaries of the landfill are not found with the projected three borings?
2. Page 1-36, Section 1.3.3.3, surficial soil sampling is collected from 0-6 inches, however, samples 71ss11,12,13 are proposed to be collected at 6-12 inches. Will surface soil be collected in the "surface material" sample? Moreover, Table 2-4 lists the three sample locations as 0-6 inches.

3. Tables 2.7 and 2.8. The RBC for pyrene may be used as a substitute for acenapthylene, benzo(ghi)perylene, and phenanthrene.

4. Table 2-9. The RBC for Endrin may be used as a substitute for endrin sulfate, endrin ketone, and endrin aldehyde. The RBC for endosulfan I may be used for endosulfan II, and the RBC for alpha BHC may be used for delta BHC.

5. Tables 2-11 and 2-12. RBCs for tap water are listed in these tables; however, there is no mention of groundwater samples in the planned field activities or proposed sampling locations (Section 1.0). According to Figure 1-13 and the text in section 1.0, leaching of contaminants into groundwater appears to be a possible route of exposure and should be investigated. Figure 1-14 does not include groundwater as an exposure pathway.

Draft Comments for Addendum 13

1. Page 1-4, MWP is not referenced.
2. Figure 1-3, is the thin lined section, near the ground water symbol and "New River", a different formation?
3. Table 1-4, what does the dashed box represent?
4. Figures 1-8 – 1-11, there are some borings that have no values.
5. Page 1-46, Ground water, 54MW4 was sampled along with 54MW1. The results from the sampling event indicate that there were hits in 54MW1 and 54MW4 is not mentioned. Does this mean there were no hits in 54MW4?

6. Page 1-77, last paragraph, tetrachloroethene should not be excluded from the COPC's from area B.

7. Table 1-10 page 1, please explain the rationale of why there will be no soil samples collected above the water table for 17A – 38B.

8. Figure 1-51, it may be advantageous to collect a soil sample in the north west section near the SWMU boundary.

9. Figure 1-54, it may be advantageous to collect additional soil samples in the southwest areas where the lead levels are greater than 1000 ppm.

10. Table 1.7: The RBC for pyrene can be used as a substitute for acenapthylene, benzo(ghi)perylene and phenanthrene.

11. Page 1-77, last paragraph, last line. J-flagged values should not be disqualified as COPCs at this early stage of assessment.

3

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

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

REPLY TO
ATTENTION OF

MCHB-TS-REH (40)

6 MAY 2002

MEMORANDUM FOR Radford Army Ammunition Plant (SMCRA-EN/Mr. Jim McKenna), P.O. Box 2, Route 114, Radford, VA 24141-0099

SUBJECT: Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, April 2002

1. The US Army Center for Health Promotion and Preventive Medicine has reviewed the subject document on behalf of the Office of The Surgeon General pursuant to AR 200-1 (Environmental Protection and Enhancement) without comment.

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 L. DAUGHDRILL
Program Manager
Environmental Health Risk
Assessment

CF:
HQDA(DASG-HS-PE)
USAMEDCOM (MCHO-CL-W)
AMC (AMCIS-A)
USACE (CENWO-HX-H)
USAEC (SFIM-AEC-ERO)

WPA 13

McKenna, Jim

From: Jenkins, Joanne
Sent: Monday, April 22, 2002 7:53 AM
To: McKenna, Jim
Cc: Robert Davie
Subject: RE: NHPA: Work Plan Addenda 13 and 14

Jim,

Reference our meeting this date.

In accordance with 36 CFR Part 800 all RFAAP actions meet the definition of an undertaking ad are therefore subject to 106 review. However, this in itself doesn't warrant full initiation of the process. RFAAP can determine that a proposed action has "no potential to cause effect" on historic properties. If we determine that an action has "no potential to cause effect", then we have no further obligations under 106. Ground disturbing activities in areas where there are no archeological sites and the activity would not compromise the setting or feel of any other historic site in the are examples of activities that would be determined to have "no potential to cause effect".

The locations of the work identified in your request contain no archeological sites and will not compromise any other historic site. Therefore, a determination of "no potential to cause effect" is appropriate and work may proceed.

Joanne Jenkins
Industrial Specialist
Operations Division
DSN 931-7480, COM 540-639-7480

-----Original Message-----
From: McKenna, Jim
Sent: Friday, April 19, 2002 1:11 PM
To: Jenkins, Joanne
Subject: NHPA: Work Plan Addenda 13 and 14

Joanne:

1. Work Plan Addendum 13 identifies sampling work that will occur at Solid Waste Management Unit (SWMU) 54 in the Horseshoe Area. The WPA has maps that show sampling locations.

2. Work Plan Addendum 14 identifies sampling work that will occur at SWMUs 40 and 71 in the Main Manufacturing Area. The WPA has maps that show sampling locations.

Need you/us to review for possible interference with historical sites.

Thanks,
Jim

ATK
ALLIANT TECHSYSTEMS

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

April 12, 2002

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

Subject: Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, April 2002
Work Plan Addendum 14 RCRA Facility Investigation at Solid Waste Management Unit 40/71, April 2002
Radford Army Ammunition Plant
EPA ID# VA1 210020730

Dear Mr. Thomson:

Enclosed is a certified copy of "Work Plan Addendum 13 RCRA Facility Investigation at Solid Waste Management Unit 54, April 2002" and a certified copy of "Work Plan Addendum 14 RCRA Facility Investigation at Solid Waste Management Unit 40/71, April 2002". Your five additional copies and copies to Virginia Department of Environmental, U.S. Army Operations Support Command, U.S. Army Environmental Center, U.S. Army Center for Health Promotion and Preventive Medicine will be sent under separate cover.

These work plans have not been submitted previously.

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

Sincerely,

C. A. Jake

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

Enclosure

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

02-815-59
JMcKenna/JJRedder

8

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

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

Kenneth G. Barnes
U.S. Army Operations Support Command
Environmental Restoration Division
1 Rock Island Arsenal, Attn: AMSOS-ISR
Rock Island, IL 61299-5500
Peter J. Rissell
U.S. Army Environmental Center
5179 Hoadley Road, Attn: SFIM-AEC-ERP
Aberdeen Proving Ground, MD 21010-5401

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

w/o enclosure
Russell Fish, P.E., EPA Region III

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

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

Coordination: J. McKenna
J. McKenna

02-815-59
JMcKenna/JJRedder

Concerning the following:

Work Plan Addendum 13
RCRA Facility Investigation at Solid Waste Management Unit 54,
April 2002
and
Work Plan Addendum 14
RCRA Facility Investigation at Solid Waste Management Unit 40/71
April 2002

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: Brian A. Butler
TITLE: LTC, CM, Commanding
Radford AAP

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

02-815-59
JMcKenna/JJRedder

(6)

DELIVERY ORDER NO. 0027
ENVIRONMENTAL SERVICES
PROGRAM SUPPORT
CONTRACT DACA31-00-D-0011

RADFORD ARMY AMMUNITION PLANT
RADFORD, VIRGINIA

WORK PLAN
ADDENDUM NO. 13
RCRA Facility Investigation at Solid Waste Management Unit 54

FINAL DOCUMENT

September 2002

PREPARED BY:

URS

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

PREFACE

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

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

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

67

MASTER WORK PLAN ADDENDUM NO. 13
SWMU 54 RCRA FACILITY INVESTIGATION
TABLE OF CONTENTS

Section ***Page***

MASTER WORK PLAN ADDENUM NO. 13
SWMU 54 RCRA FACILITY INVESTIGATION
TABLE OF CONTENTS (CONTINUED)

Section ***Page***

LIST OF FIGURES

LIST OF FIGURES (CONTINUED)

LIST OF FIGURES (CONTINUED)

LIST OF TABLES

LIST OF TABLES (CONTINUED)

LIST OF FORMS

APPENDICES

LIST OF ABBREVIATIONS AND ACRONYMS

%	Percent
2,4,6-TNT	2,4,6-Trinitrotoluene
AES	Atomic Emission Spectroscopy
AL	Action Level
ASTM	American Society for Testing and Materials
BAP	Benzo[a]pyrene
bgs	Below Ground Surface
BRA	Baseline Risk Assessment
CFR	Code of Federal Regulations
CL-ML	Clay to Sandy Silt Sandy Lean
CLP	Contract Laboratory Program
cm/sec	Centimeters Per Second
CMS	Corrective Measures Study
CN	Cyanide
CNCl	Cyanogen Chloride
COPC	Constituent of Potential Concern
CSM	Conceptual Site Model
dBA	Decibels on the A-Weighted Scale
D-Tech kits	D-Tech immunoassay test kits
DQO	Data Quality Objective
ECD	Electron Capture Detector
ELCD	Electrolytic Conductivity Detector
EM	Electromagnetic
EPIC	Environmental Photographic Interpretation Center
ERA	Ecological Risk Assessment
ERIS	Environmental Restoration Information System
ft	Feet
ft/yr	Feet Per Year
GC	Gas Chromatography
GPR	Ground Penetrating Radar
GPS	Global Positioning System
H_a	Alternative Hypothesis
HAZCOM	Hazard Communication
HBN	Health-Based Number
HHRA	Human Health Risk Assessment
HMX	Cyclotetramethylene-tetranitramine
H_o	Null Hypothesis
HPLC	High Performance Liquid Chromatography
HQ	Hazard Quotient
HRGC/HRMS	High-resolution Gas Chromatography/High-resolution Mass Spectrometry
HSA	Horseshoe Area
HSP	Health and Safety Plan
HSPA	Health and Safety Plan Addendum
HTRW	Hazardous, Toxic, and Radioactive Waste
IA	Interim Action
ICP	Inductively Coupled Plasma

LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

IDM	Investigation Derived Material
IRDMIS	Installation Restoration Data Management Information System
MCL	Maximum Contaminant Level
MCT	Matrix Conductivity Threshold
MDL	Method Detection Limit
µg/L	Micrograms Per Liter
mg/kg	Milligrams Per Kilogram
mg/L	Milligrams Per Liter
MHSP	Master Health and Safety Plan
MQAP	Master Quality Assurance Plan
MS	Mass Spectrometer
MSDS	Material Safety Data Sheet
msl	Mean Sea Level
MSE	Millennium Science and Engineering
MWP	Master Work Plan
nm	Nanometer
ORP	Oxidation-Reduction Potential
OSHA	Occupational Safety and Health Administration
PAH	Polynuclear Aromatic Hydrocarbons
PAO	Phenyl Arsine Oxide
PCB	Polychlorinated Biphenyls
PCDD	Polychlorinated dibenzo-p-dioxins
PCDF	Polychlorinated dibenzofurans
PID	Photoionization Detector
PM	Project Manager
ppb	Part Per Billion
PPE	Personal Protective Equipment
ppm	Part Per Million
ppq	Part Per Quadrillion
ppt	Part Per Trillion
PVC	Polyvinyl Chloride
QA	Quality Assurance
QC	Quality Control
QA/QC	Quality Assurance / Quality Control
QAP	Quality Assurance Plan
QAPA	Quality Assurance Plan Addendum
RBC	Risk-Based Concentration
RCRA	Resource Conservation and Recovery Act
RDX	Cyclotrimethylenetrinitramine
RFA	RCRA Facility Assessment
RFAAP	Radford Army Ammunition Plant
RFI	RCRA Facility Investigation
RL	Reporting Limit
SHSO	Site Health and Safety Officer
SM	Sandy Silt
SOP	Standard Operating Procedure
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 Leaching Procedure
TEF	Toxicity Equivalence Factors
TEQ	Toxicity Equivalent Concentration
TOC	Total Organic Carbon
TOX	Total Organic Halogen
TWA	Time-Weighted Average
USCS	United Soil Classification System
URS	URS Group, Inc.
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
UV	Ultraviolet
VDEQ	Virginia Department of Environmental Quality
VI	Verification Investigation
VOC	Volatile Organic Compound
WPA	Work Plan Addendum
XRF	X-ray Fluorescence

1.0 WORK PLAN ADDENDUM

In accordance with Contract Number DACA31-00-D-0011, Delivery Order No. 0027, URS Group Inc. (URS) has been tasked by the United States Army Corps of Engineers (USACE), Baltimore District to perform a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) and Corrective Measures Study (CMS) at Solid Waste Management Unit (SWMU) 54, Propellant Burning Ash Disposal Area, located in the easternmost portion of the Horseshoe Area (HSA) at the Radford Army Ammunition Plant (RFAAP), Radford, Virginia (Figure 1-1). This document is the RFI Work Plan for SWMU 54 and is presented as an addendum (Work Plan Addendum No. 13; WPA) to, and incorporates by reference the RFAAP Master Work Plan (MWP; URS 2002).

1.1 INTRODUCTION

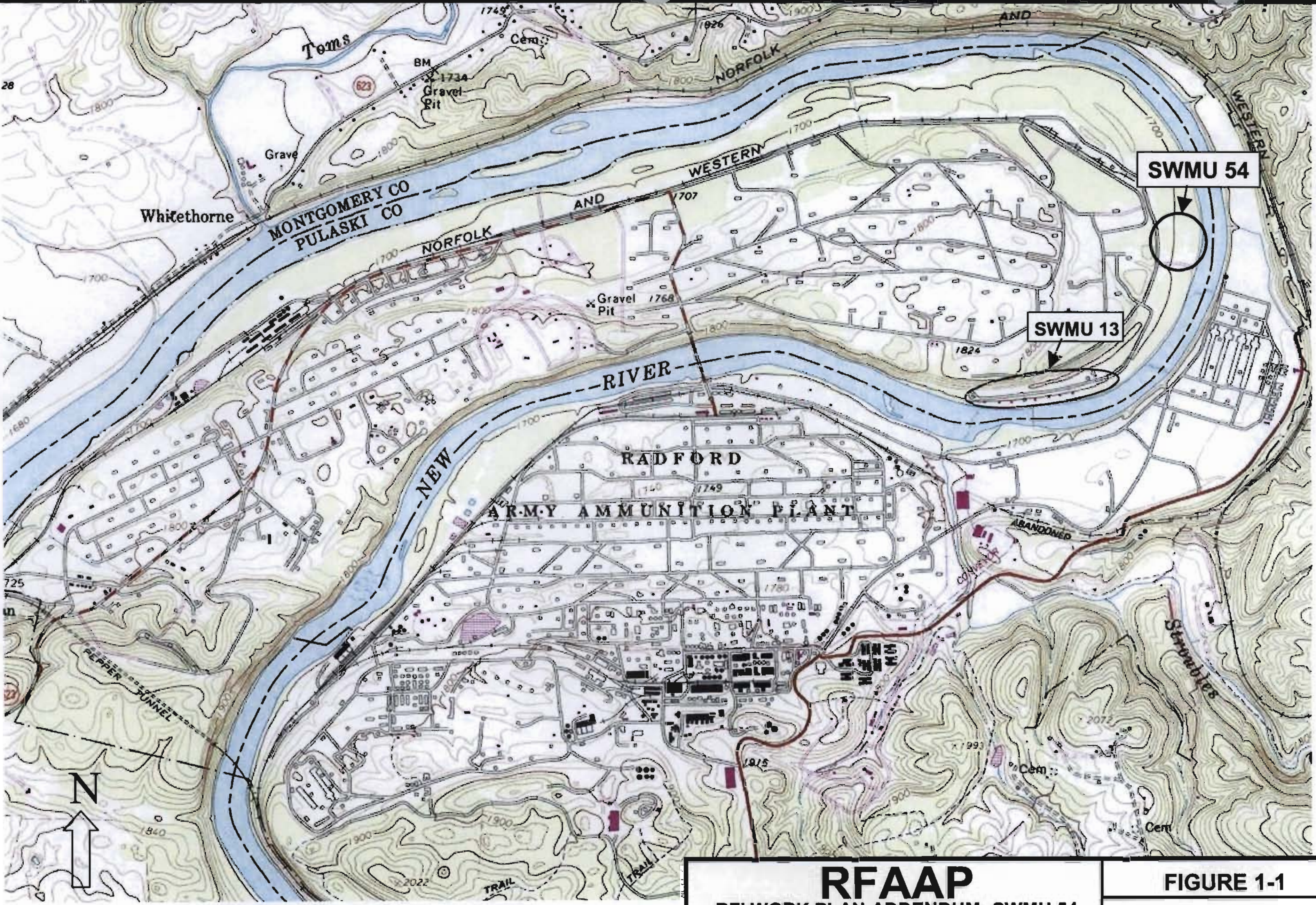
The Project Objectives of the RFI at SWMU 54 are:

- Generation of data needed to describe what risk exists toward human health and the environment;
- Characterization of the environmental hazards associated with SWMU 54, verify previous investigative results, assess potential impacts to groundwater within the overburden aquifer, and provide additional data to a follow-on CMS; and
- Following through on the 1999 Interim Action (IA) and reach a final decision as to what future action, if any, is needed.

SWMU 54 consists of two inactive areas formerly used for disposal of propellant ash (Figure 1-2). Area A is an approximate 0.58-acre elongated, triangular grassy area in the southern portion of SWMU 54. Area B is an approximate 1.09-acre irregularly shaped area in the northern portion of SWMU 54.

The RFI program at SWMU 54 is designed to:

- Collect and chemically analyze surface and subsurface soil samples;
- Conduct a groundwater investigation including installation of additional monitoring wells and groundwater sampling. The SWMU 54 groundwater study is proceeding separately from the overall HSA Groundwater Study proposed in WPA 9 due to the site setting and proximity to the New River. In addition, groundwater flow at SWMU 54 likely occurs under localized diffuse-flow conditions, warranting a focused investigation. The groundwater investigation data and results will be shared and incorporated into the WPA 9 investigation;
- Conduct aquifer testing and specific soil sampling to assess site-specific chemical mobility and fate and transport of chemicals; and
- Provide data that can be used to evaluate residual risk through comparison to United States Environmental Protection Agency (USEPA) Region III Risk-Based Concentrations (RBCs; USEPA 2002), and the Facility-Wide Background Study (IT 2002). The data will be used to perform a Baseline Risk Assessment (BRA) that is subdivided into Human Health Risk Assessment (HHRA) and Screening Level Ecological Risk Assessment (ERA). In addition, data will be used for a follow-on, site-specific CMS.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

FIGURE 1-1

SITE LOCATION MAP

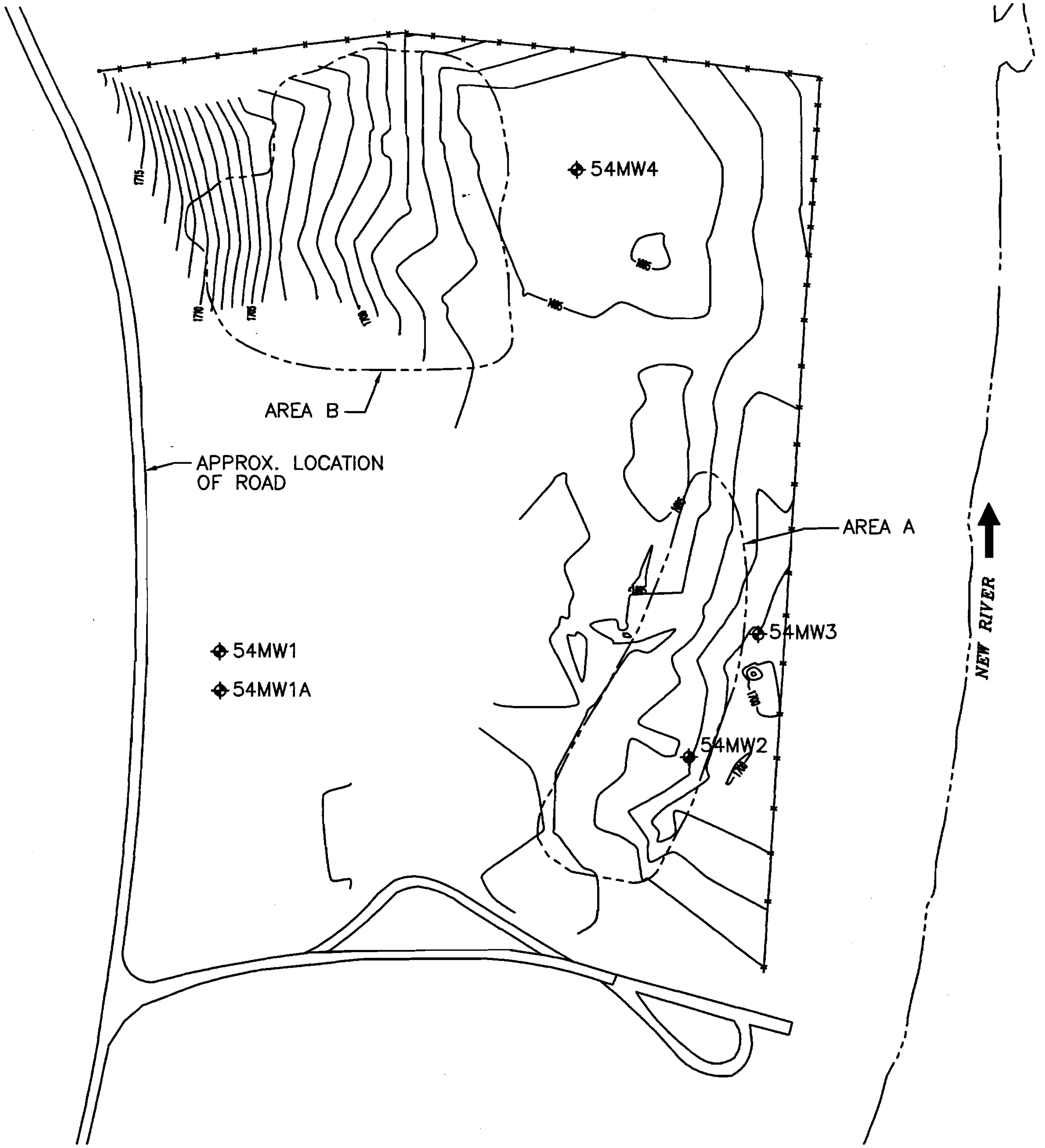
Date: *SEPTEMBER 2002*

Prepared by: *URS Corp./TAL*

Scale: *1" = 2000'*

File Name: *Figure 1-1.ppt*

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



VIRGINIA STATE PLANE COORDINATE SYSTEM SOUTH ZONE
N
GRID NORTH NAD 83

LEGEND

54MW99	EXISTING GROUNDWATER MONITORING WELL
—— 1980 ——	EXISTING TOPOGRAPHIC CONTOUR LINE FEET ABOVE MEAN SEA LEVEL
‿⁀‿⁀	APPROX. LIMITS OF SWMU AREA
—— - - ——	APPROX. WESTERN BOUNDARY OF NEW RIVER
——x——x——	EXISTING FENCELINE

100 50 0 100 200 300

SCALE IN FEET

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

FIGURE 1-2

SITE LAYOUT MAP

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./DRT
Scale: 1" = 100'	**File Name:** P:\...\09604-263.wpa.1-2.DWG

8

This site-specific WPA provides the rationale and methods for field activities at SWMU 54 in support of the RFI. Consistent with the Master Work Plan, this WPA is composed of the following sections:

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

This WPA specifically addresses sections and Standard Operating Procedures (SOPs) contained in the MWP. The MWP will be maintained on the site and referenced during field activities. The WPA provides site-specific activities for SWMU 54.

Investigative activities that will be performed as specified in the MWP are listed in Table 1-1. The investigative activities performed as part of this effort will be conducted in accordance with the MWP and the SOPs contained therein.

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

The investigative program focuses on obtaining data to achieve the Project Objectives. The program articulates project objectives, assumptions, and data use specifications. Program elements include:

- **Description of Current Conditions (Section 1.2):** A site description of SWMU 54 is included in this document and a discussion of previous investigations at SWMU 54 is provided. A Conceptual Site Model (CSM) and Data Gap Analysis are presented in this section;
- **Planned Field Activities (Section 1.3):** A site investigation will be performed to collect representative samples from SWMU 54 and achieve project Data Quality Objectives (DQOs). The sampling program presented for this investigation has been structured to meet 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 QAPA provides assurance that data of known and documented quality is generated to accurately characterize and evaluate SWMU 54 in accordance with the Project Objectives; and
- **Health and Safety (Section 3.0):** Site-specific training, personal protective equipment and clothing (PPE), and applicable monitoring requirements are presented in Section 3.0 of this WPA. These procedures provide the requirements for protection of site personnel who are expected to be involved with site activities, including government employees, regulators, contractors, and visitors.

Table 1-1
Applicable MWP Activities and Related SOPs
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

General Elements	MWP Section	Applicable Section in WPA
Introduction	2.0	1.1
Description of Current Conditions (Installation Wide for MWP and Site Specific for WPA)	2.0	1.2
Field Investigations (General for MWP and Site Specific for WPA)	5.0 - 8.0	1.3

Specific Elements of Field Investigation	MWP Section	Applicable SOP in MWP Appendix A and Appendix A to WPA No. 13
Sampling Strategies		
Systematic Grid Sampling and Biased Sampling	NA	30.7
Drilling		
Field Logbook	NA	10.1
Boring Logs	5.2	10.3
Boring Abandonment	5.2	20.3
Air Rotary Drilling	5.2	20.11
Direct Push	5.2	20.11
Split-Barrel Sampling	NA	20.11
Geoprobe Macro Core	NA	20.11
Rotosonic	5.2	NA
Rotosonic Coring	5.2	NA
Management of Investigation Derived Material	5.13	70.1
Decontamination	5.12	80.1
Air Monitoring with Photoionization Detector	NA	90.1
Soil Sampling		
Field Logbooks	NA	10.1
Sample Logbook	NA	10.2
Chain-of-Custody	NA	10.4
Surface Soil Sampling	5.2	30.1
Subsurface Soil Sampling	5.2	30.1
Sample Labels	5.1	50.1
Sample Packaging	5.1	50.2
Management of Investigation Derived Material	5.13	70.1
Decontamination	5.12	80.1
Soil Screening with a Photoionization Detector	NA	90.1

Form 1-1
Work Plan Revision Form
Work Plan – Quality Assurance Plan – Health and Safety Plan Addendum
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

SITE DESIGNATION/LOCATION:

Radford Army Ammunition Plant

Radford, VA

SUBJECT:

Section: ______________________________

Addendum: ______________________________

Version: ______________________________

Effective Date: ______________________________

Approved by:

Field Operations Leader

____

Date: ______________________________

Concurrence:

Project Manager

____

Date ______________________________

Sheet _____ of _____

Form 1-2
Worker Acknowledgement Form
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Document:	Master Work Plan/QAP/HSP and Addendum 013
Version:	Draft
Project:	Radford Army Ammunition Plant
Location:	Horseshoe Area, SWMU 54

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

Site
Personnel:

Name (please print)	Signature	Date

1.2 DESCRIPTION OF CURRENT CONDITIONS

1.2.1 Site Background – Environmental Setting

The environmental setting for the RFAAP is presented in Section 3.0 of the MWP. Project-specific information is presented below and in Section 1.2.3, Nature and Extent of Contamination.

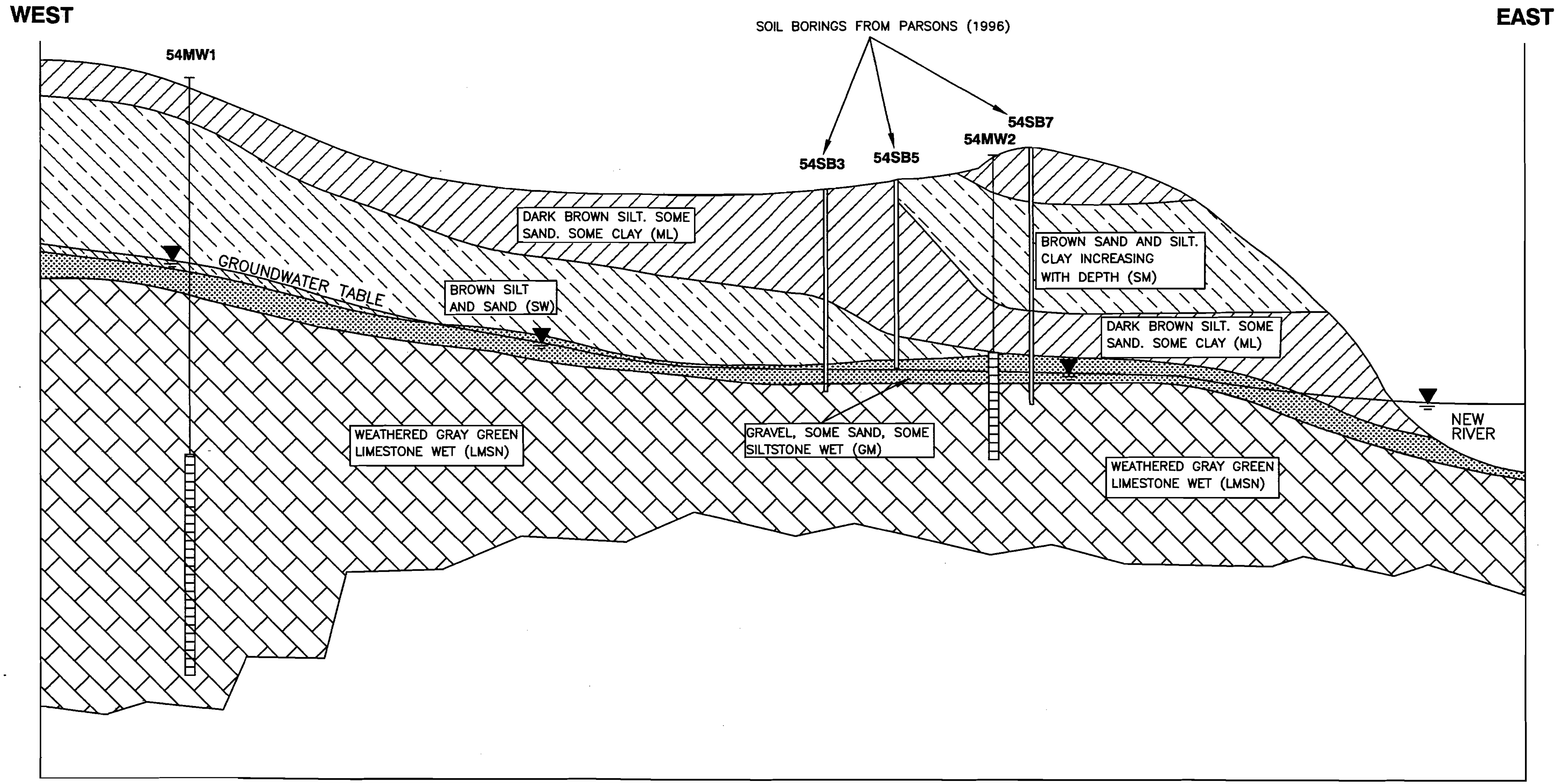
Physiography - SWMU 54 is located within the easternmost portion of the HSA at RFAAP, adjacent to the New River (Figures 1-1 and 1-2). The SWMU 54 area slopes to the east, with ground surface elevations ranging from approximately 1,710 to 1,695 feet (ft) above mean sea level (msl). SWMU 54 is located upon a terrace of the New River flood plain, approximately 20 ft above the elevation of the New River, which is located approximately 150 ft east of SWMU 54. The RFAAP Installation perimeter fence separates SWMU 54 from the New River, and prevents access by trespassers attempting to enter RFAAP from the New River. The area in and around SWMU 54 is an open field with irregular surface topography. SWMU 54 is bordered on the west by an access road and a steep incline to an upland area; to the east by woods; and to the south by a grassy area and an access road. Area A and Area B boundaries for SWMU 54 have been established based on a review of aerial photographs (USEPA 1992) and figures presented by others, and the limits of constituent detection based on site screening work of Parallax, Inc. (Parallax 1999; see Section 1.2.3.5).

Surface Water - Site topography suggests that surface water runoff flows across SWMU 54 to the east, towards the New River (Figure 1-2). Approximately 150 ft due east of SWMU 54, the New River flows north before meandering west. Surface water bodies, drainage ditches, manholes, catch basins or other flow paths are not present in the immediate SWMU 54 area. Based on site observations, however, a low-lying area in the eastern-central portion of SWMU 54 may be the location of temporary ponding of surface water during rainfall events.

Geology and Soils - A detailed description of the geology and soils of the RFAAP is presented in Sections 3.4 through 3.7 of the MWP (URS 2002), the Facility-Wide Background Study (IT 2002), and Current Conditions Report, Horseshoe Area (IT 2001). SWMU 54 is underlain by unconsolidated alluvial sediments (river terrace deposits) consisting of a generally upward-fining progression of basal sands and gravels overlain by clayey sands and silts. Stratigraphically below the terrace deposits, SWMU 54 is underlain by the Cambrian Elbrook Formation, described locally as weathered gray-green limestone interbedded with gray siltstone (Parsons 1996). Based on a review of boring logs, bedrock is highly weathered and fractured; evidence of solution enhanced features such as clay-filled seams or voids have not been reported. Depth to bedrock reportedly ranges from 18 to 24 ft below ground surface (bgs; Dames & Moore 1992a; Parsons 1996) at the site. Figure 1-3 presents a representative east-west geologic cross-section and indicates the presence of unconsolidated alluvial sediments overlying limestone and siltstone bedrock.

Soils at SWMU 54 consist of the Wheeling Sandy Loam (IT 2002), which composes approximately 25 percent (%) of the HSA soils and is described as level to nearly level (slopes ranging from zero to 2%). The seasonal high water table is not within six ft of the surface. Typically, the surface layer is a ten-inch thick, dark brown sandy loam underlain by a 42-inch thick subsoil.

The upper part of the subsoil is dark brown gravely sandy loam to a depth of 60 inches or more. At greater than 60 inches in depth, the soil is predominantly a mixture of silt and sand, with minor amounts of clay. Permeability and available water capacity of Wheeling soils is moderate; surface runoff is slow.



LEGEND

▤ WELL SCREEN INTERVAL

▼ STATIC GROUNDWATER LEVEL

NOTES:

1) GROUNDWATER LEVELS MEASURED JULY 1995.

2) SOME DATA POINTS ARE PROJECTED ONTO PROFILE.

RFAAP **RFI WORK PLAN ADDENDUM: SWMU 54**		**FIGURE 1-3**
Date: SEPTEMBER 2002	**Prepared By:** URS Corp./DRT	**GEOLOGIC CROSS-SECTION, MODIFIED FROM PARSONS, 1996**
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-3.DWG	

Natural fertility is medium, organic mater content is moderately low, and soil is moderately to strongly acidic. Potential for erosion in this soil type is slight.

Groundwater - Near SWMU 54, groundwater is present within a relatively shallow unconfined aquifer consisting of unconsolidated alluvial sediments and the underlying weathered siltstone and limestone of the Elbrook Formation. To date, five groundwater monitoring wells have been constructed in the SWMU 54 area. Wells 54MW1 and 54MW1A are located upgradient of SWMU 54. Due to faulty construction, 54MW1A is used solely for water-level gauging purposes (details in Section 1.2.3 below). Wells 54MW2, 54MW3 and 54MW4 are downgradient of SWMU 54. Well construction information (elevations, screened intervals, etc.) is presented in Table 1-2.

A representative water-table map using water-level data from April 2000 (IT 2001) is presented on Figure 1-4. Water-table elevation contours indicate eastward groundwater flow across SWMU 54. Site-wide hydraulic gradient reportedly varies from approximately 0.026 to 0.017 ft/ft (based on data from Parsons 1996 and IT 2001). Based on a lack of observed springs or seeps, groundwater appears likely to discharge directly into the New River. Gauging of the New River surface elevation indicates that groundwater at SWMU 54 is present at elevations approximately 1.5 to 2.5 ft above the elevation of the New River (IT 2001).

Detailed hydrogeology data available for SWMU 13 (location shown on Figure 1-1) can be used to draw inferences about the hydrogeologic characteristics of SWMU 54. Dames & Moore completed an RFI of SWMU 13, Waste Propellant Burning Ground, in 1992. SWMU 13 is located approximately 2,000 ft southwest of SWMU 54 in a topographically, geologically and hydrogeologically similar area of the Horseshoe. Boring logs presented in Dames & Moore (1992b) indicate a generally upward-fining progression consisting of basal sands and gravels overlain by clayey sands and silts (terrace deposits). As with SWMU 54, SWMU 13 is underlain by weathered gray-green limestone interbedded with gray siltstone stratigraphically below the terrace deposits (Dames & Moore 1992b).

Dames & Moore (1992b) performed slug tests on each of seven wells installed at SWMU 13. Dames & Moore concluded that the basal sand and gravel layer transmitted the most water (average hydraulic conductivity value of 2.0×10^{-3} centimeters per second (cm/sec)), but that the underlying weathered and fractured limestone and siltstone was also capable of transmitting large quantities of water (average hydraulic conductivity value of 1.0×10^{-3} cm/sec; Dames & Moore 1992b). Groundwater flow velocities were calculated to be 19 to 69 ft per year (ft/yr) in the basal sand and gravel layer. Site-specific characterization of hydrogeology at SWMU 54 will be assessed during this RFI.

Tanks/Structures - The lone structure present at SWMU 54 is the RFAAP Installation perimeter fence, which was relocated in 1999 to enclose the SWMU 54 area. No other tanks or structures are located in or near SWMU 54.

1.2.2 Site Background – History

The Propellant Burning Ash Disposal Area was identified in the RCRA Facility Assessment (RFA) as SWMU 54 (USEPA 1987) for having potential for releasing contaminants into the environment. SWMU 54 was included in the RCRA Permit for Corrective Action and Incinerator Operation (USEPA 2000) as warranting investigation (the latest Facility Permit effective October 31, 2000).

Ash from propellant burning operations at the Waste Propellant Burning Grounds (SWMU 13) was reportedly disposed of at SWMU 54 during the late 1970s. Propellant ash is residue from the burning of

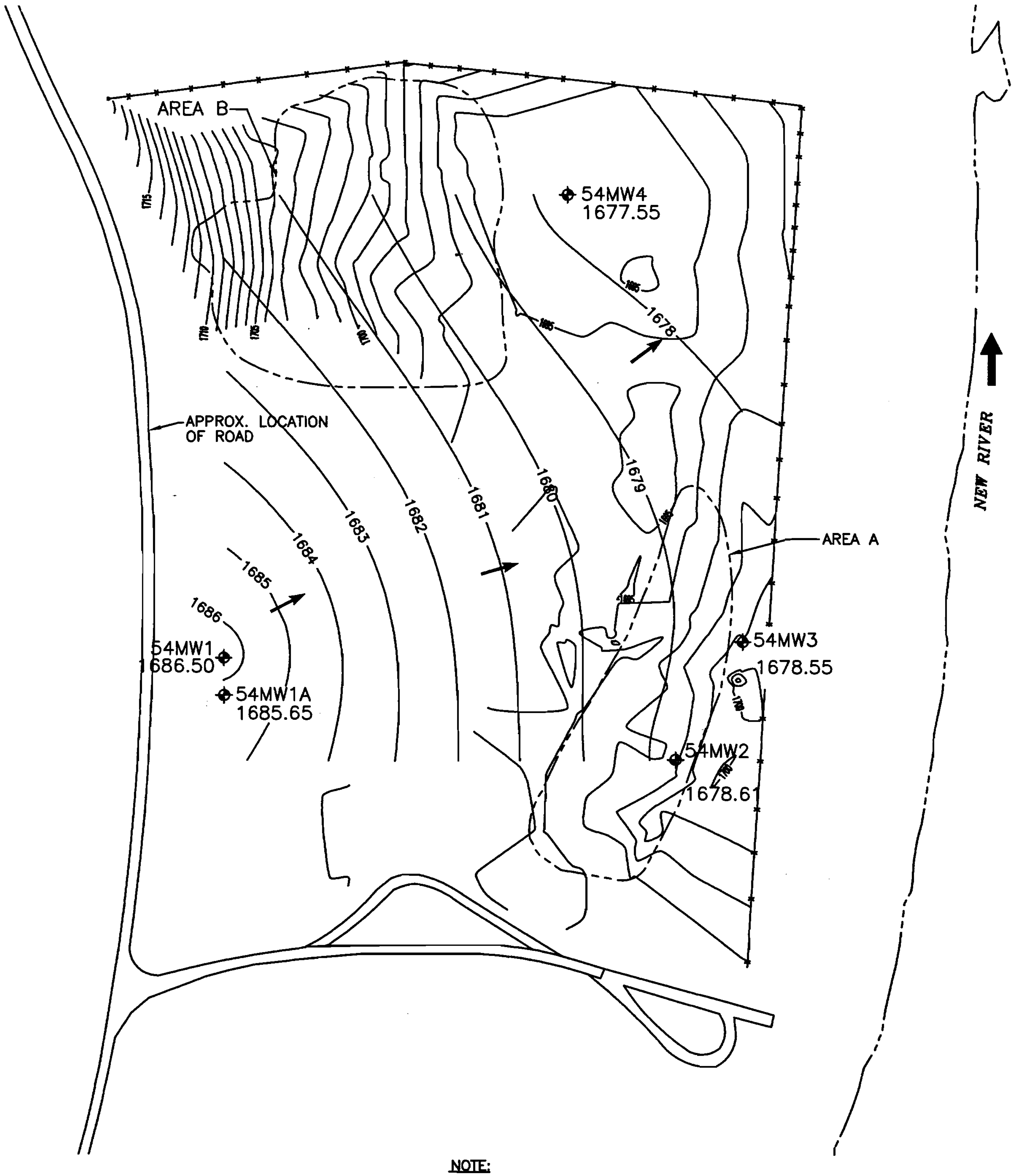
Table 1-2
Existing Monitoring Well Construction Summary
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Well Identification	Date Installed	Screened Zone	Elevation TOC (ft msl)	Boring Depth (ft bgs)	Depth to Bedrock (ft bgs)	Screened Interval (ft BTOC)	DTW (ft BTOC) 4/18/00	Water Elevation (ft msl) 4/18/00
54MW1A	9/17/1991	Bedrock	1705.58	51	20.9	36.0-51.0	19.93	1685.65
54MW1	11/6/1991	Bedrock	1705.70	60	19.5	32.0-52.0	19.2	1686.50
54MW2	9/17/1991	Interface	1701.41	30	20.7	18.0-28.0	22.8	1678.61
54MW3	9/18/1991	Interface	1702.15	35	24	20.0-30.0	23.6	1678.55
54MW4	12/3/1997	Bedrock	1694.45	45	19	30.0-45.0	16.9	1677.55

Notes:

TOC = Top of Casing
BTOC = Below Top of Casing
DTW = Depth to Water
ft = feet
msl = mean sea level
bgs = below ground surface

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



VIRGINIA STATE PLANE COORDINATE SYSTEM SOUTH ZONE
N
GRID NORTH NAD 83

LEGEND

54MW99 1999.99	EXISTING GROUNDWATER MONITORING WELL WITH GROUNDWATER ELEVATION SHOWN
—1980—	EXISTING ELEVATION CONTOUR LINE FEET ABOVE MEAN SEA LEVEL
	APPROX. LIMITS OF WASTE AREA
	APPROX. WESTERN BOUNDARY OF NEW RIVER
—x—x—	EXISTING FENCELINE
—1684—	GROUNDWATER CONTOUR FEET ABOVE MEAN SEA LEVEL
←	GROUNDWATER FLOW DIRECTION ARROW

100 50 0 100 200 300

SCALE IN FEET

NOTE:
GROUNDWATER CONTOURS GENERATED FROM APRIL 2000 MEASUREMENT DATA (IT CORP., 2001).

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./DRT
Scale: 1" = 100'	**File Name:** P:\...\09604-263.WPA.1-4.DWG

FIGURE 1-4

REPRESENTATIVE WATER-TABLE ELEVATION MAP

waste explosives, propellants, and laboratory wastes (Parsons 1996). Historically, conflicting information has been presented regarding the nature of disposal practices at SWMU 54. Information presented in the RFA (USEPA 1987) indicated that, according to plant personnel, disposal occurred on the surface, with no routine disposal in pits or trenches. Millennium Science and Engineering (MSE) reports that waste ash was buried up to 17 ft bgs in Area A of SWMU 54 and up to seven ft bgs in Area B of SWMU 54 (MSE 1998). The quantity of ash disposed of in SWMU 54 has been estimated to be ten tons (USEPA 1987; USATHAMA 1976). Prior to 1998, ash residue was visible in Area A where surface soils had been disturbed.

During the course of the RFA, a sample of ash disposed of in the hazardous waste landfill (SWMU 16) was analyzed for Toxicity Characteristic Leaching Procedure (TCLP) lead. Results indicated that the TCLP lead concentration from the ash was 51 milligrams per liter (mg/L); the TCLP regulatory limit for lead is five mg/L. It has henceforth been assumed that the ash disposed of at SWMU 54 should exhibit similar characteristics to the ash from SWMU 16. To verify this assumption, a sample of ash was collected from SWMU 54 during an investigation by Parsons (1996; see below). Sample results indicated an exceedance of hazardous waste criteria for lead (TCLP limit of five mg/L). Subsequently, Parallax (1999) analyzed approximately 217 soil composite samples from both Area A and Area B of SWMU 54 for TCLP Metals. Eleven samples were reported as exhibiting TCLP lead above regulatory criteria.

1.2.3 Nature and Extent of Contamination

The following section is intended to be a review of previous site investigations with emphasis placed on the usability of collected data and screening of historical data with respect to current criteria (i.e., April 2002 RBCs and USEPA National Primary Drinking Water Standards Maximum Contaminant Levels (MCLs) as identified in Title 40, Part 141 of the Code of Federal Regulations (CFR)) to identify constituents of potential concern (COPCs). Risk assessments conducted by others are addressed herein by summarizing results. As part of the current RFI effort, a BRA subdivided into a HHRA and a screening level ERA will be conducted utilizing selected portions of historical data and data generated from planned field activities. Table 1-3 presents a review and summary of information discussed herein.

1.2.3.1 Installation Assessment (Air Photo Interpretation) – 1992

The Environmental Photographic Interpretation Center (EPIC), under the direction of USEPA, performed an assessment of multiple SWMUs at RFAAP using selected aerial photographs from 1937 to 1986. The objective was to "concentrate upon tracking 42 known SWMUs located in the [RFAAP], and to identify other features which may represent potential groundwater or surface water contamination sources" (USEPA 1992).

Activity within the SWMU 54 area was first noted on a 1971 aerial photograph (Figure 1-5). The 1971 photograph reportedly indicated "a pit, disturbed ground, and probable liquid" as present in SWMU 54. Based on the current review of the 1971 photograph, the area described by USEPA (1992) is Area B, located in the northern portion of SWMU 54.

A 1975 photograph reportedly indicates the presence of a "probable excavation" (USEPA 1992). The Installation Assessment does not include the 1975 photograph, but provides an interpretation of the 1975 photograph with the 1981 photograph. Based on the current review of the data, the area described by USEPA (1992) is Area A, located in the southern portion of SWMU 54. A 1981 photograph reportedly depicts Area B as re-vegetating, and a 1986 photograph reportedly shows both areas re-vegetated (Figure 1-5).

Table 1-3
Summary of Previous Investigations
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

REPORT	OBJECTIVES	DATA COLLECTED			WPA 13 CONCLUSIONS	
		SAMPLING STRATEGY	MEDIA AND NO. OF SAMPLES	LABORATORY ANALYTICAL PARAMETERS[1]	DATA USEABILITY	CONSTITUENTS OF POTENTIAL CONCERN[3]
Verification Investigation, Dames & Moore (1992): **AREA A**	• evaluate whether groundwater quality has been impacted by ash disposed of in the unit..." • "delineate the boundaries of the area [to] locate buried materials" and to • "map possible locations of ash disposal"	• Installation of three groundwater monitoring wells • Geophysical survey	GROUNDWATER • 1 round of 3 samples (54MW1, 54MW2 and 54MW3)	GROUNDWATER[2] • TAL dissolved metals (200) • Explosives (609) • VOCs (624) • SVOCs (625) • TOC (415.2) • TOX (9020)	GROUNDWATER • Definitive data for COPC identification	GROUNDWATER – AREA A • 2,4,6-TNT
RFI for SWMUs 17, 31, 48, and 54, Parsons (1996): **AREA A**	• "define the extent of ash and the limits of soil contamination"	• Biased sampling, based upon previous geophysical investigation • Sediment and surface water samples collected • Samples collected for geotechnical analysis • Waste ash sampling	SOIL • 16 shallow (0-2 ft bgs) samples • 15 deep (10-22 ft bgs) samples GROUNDWATER • 1 round of 3 samples (54MW1, 54MW2 and 54MW3) ASH • 2 samples for TCLP analysis	SOIL • Metals (6010/7000) • Explosives (8330) • Select for TOC (415.1)[2] GROUNDWATER • Total & dissolved metals (6010/7000) • Explosives (8330) • TOC (415.1) 2 • TOX (9020) ASH • TCLP Metals (1211/6010/7000) • Ignitability (7.1.2.2) • Corrosivity (9045) • Reactivity (7/9030/9012) • Paint Filter Test (9095)	SOIL *Shallow soil* • Definitive data for COPC identification • Screening data for site characterization *Deep soil* • Definitive data for COPC identification • Definitive data for site characterization and risk assessment GROUNDWATER • Definitive data for COPC identification ASH • Definitive data for waste characterization	SOIL – AREA A • Arsenic • Barium • Cadmium • Chromium • Lead • Mercury • 2,4,6-TNT • 2,4-DNT • 2,6-DNT GROUNDWATER – AREA A • Beryllium
Supplemental RFI Report, SWMU 54, MSE (1998): **AREA B**	• "to characterize the nature and extent of contamination within SWMU 54 and to summarize potential risks to human health."	• GPR to survey Area B • Used geophysics results to locate borings - biased sampling • Installed new well (54MW4), screened in bedrock	SOIL • 6 shallow depth samples • 5 intermediate depth samples GROUNDWATER • 1 round of 2 samples (54MW1 and 54MW4)	SOIL • TCL VOCs (8260B) • Explosives (8330) • TAL Inorganics (6010/7471) • TCLP SVOC (1311/8270) • TCLP VOC (1311/8260) • TCLP Metals (1311/6010/700) • TOC (9060 • TOX (9020) GROUNDWATER • TCL Organics (8260/8270) • TAL Inorganics (6010/7470) • Explosives (8330)	SOIL • Definitive data for COPC identification • Screening data for site characterization GROUNDWATER • Definitive data for COPC identification	SOIL – AREA B • Aluminum • Antimony • Arsenic • Chromium • Copper • Iron • Lead • Manganese • Mercury • 2,4,6-TNT • 2,4-DNT • 2,6-DNT • Benzo[a]anthracene • Benzo[b]fluoranthene • Indeno[1,2,3-cd]pyrene • 2-amino-4,6-DNT • Dibenz[a,h]anthracene • Benzo[a]pyrene
Department of the Army, Decision Document Interim Action, (1999): **AREA A and AREA B**	• "define the COPCs, determine the vertical and lateral extent of contamination, and effect the removal, and treatment of disposal of the COPCs thereby allowing closure of the SWMU"	• Systematic grid sampling • Field screening for explosives and metals	SOIL • Approx. 1600 samples field screened based on systematic grid • >200 composite samples submitted for lab analysis (one per grid) • 217 samples submitted for TCLP metals GROUNDWATER • 1 round of 4 samples (54MW1, 54MW2, 54MW3 and 54MW4)	SOIL • VOCs (8260B) • Explosives (8330) • Metals (6010) • TCLP Metals (6010T) GROUNDWATER • VOCs (8260B) • SVOCs (8270C) • Pest/PCBs (8082) • Explosives (8330) • Metals (6010)	SOIL • Definitive data for COPC identification • Screening data for site characterization • Not suitable for risk assessment GROUNDWATER • Definitive data for COPC identification • Definitive data for risk assessment	SOIL – AREA A • Aluminum • Arsenic • Chromium • Iron • Lead • Manganese • Mercury • 2,4,6-TNT • 4-amino-2,6-DNT • 2,6-DNT • 2,4-DNT • RDX • 2-amino-4,6-DNT SOIL – AREA B • Aluminum • Antimony • Arsenic • Cadmium • Chromium • Copper • Iron • Lead • Manganese • Thallium • 2,4,6-TNT • 4-amino-2,6-DNT • 2-amino-4,6-DNT • 2,4-DNT GROUNDWATER – AREA A • 2,4,6-TNT • 2-amino-4,6-DNT • Iron

NOTES:

RCRA = Resource Conservation & Recovery Act
SWMU = Solid Waste Management Unit
TCLP = Toxicity Characteristic Leaching Procedure
COPC = Constituent of Potential Concern
TAL = Target Analyte List
GPR = Ground Penetrating Radar
GW = Groundwater
TCL = Target Compound List
VOC = Volatile Organic Compounds
SVOC = Semi-volatile Organic Compounds
Pest/PCBs = Pesticides and Polychlorinated Biphenyls
RDX = Hexahydro-1,3,5-trinitro-1,3,5-triazine
WPA = Work Plan Addendum
TOC = Total Organic Carbon
EM = Electromagnetic
ATK = Alliant Techsystems, Inc.

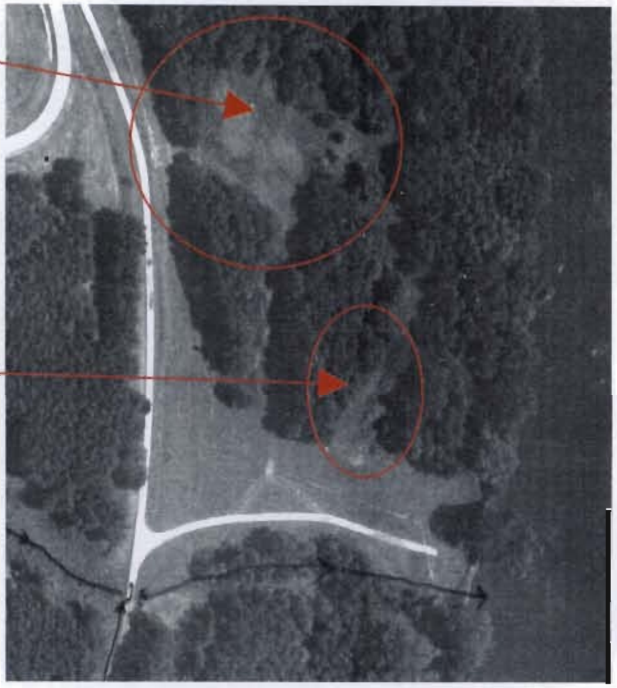
1. Method of analysis from USEPA SW-846 Test Methods, unless otherwise noted
2. Method of analysis from "Methods of Chemical Analysis of Water and Wastes"
3. COPCs as determined by comparison of historical data to 2002 screening criteria

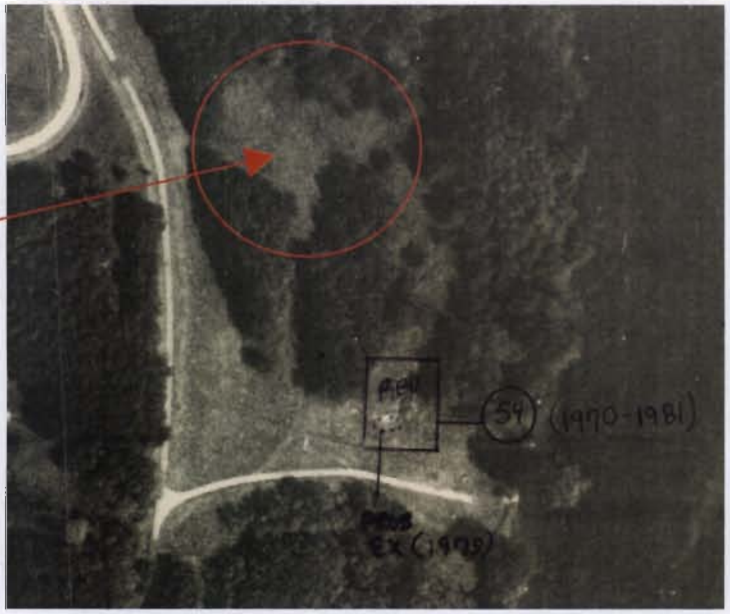
ft bgs = feet below ground surface

TNT= Trinitrotoluene
DNT= Dinitrotoluene
TOX = Total Organic Halogens
CMS = Corrective Measures Study

1971 PHOTOGRAPH

1986 PHOTOGRAPH





1981 PHOTOGRAPH

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared by:** *URS Corp./TAL*
Scale: *1" = 2000'*	**File Name:** *Figure 1-5.ppt*

FIGURE 1-5

INTERPRETATION OF AERIAL PHOTOGRAPHS, USEPA, 1992

Additionally, a photogeologic interpretation was performed to identify solution features, such as fractures and sinkholes, potentially present beyond and upgradient of the site. Sinkholes or fracture traces were not identified in the SWMU 54 area and no visible geologic features were interpreted to influence this SWMU.

1.2.3.2 Verification Investigation – 1992

The results of a (VI) were reported by Dames & Moore in 1992 (Dames & Moore 1992a). The VI was performed after the RFA in 1987 (USEPA 1987) and the original issuance of a RCRA permit in 1989. Note that the VI addressed Area A of SWMU 54 and that soil samples were not submitted for chemical analysis as part of the VI (Dames & Moore 1992a). Analytical results for groundwater from the VI were validated and entered into the Installation Restoration Data Management Information System (IRDMIS) at Level III.

Dames & Moore (1992a) identified two "mounds" of soil and ash, two to four ft high, and two "pits," three to five ft deep, within Area A. The mounds were referred to as the north and south mounds within Area A. Dames & Moore concluded that the pits appeared to be borrow areas for soil-cover used for each mound.

Groundwater - VI investigations at Area A were designed to "evaluate whether groundwater quality has been impacted by ash disposed of in the unit" (Dames & Moore 1992a). Three groundwater monitoring wells were installed including well 54MW1 (upgradient) and wells 54MW2 and 54MW3 (downgradient; Figure 1-2). Well 54MW1A was also constructed during the VI; however, unusually high pH and the presence of light-colored sediment were noted during well development (Dames & Moore 1992a). Dames & Moore (1992a) concluded that faulty well construction led to the presence of grout in the well. Subsequently, well 54MW1A has been used for water-level gauging purposes (historically referred to as a piezometer; however, not *sensu stricto;* cf. Freeze and Cherry 1979).

The upgradient well, 54MW1 was screened in bedrock and the downgradient wells, 54MW2 and 54MW3, were screened across the bedrock/overburden interface (Table 1-2). Static groundwater levels in the unconfined aquifer were reported at between 18.5 to 22.5 ft bgs (Dames & Moore, 1992a).

Groundwater samples were collected from wells 54MW1, 54MW2, and 54MW3 and were submitted for analysis of Target Analyte List (TAL) Dissolved Metals, TCL Semivolatile Organic Compounds (SVOCs), TCL Volatile Organic Compounds (VOCs), total organic carbon (TOC), total organic halogens (TOX), and explosives. Table 1-4 presents a summary of detected constituents in groundwater.

At the time, analytical data were compared to health-based numbers (HBNs) included in the then-current Facility Permit. For the purposes of this WPA, and because HBNs are no longer promulgated within the current Facility Permit (USEPA 2000), historical data are compared herein to current RBCs for tap water ingestion and to MCLs for drinking water (Table 1-4). At the request of USEPA Region III, a Hazard Quotient (HQ) of 0.1 or lifetime cancer risk of $1x10^{-6}$ (whichever occurs at a lower concentration) is used for risk screening with RBCs.

A review of the data also indicates that the explosive 2,4,6-trinitrotoluene (2,4,6-TNT) was reported in the sample from downgradient well 54MW2 at 2.81 micrograms per liter (μg/L); the 2002 Tap Water RBC for this constituent is 2.2 μg/L. No other explosives were reported above their respective 2002 Tap Water RBCs. Note that MCLs have not been promulgated for explosives at this time.

Table 1-4
Historical Groundwater Analytical Results
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Groundwater Mon. Well	54MW1					54MW2				54MW3				54MW4		Tap Water RBC	MCL
Investigation	D & M, 1992	Parsons, 1996		MSE, 1996	Parallax, 1999	D & M, 1992	Parsons, 1996		Parallax, 1999	D & M, 1992	Parsons, 1996		Parallax, 1999	MSE, 1998	Parallax, 1999		
Date Sampled	2/6/1992	7/1/1995		12/1/1997	4/26/1999	2/6/1992	7/1/1995		5/17/1999	2/6/1992	7/1/1995		5/18/1999	12/1/1997	6/2/1999		
Paramaters	Diss.	Total	Diss.	Total	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	Total	Total		
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
TAL INORGANICS																	
Aluminum	154			10400	<200	< 141			<200	< 141			930	264	599	3700	–
Antimony	<38	110	97.5	<5.0	<5.0	<38	<60	<60	<5.0	<38	<60	<60	<5.0	<5.0	<5.0	1.5	6.0
Arsenic	5.44	20.7	15.1	<10.0	<5.0	< 2.54	<2.35	<2.35	<5.0	< 2.54	<2.35	<2.35	<5.0	<10.0	<5.0	0.045	10
Barium	97.2	1060	519	261	13.4	104	144	89.5	156	104	175	106	134	16.3	110	260	2000
Beryllium	<5.0	20	13.2	<3.0	<3.0	<5.0	3.19	2.96	<3.0	<5.0	4.09	2.82	<3.0	<3.0	<3.0	7.3	4.0
Cadmium	<4.0	<6.78	<6.78	<3.0	<3.0	<4.0	<6.78	<6.76	<3.0	<4.0	<6.78	<6.76	<3.0	<3.0	<3.0	1.6	5.0[4]
Calcium	59100			128000	126000	71600			79400	74000			73600	127000	95400	–	–
Chromium	<6.02	66.7	26.6	19.2	<5.0	<6.02	<16.6	<16.6	<5.0	<6.02	<16.6	<16.6	<5.0	<5.0	<5.0	11[1]	100[2]
Cobalt	<25			<5.0	<5.0	<25			<5.0	<25			<5.0	<5.0	<5.0	73	–
Copper	<6.09			11.4	<5.0	<6.09			5.4	<6.09			<5.0	<5.0	<5.0	150	1300 (AL)
Iron	61.7			11400	<100	63.6			<100	74.5			1440	100	1640	1100	–
Lead	<1.26	16.6	6.33	14.1	<3.0	<1.26	9.31	<4.47	<3.0	<1.26	<4.47	<4.47	<3.0	<3.0	<3.0	–	15 (AL)
Magnesium	26300			71500	52800	34500			28000	25000			28400	63200	40600	–	–
Manganese	17			130	<5.0	59.5			<5.0	7.38			43.9	5.7	51.6	73	–
Mercury	<0.2	<0.1	<0.1	<0.0002	<0.20	<0.2	<0.1	<0.1	<0.20	<0.2	<0.1	<0.1	<0.20	<0.0002	<0.20	1.1[3]	2.0
Nickel	<34.3	37.4	<32.1	10.4	<5.0	<34.3	<32.1	<32.1	<5.0	37.4	<32.1	<32.1	<5.0	5.4	<5.0	73	–
Potassium	1630			4660	2120	2320			1390	1990			1400	2460	1540	–	–
Selenium	<3.02	<2.53	<2.53	<5.0	<5.0		<2.53	<2.53	<5.0		<2.53	<2.53	<5.0	<5.0	<5.0	18	50
Silver	0.255	<0.333	<0.333	<3.0	<3.0	< 0.25	<0.333	<0.333	<3.0	< 0.25	<0.333	<0.333	<3.0	<3.0	<3.0	18	–
Sodium	3140			<5000	3290	6350			5050	5400			4750	3700	3110	–	–
Thallium	<6.62	<125	<125	<10.0	<10.0	<6.62	<125	<125	<10.0	<6.62	<125	<125	<10.0	<10.0	<10.0	0.26	2.0
Vanadium	<11.0			20	<5.0	<11.0			<5.0	<11.0			<5.0	<5.0	<5.0	26	–
Zinc	23.1			42.1	<5.0	< 21.1			<5.0	< 21.1			14.5	10.6	32.3	1100	–
EXPLOSIVES																	
1,3,5-Trinitrobenzene	<0.449			<1.2	<1.2	<0.449			<1.2	<0.449			2.3	<1.2	<1.2	110	–
1,3-Dinitrobenzene	<0.611			<1.2	<1.2	<0.611			<1.2	<0.611			<1.2	<1.2	<1.2	0.37	–
2,4,6-Trinitrotoluene	< 0.635	<0.426		<1.2	<1.2	2.81	<17.5		<1.2	< 0.635	<0.426		7.4	<1.2	<1.2	2.2	–
2,4-Dinitrotoluene	<0.612	<0.397		<1.2	<1.2	<0.612	<0.397		<1.2	<0.612	<0.397		<1.2	<1.2	<1.2	7.3	–
2,6-Dinitrotoluene	<1.15	<0.6		<1.2	<1.2	<1.15	<0.6		<1.2	<1.15	<0.6		<1.2	<1.2	<1.2	3.7	–
2-Amino-4,6-Dinitrotoluene				<1.2	<1.2				<1.2				5.3	<1.2	<1.2	0.22	–
2-Nitrotoluene				<2.6	<2.6				<2.6				<2.6	<2.6	<2.6	6.1	–
3-Nitrotoluene				<2.6	<2.6				<2.6				<2.6	<2.6	<2.6	12	–
4-Amino-2,6-Dinitrotoluene				<1.2	<1.2				<1.2				<1.2	<1.2	<1.2	0.22	–
4-Nitrotoluene				<2.6	<2.6				<2.6				<2.6	<2.6	<2.6	6.1	–
HMX	< 1.21	<0.533		<2.6	<1.2	< 1.21	4.63		5.4	3.07	3.16 J10		15.6	<2.6	<2.6	180	–
Nitrobenzene	<0.645			<1.2	<1.2	<0.645			<1.2	<0.645			<1.2	<1.2	<1.2	0.35	–
RDX	<2.11	<0.416		<2.6	<2.6	<2.11	<0.416		<2.6	<2.11	<0.416		<2.6	<2.6	<2.6	0.61	–
Tetryl	<0.556	<0.631		<2.6	<2.6	<0.556	<0.631		<2.6	<0.556	<0.631		<2.6	<2.6	<2.6	37	–

Table 1-4 (Continued)
Historical Groundwater Analytical Results
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Groundwater Mon. Well	54MW1					54MW2				54MW3				54MW4			
Investigation	D & M, 1992	Parsons, 1996		MSE, 1996	Parallax, 1999	D & M, 1992	Parsons, 1996		Parallax, 1999	D & M, 1992	Parsons, 1996		Parallax, 1999	MSE, 1998	Parallax, 1999	Tap Water RBC	MCL
Date Sampled	2/6/1992	7/1/1995		12/1/1997	4/26/1999	2/6/1992	7/1/1995		5/17/1999	2/6/1992	7/1/1995		5/18/1999	12/1/1997	6/2/1999		
Parameters	Diss.	Total	Diss.	Total	Total	Diss.	Total	Diss.	Total	Diss.	Total	Diss.	Total	Total	Total		
Units	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
VOLATILES																	
Tetrachloroethene	<5			<10	<5	<5			<5	<5			<5	<10	2 J	1.1	5
Toluene	<5			<10	<5	<5			<5	<5			<5	<10	1 J	75	1000
Chlorobenzene	<5			<10	<5	<5			<5	<5			<5	<10	2 J	11	100
Carbon Disulfide	1.25			<10	<5	7.03			2 J	13.6			2 JB	<10	<5	100	--
Methylene Chloride	<5			1 JB	<5	<5			3 JB	<5			3 JB	1 J	5 JB	4.1	--
Acetone	<10			8 JB	<10	<10			16	<10			9 JB	<10	11 B	61	--
Chloroform	<5			<10	<5	<5			<5	<5			<5	<10	<5	0.15	--
SEMIVOLATILES																	
Bis(2-ethylhexyl)phthalate	<10			1 J	<11	<10			6 J	<10			4 J	7J	3 JB	4.80	--
Di-n-butylphthalate	<10			1 JB	1	<10			<11	<10			<10	27 B	1 JB	370	--
2,4-Dinitrotoluene	<10			<11	<11	<10			<11	<10			8 J	<10	<10	7.3	--
OTHER																	
Perchlorate					<5.00				<5.00				10.7		<5.0	--	--
TOC	10.5	1170				5.45	<1000 J7			3.67	<1000 J7					--	--
TOX	158	10.8				138	13 J7			117	<10 J7					--	--
pH	7.29					6.99				7.02						--	--

Notes:
TAL = Target Analyte List
D & M = Dames & Moore
ATK = Alliant Techsystems, Inc.
TOC = Total Organic Carbon
TOX = Total Organic Halides
J7/UJ7 = Samples were received by the laboratory at or below 8 degrees Centigrade. Results are estimated
J = Results are qualified as estimated due to a QC problem
J10 = Result for the explosive HMX for sample 54MW3 was not confirmed by confirmatory analysis
UJ = Laboratory calibration problem associated with the result for the explosive cyclonite for sample 54MW2
B = Results are qualified due to analyte found in the associated blank
15 (AL) = 15 µg/L is the USEPA Action Level for tap water. An RBC does not exist for lead
MCL = National Primary Drinking Water Regulations (40 CFR 141): Maximum Contaminant Level
RBC = Risk Based Concentrations, USEPA Region III, September 25, 2001 (Non-carcinogenic values have been adjusted for a hazard quotient of 0.1.)
AL = Copper and lead action level, National Primary Drinking Water Regulations
The copper and lead action level, contained in 40 CFR 141.80 Subpart I - Control of Copper and Lead, is considered to be exceeded if the concentration of copper or lead in more than 10 percent of the samples collected during a monitoring period and is greater than 1300 µg/L and 15 µg/L, respectively
µg/L = Microgram per liter
diss. = Dissolved

-- = Screening criteria not available.
< = Value is less than the sample detection limit
Blank cell indicates that analyte was not analyzed
(1) = Value for chromium VI used
(2) = MCL is for Total chromium
(3) = Value for mercuric chloride used
(4) = Value for cadmium water used
☐ = Concentration above April 4,2002 Tap Water RBC
▭ = Concentration above both 2001 Tap Water RBC and MCL
⬚ = Concentration above MCL or AL

A review of the data indicates that the TAL Dissolved Metal arsenic was reported in the sample from upgradient well 54MW1as present at 5.44 µg/L, above its 2002 Tap Water RBC of 0.045 µg/L. No other TAL Dissolved Metals were reported as present in concentrations above their respective 2002 Tap Water RBCs or MCLs.

No other detected constituents from the analyses for TAL Dissolved Metals, SVOCs, VOCs, or explosives were present at levels above their respective 2002 Tap Water RBCs or MCLs.

Geophysical Investigation - A geophysical investigation using electromagnetic (EM) and magnetic techniques was performed by Dames & Moore to "delineate the boundaries of the area [to] locate buried materials" and to "map possible locations of ash disposal" (Dames & Moore 1992a). Results from this survey were interpreted by Dames & Moore (1992a) to indicate burial of non-metallic debris near the north mound of Area A and burial of both conductive materials and metallic debris near the south mound of Area A. The VI interpretation of the geophysical results is presented in Figure 1-6. Additional information to define metallic and conductive materials versus non-metallic debris, and the reasons for the apparent disparity in buried materials between the northern and southern mounds of Area A in SWMU 54, are not clear. Subsequent investigations have not yielded specific information identifying macroscopic metallic debris at SWMU 54.

Risk Assessment - A BRA was not completed because "contaminants of concern" were not identified based on screening using HBNs. Dames & Moore concluded, "there is the potential for significant soil contamination [at SWMU 54]" and "potential exposure to human and environmental receptors is high" (Dames & Moore 1992a). Potential routes of exposure were identified as incidental ingestion, inhalation, and dermal absorption. Surface runoff was also considered a potential migration pathway, possibly resulting in migration of constituents to surface water and/or sediment of the New River.

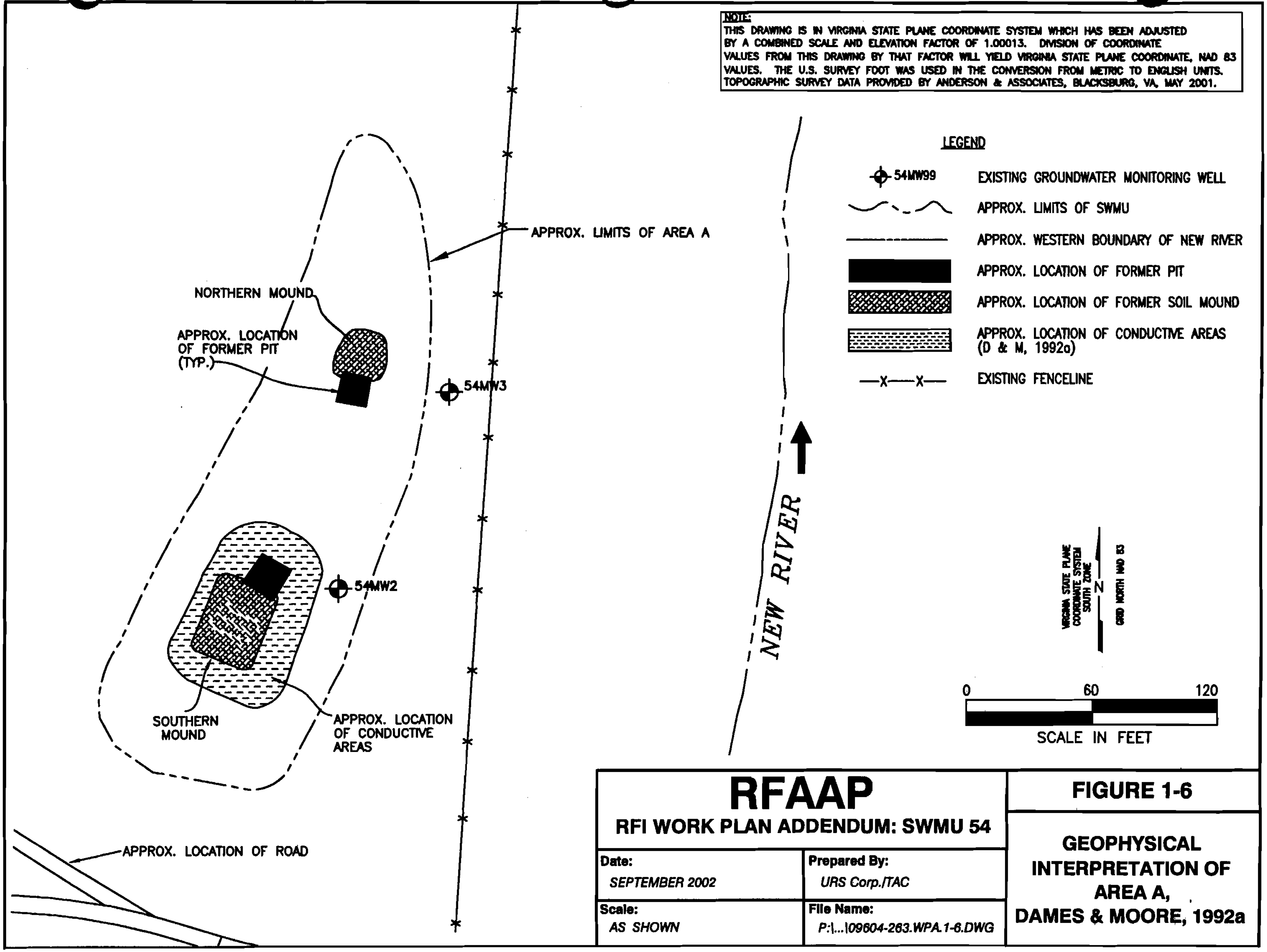
Conclusions - Based on the current review of chemical data for groundwater collected during the 1992 VI, one explosive, 2,4,6-TNT, is identified as a COPC (Table 1-3). While arsenic was reported as present above its Tap Water RBC, the detection is limited to the upgradient well 54MW1, which is screened wholly within bedrock. Downgradient wells 54MW2 and 54MW3 are not constructed in a similar manner, potentially leading to erroneous comparisons. In addition, more recent groundwater sampling results indicate that arsenic is not present at detectable levels (see below). Data presented by Dames & Moore are considered definitive for identification of COPCs.

1.2.3.3 RFI for Solid Waste Management Units 17, 31, 48, and 54 – 1996

Parsons Engineering Science, Inc. (Parsons) submitted an RFI that included SWMU 54 in 1996. The objectives of RFI activities at SWMU 54 were to "define the extent of ash and the limits of soil contamination" (Parsons 1996). The RFI addressed Area A of SWMU 54 and included groundwater monitoring well sampling and chemical analysis; shallow and deep soil sampling, chemical analysis, and geotechnical analysis; and waste ash sampling and chemical analysis. Analytical results from the RFI were validated and entered into IRDMIS at Level III.

Groundwater - Parsons sampled groundwater monitoring wells 54MW1, 54MW2, and 54MW3 in July 1995 for laboratory analysis of total and dissolved metals, explosives, TOX, and TOC (Table 1-3).

A review of the data indicates that total and dissolved barium and chromium were reported in the sample from upgradient well 54MW1 as present above their respective 2002 Tap Water RBCs (Table 1-4). Total lead was reported as present at 16.6 µg/L in upgradient well 54MW1, above its 2001 informal Action



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*

Prepared By: *URS Corp./TAC*

Scale: *AS SHOWN*

File Name: *P:\...\09604-263.WPA.1-6.DWG*

FIGURE 1-6

GEOPHYSICAL INTERPRETATION OF AREA A, DAMES & MOORE, 1992a

Level (AL) of 15 µg/L. Total and dissolved arsenic, antimony and beryllium were reported as present in upgradient well 54MW1 above their 2002 MCLs and Tap Water RBCs. Total and dissolved beryllium was also reported as present above its 2002 MCL of 4.0 µg/L in downgradient well 54MW3 (4.09 µg/L). No other total or dissolved metals were reported as present in concentrations above their respective 2002 Tap Water RBCs or MCLs.

Soil - Parsons advanced 16 soil borings using hollow-stem augers and split spoon sampling within Area A (Figure 1-7); bedrock refusal was reportedly encountered between 20 and 23 ft bgs, and groundwater was reported as shallow as 17 ft bgs. Note that one boring (54SB15), located in the central portion of the north mound in Area A, was a hand-auger boring. Two borings (54SB6 and 54SB14) were sampled continuously, whereas the remaining borings were sampled at five-ft intervals. Two samples were collected from each boring, one "shallow" (i.e., zero to two ft bgs) and one "deep" (i.e., from ten to 22 ft bgs). Parsons (1996) indicates that shallow samples were collected from below visual evidence of propellant ash, or from six to 12 inches if no ash was visible, and deep samples were collected from other areas of visible contamination, or above the water table if contamination was not evident (Parsons 1996).

A review of Parsons (1996) boring logs indicates that, of 14 borings that were advanced below seven ft bgs, seven samples for chemical analysis were collected within two ft, or immediately above, the water table. Thirty-one samples were submitted for laboratory analysis of VOCs, SVOCs, metals, and explosives (Table 1-5).

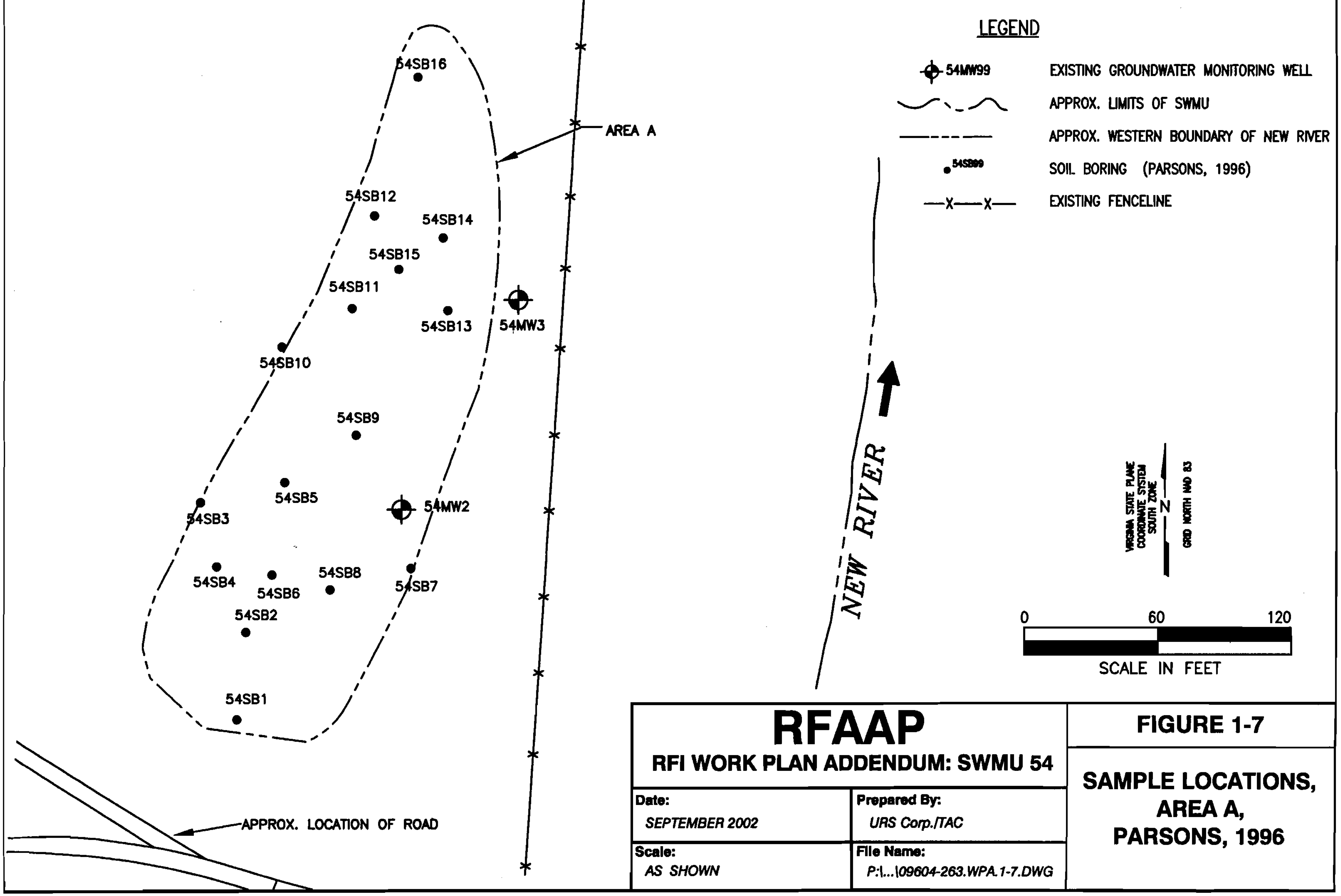
Shallow Soil - A review of the data indicates that arsenic, barium, cadmium, chromium, lead, mercury, 2,4,6-TNT and 2,4-dinitrotoluene (2,4-DNT) were present above their respective 2002 Residential Soil RBCs in at least one sample collected from zero to two ft bgs (Table 1-5).

A review of the data indicates that arsenic, lead, mercury and 2,4,6-TNT were also present above their respective 2002 Industrial Soil RBCs (Industrial AL for lead) in at least one sample collected from zero to two ft bgs (Table 1-5). Figure 1-8 represents the distribution of arsenic detections and detection limits in shallow soil. Due to the limited number of detections and the lack of spread in the values, an isoconcentration map has not been prepared. Arsenic concentrations above the 2002 Industrial Soil RBC of 3.8 milligrams per kilogram (mg/kg) were limited to two areas centered on borings 54SB6 and 54SB10. Arsenic concentrations above the 2002 Residential Soil RBC of 0.43 mg/kg were limited to one area centered on boring 54SB2. Figures 1-9 through 1-11 represent isoconcentration maps for lead, mercury and 2,4,6-TNT in shallow soil samples. As indicated by the Figures, concentrations of these constituents were generally limited to the central and southern portions of Area A.

Lead concentrations above 1,000 mg/kg, the 2001 Industrial AL, were centered on borings 54SB2 and 54SB6 in the southern portion of Area A. Lead was present in one sample in the southern portion of Area A from boring 54SB1 at a concentration above 400 mg/kg, the 2001 Residential AL. Mercury concentrations above 61 mg/kg, the 2002 Industrial Soil RBC, were limited to one area centered on boring 54SB6. 2,4,6-TNT concentrations above 190 mg/kg, the 2002 Industrial Soil RBC, were limited to one area centered on boring 54SB3, the westernmost boring in the Parsons (1996) field program.

Deep Soil - A review of the data indicates that chromium, lead, 2,4,6-TNT, 2,4-DNT, and 2,6-dinitrotoluene (2,6-DNT) were present above their respective 2002 Residential Soil RBCs (Industrial AL for lead) in at least one sample collected from deep soil from borings in Area A of SWMU 54.

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS [illegible] ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002
Prepared By: URS Corp./TAC
Scale: AS SHOWN
File Name: P:\...\09604-263.WPA.1-7.DWG

FIGURE 1-7

SAMPLE LOCATIONS, AREA A, PARSONS, 1996

Table 1-5
Summary of Soil Analytical Results - Area A
SWMU 54 RCRA Facility Investigation
Radford Army Amunition Plant, Radford, Virginia

Sample ID	54SB1A2	54SB2A2	54SB3A2	54SB4A2	54SB5A2	54SB6A2	54SB7A2	54SB8A2	54SB10A2	54SB11A2	54SB12A2	54SB13A2	54SB14A2	54SB16A2		
Field ID	54SB1A	54SB2A	54SB3A	54SB4A	54SB5A	54SB6A	54SB7A	54SB8A	54SB10A	54SB11A	54SB12A	54SB13A	54SB14A	54SB16A	Soil Industrial RBC	Soil Residential RBC
Lab ID	UB06593	UB06595	UB06597	UB06599	UB06601	UB06642	UB06644	UB06646	UB06605	UB06631	UB06633	UB06635	UB06637	UB06639		
Sample Date	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95		
Sample Depth*	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2	0-2		
TAL Metals (mg/kg)																
Antimony	<23.03 J4	<21.97 J4	<22.53 J4	<24.29 J4	<24.44 J4	<23.96 J4	<22.4 J4	<23.7 J4	<23.7 J4	<23.82 J4	<24.47 J4	<24.05 J4	<23.11 J4	<23.99 J4	82	3.1
Arsenic	<2.94 J4	3.27 J4	<2.87 J4	<3.1 J4	<3.12 J4	4.08 J4	<2.88 J4	<3.02 J4	4.28 J4	<3.04 J4	<3.12 J4	<3.07 J4	<2.95 J4	<3.06 J4	3.8	0.43
Barium	164.51 J1	224.22 J1	178.16 J1	313.51 J1	281.80 J1	1077.02 J1	138.29 J1	188.63 J1	319.23 J1	223.57 J1	235.98 J1	226.99 J1	153.30 J1	231.33 J1	14000	550
Beryllium	0.93 J4	1.76 J4	1.11 J4	1.78 J4	1.55 J4	1.11 J4	0.82 J4	1.15 J4	1.81 J4	1.49 J4	1.54 J4	1.42 J4	0.89 J4	1.47 J4	410	16
Cadmium	2.40 J4	<1.35 J4	<1.38 J4	<1.49 J4	<1.5 J4	11.75 J4	<1.37 J4	<1.45 J4	<1.45 J4	<1.46 J4	<1.5 J4	<1.47 J4	<1.42 J4	<1.47 J4	200	7.8
Chromium	25.38 J6	27.91 J6	28.16 J6	35.56 J6	34.54 J6	136.92 J6	24.00 J6	27.69 J6	33.86 J6	33.17 J6	36.06 J6	31.29 J6	20.52 J6	34.27 J6	610[1]	23[1]
Lead	716.80 J6	2354.26 J6	321.84 J6	84.26 J6	39.90 J6	3789.73 J6	50.29 J6	229.75 J6	205.56 J6	91.13 J6	21.22 J6	134.97 J6	36.56 J6	31.82 J6	1000[2]	400[2]
Mercury	0.09 J4	0.13 J4	5.06 J4	<0.06 J4	<0.06 J4	72.13 J4	<0.06 J4	<0.06 J4	<0.06 J4	<0.06 J4	<0.06 J4	<0.06 J4	<0.06 J4	<0.06 J4	61[3]	2.3[3]
Nickel	11.68 J4	10.25 J4	13.45 J4	21.44 J4	21.20 J4	16.99 J4	12.34 J4	15.60 J4	19.71 J4	20.05 J4	20.10 J4	18.90 J4	12.36 J4	20.58 J4	4100	160
Selenium	<0.53 J4	<0.5 J4	<0.52 J4	<0.56 J4	<0.56 J4	<0.55 J4	<0.51 J4	<0.54 J4	<0.54 J4	<0.55 J4	<0.56 J4	<0.55 J4	<0.53 J4	<0.55 J4	1000	39
Silver	0.07 J4	0.03 J4	0.03 J4	0.04 J4	0.04 J4	0.30 J4	<0.01 J4	<0.04 J4	0.07 J4	<0.02 J4	<0.02 J4	0.07 J4	<0.01 J4	<0.02 J4	1000	39
Thallium	<40.31 J4	<38.45 J4	<39.43 J4	<42.5 J4	<42.77 J4	<41.93 J4	<39.2 J4	<41.48 J4	<41.48 J4	<41.68 J4	<42.82 J4	<42.09 J4	<40.45 J4	<41.98 J4	14	0.55
Explosives (mg/kg)																
2,4,6-Trinitrotoluene	<2.35 J4	4.41 J4	2988.51 J4	<2.48 J4	<2.49 J4	4.71 J4	2.85 J6	<2.42 J4	<2.42 J4	<2.43 J4	<2.5 J4	<2.45 J4	<2.36 J4	<2.45 J4	190	21
2,4-Dinitrotoluene	<2.94 J4	<2.8 J4	12.76 J4	<3.1 J4	<3.12 J4	25.31 J4	<2.86 J4	<3.02 J4	<3.02 J4	<3.04 J4	<3.12 J4	<3.07 J4	<2.95 J4	<3.06 J4	410	16
2,6-Dinitrotoluene	<2.35	<2.24	<2.3	<2.46	<2.49	<2.44	<2.29	<2.42	<2.42	<2.43	<2.5	<2.45	<2.36	<2.45	200	7.8
HMX	<2.35	<2.24	<4.68	<2.48	<2.49	<2.44	<2.29	<2.42	<2.42	<2.43	<2.5	<2.45	<2.36	<2.45	10000	390
RDX	<1.5 J4	<1.43 J4	1.98 J4	<1.59 J4	<1.6 J4	<1.58 J4	<1.46 J4	<1.55 J4	<1.55 J4	<1.56 J4	<1.6 J4	<1.57 J4	<1.51 J4	<1.57 J4	52	5.8
Tetryl	<2.48	<2.37	<2.43	<2.61	<2.63	<2.58	<2.41	<2.55	<2.55	<2.56	<2.63	<2.59	<2.49	<2.58	2000	78

Table 1-5 (Continued)
Summary of Soil Analytical Results - Area A
SWMU 54 RCRA Facility Investigation
Radford Army Amunition Plant, Radford, Virginia

Sample ID	54SB1B22	54SB2B17	54SB3B17	54SB4B17	54SB5B17	54SB6B15	54SB7B17	54SB8B17	54SB9A7		
Field ID	54SB1B	54SB2B	54SB3B	54SB4B	54SB5B	54SB6B	54SB7B	54SB8B	54SB9A	Soil	Soil
Lab ID	UB06594	UB06596	UB06598	UB06600	UB06602	UB06643	UB06645	UB06647	UB06603	Industrial	Residential
Sample Date	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-96	RBC	RBC
Sample Depth^{+}	20-22	15-17	15-17	15-17	15-17	10-15	15-17	15-17	5-7		
TAL Metals (mg/kg)											
Antimony	<21.44 J4	<24.05 J4	<25.79 J4	<23.59 J4	<24.97 J4	<27.22 J4	<26.27 J4	<24.44 J4	<23.9 J4	82	3.1
Arsenic	<2.74 J4	<3.07 J4	<3.29 J4	<3.01 J4	<3.16 J4	<3.47 J4	<3.35 J4	<3.12 J4	<3.05 J4	3.8	0.43
Barium	307.44 J1	175.46 J1	67.63 J1	108.30 J1	244.59 J1	362.50 J1	420.91 J1	243.14 J1	193.90 J1	14000	550
Beryllium	<0.47 J4	1.33 J4	<0.56 J4	<0.51 J4	1.61 J4	2.43 J4	2.47 J4	1.72 J4	1.39 J4	410	16
Cadmium	<1.31 J4	<1.47 J4	<1.58 J4	<1.44 J4	<1.53 J4	<1.67 J4	<1.61 J4	<1.5 J4	<1.46 J4	200	7.8
Chromium	9.80 J6	29.45 J6	37.76 J6	21.30 J6	40.64 J6	70.14 J6	57.10 J6	40.15 J6	27.93 J6	610^{1}	23^{1}
Lead	5.77 J6	14.23 J6	14.74 J6	6.36 J6	16.82 J6	430.56 J6	22.79 J6	21.20 J6	20.85 J6	1000^{2}	400^{2}
Mercury	<0.05 J4	<0.06 J4	0.21 J4	<0.06 J4	<0.06 J4	<0.07 J4	<0.07 J4	<0.06 J4	<0.06 J4	61^{3}	2.3^{3}
Nickel	6.23 J4	16.69 J4	10.26 J4	9.19 J4	24.46 J4	30.14 J4	34.72 J4	25.56 J4	17.66 J4	4100	160
Selenium	<0.49 J4	<0.55 J4	<0.59 J4	<0.54 J4	<0.57 J4	<0.62 J4	<0.6 J4	<0.56 J4	<0.55 J4	1000	39
Silver	<0.01 J4	0.03 J4	0.04 J4	0.03 J4	0.05 J4	<0.02 J4	<0.02 J4	<0.02 J4	<0.03 J4	1000	39
Thallium	<37.53 J4	<42.09 J4	<45.13 J4	<41.28 J4	<43.69 J4	<47.64 J4	<45.98 J4	<42.77 J4	<41.63 J4	14	0.55
Explosives (mg/kg)											
2,4,6-Trinitrotoluene	<2.19 J4	<2.45 J4	48.42 J4	<2.41 J4	<2.55 J4	6527.78 J4	<2.68 J4	<2.49 J4	48.54 J4	190	21
2,4-Dinitrotoluene	<2.74 J4	<3.07 J4	<3.29 J4	<3.01 J4	<3.16 J4	56.67 J4	<3.35 J4	<3.12 J4	<3.05 J4	410	16
2,6-Dinitrotoluene	<2.19	<2.45	<2.63	<2.41	<2.55	112.50	<2.68	<2.49	<2.44	200	7.8
HMX	<2.19	<2.45	<2.63	<2.41	<2.55	7.28 J9	<2.68	<2.49	<2.44	10000	390
RDX	<1.4 J4	<1.57 J4	<1.68 J4	<1.54 J4	<1.63 J4	<1.78 J4	<1.72 J4	<1.6 J4	<1.56 J4	52	5.8
Tetryl	<2.31	<2.59	<2.78	<2.54	<2.69	<2.93	<2.83	<2.63	<2.57	2000	78

Table 1-5 (Continued)
Summary of Soil Analytical Results - Area A
SWMU 54 RCRA Facility Investigation
Radford Army Amunition Plant, Radford, Virginia

Sample ID	54SB9B17	54SB10B17	54SB11B17	54SB12B17	54SB13B22	54SB14B15	54SB15A6	54SB16B12		
Field ID	54SB9B	54SB10B	54SB11B	54SB12B	54SB13B	54SB14B	54SB15A	54SB16B	Soil	Soil
Lab ID	UB06604	UB06606	UB06632	UB06634	UB06636	UB06638	UB06648	UB06640	Industrial	Residential
Sample Date	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	Jan-95	RBC	RBC
Sample Depth*	15-17	15-17	15-17	15-17	20-22	11-12	4-6	10-12		
TAL Metals (mg/kg)										
Antimony	<24.82 J4	<24.02 J4	<23.73 J4	<26.03 J4	<23.73 J4	<23.81 J4	<24.2 J4	<24.2 J4	82	3.1
Arsenic	<3.14 J4	<3.06 J4	<3.03 J4	<3.32 J4	<3.03 J4	<3.01 J4	<3.09 J4	<3.09 J4	3.8	0.43
Barium	201.01 J1	158.09 J1	175.55 J1	248.34 J1	118.64 J1	166.27 J1	338.27 J1	203.70 J1	14000	550
Beryllium	1.53 J4	1.20 J4	1.34 J4	1.82 J4	<0.52 J4	1.06 J4	1.93 J4	1.48 J4	410	16
Cadmium	<1.51 J4	<1.47 J4	<1.45 J4	<1.59 J4	<1.45 J4	<1.45 J4	<1.48 J4	<1.48 J4	200	7.8
Chromium	37.56 J6	29.78 J6	32.93 J6	46.48 J6	32.32 J6	34.10 J6	45.93 J6	34.20 J6	610^1	23^1
Lead	15.83 J6	11.69 J6	12.11 J6	13.28 J6	6.23 J6	13.25 J6	28.40 J6	14.81 J6	1000^2	400^2
Mercury	<0.06 J4	0.12 J4	<0.06 J4	<0.07 J4	<0.06 J4	<0.06 J4	<0.06 J4	<0.06 J4	61^3	2.3^3
Nickel	22.81 J4	18.01 J4	16.89 J4	26.43 J4	13.20 J4	20.12 J4	26.05 J4	20.12 J4	4100	160
Selenium	<0.56 J4	<0.55 J4	<0.54 J4	<0.6 J4	<0.54 J4	<0.54 J4	<0.55 J4	<0.55 J4	1000	39
Silver	0.04 J4	0.03 J4	<0.02 J4	<0.02 J4	<0.02 J4	<0.01 J4	<0.02 J4	<0.02 J4	1000	39
Thallium	<43.09 J4	<42.03 J4	<41.53 J4	<45.55 J4	<41.53 J4	<41.33 J4	<42.35 J4	<42.35 J4	14	0.55
Explosives (mg/kg)										
2,4,6-Trinitrotoluene	<2.51 J4	<2.45 J4	<2.42 J4	<2.66 J4	<2.42 J4	<2.41 J4	<2.47 J4	<2.47 J4	190	21
2,4-Dinitrotoluene	<3.14 J4	<3.06 J4	<3.03 J4	<3.32 J4	<3.03 J4	<3.01 J4	<3.09 J4	<3.09 J4	410	16
2,6-Dinitrotoluene	<2.51	<2.45	<2.42	<2.66	<2.42	<2.41	<2.47	<2.47	200	7.8
HMX	<2.51	<2.45	<2.42	<2.66	<2.42	<2.41	<2.47	<2.47	10000	390
RDX	<1.61 J4	<1.57 J4	<1.55 J4	<1.7 J4	<1.55 J4	<1.54 J4	<1.58 J4	<1.58 J4	52	5.8
Tetryl	<2.65	<2.59	<2.55	2.80	<2.55	<2.54	<2.6	<2.6	2000	78

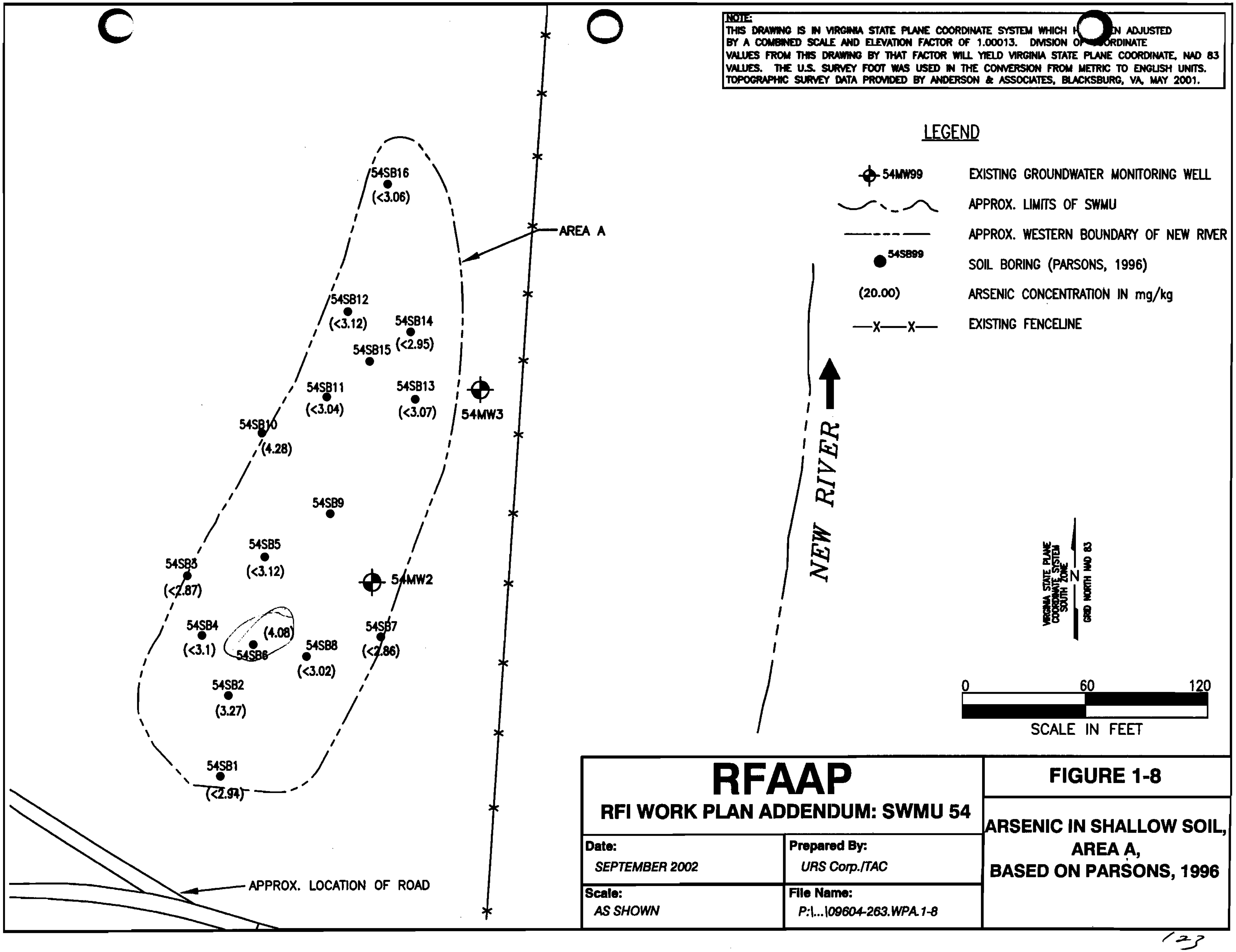
Notes:
Modified from Parsons (1996)
J1 = Analyte detected in the field or laboratory blank associated with this sample
J4 = Accuracy or precision outlier reported for quality control results associated with the reported results
J6 = Multiple quality control criteria outside acceptance limits (e.g., precision and accuracy outliers)
J9 = Reported results have been qualified as estimated due to matrix interferences in the affected sample
< = value is less than the sample detection limit
mg/kg = milligram per kilogram
* = feet below ground surface
TAL = Target Analyte List
TOC = Total Organic Carbons
RBC = Risk-Based Concentrations, USEPA Region III, April 2, 2002 (Non-carcinogenic values have been adjusted for a hazard quotient of 0.1).

(1) Chromium VI value used.
(2) Action Level (see USEPA Region III guidance)
(3) Mercuric Chloride value used.

☐ Value exceeds Industrial RBC or AL

☐ Value exceeds Residential RBC or AL

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH H[illegible]N ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION O[illegible]ORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

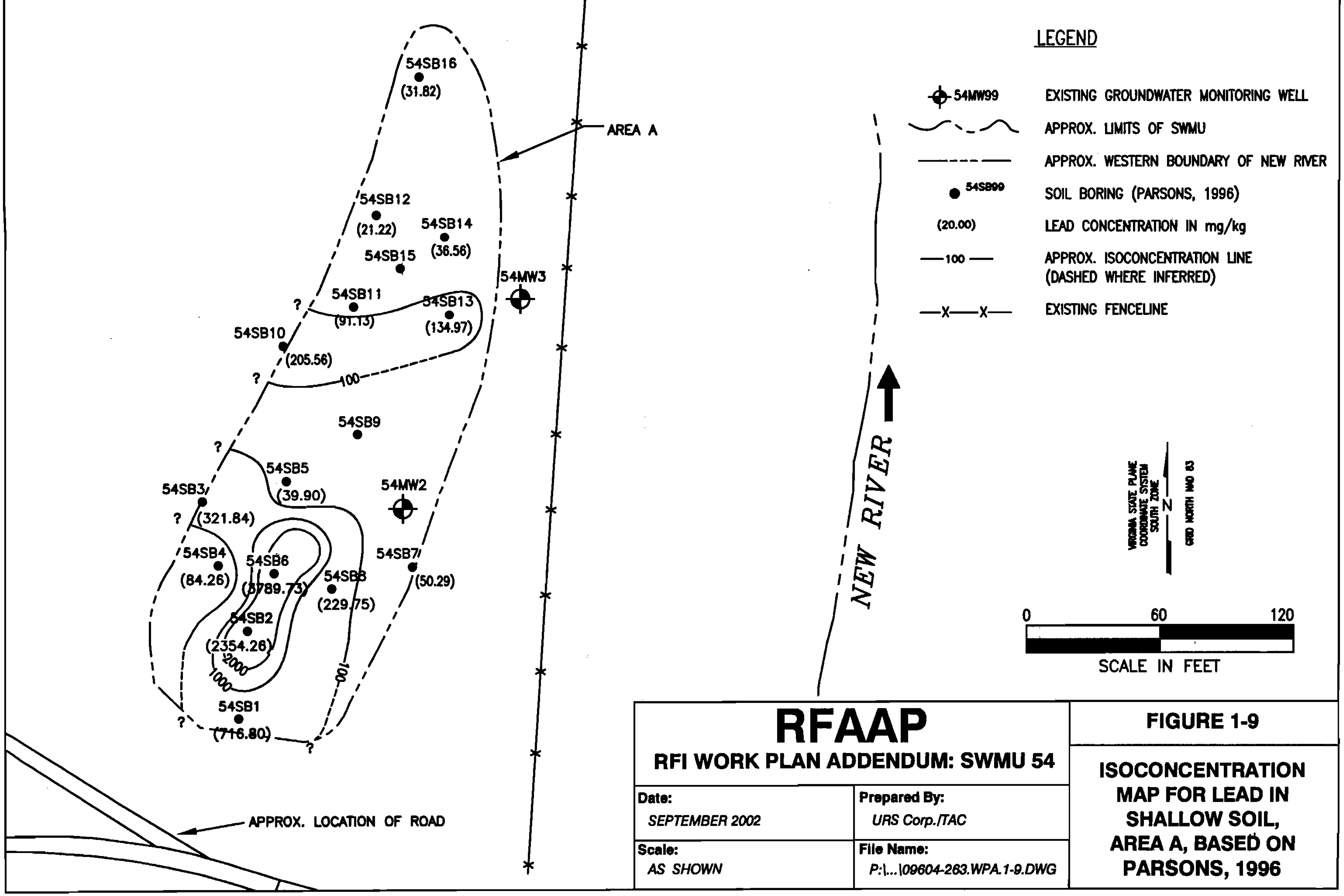
Date:	Prepared By:
SEPTEMBER 2002	*URS Corp./TAC*
Scale:	**File Name:**
AS SHOWN	*P:\...\09604-263.WPA.1-8*

FIGURE 1-8

ARSENIC IN SHALLOW SOIL, AREA A, BASED ON PARSONS, 1996

123

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



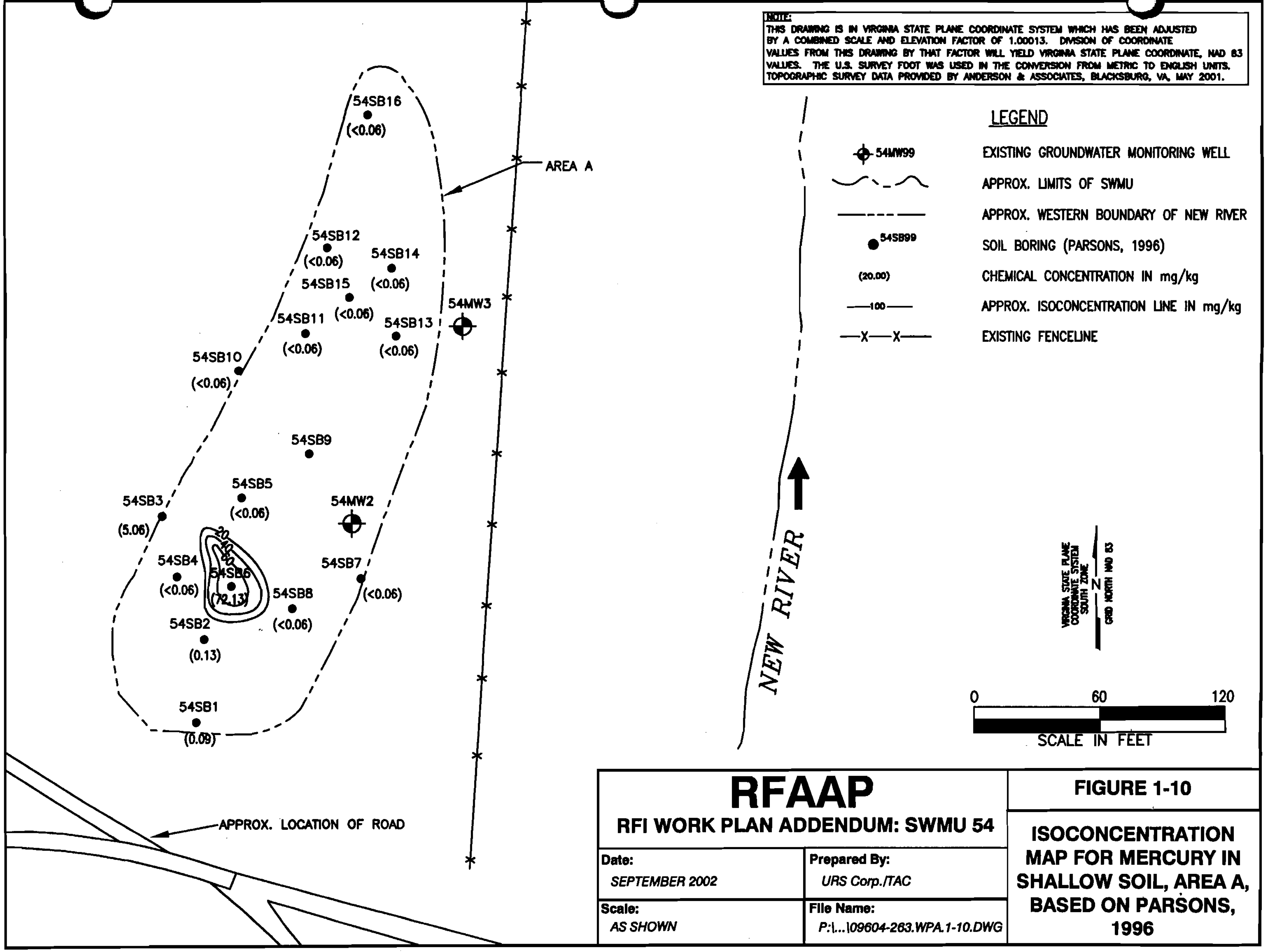
RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-9.DWG*

FIGURE 1-9

ISOCONCENTRATION MAP FOR LEAD IN SHALLOW SOIL, AREA A, BASED ON PARSONS, 1996



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

LEGEND

54MW99	EXISTING GROUNDWATER MONITORING WELL
	APPROX. LIMITS OF SWMU
	APPROX. WESTERN BOUNDARY OF NEW RIVER
● 54SB99	SOIL BORING (PARSONS, 1996)
(20.00)	CHEMICAL CONCENTRATION IN mg/kg
——100——	APPROX. ISOCONCENTRATION LINE IN mg/kg
—X—X—	EXISTING FENCELINE

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date:
SEPTEMBER 2002

Prepared By:
URS Corp./TAC

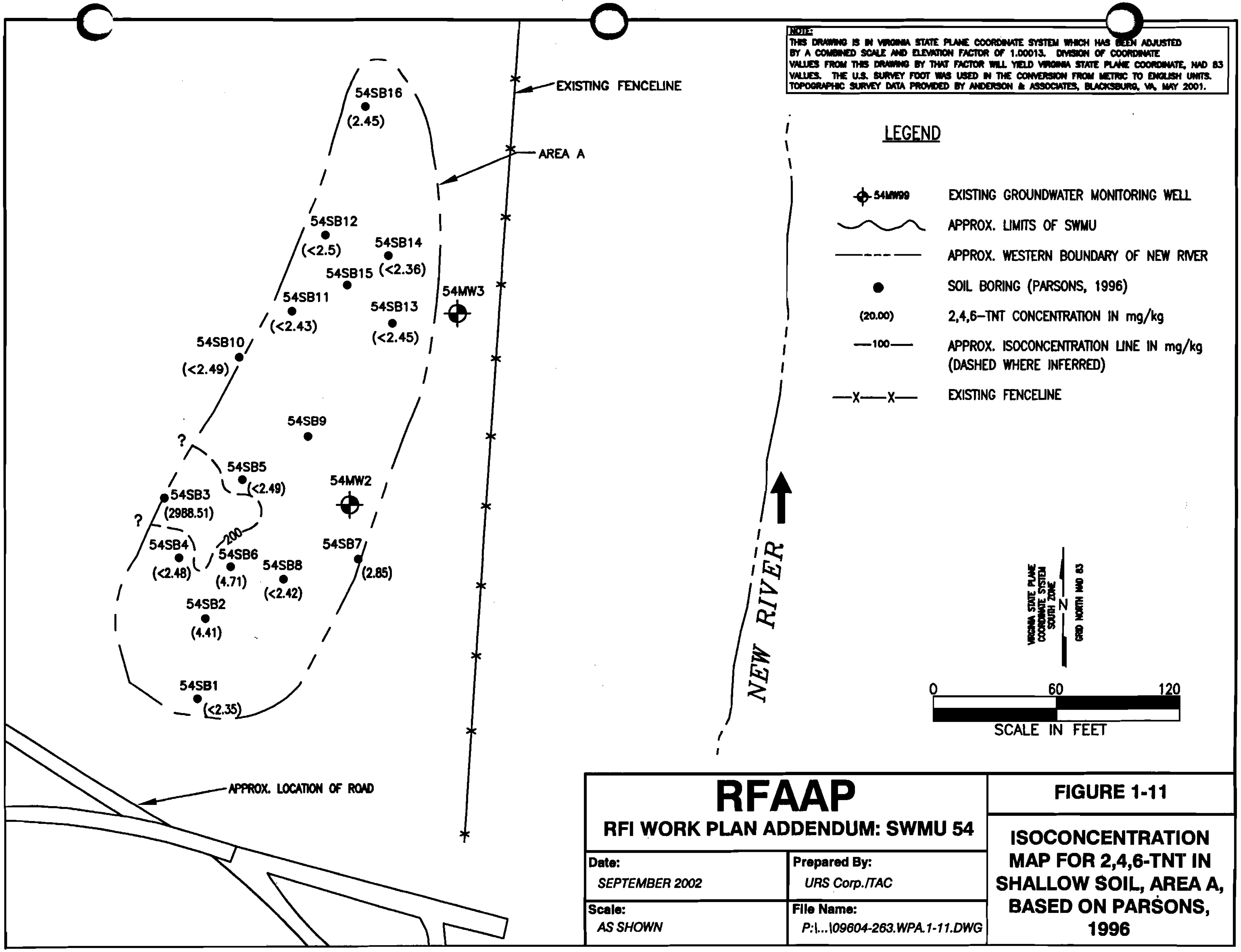
Scale:
AS SHOWN

File Name:
P:\...\09604-263.WPA.1-10.DWG

FIGURE 1-10

ISOCONCENTRATION MAP FOR MERCURY IN SHALLOW SOIL, AREA A, BASED ON PARSONS, 1996

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-11.DWG

FIGURE 1-11

ISOCONCENTRATION MAP FOR 2,4,6-TNT IN SHALLOW SOIL, AREA A, BASED ON PARSONS, 1996

A review of the data indicates that 2,4,6-TNT also was present above its 2002 Industrial Soil RBC (190 mg/kg) in a single sample collected from ten to 15 ft bgs (54SB6). Due to the limited number of detections, isoconcentration maps of the constituents detected above the Industrial and/or Residential RBCs have not been prepared. Arsenic, lead and mercury were not detected at concentrations above their respective Industrial Soil RBCs (or Industrial AL for lead) in the deep samples collected by Parsons (1996).

Geotechnical - During drilling, one sample per borehole (excluding the hand-augered boring) was collected and submitted for geotechnical analysis (particle size distribution, Atterberg limits, and Unified Soil Classification System [USCS] categorization). Geotechnical data are summarized in Table 1-6. The majority of site soils (approximately 73%) were classified as silty sand (SM). Two samples were classified as sandy silt (ML) and two samples were classified as sandy lean clay to sandy silt (CL-ML). A review indicates that the geotechnical data is limited to selected depth intervals and locations, but can be interpreted to represent an upward-fining soil profile from silty sand to sandy silt and sandy lean clay.

Waste Ash Sampling - Parsons (1996) collected two samples of ash from Area A (one sample from the northern mound and one sample from the southern mound) that were submitted for laboratory analysis of TCLP Metals, corrosivity, reactivity, ignitability, and paint filter liquids. The text of Parsons (1996) indicates that the TCLP lead concentration in the sample collected from the southern mound of Area A in SWMU 54 exceeded the regulatory limit. No additional data were available regarding the concentration of TCLP lead in the samples.

Risk Assessment - A BRA was conducted by Parsons (1996). Mercury and 2,4,6-TNT were concluded to be the risk drivers for subsurface soils based upon exceedance of calculated hazard indices. Antimony, arsenic, and beryllium were identified as the risk drivers for groundwater. The risk assessment results indicated that potential adverse health effects were possible because of dermal contact and ingestion exposure scenarios for groundwater and subsurface soils for construction worker and site worker receptors. Parsons also concluded that surface and groundwater were potential migration pathways to the New River.

Conclusions - Data regarding shallow soils in Area A are suitable for site-screening purposes and for identification of COPCs due to excavation activities that have occurred at the site.

Data regarding deep (i.e., above bedrock) soils in Area A within SWMU 54 are suitable for identification of COPCs and for definitive site characterization. Multiple samples collected immediately above, or within three to five ft of groundwater will be used as definitive data and will be carried forward into the RFI and subsequent CMS as defining the lateral and vertical extent of deep contamination within Area A of SWMU 54.

Based on the current review of information presented in Parsons (1996), arsenic, barium, cadmium, chromium, lead, mercury and 2,4,6-TNT, 2,4-DNT, and 2,6-DNT are identified as COPCs in shallow and deep soils at the site (Table 1-3). The western- and southern-most soil samples collected at Area A of SWMU 54 indicate that constituents are present at relatively high concentrations near the then-presumed limits of the SWMU area.

Groundwater data presented by Parsons (1996) are considered definitive for identification of COPCs. Beryllium is identified as a COPC in groundwater at the site. While antimony, arsenic, barium, chromium and lead were reported as present above screening criteria, the detections are limited to the upgradient well 54MW1. Well 54MW1 is screened wholly within bedrock. Downgradient wells 54MW2 and 54MW3 are not constructed in a similar manner, potentially leading to erroneous

Table 1-6
Geotechnical Data
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Sample ID	Sample Depth (ft bgs)	Description	USCS[1]	Grain Size Distribution[2]			Atterberg Limits[3]		
				Percent Gravel	Percent Sand	Percent Fines	LL	PL	PI
54SB4	5-7	Brown sandy silt	CL-ML	0	40	60	26	21	5
54SB12	5-7	Brown sandy lean clay	CL-ML	0	42	58	23.2	18	5.2
54SB13	5-7	Brown silty sand	SM	0	48	52	NP	NP	NP
54SB14	7-9	Brown silty sand	SM	0	75	25	NP	NP	NP
54SB2	10-12	Brown sandy silt	ML	0	47	53	NP	NP	NP
54SB3	10-12	Brown silty sand	SM	0	68	32	NP	NP	NP
54SB7	10-12	Brown silty sand	SM	0	82	18	NP	NP	NP
54SB9	10-12	Brown sandy silt	ML	0	46	54	24.1	21.2	2.9
54SB10	10-12	Brown silty sand	SM	0	63	37	NP	NP	NP
54SB16	10-12	Brown silty sand	SM	0	71	29	NP	NP	NP
54SB1	15-17	Brown silty sand	SM	0	68	32	NP	NP	NP
54SB5	15-17	Brown silty sand	SM	0	52	48	NP	NP	NP
54SB8	15-17	Brown silty sand	SM	0	59	41	NP	NP	NP
54SB11	15-17	Brown silty sand	SM	0	63	37	NP	NP	NP
54SB6	15-20	Brown silty sand	SM	0	52	48	NP	NP	NP

Notes:

Modified from Parsons (1996)

Sorted by sample depths.

ft bgs = feet below ground surface

(1) USCS: Unified Soil Classification System

CL = Clay
SM = Sandy silt
ML = Silty sand

(2) Grain Size Distribution:

Gravel: Particles of rock that are retained on a 4.75 millimeter (No. 4) sieve

Sand: Particles that will pass a 4.75 millimeter sieve, but are retained on a 0.075 millimeter (No. 200) sieve

Fines: Includes silt and sand. Particles that will pass a 0.075 millimeter (No. 200) sieve

(3) Atterberg Limits:

LL: Liquid Limit
PL: Plasticity Limit
PI: Plasticity Index (PI = LL - PL)
NP: Nonplastic

comparisons. In addition, more recent groundwater sampling results indicate that these constituents are not present at concentrations exceeding screening criteria (see Section 1.2.3.5).

1.2.3.4 Supplemental RFI Report, SWMU 54 – 1998

In 1998, a Supplemental RFI Report was submitted by MSE. During analysis of aerial photographs of SWMU 54 by the USEPA, and coincident with field observations, a flat grassy area ringed by mature pine trees was identified northwest of Area A. This area was defined as Area B within SWMU 54. The purpose of the supplemental RFI was "to characterize the nature and extent of contamination within SWMU 54 and to summarize potential risks to human health."

MSE's field program included a geophysical investigation to assess limits of the fill material/disposal area, followed by a biased soil-sampling program. In addition, one new groundwater monitoring well was installed downgradient of Area B to further characterize potential groundwater impact. MSE's investigation was limited to Area B of SWMU 54.

A detailed analysis of historical site photographs and figures was conducted for the development of this WPA. The analysis (based on six data sets including two aerial photographs; figures presented in Dames & Moore (1992a), Parsons (1996), MSE (1998), and Parallax (1999); and Installation-wide flown topography) indicates that the figures prepared by MSE (1998) present an inaccurate representation of sampling locations. The figures presented herein are representative of MSE's data and should be considered a best-fit approximation of the MSE spatial data. Data generated by MSE (1998) can be used for site screening purposes (including identification of COPCs) and should not be relied upon as definitive data for characterization purposes.

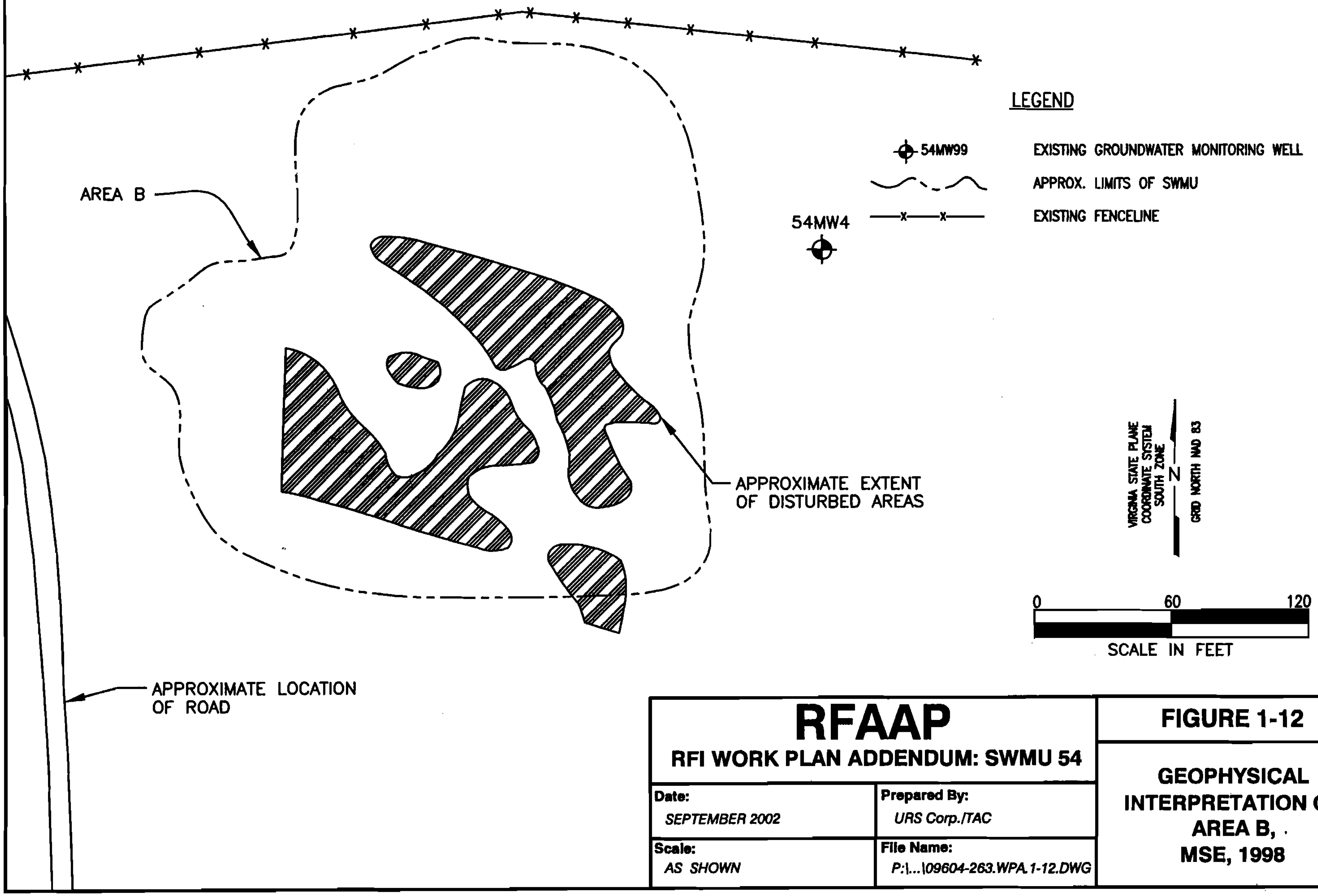
<u>Geophysical Investigation</u> - A ground penetrating radar (GPR) investigation was conducted in Area B of SWMU 54 to "indicate potential burial areas (disturbed areas) where further testing by drilling and soil sampling should be done" (MSE 1998). The results were interpreted to indicate four areas of "potential burial" at depths of less than one ft bgs to less than seven ft bgs (Figure 1-12). MSE estimated 1,600 cubic yards of disturbed soil was present at the site.

<u>Soil</u> - MSE advanced twelve borings in the disturbed areas identified during the GPR survey; seven borings were completed using hand-auger methods and five borings were completed using hollow-stem auger and split-spoon sampling methods (Figure 1-13; MSE 1998). According to MSE, soil samples were collected from the "surface" (hand auger) or "subsurface" (split spoon); however, sample depths were not included in the report (MSE 1998).

Soil samples were selected for laboratory analysis based upon "visual properties and/or depth of sample." Soil samples were analyzed for Target Compound List (TCL) VOCs (listed as TCL organics in MSE 1998), TAL Metals (listed as TAL inorganics in MSE 1998), SVOCs (analyte list unclear), explosives, TOC and TOX. In addition, "surface" samples were composited and analyzed for TCLP VOCs, SVOCs, and RCRA Metals, as well as ignitability and reactivity.

Based on the lack of sample depth information presented in MSE (1998) and on a review of MSE's boring logs, it is assumed herein that the "surface" samples collected by MSE represent zero to two ft bgs; thus they will henceforth be referred to as shallow soil. MSE's "subsurface" samples are herein assumed to represent eight to ten ft bgs (54BSB3 is assumed to represent ten to 12 ft bgs). Based on the presence of bedrock at 19 ft bgs in well 54MW4 near Area B of SWMU 54, and on the presence of

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*

Prepared By: *URS Corp./TAC*

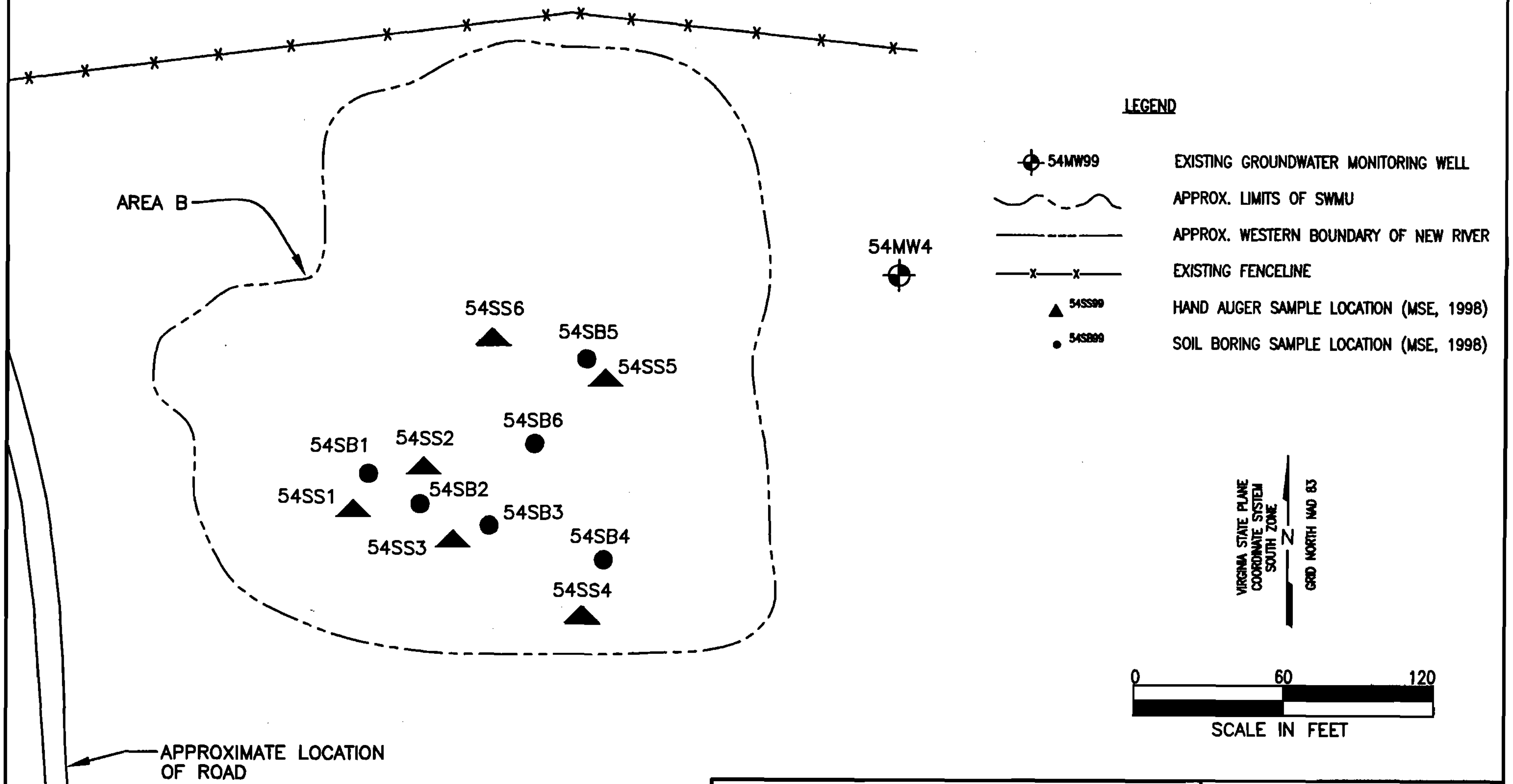
Scale: *AS SHOWN*

File Name: *P:\...\09604-263.WPA.1-12.DWG*

FIGURE 1-12

GEOPHYSICAL INTERPRETATION OF AREA B, MSE, 1998

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-13.DWG

FIGURE 1-13

SAMPLE LOCATIONS, AREA B, MSE, 1998

bedrock from 20 to 23 ft bgs in Area A of SWMU 54 (Parsons 1996), the "subsurface" samples collected by MSE are referred to herein as intermediate depth samples.

Soil types described by MSE (1998) in Area B of SWMU 54 are consistent with those described by Parsons (1996) in Area A of SWMU 54 (i.e., a generally upward-fining soil profile from silty sand to sandy silt and clay).

Shallow Soil - A review of the data indicates that aluminum, antimony, arsenic, chromium, iron, lead, manganese, mercury, 2,4,6-TNT, 2-amino-4,6-dinitrotoluene, 2,6-DNT, 2,4-DNT, benzo[a]anthracene, benzo[a]pyrene (BAP), benzo[b]fluoranthene, dibenz[a]anthracene and indeno[1,2,3-cd]pyrene were detected at concentrations above their respective 2002 Residential Soil RBCs (Residential AL for lead) in samples assumed to have been collected from zero to two ft bgs (Table 1-7).

In addition, a review of the data indicates that arsenic, lead, 2,4,6-TNT and BAP were also reported as present above their respective 2002 Industrial Soil RBCs (Industrial AL for lead) in samples assumed to have been collected from zero to two ft bgs (Table 1-7). Figures 1-14 through 1-17 represent isoconcentration maps for arsenic, lead, 2,4,6-TNT and BAP in shallow samples. Arsenic concentrations above 3.8 mg/kg, the 2002 Industrial Soil RBC, were reported in the southernmost (54BSS4), the westernmost (54BSS1) and northernmost (54BSS6) sample locations. Lead concentrations above 1,000 mg/kg, the 2002 Industrial AL, were reported in three samples (54BSS3, 54BSS5 and 54BSS6). 2,4,6-TNT concentrations above 190 mg/kg, the 2002 Industrial Soil RBC, were limited to one sample (54BSS3). BAP concentrations above 0.78 mg/kg, the 2002 Industrial Soil RBC, were limited to one sample (54BSS6) with detections below 0.78 mg/kg reported in two additional samples.

Graphical representations of the distribution of constituents are based on a spatially limited data set. As such, the areas data depicted should be considered as preliminary, and for site screening purposes.

Intermediate Depth Soil - A review of the data indicates that aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, 2,4,6-TNT, 2-amino-4,6-dinitrotoluene, 2,4- DNT, benzo[a]anthracene, benzo[b]fluoranthene, indeno[1,2,3-cd]pyrene, and BAP were detected at concentrations above their respective 2002 Residential Soil RBCs (Residential AL for lead) in samples assumed to have been collected from eight to 12 ft bgs (Table 1-7).

In addition, a review of the data indicates that arsenic, lead, and BAP were also reported as present above their respective 2002 Industrial Soil RBCs (Industrial AL for lead) in samples assumed to have been collected from eight to 12 ft bgs (Table 1-7). Figure 1-18 represents the distribution of arsenic detections and detection limits in intermediate depth soil. Due to the limited number of detections and the lack of spread in the values, an isoconcentration map has not been prepared. Arsenic concentrations above 3.8 mg/kg, the 2002 Industrial Soil RBC, were reported in borings 54BSB4 and 54BSB5. Figure 1-19 represents an isoconcentration map for lead in intermediate depth samples. Lead concentrations above 1,000 mg/kg, the 2002 Industrial AL, were reported in borings 54BSB2 and 54BSB5. Figure 1-20 represents the distribution of BAP detections and detection limits in intermediate depth soil. Due to the limited number of detections and the lack of spread in the values, an isoconcentration map has not been prepared. BAP concentrations above 0.78 mg/kg, the 2002 Industrial Soil RBC, were limited to one sample (54BSB5) with detections below 0.78 mg/kg reported in the sample from 54BSB1.

Graphical representations of the distribution of constituents are based on a spatially limited data set. As such, the areas data depicted should be considered as preliminary, and for site screening purposes.

Table 1-7
Summary of Soil Analytical Results - Area B
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Estimated Sample Depth (ft bgs) Estimated Sample Date	54BSS1 0-2 Dec-97	54BSS2 0-2 Dec-97	54BSS3 0-2 Dec-97	54BSS4 0-2 Dec-97	54BSS5 0-2 Dec-97	54BSS6 0-2 Dec-97	54BSB1 10 Dec-97	54BSB2 10 Dec-97	54BSB3 12 Dec-97	54BSB4 10 Dec-97	54BSB5 10 Dec-97	Soil Industrial RBC	Soil Residential RBC
TAL Inorganics (mg/kg)													
Aluminum	13700	19200	20700	16500	12800	16600	9480	35500	17200	16400	13900	200000	7800
Antimony	<41.19	<1.13	2.74	4.53	<1.14	6.92	<1.13	6.79	<1.08	<1.20	5.41	82	3.1
Arsenic	4.39	<2.26	3.65	4.75	2.72	8.00	2.73	2.69	<2.17	<2.39	5.9	3.8	0.43
Barium	179	121	217	211	148	212	133	243	106	207	384	14000	550
Cadmium	1.18	<0.679	2.55	1.25	1.04	1.88	0.828	1.47	<0.650	<0.717	1.68	200	7.8
Calcium	2320	1500	13000	2680	8220	25400	2220	10300	1440	2060	6320	—	—
Chromium	23.4	27.6	38.1	38.4	22.6	42	20	23.1	28.5	25.4	43.5	610[1]	23[1]
Cobalt	10.3	11	8.93	11.1	8.96	10.2	8.34	7.33	10.4	11	11.4	4100	160
Copper	43.3	16.4	138	53.9	54	155	14.4	609	16.4	15.8	385	8200	310
Iron	36800	30100	34300	29800	28500	35700	29300	26100	27800	27100	30300	61000	2300
Lead	562	14	2340	600	1060	2660	196	5560	11.9	56.6	1090	1000[2]	400[2]
Magnesium	2960	4560	6280	4410	6670	13500	2610	4880	5190	3580	6380	—	—
Manganese	1190	440	839	953	814	652	855	788	381	900	908	4100	160
Mercury	0.179	<0.042	2.07	0.103	3.73	1.19	0.332	1.17	<0.038	0.052	0.863	61[3]	2.3[3]
Nickel	14.6	16.3	18.7	17.4	14.6	19.7	11.6	18.7	16	15.7	26.3	4100	160
Potassium	1810	2630	1910	2000	1760	1320	1420	1870	2640	2180	1960	—	—
Vanadium	29.5	51.3	28.1	38.8	26.4	43.3	23.6	21.8	44.1	37.3	29.9	1400	55
Zinc	562	70.3	744	368	439	616	371	590	62.3	169	700	61000	2300
Explosives mg/kg													
2,4,6-Trinitrotoluene	<0.250	<0.250	499	<0.250	<0.250	83.3	<0.250	0.454	<0.250	<0.250	22.7	190	21
2,4-Dinitrotoluene	<0.250	<0.250	<25.0	<0.250	0.392	8.02	<0.250	<0.250	<0.250	<0.250	5.28	410	16
2-Amino-4,6-Dinitrotoluene	<0.250	<0.250	5.19 J	<0.250	<0.250	10.8	<0.250	<0.250	<0.250	<0.250	3.27	12.4[4]	0.47[4]
HMX	<0.500	<0.500	<50.0	<0.500	0.891	123	<0.500	2.86	1.21	1.95	63.4	10000	390
VOCs (mg/kg)													
Acetone	<0.012	<0.012	<0.012	0.006 J	<0.012	<0.012	<0.011	0.005 J	<0.011	<0.012	0.006 J	20000	780
Carbon Disulfide	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.002 J	20000	780
Carbon Tetrachloride	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.001 J	44	4.9
Methylene Chloride	0.034	0.01	0.067	0.041	0.033	0.08	0.017	0.061	0.003 J	0.038	0.063	760	85
Trichloroethene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.001 J	<0.006	14	1.6
Toluene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006	0.008	41000	1600

Table 1-7 (Continued)
Summary of Soil Analytical Results - Area B
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Sample ID Estimated Sample Depth (ft bgs) Estimated Sample Date	54BSS1 0-2 Dec-97	54BSS2 0-2 Dec-97	54BSS3 0-2 Dec-97	54BSS4 0-2 Dec-97	54BSS5 0-2 Dec-97	54BSS6 0-2 Dec-97	54BSB1 10 Dec-97	54BSB2 10 Dec-97	54BSB3 12 Dec-97	54BSB4 10 Dec-97	54BSB5 10 Dec-97	Soil Industrial RBC	Soil Residential RBC
SVOCs (mg/kg)													
2,6-Dinitrotoluene	0.33	<0.390	14 D	<0.380	0.056 J	3.7	0.53	<4.0	<0.370	<0.410	5.1	200	7.8
2,4-Diniitrotoluene	2.6	<0.390	19 D	0.11 J	0.22 J	16	2.7	1.3 J	<0.370	<0.410	46	410	16
2-Chloronaphthalene	<0.400	<0.390	<0.410	<0.380	<0.390	0.34 J	0.036 J	<4.0	<0.370	<0.410	<3.90	16000^{5}	630^{5}
Acenaphthalene	<0.400	<0.390	<0.410	<0.380	<0.390	1.6 J	0.12 J	<4.0	<0.370	<0.410	0.76 J	6100^{6}	230^{6}
Anthracene	<0.400	<0.390	BDL	<0.380	<0.390	1.3 J	0.097 J	<4.0	<0.370	<0.410	0.56 J	61000	2300
Benzo[a]anthracene	<0.400	<0.390	0.046 J	<0.380	0.059 J	3.3	0.28 J	<4.0	<0.370	<0.410	1.7 J	7.8	0.87
Benzo[a]pyrene	<0.400	<0.390	0.042 J	<0.380	0.11 J	4.0	0.32 J	<4.0	<0.370	<0.410	2.4 J	0.78	0.087
Benzo[b]fluoranthene	<0.400	<0.390	0.12 J	<0.380	0.13 J	4.9	0.35 J	<4.0	<0.370	<0.410	1.8 J	7.8	0.87
Benzo[g,h,i]perylene	<0.400	<0.390	0.05 J	<0.380	<0.390	2.1	0.19 J	<4.0	<0.370	<0.410	1.3 J	6100^{6}	230^{6}
Benzo[k]fluoranthene	<0.400	<0.390	0.061 J	<0.380	0.1 J	2.9	0.28 J	<4.0	<0.370	<0.410	2.3 J	78	8.7
Bis(2-ethylhexyl)phthalate	0.5	<0.390	1.4	1.5	1.8	8.2	0.84	1.6 J	<0.370	<0.410	15 J	410	46
Chrysene	<0.400	<0.390	0.056 J	<0.380	0.11 J	3.7	0.29 J	<4.0	<0.370	<0.410	2.2 J	780	87
Di-n-butylphthalate	2.6	<0.390	15 D	0.59	1.6	18 B	3.1 B	5.9	<0.370	0.39 J	53 B	20000^{7}	780^{7}
Di-n-octylphthalate	<0.400	<0.390	0.046 J	<0.380	<0.390	<2.0	<0.380	<4.0	<0.370	<0.410	<3.90	4100^{8}	160^{8}
Dibenzofuran	<0.400	<0.390	<0.410	<0.380	<0.390	0.5 J	0.042 J	<4.0	<0.370	<0.410	<3.90	820	31
Dibenz[a,h]anthracene	<0.400	<0.390	<0.410	<0.380	<0.390	0.44 J	0.043 J	<4.0	<0.370	<0.410	<3.90	0.78	0.087
Diethylphthalate	2.2	<0.390	1	1.6	4.2	58 D	16 D	19	<0.370	<0.410	36 D	160000	6300
Dimethyl phthalate	0.71	<0.390	<0.410	0.087 J	1.1	13	4	<4.0	<0.370	<0.410	11	2000000	78000
Fluoranthene	<0.400	<0.390	0.061 J	<0.380	0.049 J	6.2	0.055	<4.0	<0.370	<0.410	3.6 J	8200	310
Fluorene	<0.400	<0.390	<0.410	<0.380	<0.390	0.79 J	0.063 J	<4.0	<0.370	<0.410	0.42 J	8200	310
Indeno[1,2,3-cd]pyrene	<0.400	<0.390	0.042 J	<0.380	<0.390	2	0.22 J	<4.0	<0.370	<0.410	1.6 J	7.8	0.87
N-nitrosodiphenylamine	1.8	<0.390	1.4	0.49	0.22 J	3	0.51	1.5 J	<0.370	<0.410	7.6	1200	130
Naphthalene	<0.400	<0.390	<0.410	<0.380	<0.390	0.85 J	0.07 J	<4.0	<0.370	<0.410	0.49 J	4100	160
Phenanthrene	<0.400	<0.390	<0.410	<0.380	0.04 J	6	0.48	<4.0	<0.370	<0.410	3.2 J	6100^{6}	230^{6}
Pyrene	<0.400	<0.390	0.067 J	<0.380	0.1 J	8.2	0.57	<4.0	<0.370	<0.410	4.4	6100	230
Other													
EOX							249	489	331			---	---
pH							8.05	8.03	7.14			---	---
TOC							7360	10900	9750			---	---
Percent Solids	82.6	85.8	82.1	86.6	84.9	85.2	87.1	83.3	88.8	82	85.7	---	---

<u>Notes:</u>

Modified from MSE (1996)

J = The analyte value is imprecise due to quality control problems as follows:

B = Analyte detected in laboratory blank, result is estimated and biased high

D = The analyte concentration results from a required dilution of the sample

TAL = Target Analyte List

SVOC = Semi-volatile Organic Compound

TOC = Total Organic Carbon

EOX = Extractable Organic Halogens

mg/kg = Milligrams per kilogram

RBC = Risk-Based Concentration, USEPA Region III, April 2, 2002 (Non-carcenogenic constituents have been adjusted for a hazard quotient of 0.1)

ft bgs = feet below ground surface

Blank cell indicates sample not submitted for laboratory analysis

(1) Chromium VI values used from RBC table

(2) Lead Screening Values (Action Level; from 2002 RBC table)

(3) Mercuric Chloride value used from RBC table

(4) Aminodinitrotoluenes value used from RBC table

(5) Beta-chloronaphthalene value used from RBC table

(6) Pyrene value used from RBC table

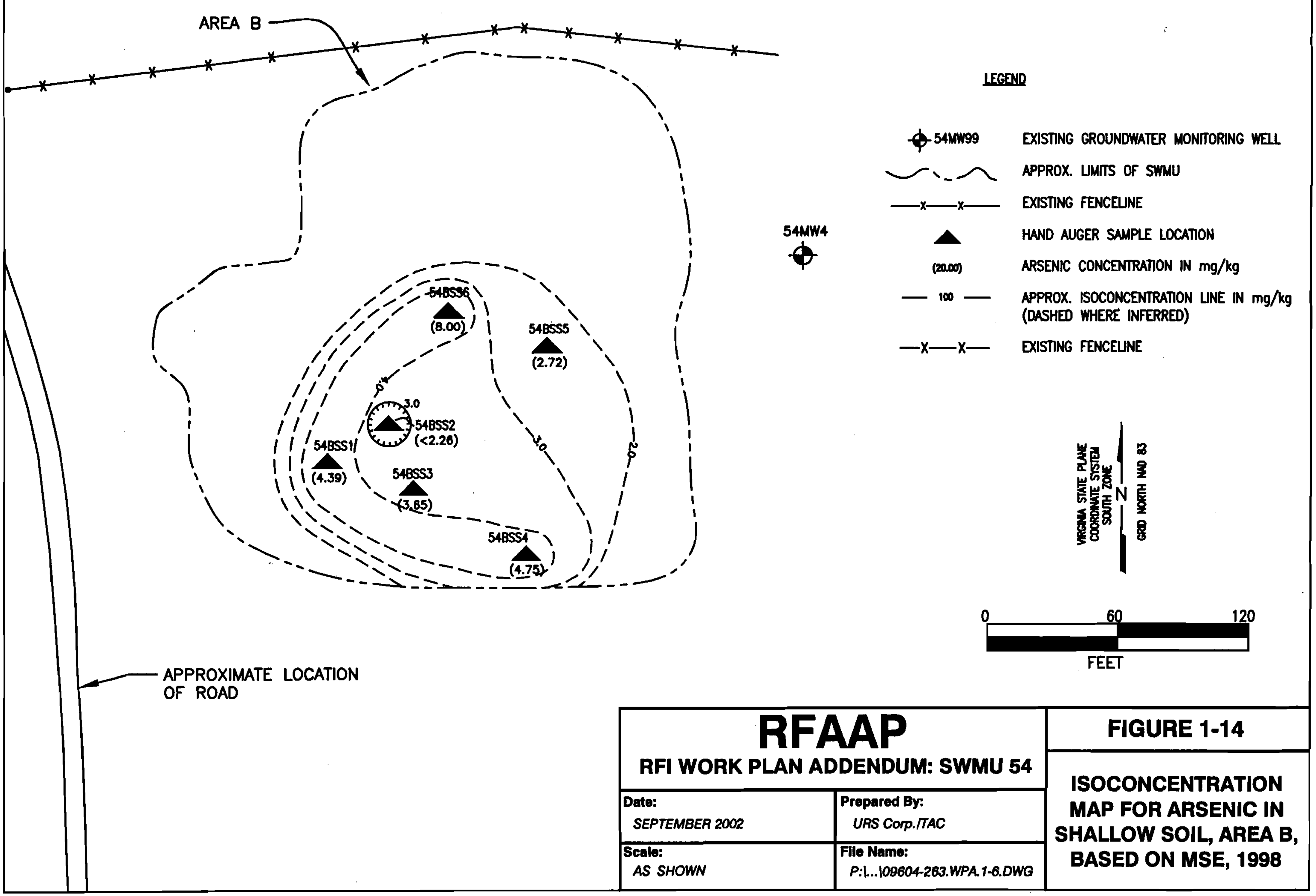
(7) Dibutylphthalate value used from RBC table

(8) Dioctylphthalate value used from RBC table

☐ Value exceeds Industrial RBC/AL

☐ Value exceeds Residential RBC/AL

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

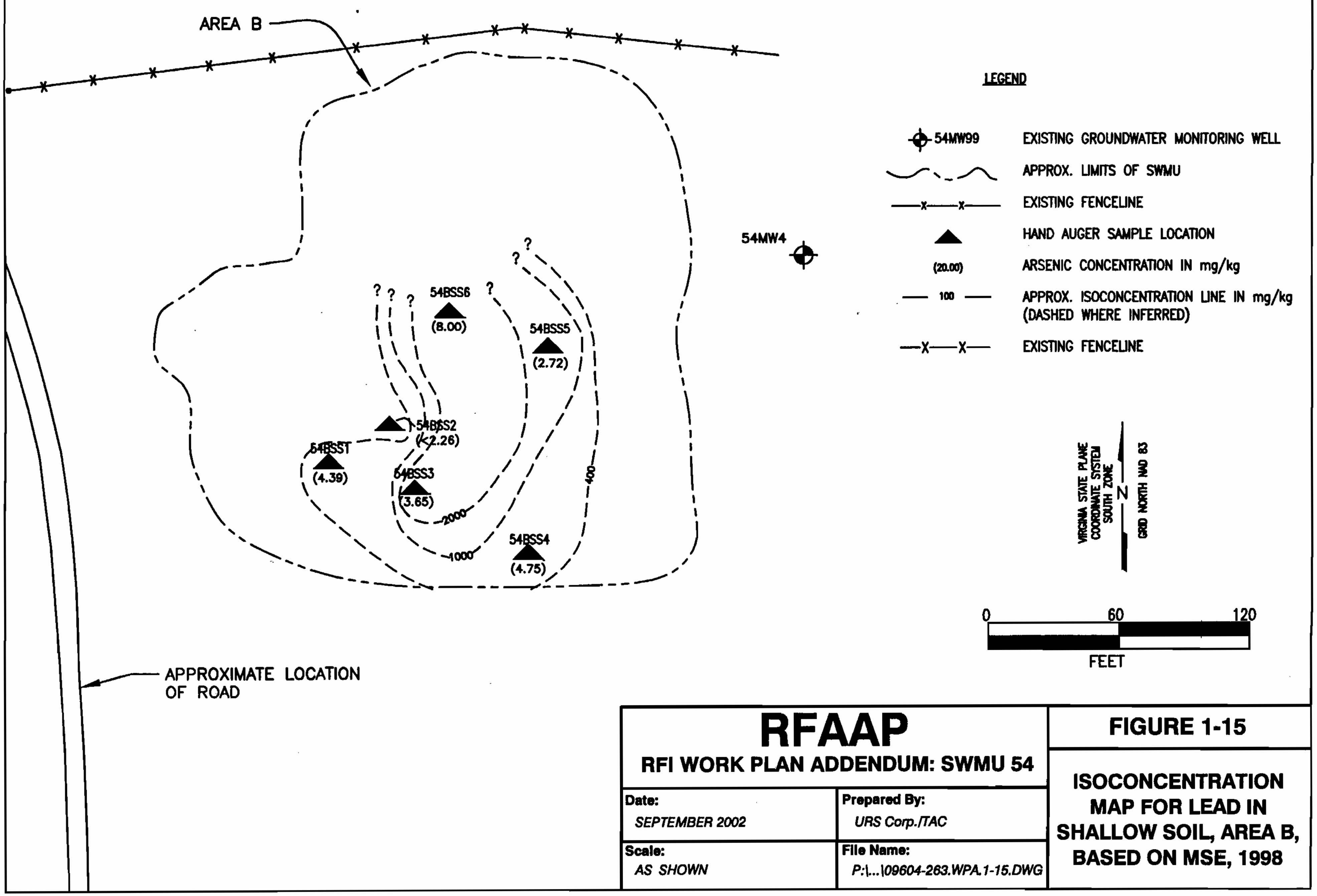
RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-6.DWG*

FIGURE 1-14

ISOCONCENTRATION MAP FOR ARSENIC IN SHALLOW SOIL, AREA B, BASED ON MSE, 1998

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

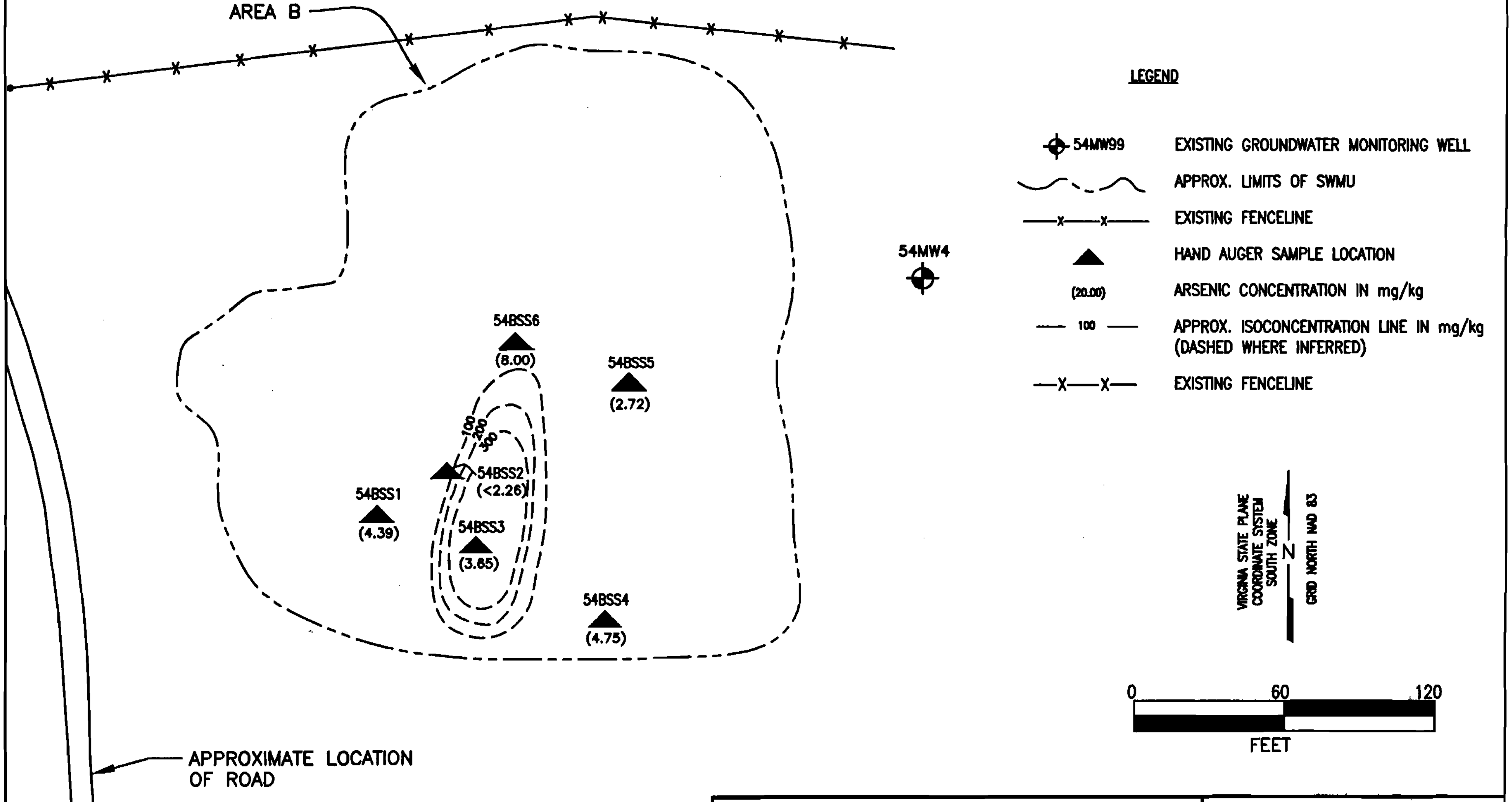
RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-15.DWG*

FIGURE 1-15

ISOCONCENTRATION MAP FOR LEAD IN SHALLOW SOIL, AREA B, BASED ON MSE, 1998

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

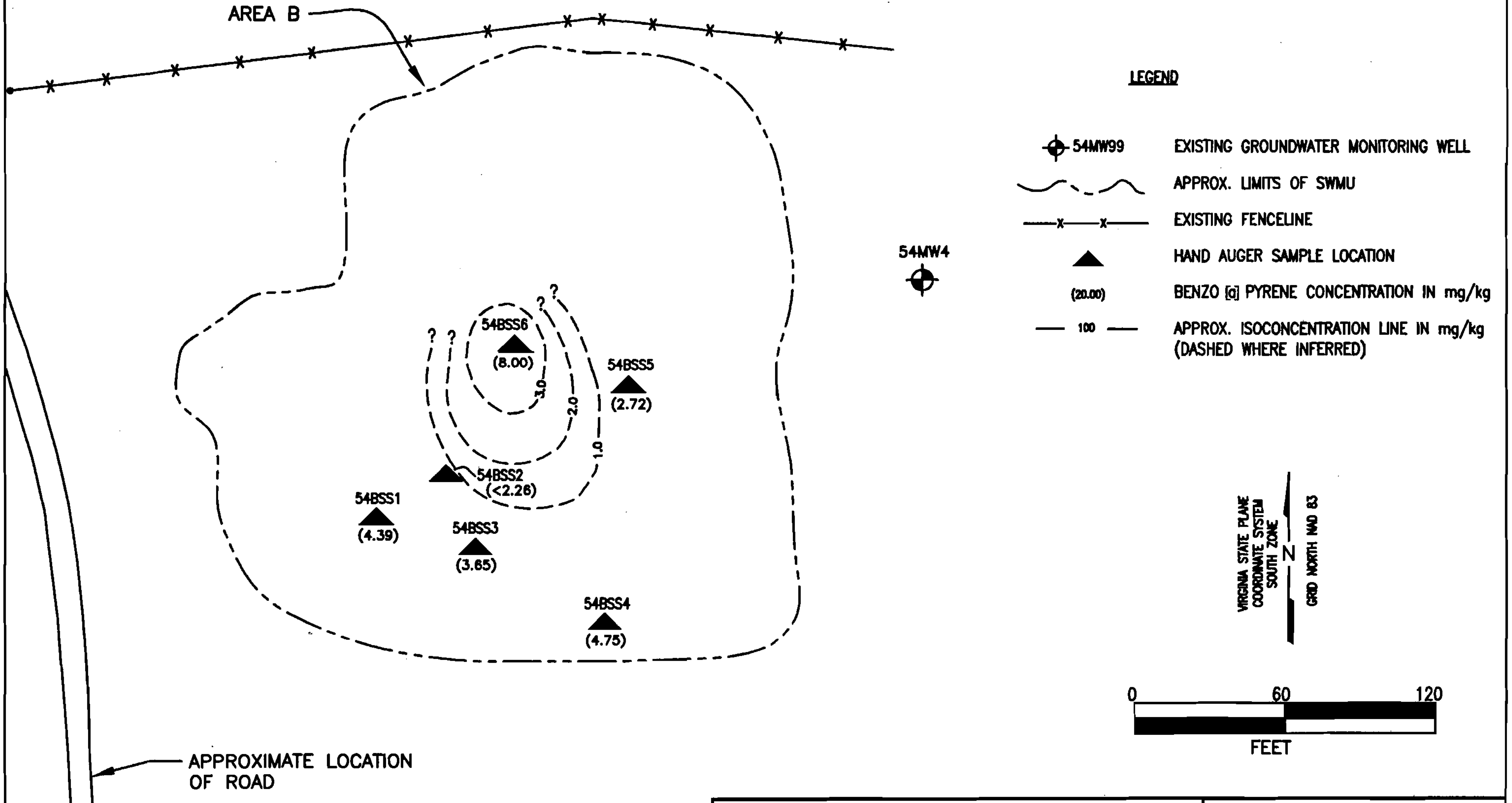
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-16.DWG

FIGURE 1-16

ISOCONCENTRATION MAP FOR 2,4,6-TNT IN SHALLOW SOIL, AREA B, BASED ON MSE, 1998

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

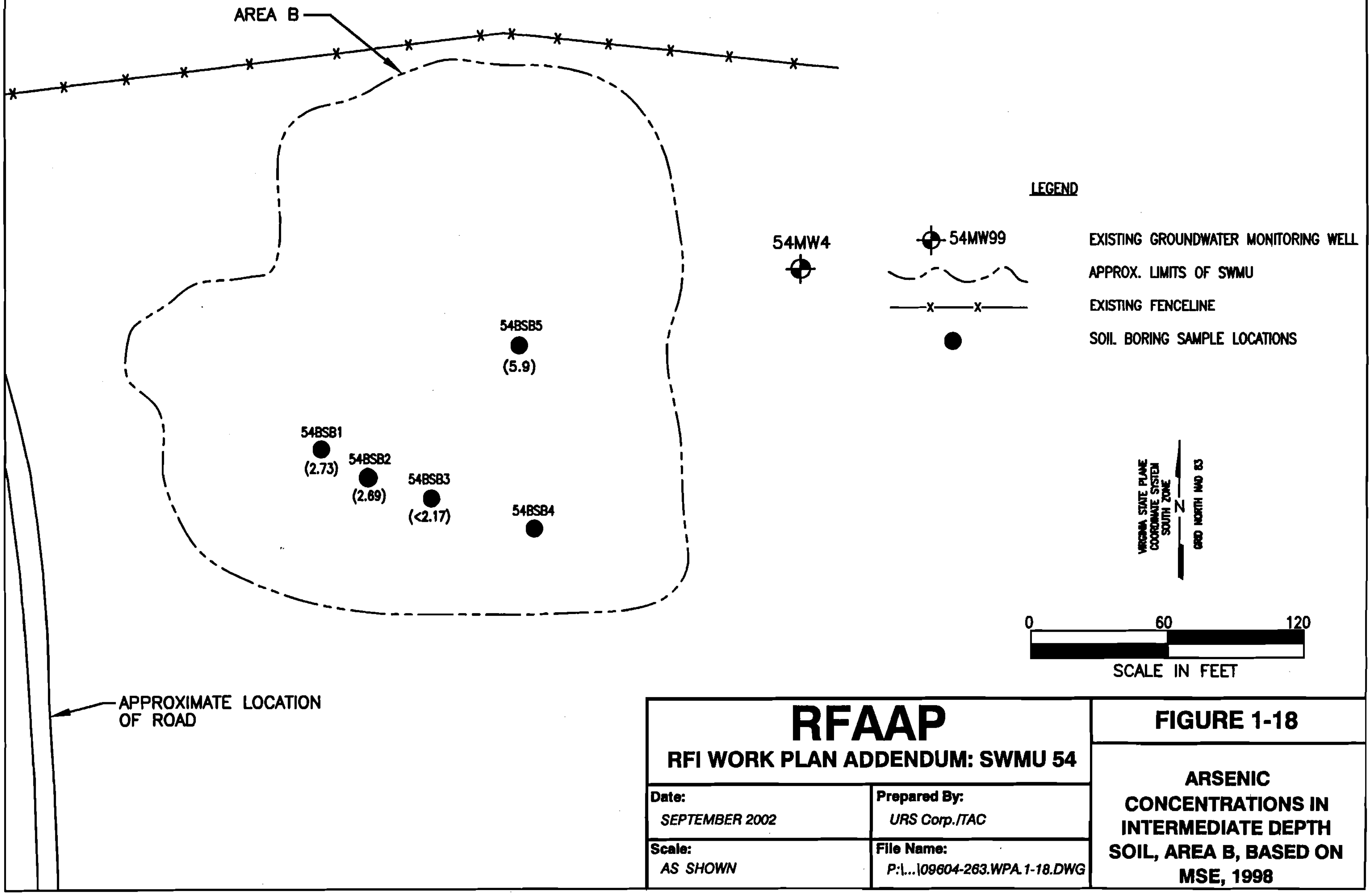
Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-17.DWG*

FIGURE 1-17

ISOCONCENTRATION MAP FOR BENZO [a] PYRENE IN SHALLOW SOIL, AREA B, BASED ON MSE, 1998

17

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date:
SEPTEMBER 2002

Prepared By:
URS Corp./TAC

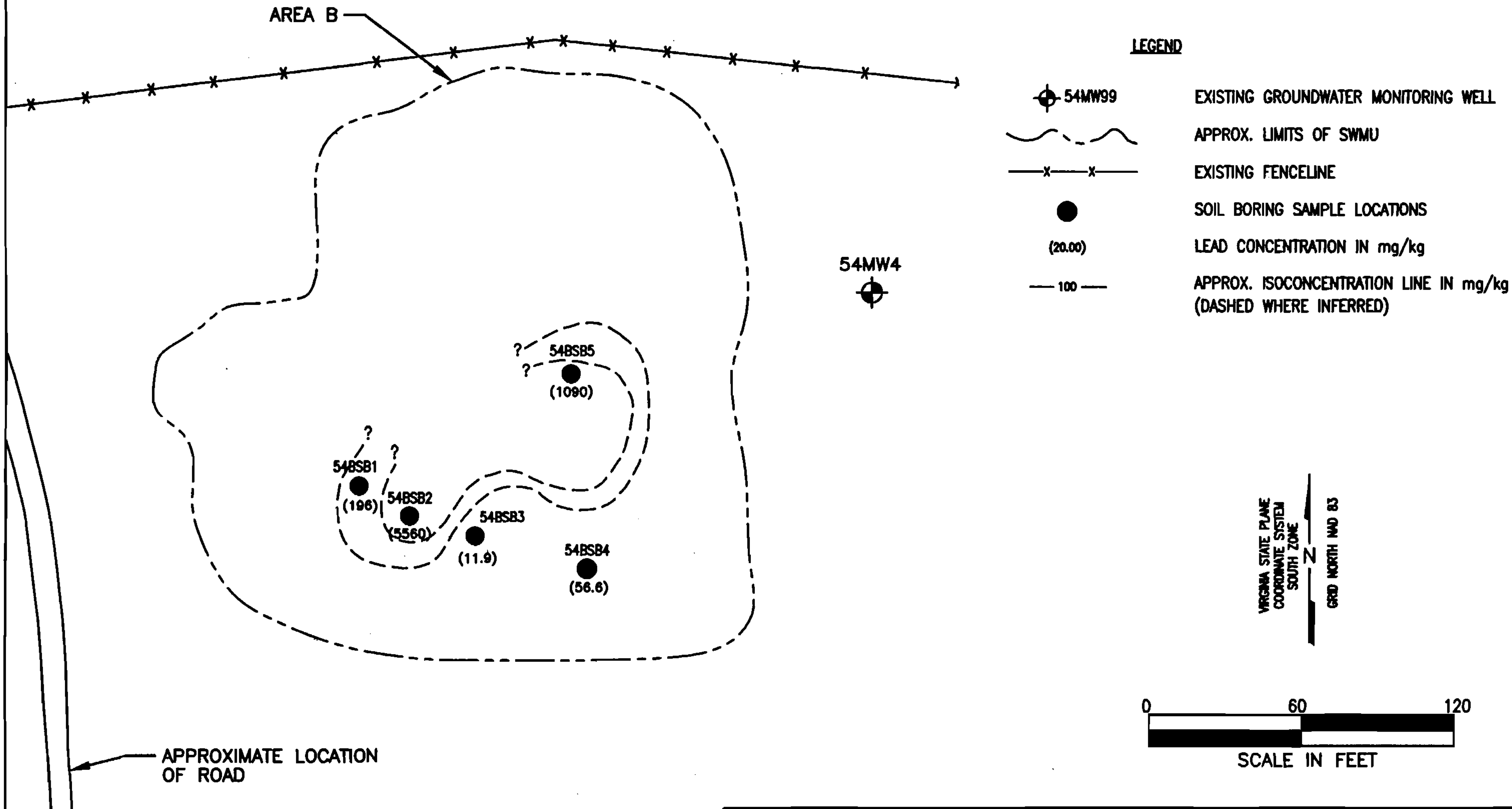
Scale:
AS SHOWN

File Name:
P:\...\09604-263.WPA.1-18.DWG

FIGURE 1-18

ARSENIC CONCENTRATIONS IN INTERMEDIATE DEPTH SOIL, AREA B, BASED ON MSE, 1998

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⊕ 54MW99	EXISTING GROUNDWATER MONITORING WELL
⌒ . ⌒	APPROX. LIMITS OF SWMU
—x—x—	EXISTING FENCELINE
●	SOIL BORING SAMPLE LOCATIONS
(20.00)	LEAD CONCENTRATION IN mg/kg
— 100 —	APPROX. ISOCONCENTRATION LINE IN mg/kg (DASHED WHERE INFERRED)

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*

Prepared By: *URS Corp./TAC*

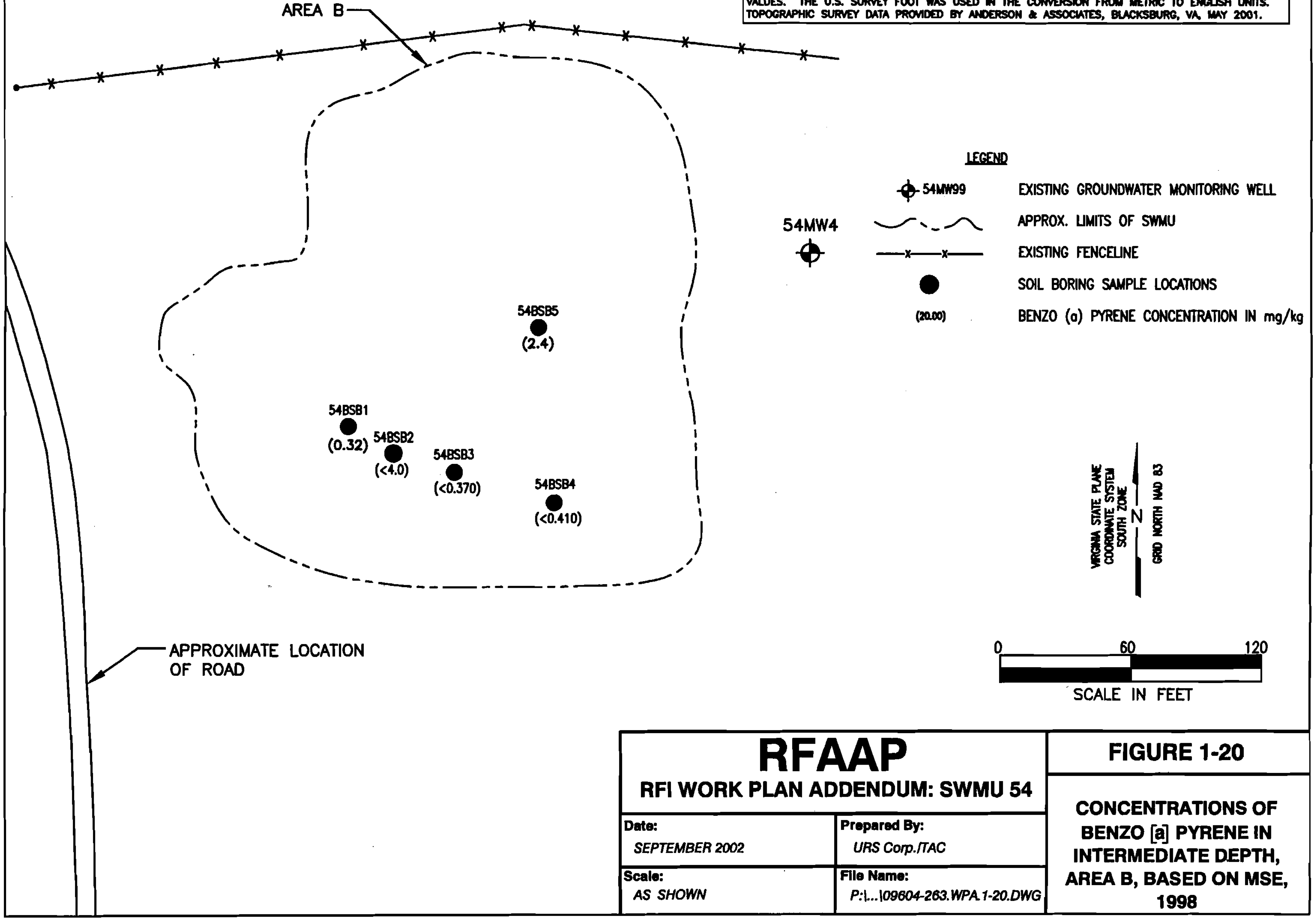
Scale: *AS SHOWN*

File Name: *P:\...\09604-263.WPA.1-19.DWG*

FIGURE 1-19

ISOCONCENTRATION MAP FOR LEAD IN INTERMEDIATE DEPTH SOIL, AREA B, BASED ON MSE, 1998

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-20.DWG

FIGURE 1-20

CONCENTRATIONS OF BENZO [a] PYRENE IN INTERMEDIATE DEPTH, AREA B, BASED ON MSE, 1998

Composited Soil - A review of the data for sample SC1, noted by MSE (1998) to represent a composite of 54BSS1 through 54BSS6, indicates that TCLP regulatory levels were not exceeded in the sample; however, it should be noted that the lack of detections in the analysis for TCLP VOCs is called into question. Samples for TCLP VOC analysis should be collected as discrete, non-composited samples to avoid the potential for volatilization of constituents during the compositing. Sample results from MSE (1998) for TCLP VOCs are biased low.

Groundwater - As part of the field investigation, MSE installed groundwater monitoring well 54MW4 downgradient of Area B within SWMU 54 (Figure 1-2). Bedrock was encountered at 19 ft bgs and the boring for well 54MW4 was advanced to 45 ft bgs. The well screen was set from 30 to 45 ft bgs, wholly within bedrock, and the well seal was placed across the bedrock/soil contact. The stabilized water level was reported as 17 ft bgs. MSE sampled groundwater monitoring wells 54MW1 and 54MW4 for laboratory analysis of TAL Metals (listed as TAL inorganics in MSE 1998), TCL VOCs and SVOCs (listed as TCL organics in MSE 1998), and explosives.

A review of the data indicates that total and dissolved aluminum, barium, chromium, iron and manganese were reported in the sample from upgradient well 54MW1 above their respective 2002 Tap Water RBCs (Table 1-4). No other total metals were reported as present in concentrations above their respective 2002 Tap Water RBCs or MCLs.

Risk Assessment - MSE conducted a conservative evaluation of baseline risk by comparing the maximum concentration of the COPCs identified by MSE (arsenic, lead, mercury, ten SVOCs and six explosives) to their then-current USEPA Region III RBCs and evaluating Residential and Industrial exposure potential. The risk analysis indicated "trespassers and recreational users of the site may be significantly exposed to lead in surface soil" (MSE 1998). In addition, MSE concluded that arsenic, lead, 2,4-DNT, 2,6-DNT, 2,4,6-TNT, and 2-amino-4,6-dinitrotoluene may pose risk to future residential receptors. MSE recommended that a CMS be conducted and that restrictions to site access be implemented to reduce exposure to potential receptors.

Conclusions - Based on information presented in MSE (1998) aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, mercury, 2,4,6-TNT, 2-amino-4,6-dinitrotoluene, 2,6-DNT, 2,4-DNT, benzo[a]anthracene, BAP, benzo[b]fluoranthene, dibenz[a,h]anthracene and indeno[1,2,3-cd]pyrene are identified as COPCs in Area B of SWMU 54. Lack of information regarding sampling methodologies and more importantly, sample depths and locations, does not allow for adequate characterization of soils in Area B within SWMU 54. Data generated by MSE and presented in MSE (1998) will be used as site-screening data.

COPCs in groundwater at Area B of SWMU 54 are not identified based on information presented in MSE (1998). While several constituents were reported as present above screening criteria, the detections are limited to the upgradient well 54MW1. Well 54MW1 is located upgradient of Area A in SWMU 54 and is located approximately 300 ft south of Area B. This distance could potentially lead to erroneous comparisons. In addition, more recent groundwater sampling results indicate that constituents are not present at concentrations exceeding screening criteria (see Section 1.2.3.5).

1.2.3.5 Correspondence August 20, 1999, Subject SWMU 54 Interim Action

On August 20, 1999, a letter report was sent to the USEPA that discussed actions to be taken by Parallax, Inc. The IA objectives were to eliminate the trespasser pathway and to mitigate source area impact consistent with any final remedy (Parallax 1999). IA activities conducted by Parallax included both Areas A and B of SWMU 54. IA activities included an initial phase of site screening and laboratory analysis of soils and groundwater followed by a subsequent phase of excavation and removal of approximately 1,827 tons of soil. IA activities took place within systematic grids established for both Areas A and B of SWMU 54. Further evaluation and reporting was to occur subsequent to this action. These follow-on actions were programmed in the later editions of the RFAAP Installation Action Plan (RFAAP 2002) that was discussed with the USEPA and the Virginia Department of Environmental Quality (VDEQ).

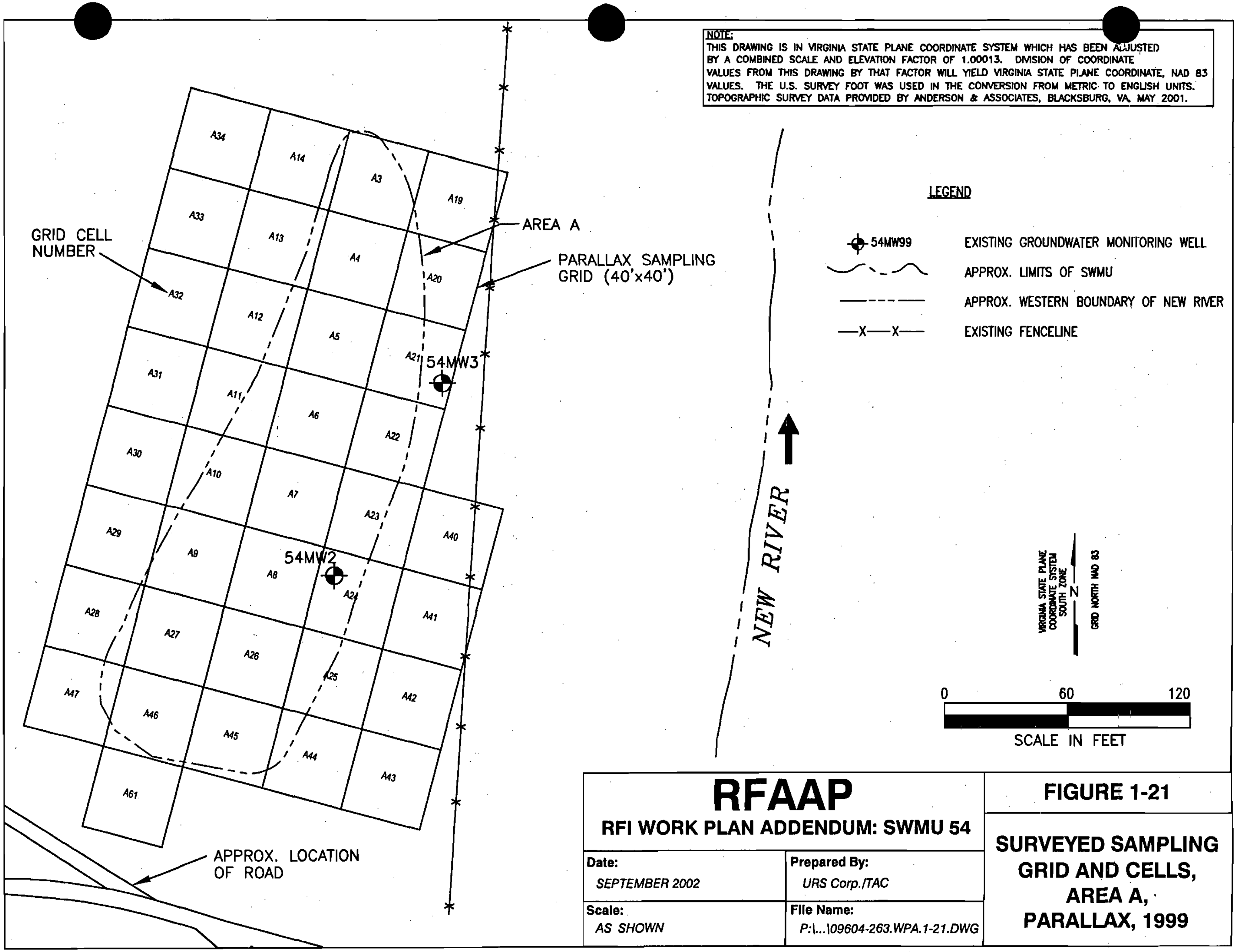
Prior to initiation of IA activities, Areas A and B of SWMU 54 were cleared of vegetation and a gravel road was constructed to facilitate access to Area B. Parallax then repositioned the Installation perimeter fence; the SWMU 54 area is located on RFAAP property but was previously located outside of the Installation perimeter fence. Old fencing was removed and new fencing was installed along the eastern and northern boundaries of the SWMU 54 area, thereby enclosing the area. Following site preparation, a surveyed grid was established. The grid was designed to extend beyond the presumed limits of both Area A and Area B of SWMU 54. Grid spacing for Area A was established as 40 ft by 40 ft, and grid spacing for Area B was established as 20 ft by 20 ft (Figures 1-21 and 1-22).

Site Screening - Sampling was initiated in the cell considered closest to an identified source area with subsequent samples collected from additional cells in a clockwise manner. Soil samples were collected from the approximate center of each grid cell using a small backhoe. Discrete samples were collected at 0.5 ft, 3.0 ft, 6.0 ft, etc. to the bottom sample depth. These discrete samples were field-screened using D-Tech immunoassay test kits (D-Tech kits) for explosives and portable x-ray fluorescence (XRF) for metals. Aliquots of each discrete sample from various elevations within each grid were then composited into a single sample that was submitted for laboratory analysis. Laboratory analysis on each of over 200 composite samples (not including QA/QC samples) included TAL Metals, explosives, VOCs and TCLP Metals. In some cases, Parallax considered lateral and vertical characterization to be complete in an area and a series of grid cells were skipped. Approximately 1,600 samples were screened in the field from 231 grid cells. Site screening in Area A extended to depths of 15.0 to 22.0 ft bgs. Site screening in Area B extended to depths of 7.0 to 12.0 ft bgs.

Parallax field screening and composite sampling data are presented herein as isoconcentration maps. Due to the large number of samples, the uncertainty with respect to exact sample locations (within 40 by 40 ft grids), and the screening level nature of the data, isoconcentration maps for lead were generated using default geostatistical procedures in the contouring program Surfer 7.02 by Golden Software, Inc. (i.e., kriging and variogram algorithms). As such, several assumptions were made in order to generate the maps including:

- Samples are assumed to come from the center of each grid;
- When computing interpolation weights, the algorithm considers the spacing between the point and the data locations;
- The algorithm considers the inherent length scale of the data;
- The algorithm considers the inherent trustworthiness of the data; and
- The algorithm incorporates natural anisotropy.

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

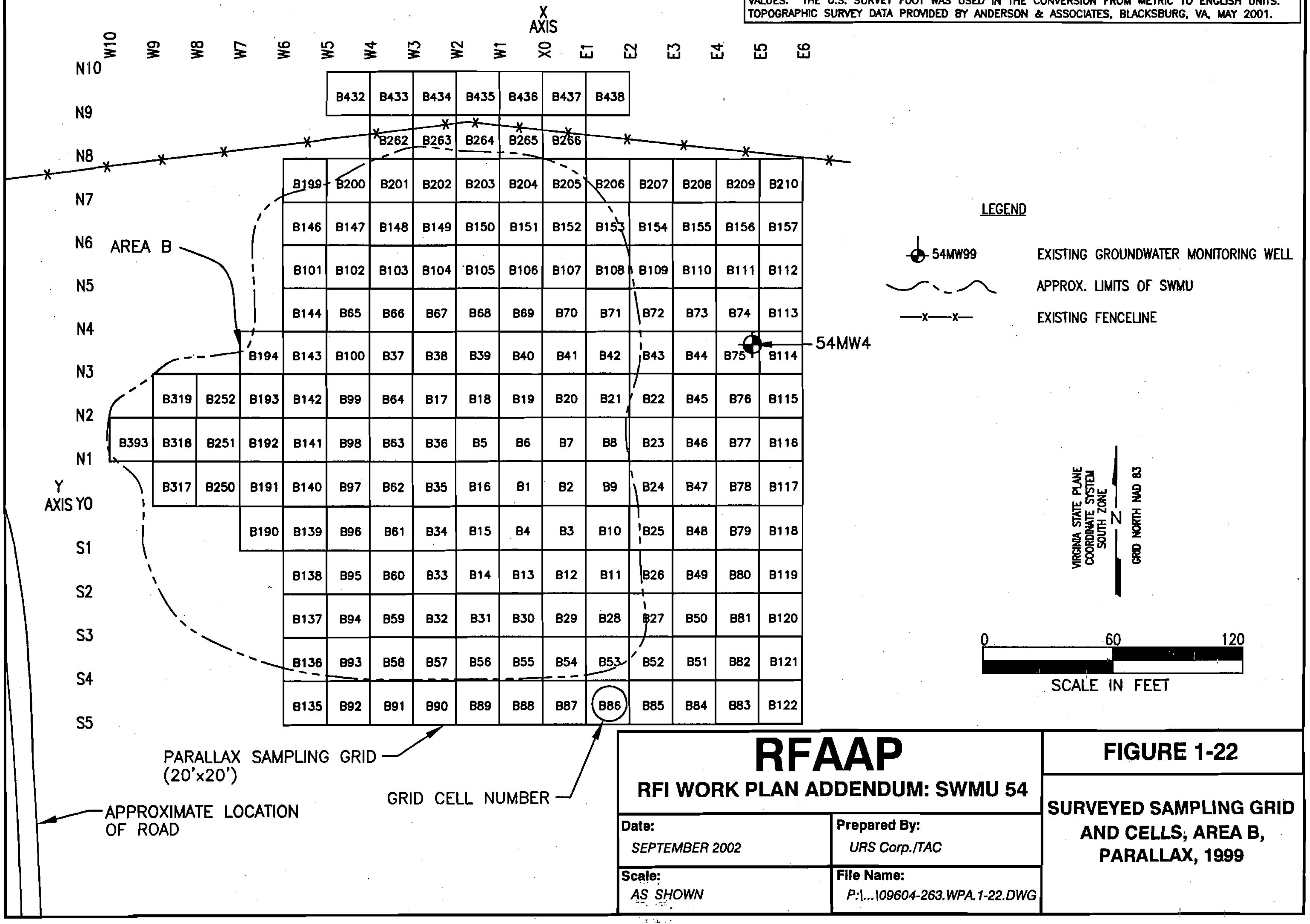
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-21.DWG

FIGURE 1-21

SURVEYED SAMPLING GRID AND CELLS, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



					B432	B433	B434	B435	B436	B437	B438				
						B262	B263	B264	B265	B266					
				B199	B200	B201	B202	B203	B204	B205	B206	B207	B208	B209	B210
				B146	B147	B148	B149	B150	B151	B152	B153	B154	B155	B156	B157
				B101	B102	B103	B104	B105	B106	B107	B108	B109	B110	B111	B112
				B144	B65	B66	B67	B68	B69	B70	B71	B72	B73	B74	B113
			B194	B143	B100	B37	B38	B39	B40	B41	B42	B43	B44	B75	B114
	B319	B252	B193	B142	B99	B64	B17	B18	B19	B20	B21	B22	B45	B76	B115
B393	B318	B251	B192	B141	B98	B63	B36	B5	B6	B7	B8	B23	B46	B77	B116
	B317	B250	B191	B140	B97	B62	B35	B16	B1	B2	B9	B24	B47	B78	B117
			B190	B139	B96	B61	B34	B15	B4	B3	B10	B25	B48	B79	B118
				B138	B95	B60	B33	B14	B13	B12	B11	B26	B49	B80	B119
				B137	B94	B59	B32	B31	B30	B29	B28	B27	B50	B81	B120
				B136	B93	B58	B57	B56	B55	B54	B53	B52	B51	B82	B121
				B135	B92	B91	B90	B89	B88	B87	B86	B85	B84	B83	B122

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-22.DWG

FIGURE 1-22

SURVEYED SAMPLING GRID AND CELLS, AREA B, PARALLAX, 1999

163

Because these data are henceforth used to focus further investigation, which are intended to produce definitive data, these assumptions are herein considered valid for screening purposes. Analytical data tables for Parallax soil composite samples are presented in Appendix B of this document.

Area A Site Screening - Figures 1-23 through 1-30 present isoconcentration maps developed based on the results of field screening for lead in Area A of SWMU 54 using portable XRF technology. Screening results are presented for samples collected from 0.5, three, six, nine, 12, 15, 18, and 22 ft bgs. As indicated by the isoconcentration maps, concentrations of lead were highest in the southern portion of Area A in SWMU 54 (i.e., near the previously defined southern mound in Area A of SWMU 54). Lead concentrations above 1,000 mg/kg, the lead AL for Industrial soils, were not recorded at depths greater than three ft bgs. Quantification of lead concentrations using the portable XRF was intended for site screening and does not allow for definitive identification of COPCs.

A review of the data for laboratory analytical results of the composite samples indicates that aluminum, arsenic, chromium, iron, lead, manganese and mercury were reported above their respective 2002 Residential Soil RBCs in at least one sample from Area A. In addition, the explosives 2,4,6-TNT, 4-amino-2,6-dinitrotoluene, 2,6-DNT, cyclotrimethylenetrinitramine (RDX), 2-amino-4,6-dinitrotoluene, and 2,4-DNT were detected at concentrations above their respective 2002 Residential Soil RBCs in at least one sample collected from Area A.

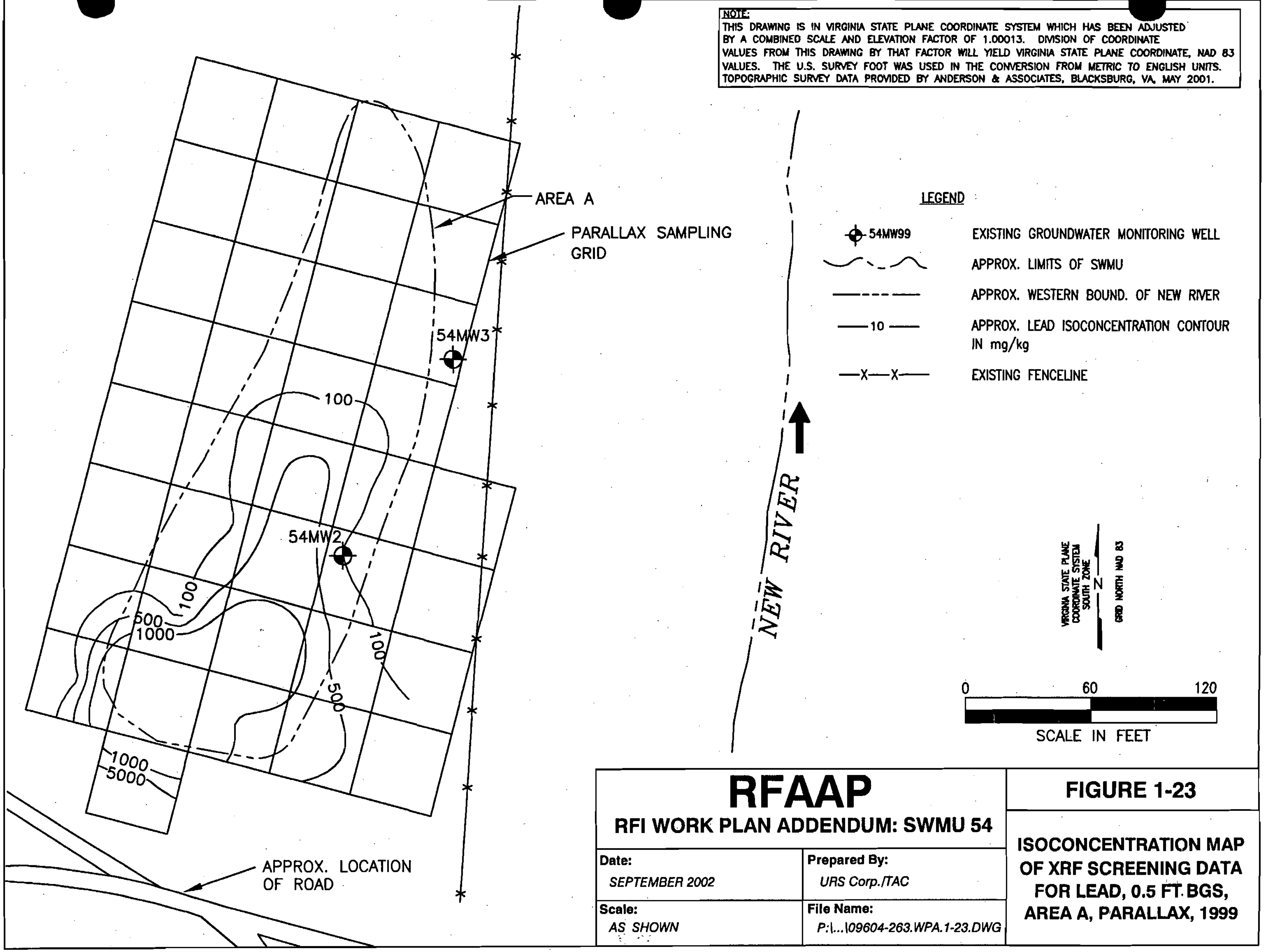
Data for laboratory analytical results indicates that lead was reported as equal to its 2002 Industrial AL of 1,000 mg/kg in one composite soil sample. Figure 1-31 presents isoconcentration contours in Area A of SWMU 54 for lead in composite samples (analytical laboratory data). As indicated, concentrations of lead reported from composite samples were also highest in the southern portion of Area A in SWMU 54, thus, the field-screening data are corroborated by composite laboratory analytical data.

2,4,6-TNT was reported above its 2002 Industrial Soil RBC of 190 mg/kg in three composite soil samples collected from Area A of SWMU 54. Figure 1-32 presents isoconcentration lines in Area A of SWMU 54 for 2,4,6-TNT in composite samples (analytical laboratory data).

A review of the laboratory data for TCLP Metals analysis on composite samples indicates that TCLP lead was reported above its regulatory limit of 5.0 mg/L in one sample from Area A of SWMU 54.

Area B Site Screening - Figures 1-33 through 1-37 present the isoconcentration maps developed based on the results of the field screening for lead in Area B of SWMU 54 using portable XRF technology. Screening results are presented for samples collected from 0.5, three, six, nine, and 12 ft bgs. As indicated by the field-screening analysis data, concentrations of lead were highest in two distinct areas in the western and northwestern portions of Area B in SWMU54. Lead concentrations above 1,000 mg/kg, the Industrial Soil AL, were not recorded at depths greater than nine ft bgs. Quantification of lead concentrations using the portable XRF was intended for site screening and does not allow for definitive identification of COPCs.

A review of the data for laboratory analytical results of the composite samples indicates that aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, and thallium were reported above their respective 2002 Residential Soil RBCs (Residential AL for lead) in at least one sample collected from Area B. In addition, the explosives 2,4,6-TNT, 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, and 2,4-DNT were detected at concentrations above their respective 2002 Residential Soil RBCs in at least one Area B sample.



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

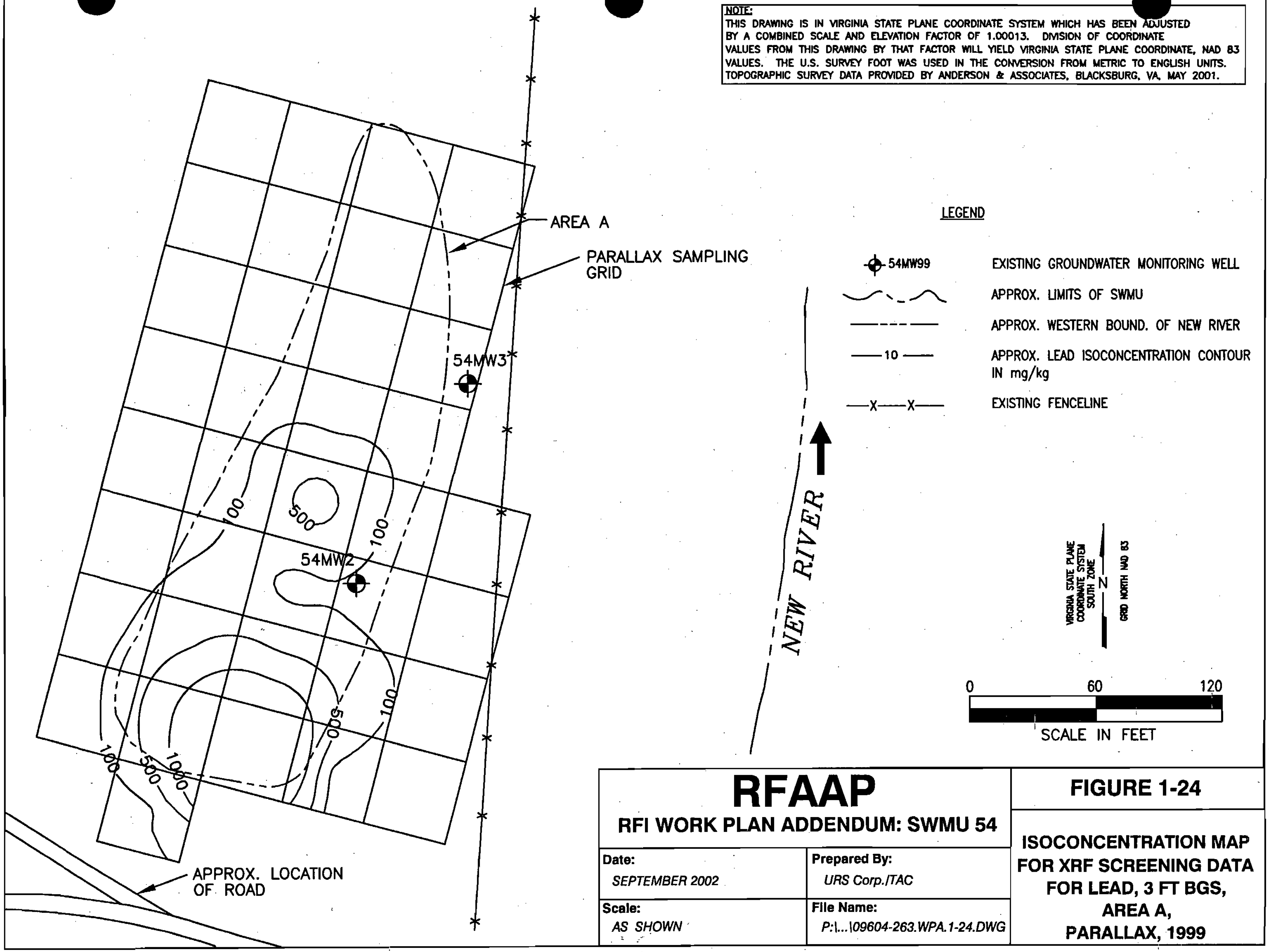
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-23.DWG

FIGURE 1-23

ISOCONCENTRATION MAP OF XRF SCREENING DATA FOR LEAD, 0.5 FT BGS, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

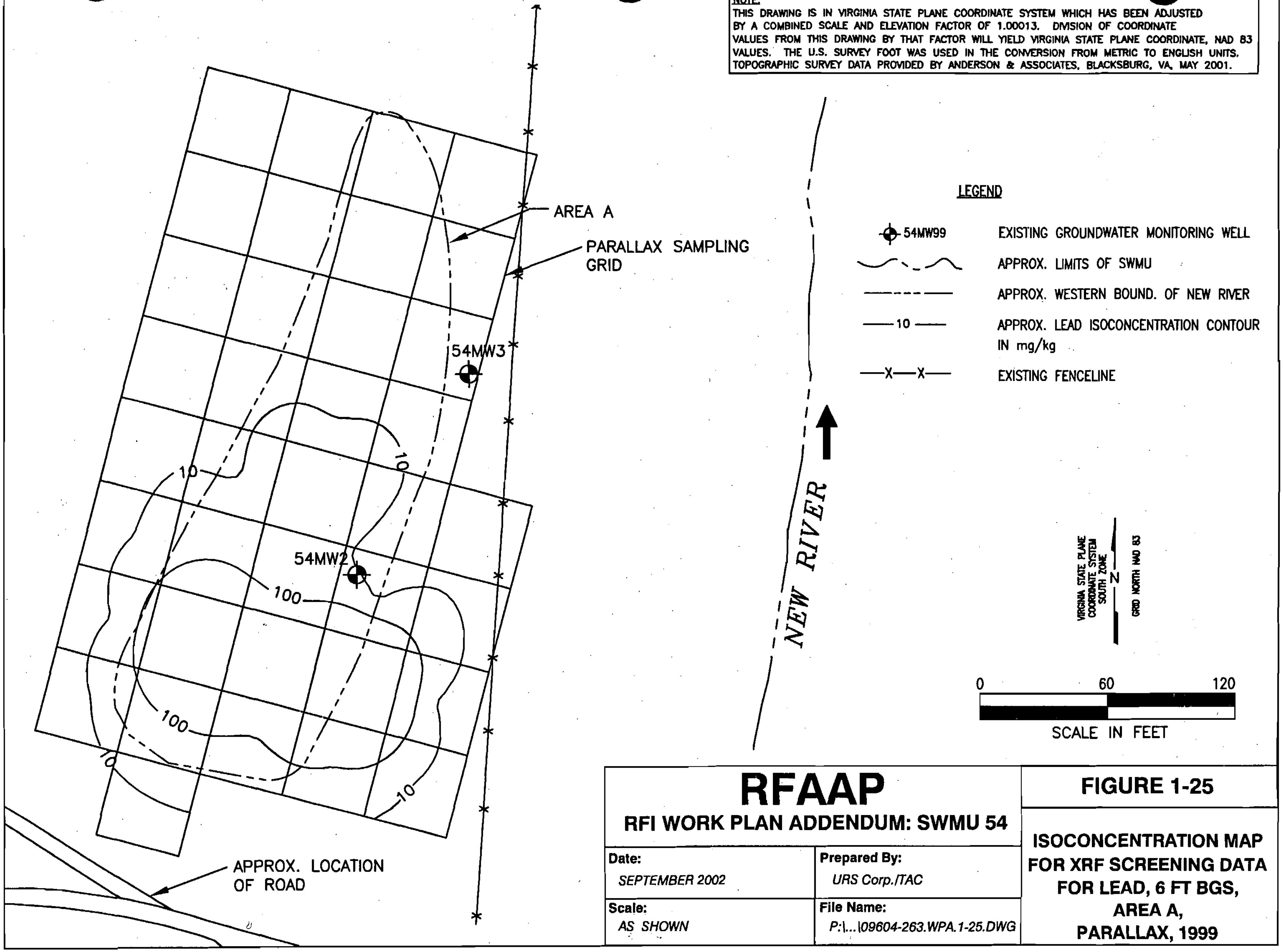
Date: SEPTEMBER 2002
Prepared By: URS Corp./TAC
Scale: AS SHOWN
File Name: P:\...\09604-263.WPA.1-24.DWG

FIGURE 1-24

ISOCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 3 FT BGS, AREA A, PARALLAX, 1999

16p

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

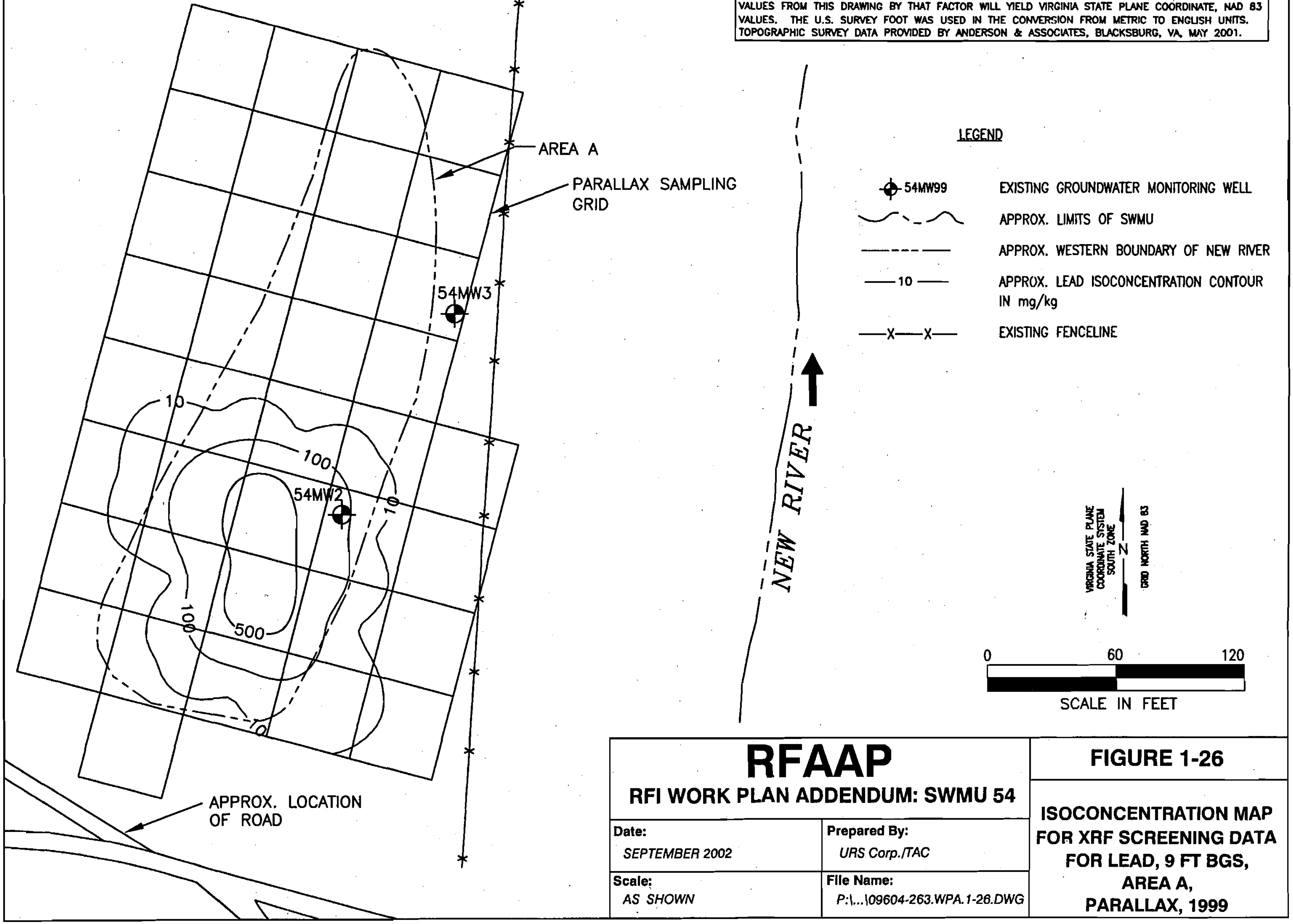
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-25.DWG

FIGURE 1-25

ISOCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 6 FT BGS, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

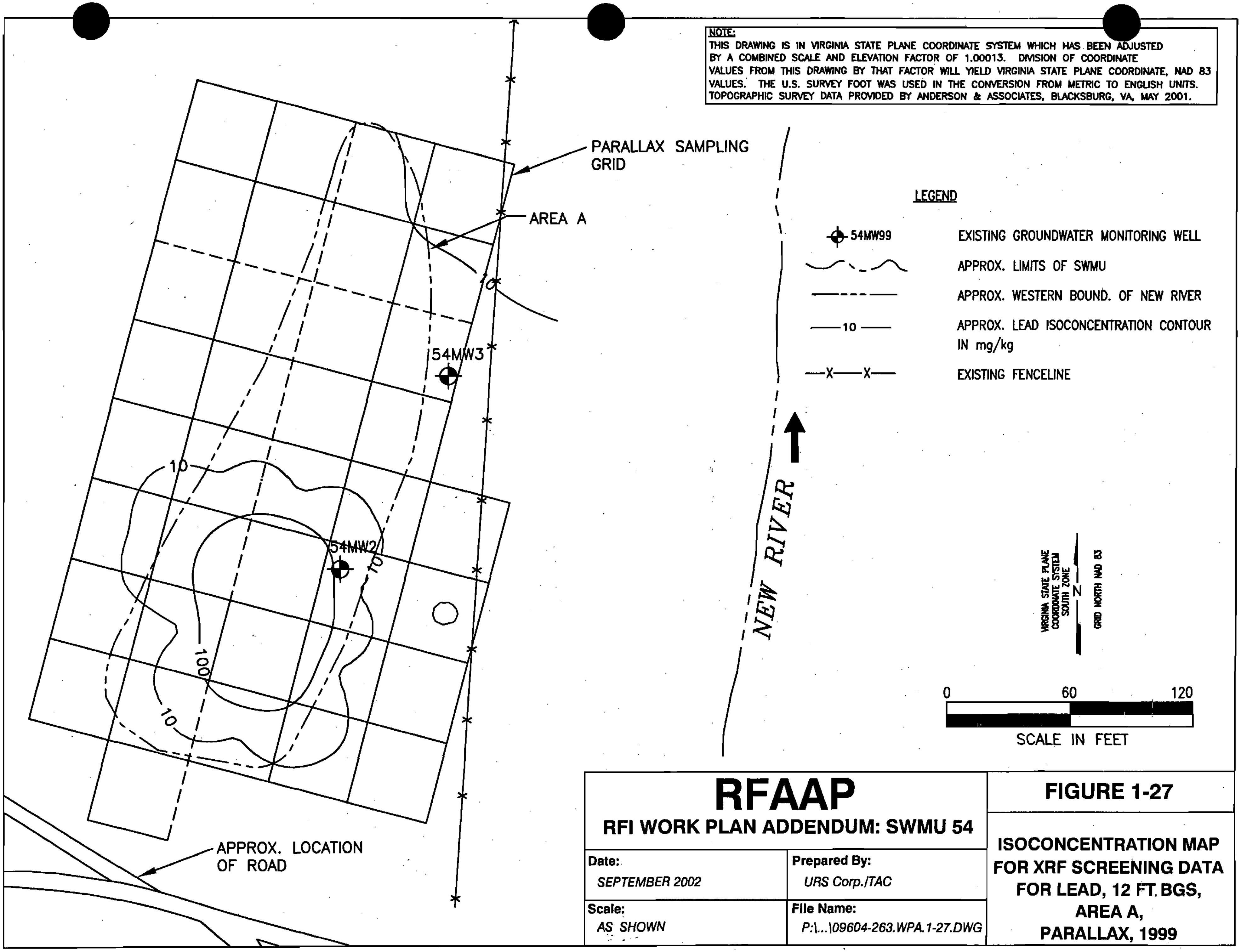
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-26.DWG

FIGURE 1-26

ISOCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 9 FT BGS, AREA A, PARALLAX, 1999

123



NOTE:

THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

LEGEND

⊕ 54MW99	EXISTING GROUNDWATER MONITORING WELL
	APPROX. LIMITS OF SWMU
— - - - —	APPROX. WESTERN BOUND. OF NEW RIVER
—— 10 ——	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
—X——X—	EXISTING FENCELINE

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

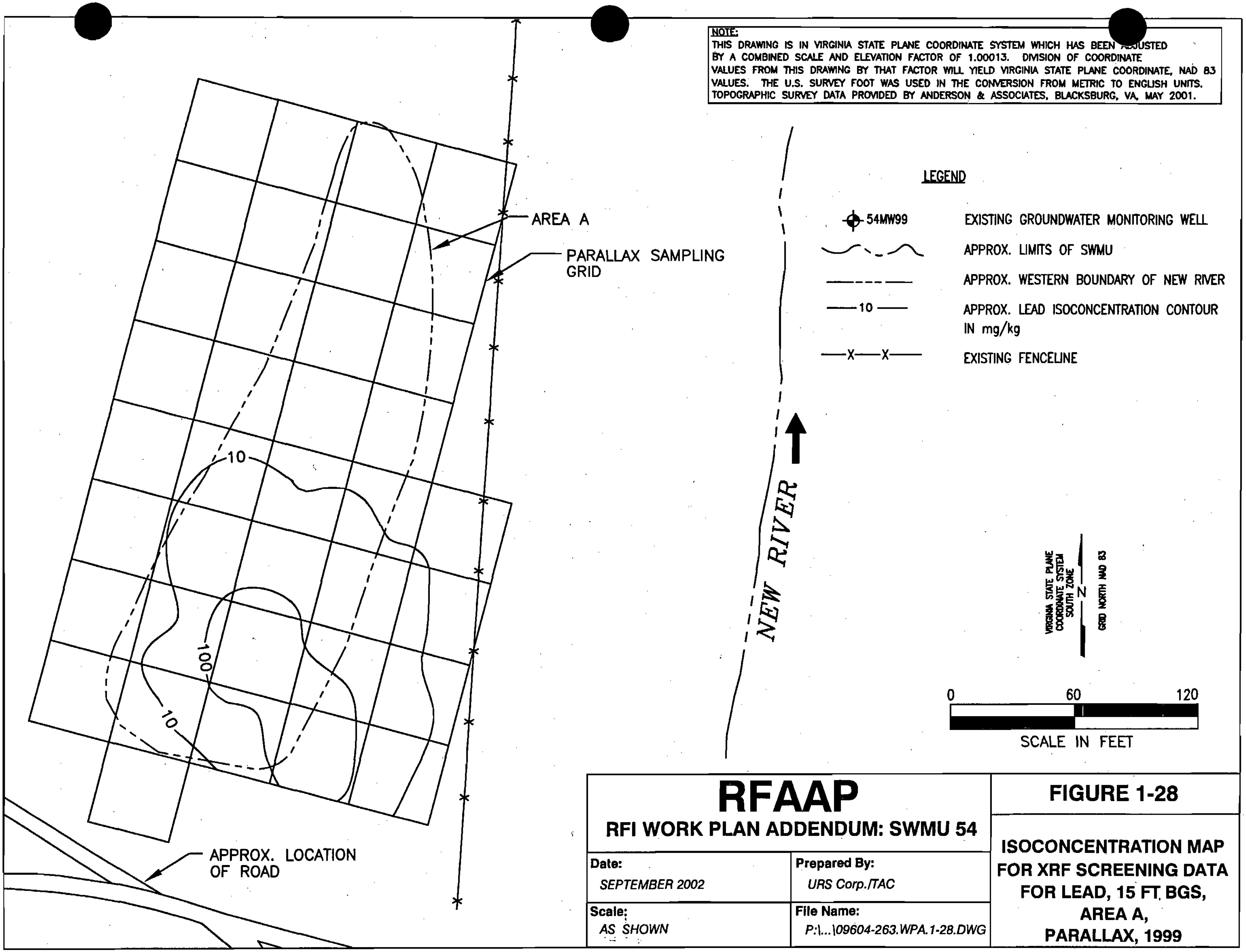
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-27.DWG

FIGURE 1-27

ISOCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 12 FT. BGS, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



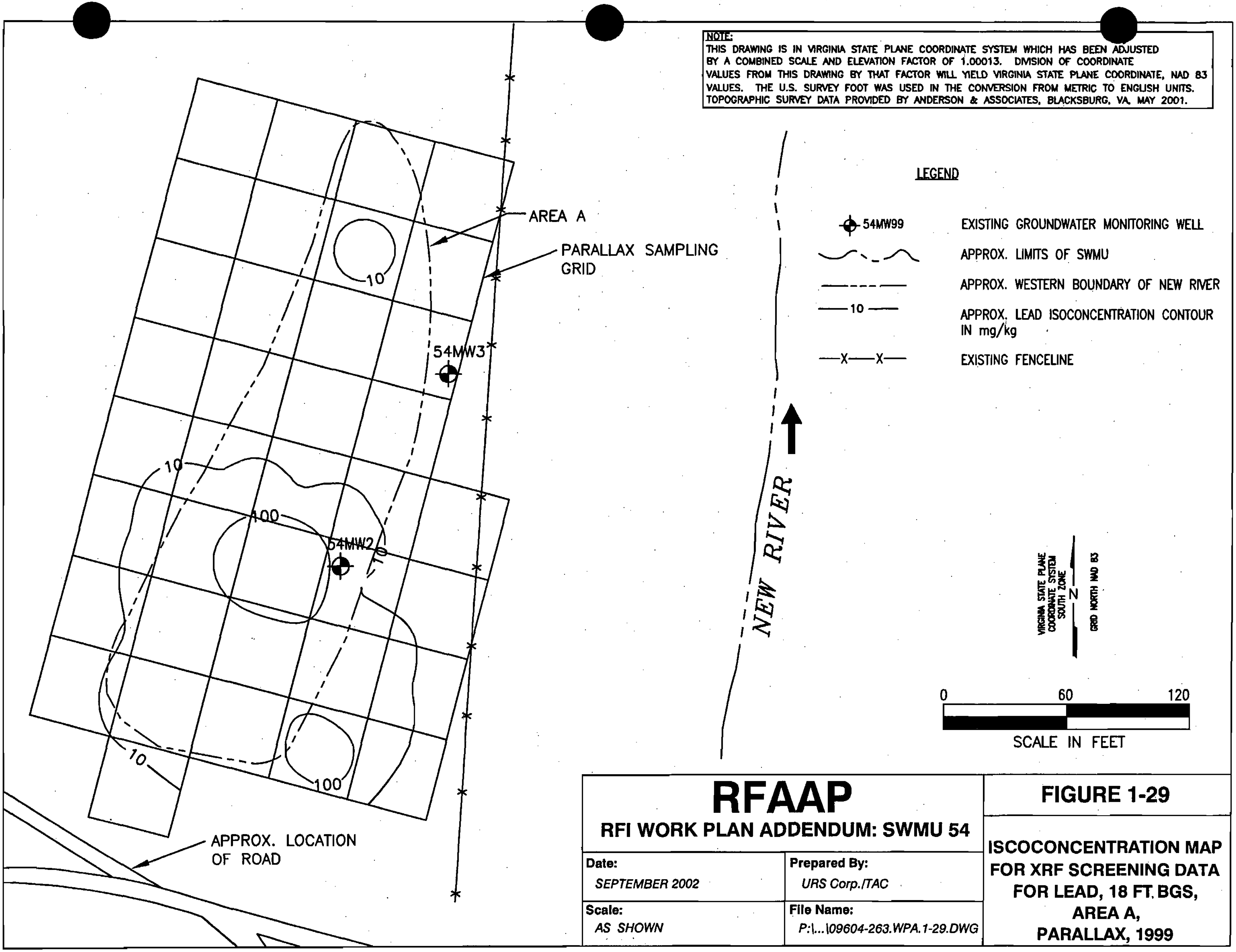
RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-28.DWG

FIGURE 1-28

ISOCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 15 FT. BGS, AREA A, PARALLAX, 1999



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA. MAY 2001.

LEGEND

⊕ 54MW99	EXISTING GROUNDWATER MONITORING WELL
〜 - 〜	APPROX. LIMITS OF SWMU
— — — ——	APPROX. WESTERN BOUNDARY OF NEW RIVER
—— 10 ——	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
—X—X—	EXISTING FENCELINE

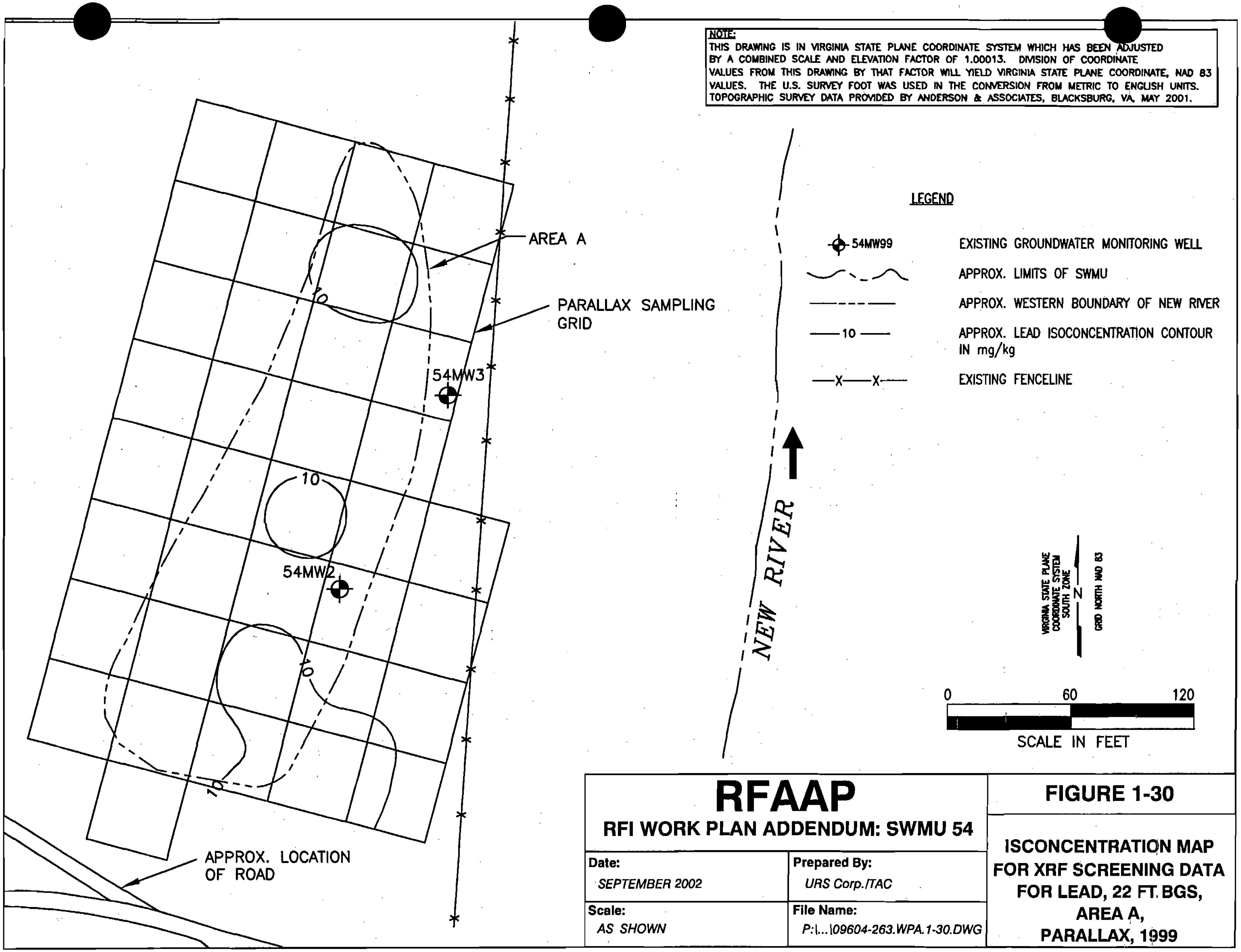
RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-29.DWG*

FIGURE 1-29

ISCOCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 18 FT. BGS, AREA A, PARALLAX, 1999



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

LEGEND

54MW99	EXISTING GROUNDWATER MONITORING WELL
	APPROX. LIMITS OF SWMU
	APPROX. WESTERN BOUNDARY OF NEW RIVER
—10—	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
—X—X—	EXISTING FENCELINE

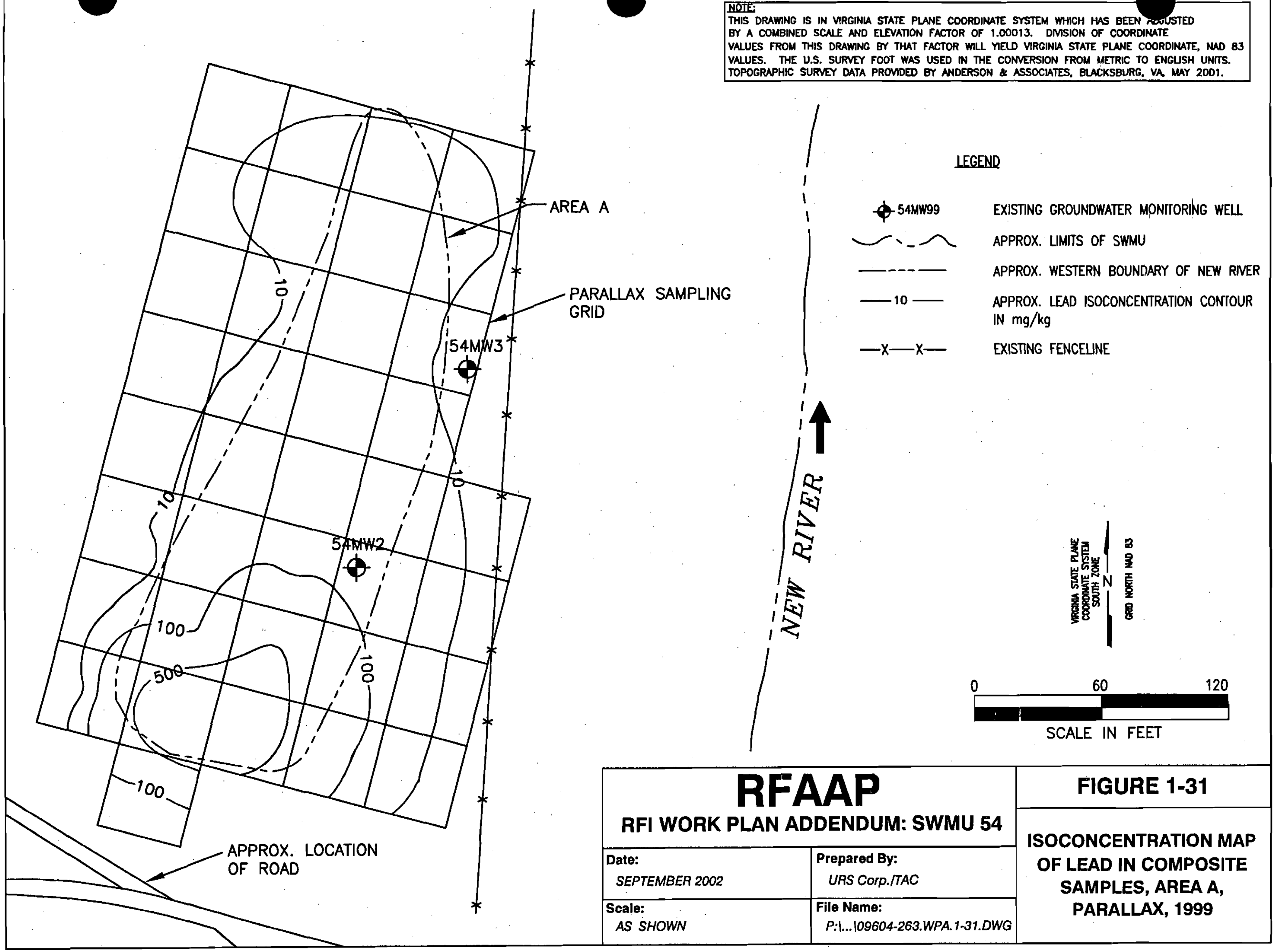
RFAAP
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-30.DWG

FIGURE 1-30

ISCONCENTRATION MAP FOR XRF SCREENING DATA FOR LEAD, 22 FT. BGS, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

54MW99	EXISTING GROUNDWATER MONITORING WELL
	APPROX. LIMITS OF SWMU
	APPROX. WESTERN BOUNDARY OF NEW RIVER
10	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
X X	EXISTING FENCELINE

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

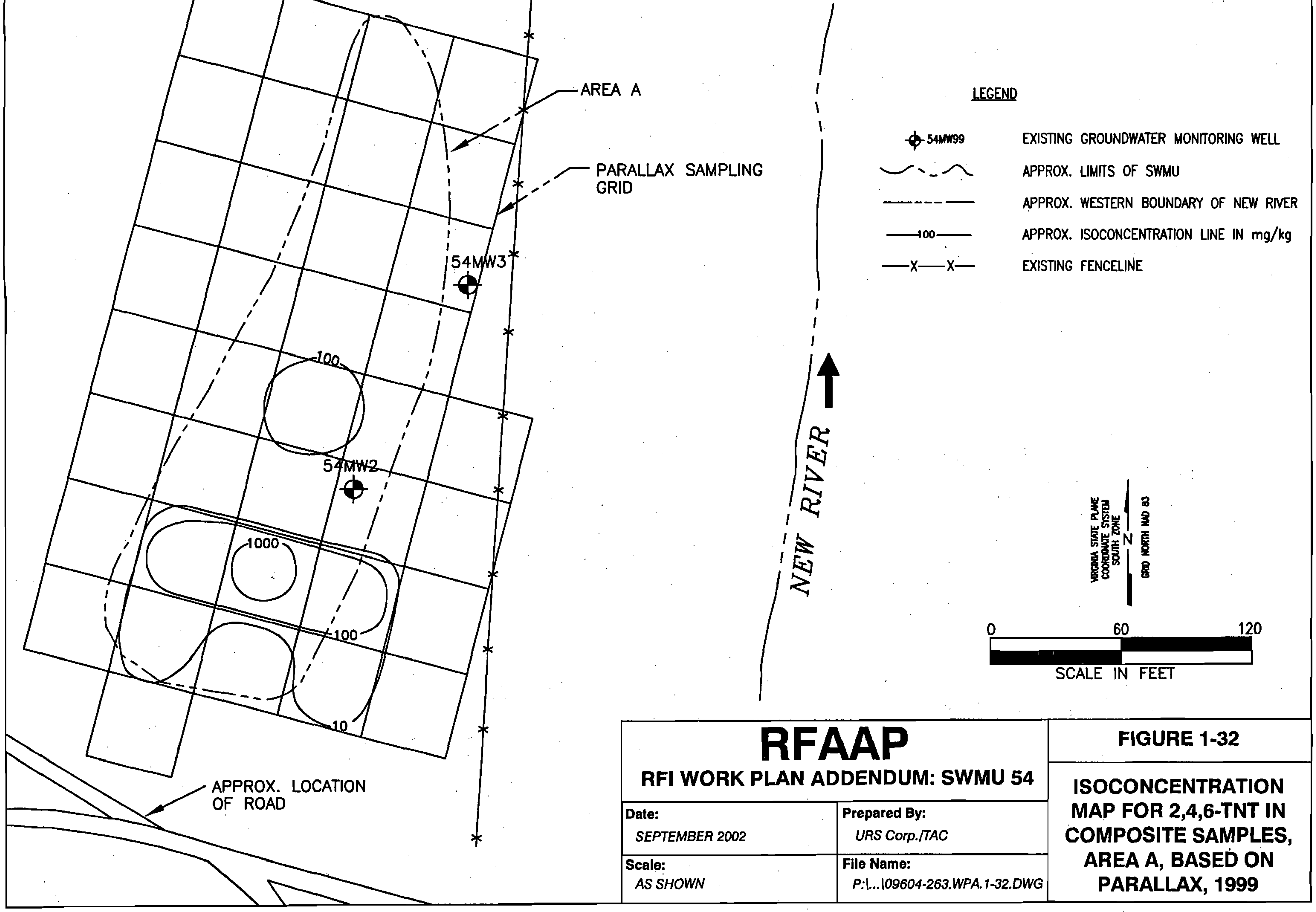
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-31.DWG

FIGURE 1-31

ISOCONCENTRATION MAP OF LEAD IN COMPOSITE SAMPLES, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

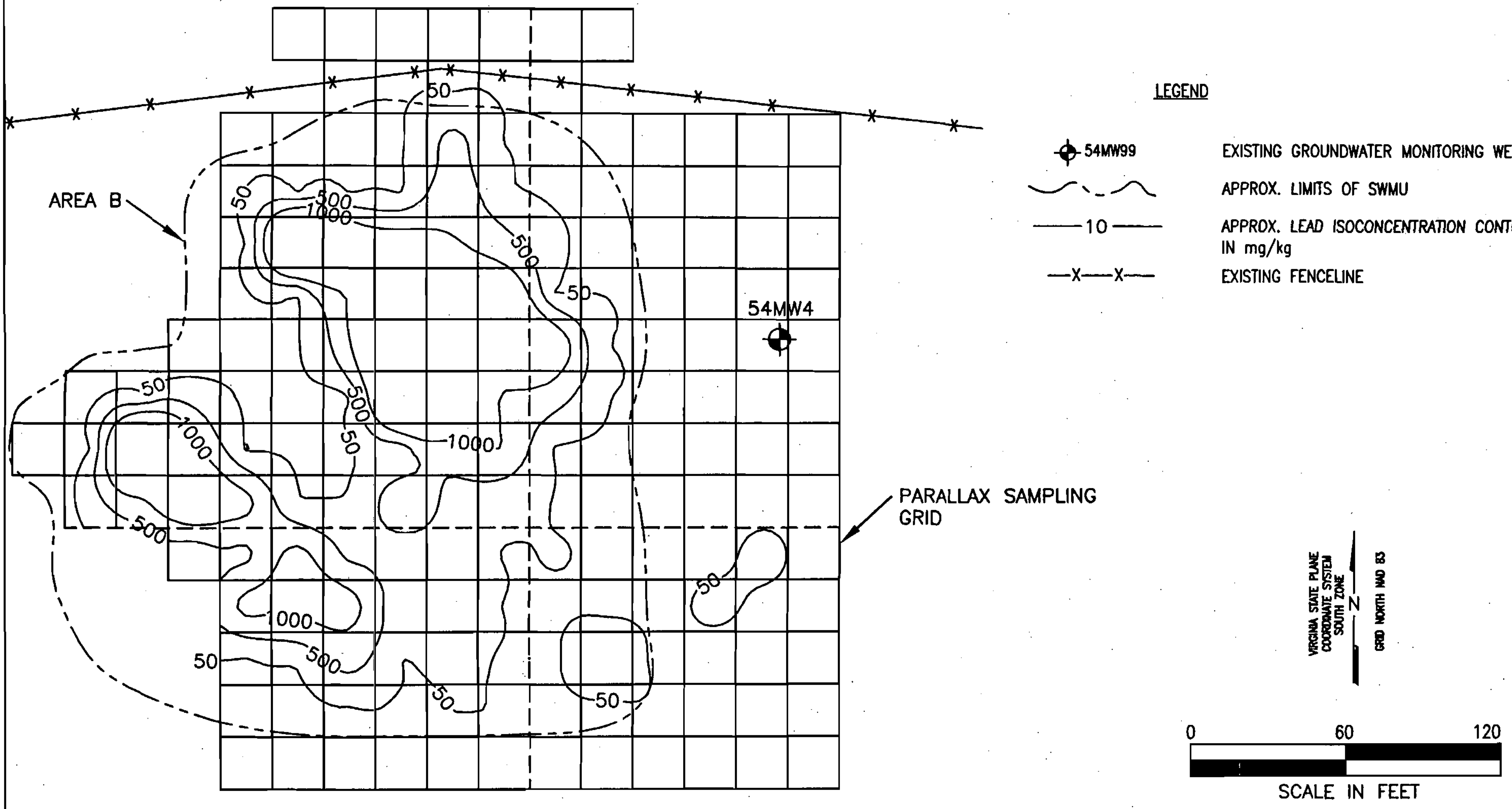
Date:	Prepared By:
SEPTEMBER 2002	URS Corp./TAC

Scale:	File Name:
AS SHOWN	P:\...\09604-263.WPA.1-32.DWG

FIGURE 1-32

ISOCONCENTRATION MAP FOR 2,4,6-TNT IN COMPOSITE SAMPLES, AREA A, BASED ON PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
︵‿︵	APPROX. LIMITS OF SWMU
——10——	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
—X—X—	EXISTING FENCELINE

RFAAP

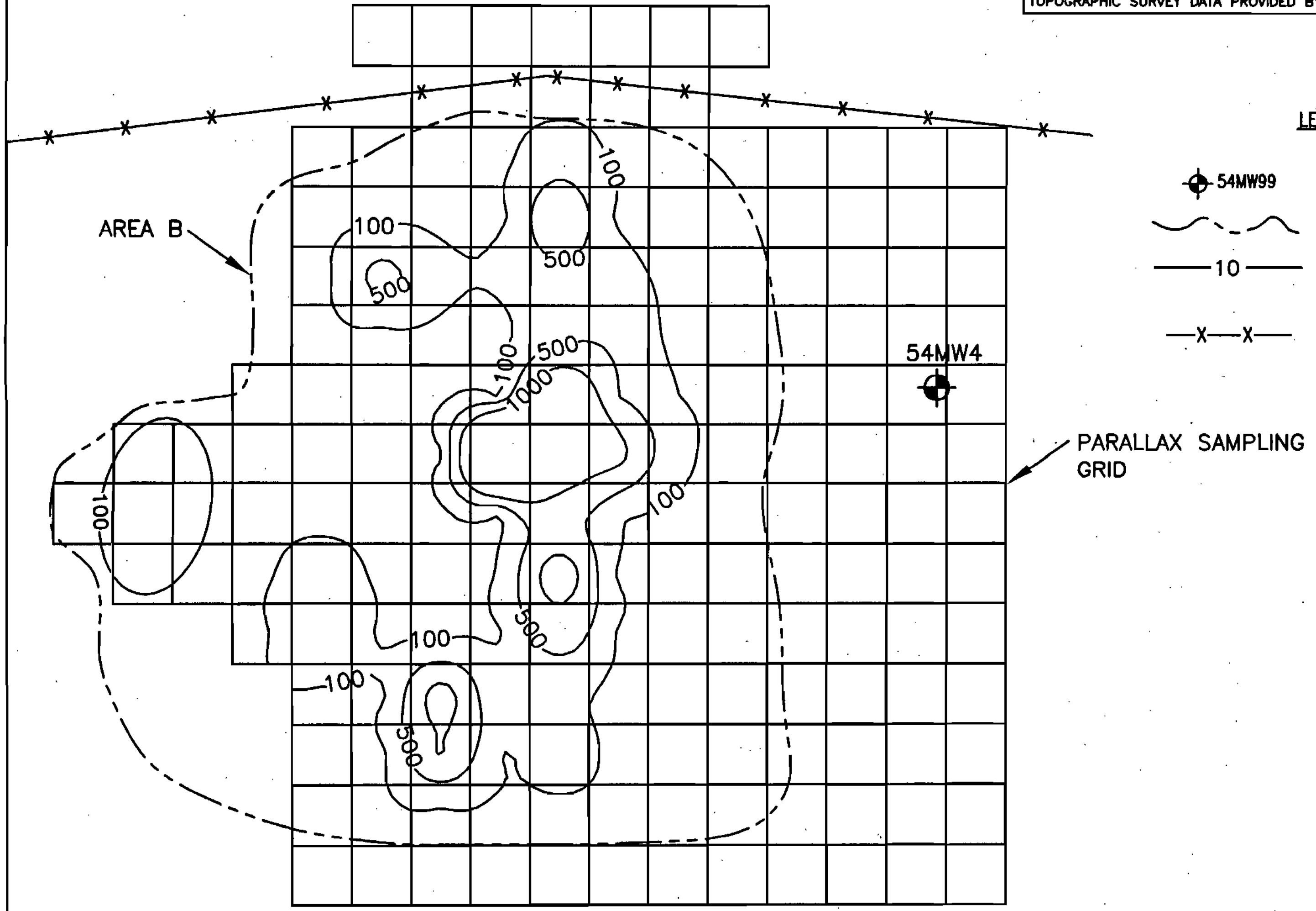
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-33.DWG

FIGURE 1-33

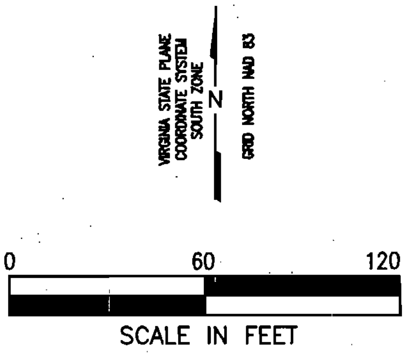
ISOCONCENTRATION MAP OF XRF SCREENING DATA FOR LEAD, 0.5 FT BGS, AREA B, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⊕ 54MW99	EXISTING GROUNDWATER MONITORING WELL
∿ - ∿	APPROX. LIMITS OF SWMU
—— 10 ——	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
—X—X—	EXISTING FENCELINE



RFAAP

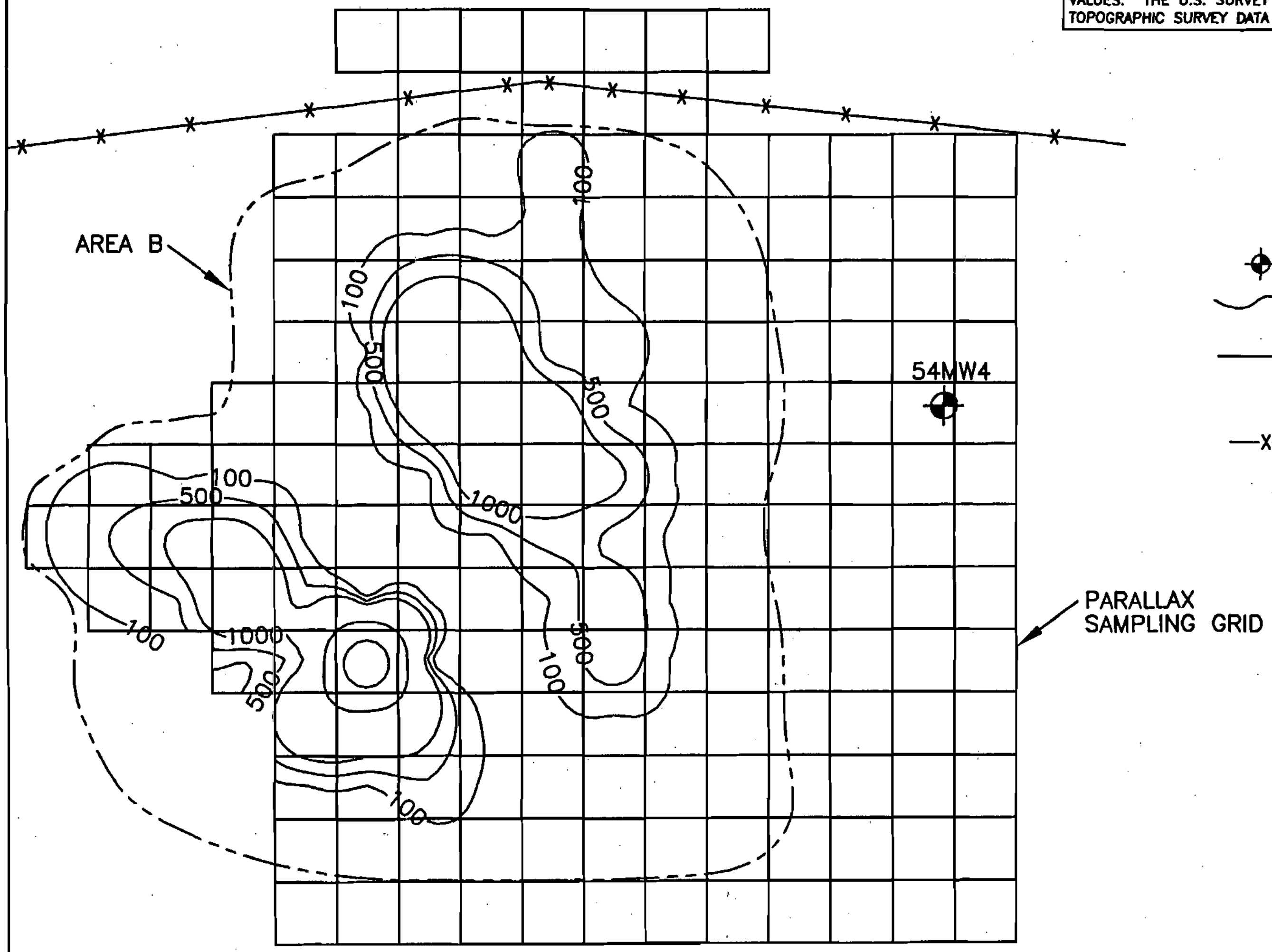
RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-34.DWG*

FIGURE 1-34

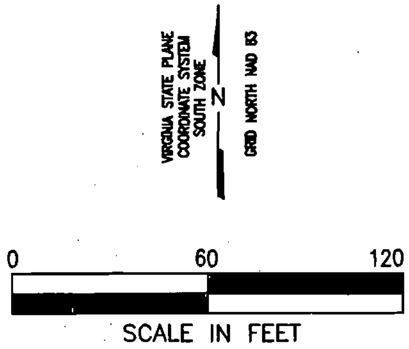
ISOCONCENTRATION MAP OF XRF SCREENING DATA FOR LEAD, 3 FT BGS, AREA B, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
～ - ～	APPROX. LIMITS OF SWMU
—— 10 ——	APPROX. LEAD ISOCONCENTRATION CONTOUR IN mg/kg
—X—X—	EXISTING FENCELINE



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

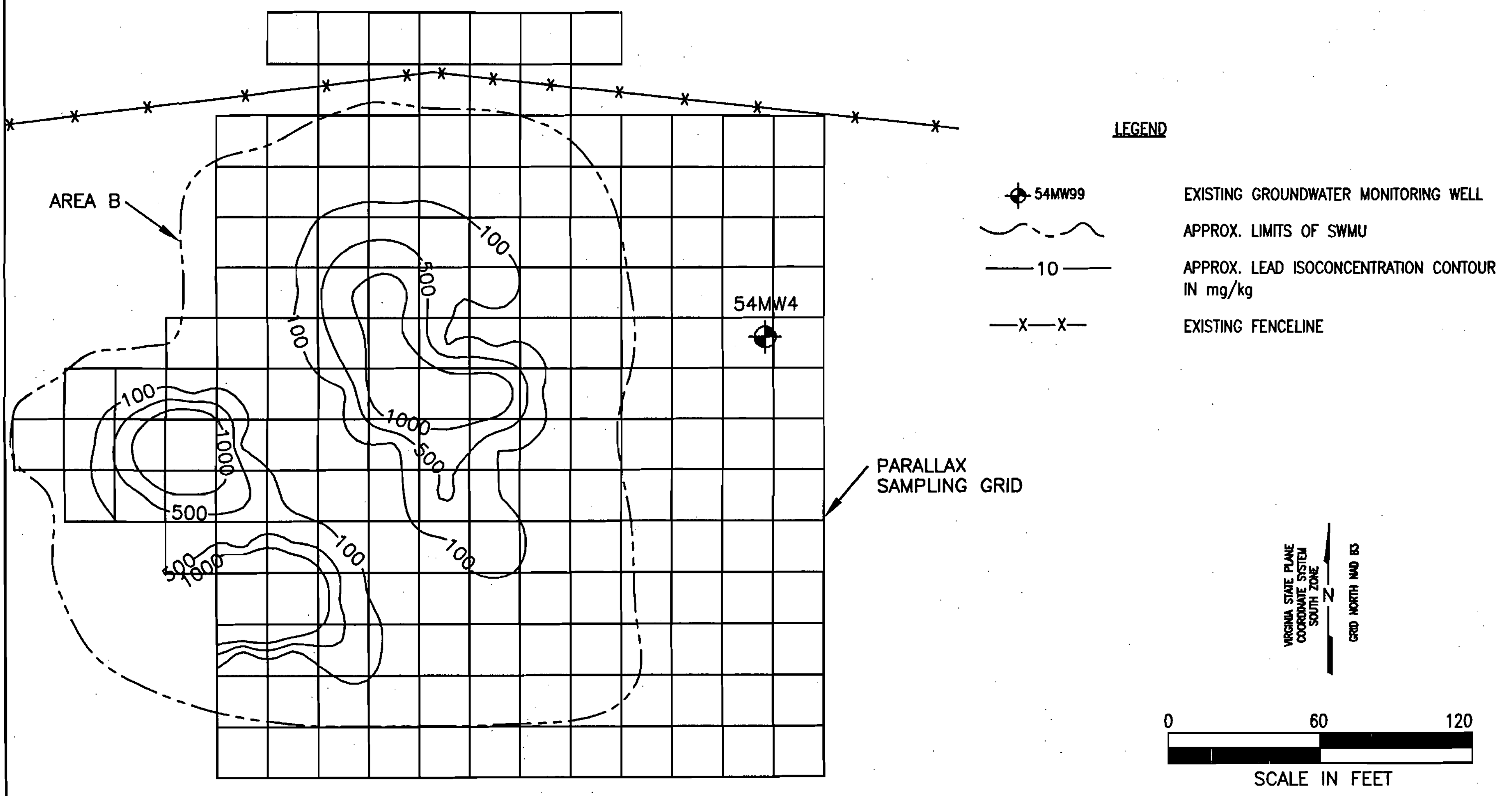
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-35.DWG

FIGURE 1-35

ISOCONCENTRATION MAP OF XRF SCREENING DATA FOR LEAD, 6 FT BGS, AREA B, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

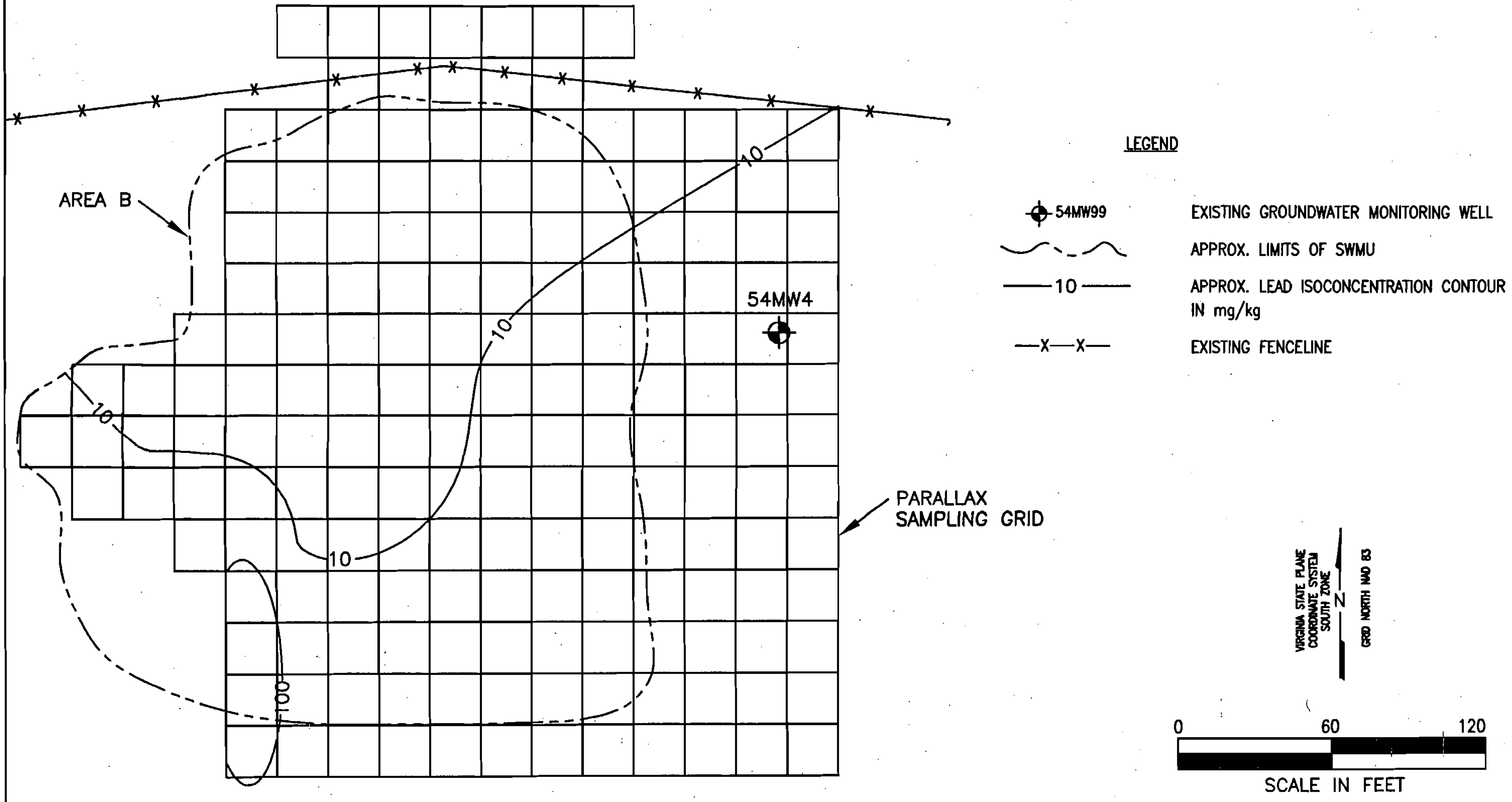
RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-36.DWG*

FIGURE 1-36

ISOCONCENTRATION MAP OF XRF SCREENING DATA FOR LEAD, 9 FT BGS, AREA B, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-37.DWG*

FIGURE 1-37

ISOCONCENTRATION MAP OF XRF SCREENING DATA FOR LEAD, 12 FT BGS, AREA B, PARALLAX, 1999

13

A review of the data for laboratory analytical results of the composite samples indicates that lead was reported above its 2002 Industrial AL of 1,000 mg/kg in 22 composite soil samples and arsenic was reported above its 2002 Industrial Soil RBC of 3.8 mg/kg in 28 composite soil samples. Figure 1-38 presents isoconcentration lines in Area B of SWMU 54 for lead in composite samples (analytical laboratory data). Figure 1-39 presents isoconcentration lines in Area B of SWMU 54 for arsenic in composite samples (analytical laboratory data). As indicated, concentrations of lead and arsenic reported from composite samples are highest in the western and northwestern portions of Area B in SWMU54, thus field-screening data results for lead are corroborated by composite laboratory analytical data for lead.

2,4,6-TNT was reported above its 2002 Industrial Soil RBC of 190 mg/kg in one composite soil sample. Figure 1-40 presents isoconcentration lines in Area A of SWMU 54 for 2,4,6-TNT in composite samples. 2-amino-4,6-dinitrotoluene and 4-amino-2,6-dinitrotoluene were both reported as present above their 2002 Industrial Soil RBCs of 12.0 mg/kg in a single sample from Area B of SWMU 54.

A review of the laboratory data for TCLP Metals analysis on composite samples indicates that TCLP lead was reported above its regulatory limit of 5.0 mg/L in ten samples from Area B of SWMU 54. The data are presented in Appendix B of this WPA.

Limited detections of the common laboratory contaminants acetone and methylene chloride were also reported. These compounds are not considered site-related, based on their presence in blank samples, their status as common laboratory artifacts and a lack of significant historical detections.

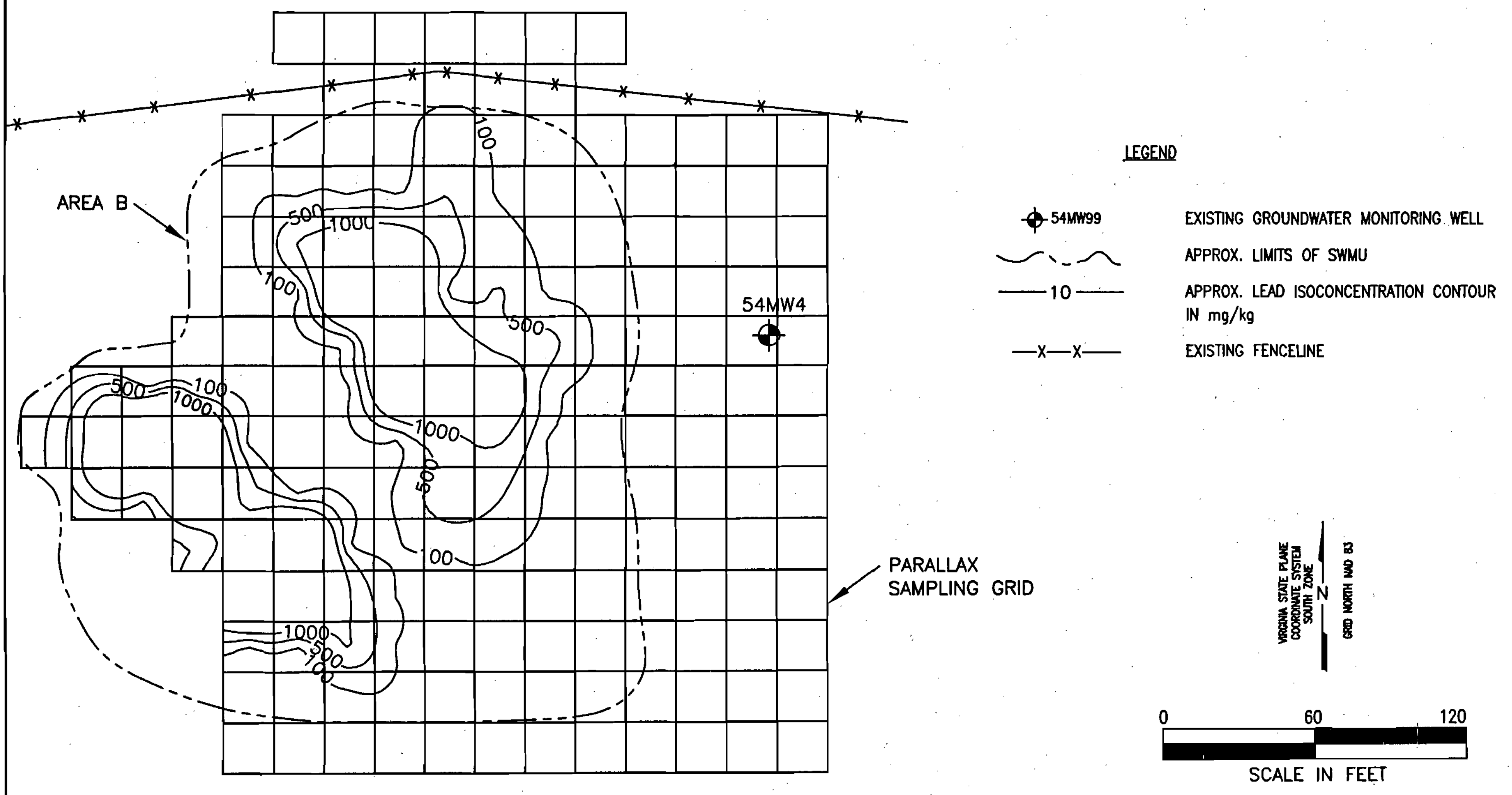
Excavation and Removal - Following completion of the site-screening program, Parallax re-mobilized to the site to conduct source removal. Three grid cells were excavated from Area A and ten grid cells were excavated from Area B (Figures 1-41 and 1-42). The decision for grid excavation was based upon exceedance of then-current Industrial and/or Residential Soil ALs for lead and 2,4,6-TNT as well as exceedance of TCLP lead regulatory criteria. Excavated soils were disposed of at the Pinewood South Carolina Landfill.

Following excavation, the cells were backfilled with clean fill from a borrow area within RFAAP. Analytical results for two backfill material samples identified as 54BF1 and 54BF2 are summarized in Appendix B. Prior to backfilling, discrete soil samples were collected from the sidewalls and the bottom of selected excavations. These results (results exceeding sample detection limits) are summarized in Appendix B.

Figure 1-43 presents an estimated, post-excavation isoconcentration map of Area A of SWMU 54 for laboratory analysis of lead in composite samples. A lead concentration of 17.2 mg/kg, the average for backfill sample analysis, has been used for excavated and backfilled cells. Figure 1-44 presents an estimated post-excavation isoconcentration map of Area A of SWMU 54 for laboratory analysis of arsenic in composite samples. An arsenic concentration of 3.1 mg/kg, the average for backfill sample analysis, has been used for excavated and backfilled cells. Figure 1-45 presents an estimated post-excavation isoconcentration map of Area A of SWMU 54 for laboratory analysis of 2,4,6-TNT in composite samples. Data for 2,4,6-TNT have been adjusted to zero for excavated and backfilled cells.

Figure 1-46 presents an estimated post-excavation isoconcentration map of Area B of SWMU 54 for laboratory analysis of lead in composite samples. A lead concentration of 17.2 mg/kg, the average for backfill sample analysis, has been used for excavated and backfilled cells. Figure 1-47 presents an estimated post-excavation isoconcentration map of Area B of SWMU 54 for laboratory analysis of

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

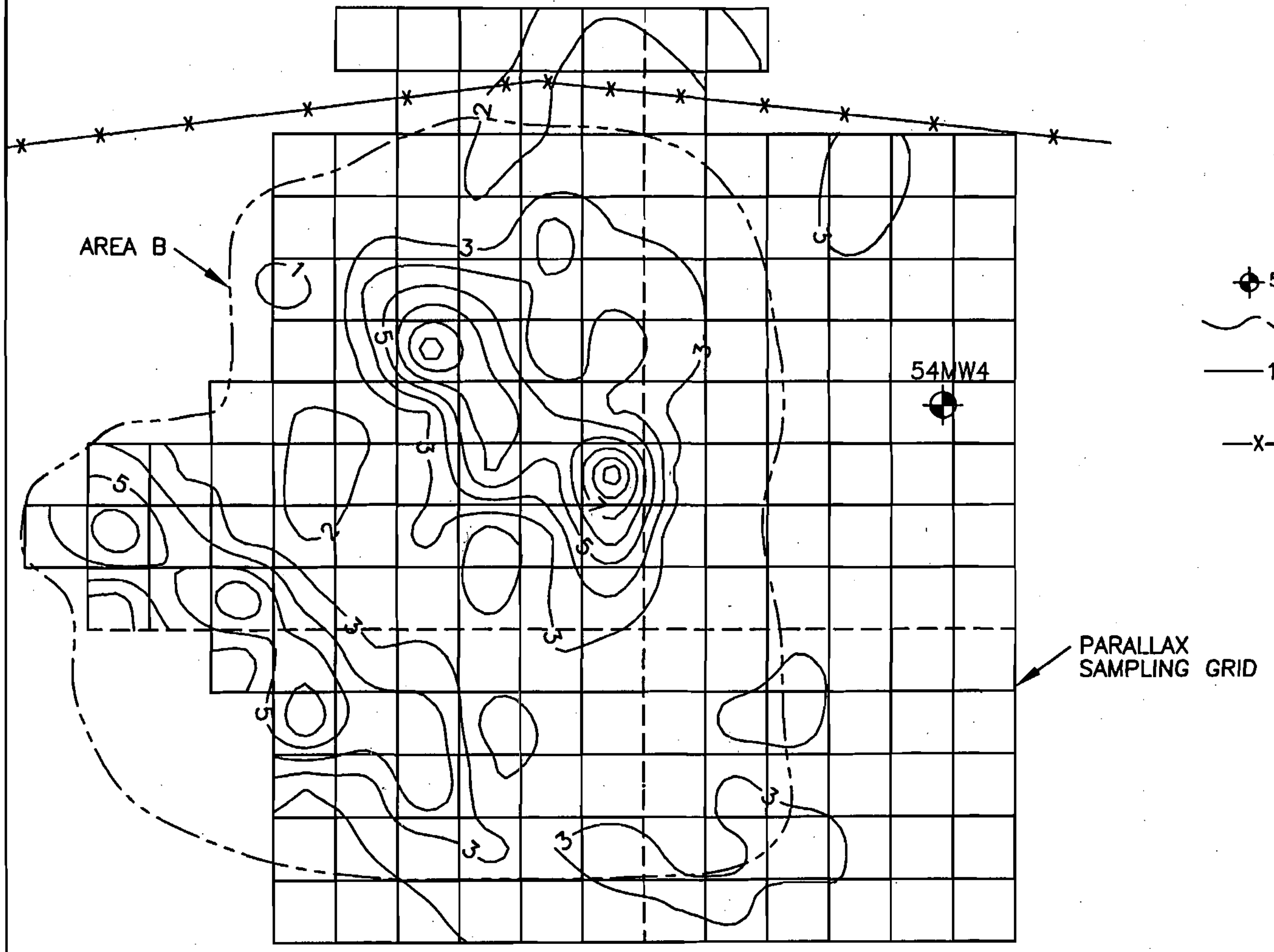
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-38.DWG

FIGURE 1-38

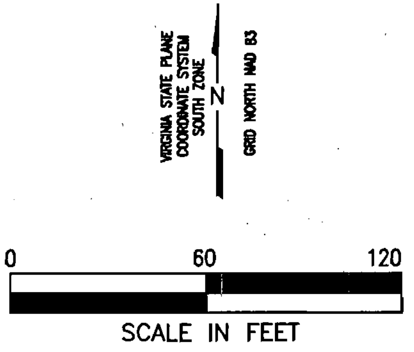
ISOCONCENTRATION MAP OF LEAD IN COMPOSITE SAMPLES, AREA B, BASED ON PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⊕ 54MW99	EXISTING GROUNDWATER MONITORING WELL
～‒～	APPROX. LIMITS OF SWMU
—10—	APPROX. ARSENIC ISOCONCENTRATION CONTOUR IN mg/kg
—X—X—	EXISTING FENCELINE



RFAAP

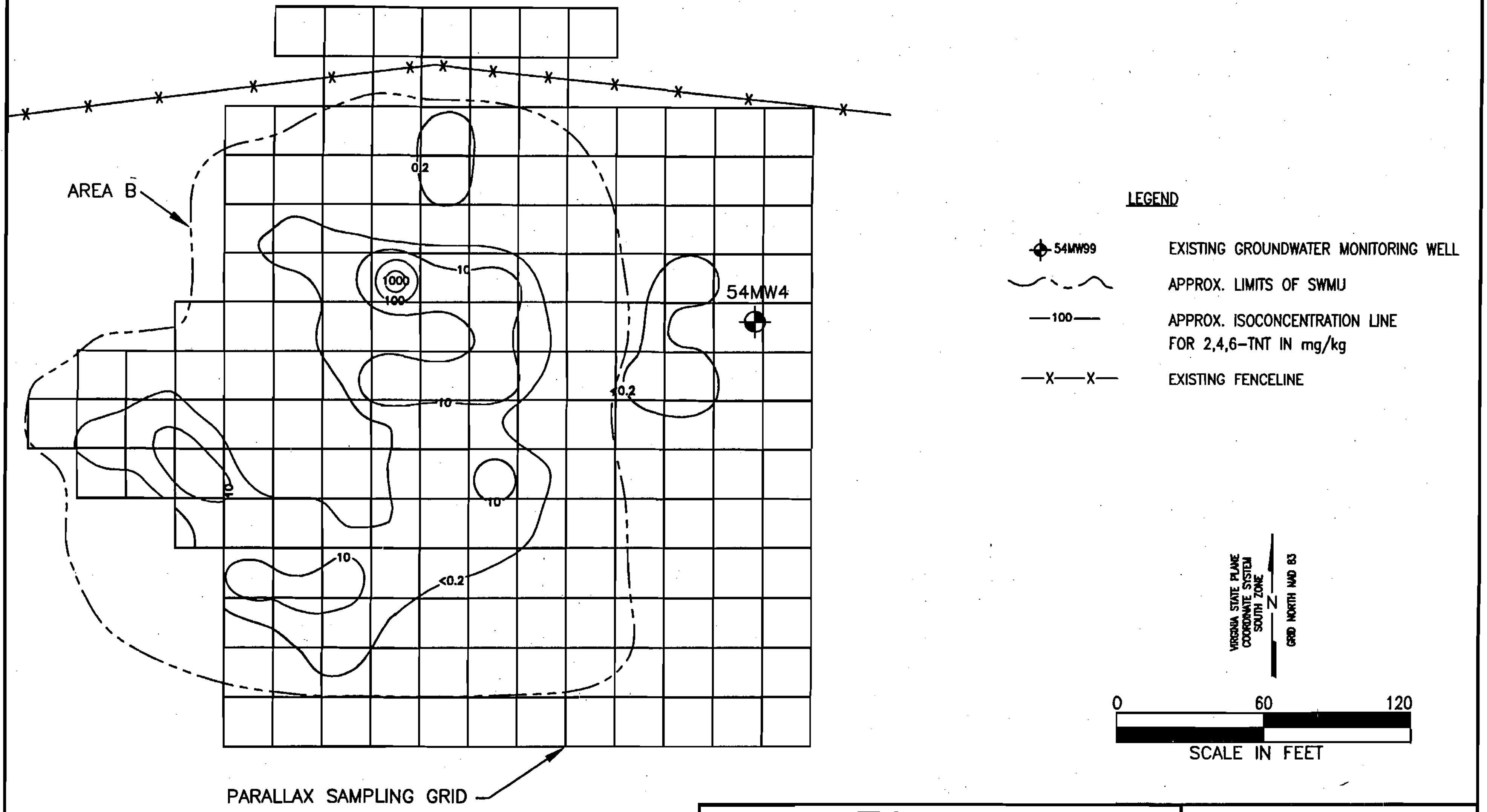
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-39.DWG

FIGURE 1-39

ISOCONCENTRATION MAP OF ARSENIC IN COMPOSITE SAMPLES, AREA B, BASED ON PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP
RFI WORK PLAN ADDENDUM: SWMU 54

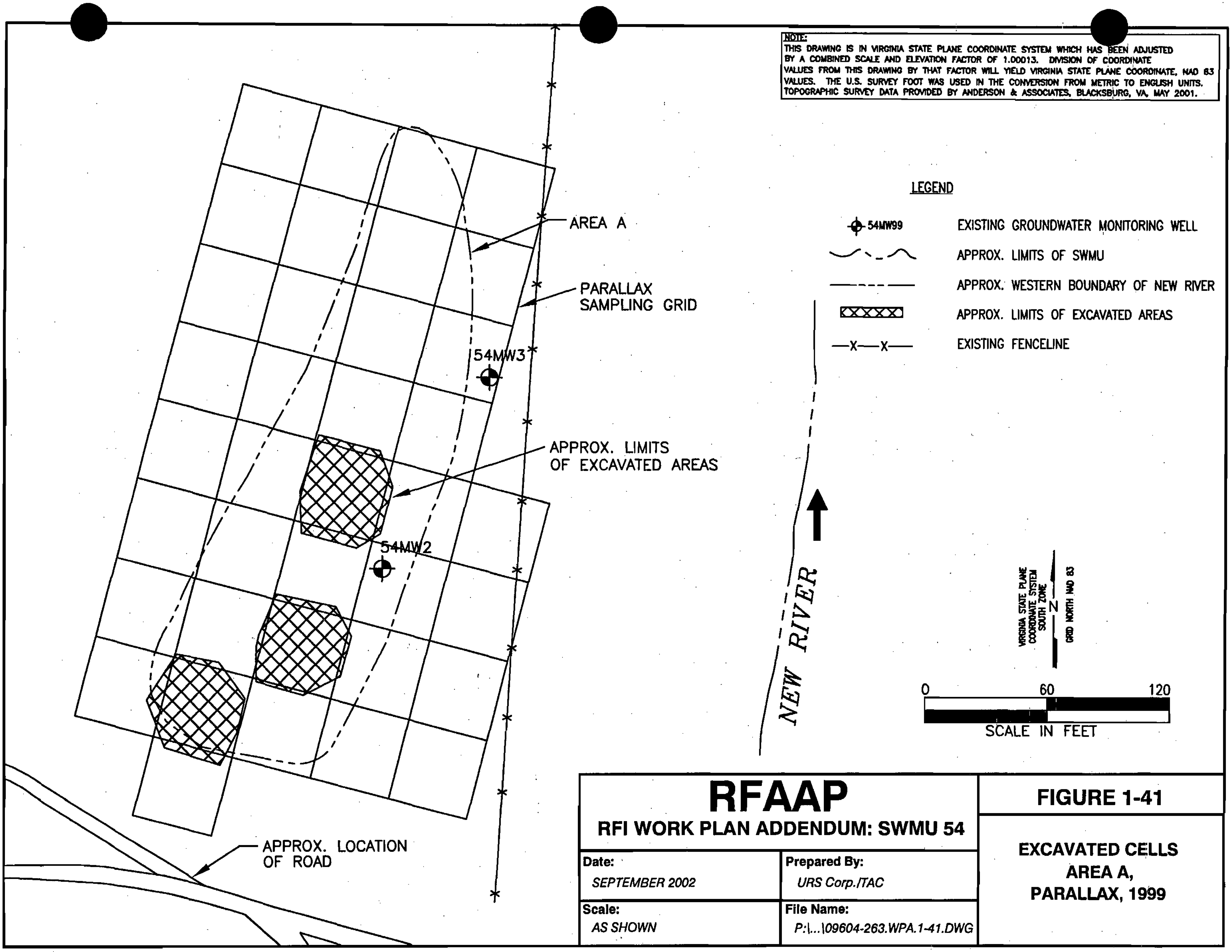
Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-40.DWG*

FIGURE 1-40

ISOCONCENTRATION MAP OF 2,4,6-TNT IN COMPOSITE SAMPLES, AREA B, BASED ON PARALLAX, 1999

NOTE:

THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
⌒ ⁃ ⌒	APPROX. LIMITS OF SWMU
—— - - - ——	APPROX. WESTERN BOUNDARY OF NEW RIVER
▨	APPROX. LIMITS OF EXCAVATED AREAS
—X—X—	EXISTING FENCELINE

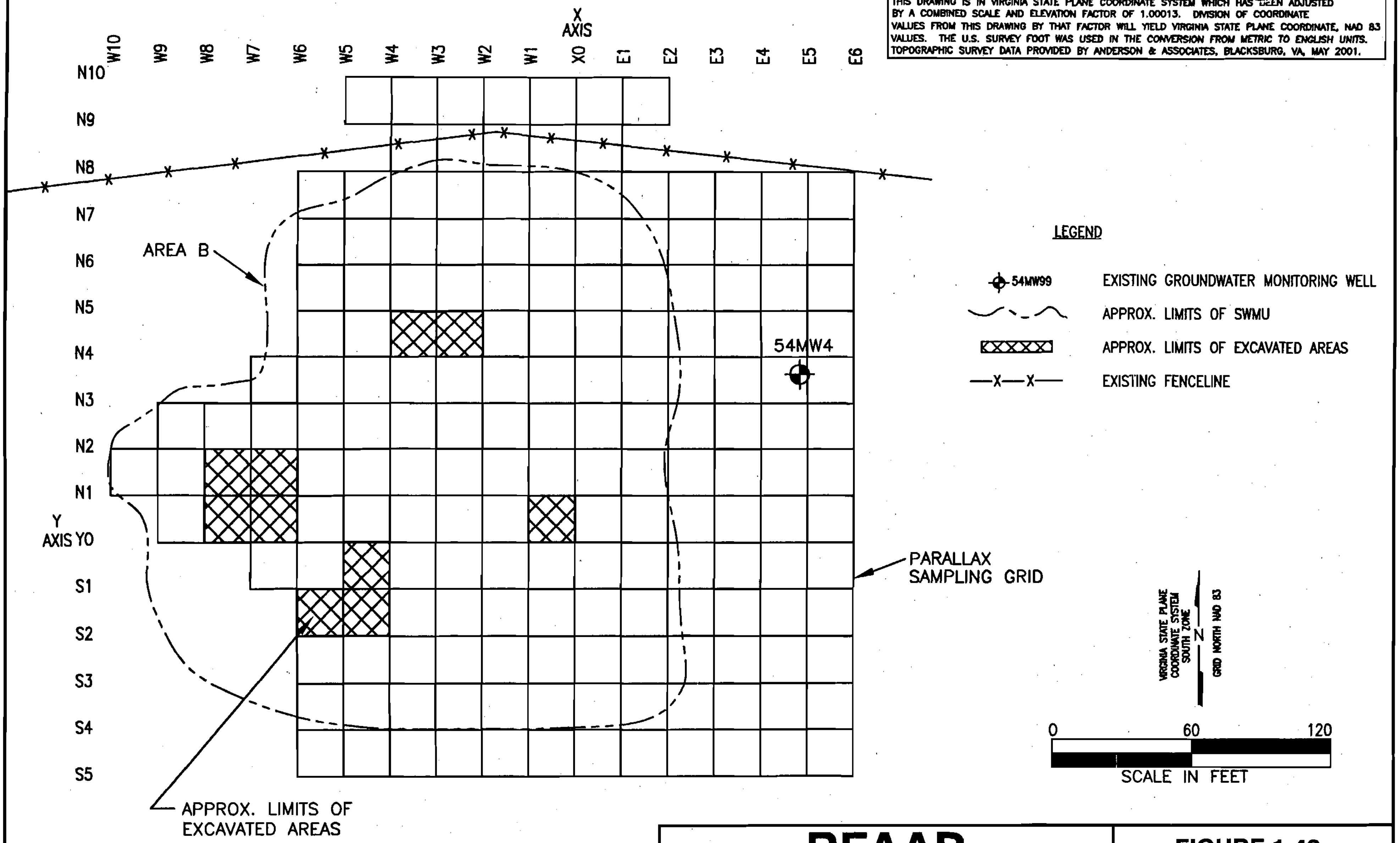
RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *AS SHOWN*	**File Name:** *P:\...\09604-263.WPA.1-41.DWG*

FIGURE 1-41

**EXCAVATED CELLS
AREA A,
PARALLAX, 1999**



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

FIGURE 1-42

EXCAVATED CELLS, AREA B, PARALLAX, 1999

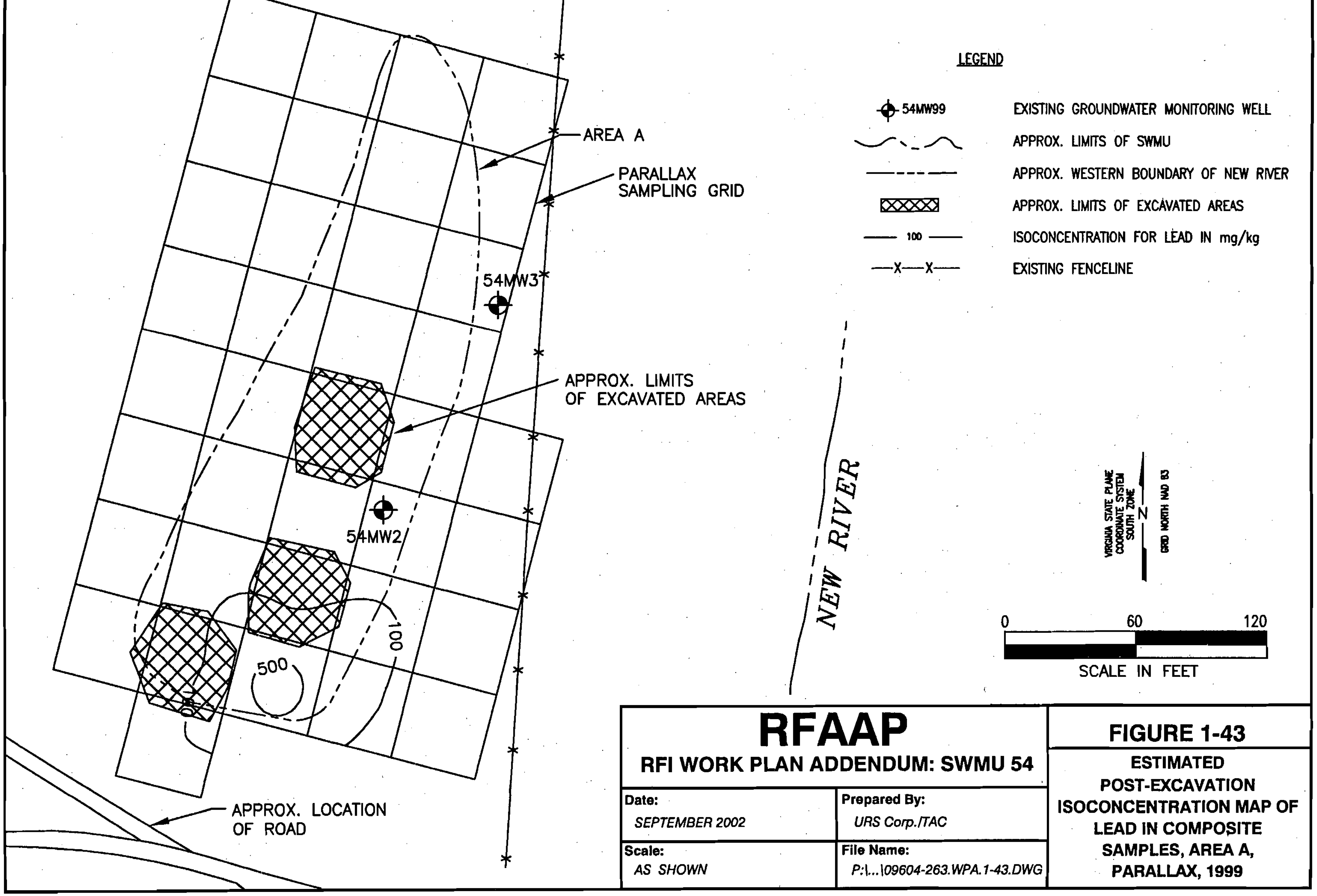
Date: *SEPTEMBER 2002*

Prepared By: *URS Corp./TAC*

Scale: *AS SHOWN*

File Name: *P:\...\09604-263.WPA.1-42.DWG*

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

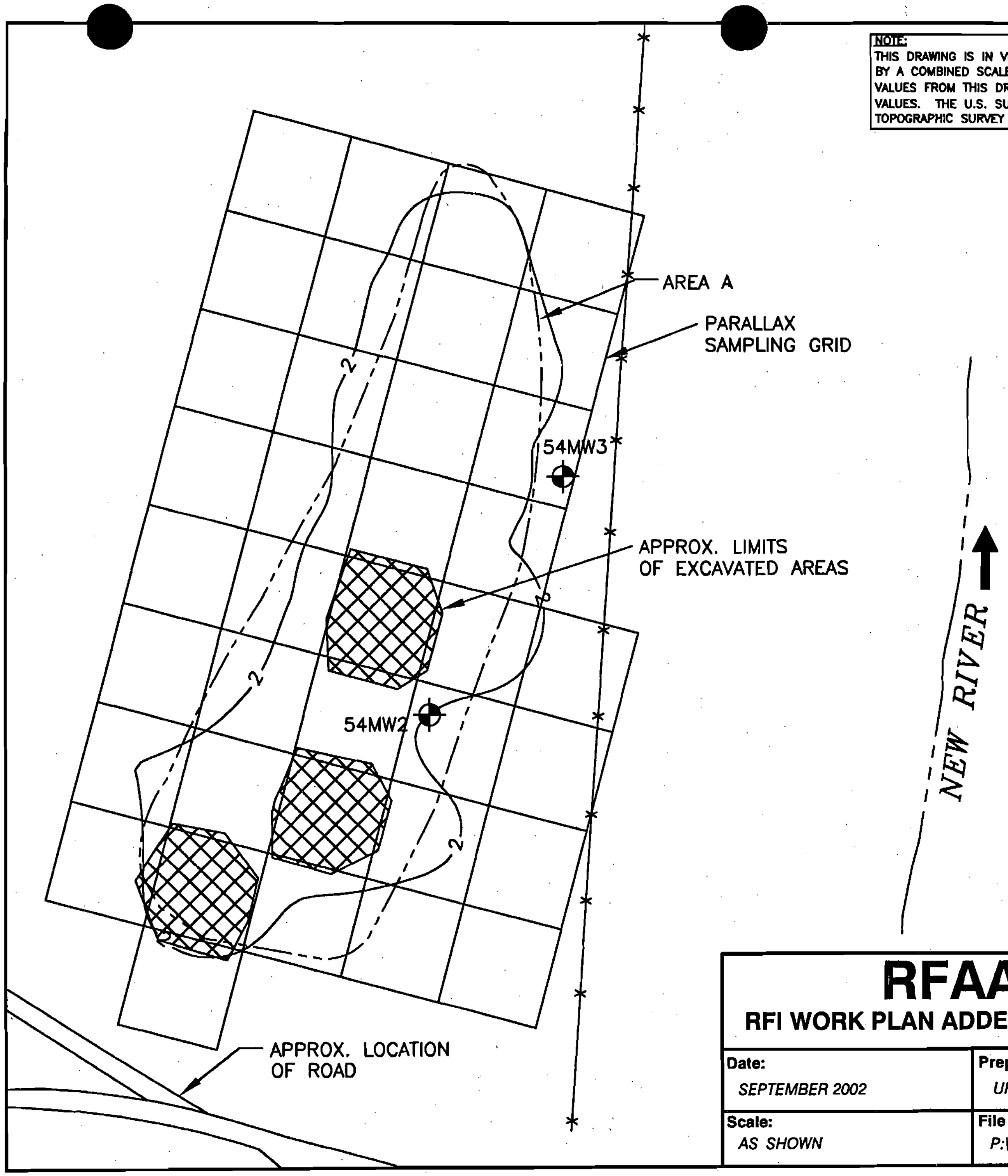
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-43.DWG

FIGURE 1-43

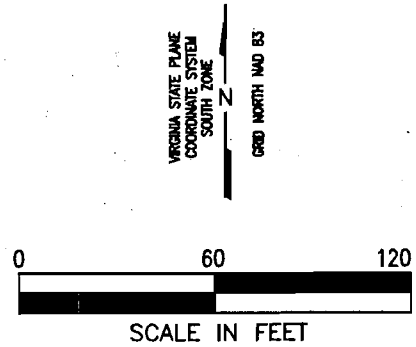
ESTIMATED POST-EXCAVATION ISOCONCENTRATION MAP OF LEAD IN COMPOSITE SAMPLES, AREA A, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
~ - ~	APPROX. LIMITS OF SWMU
— - - —	APPROX. WESTERN BOUND. OF NEW RIVER
—10—	ISOCONCENTRATION FOR ARSENIC IN mg/kg
▨	APPROX. LIMITS OF EXCAVATED AREAS
—X—X—	EXISTING FENCELINE

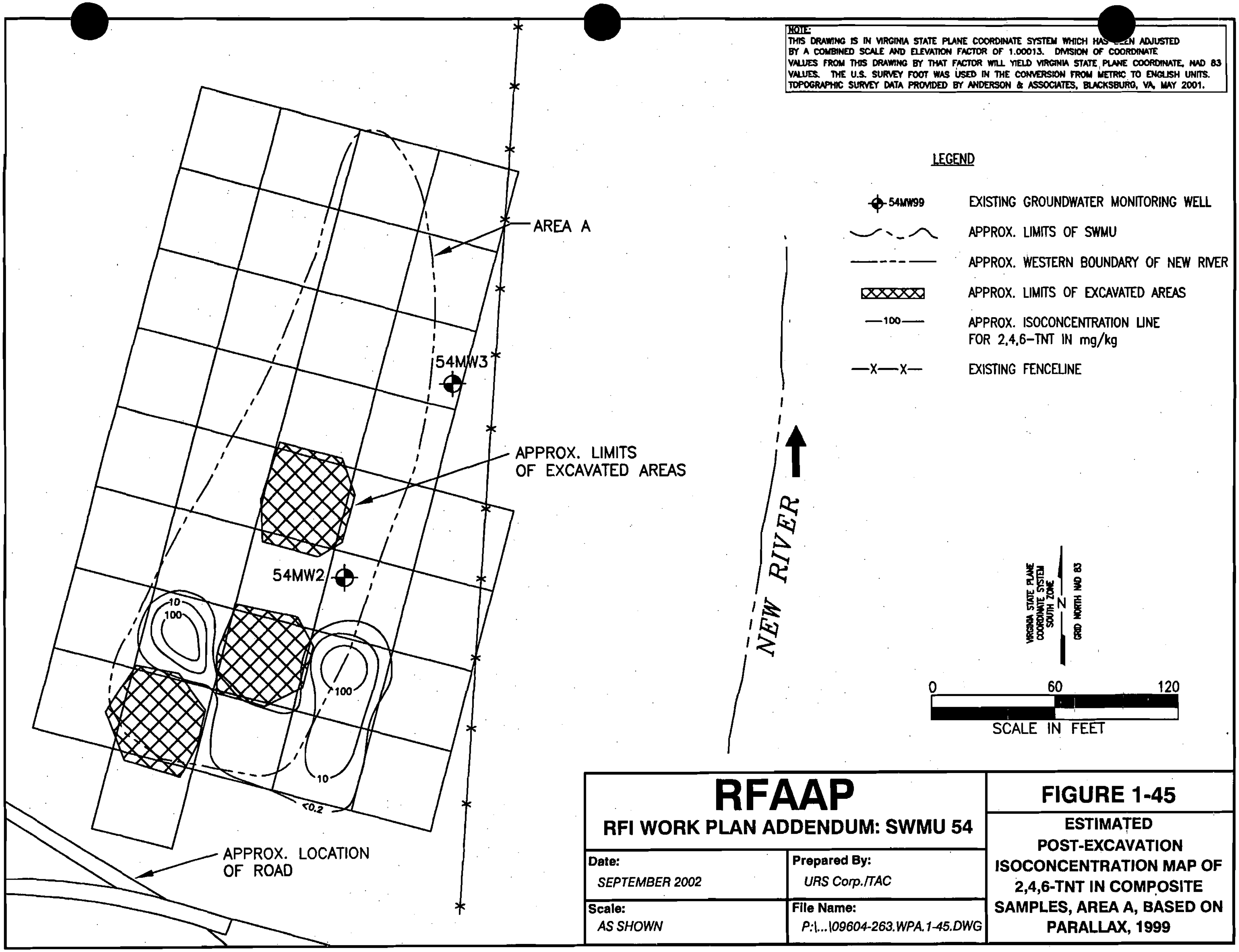


RFAAP
RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-44.DWG

FIGURE 1-44

ESTIMATED POST-EXCAVATION ISOCONCENTRATION MAP OF ARSENIC IN COMPOSITE SAMPLES, AREA A, BASED ON PARALLAX, 1999



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

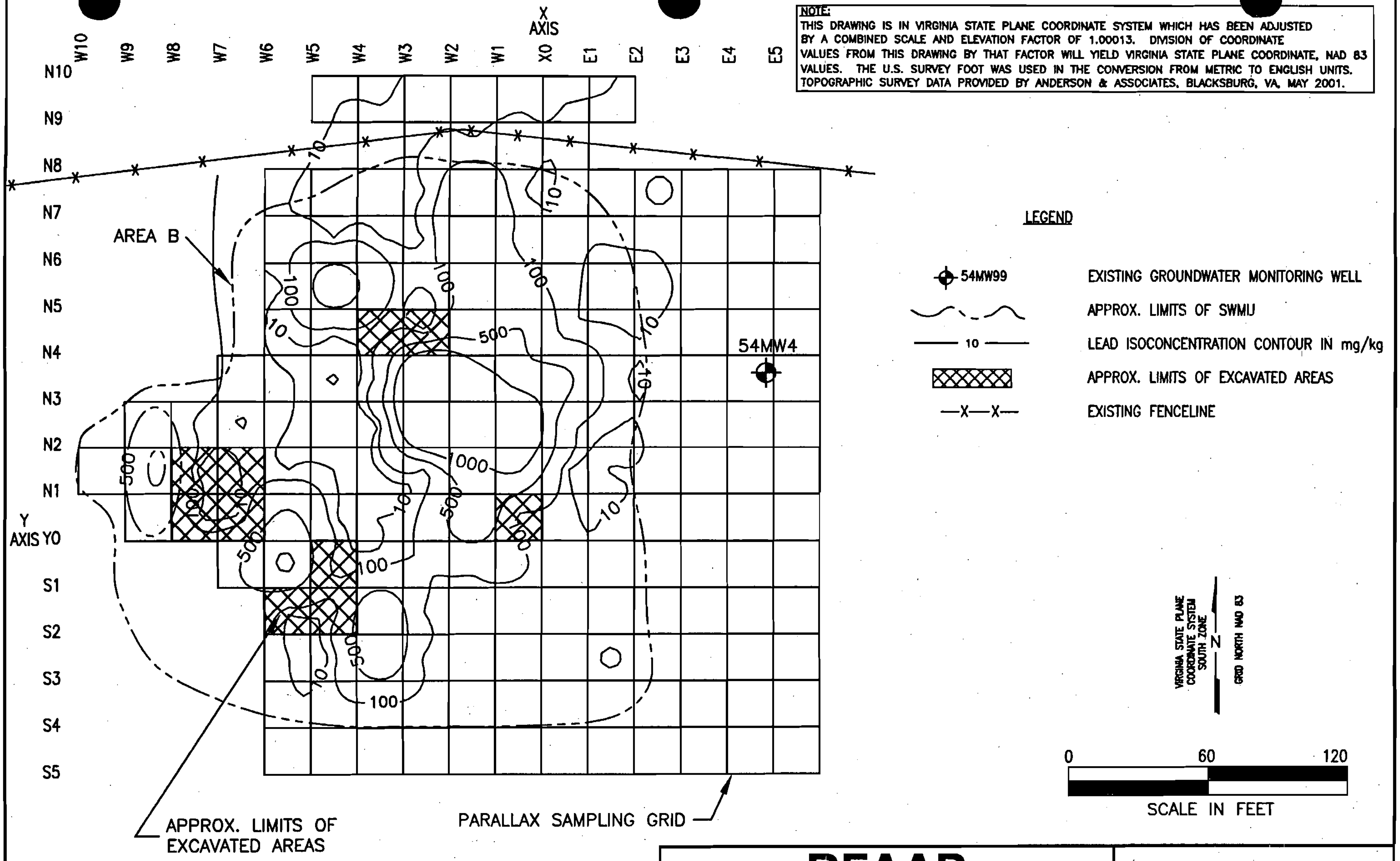
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-45.DWG

FIGURE 1-45

ESTIMATED POST-EXCAVATION ISOCONCENTRATION MAP OF 2,4,6-TNT IN COMPOSITE SAMPLES, AREA A, BASED ON PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

Scale: AS SHOWN

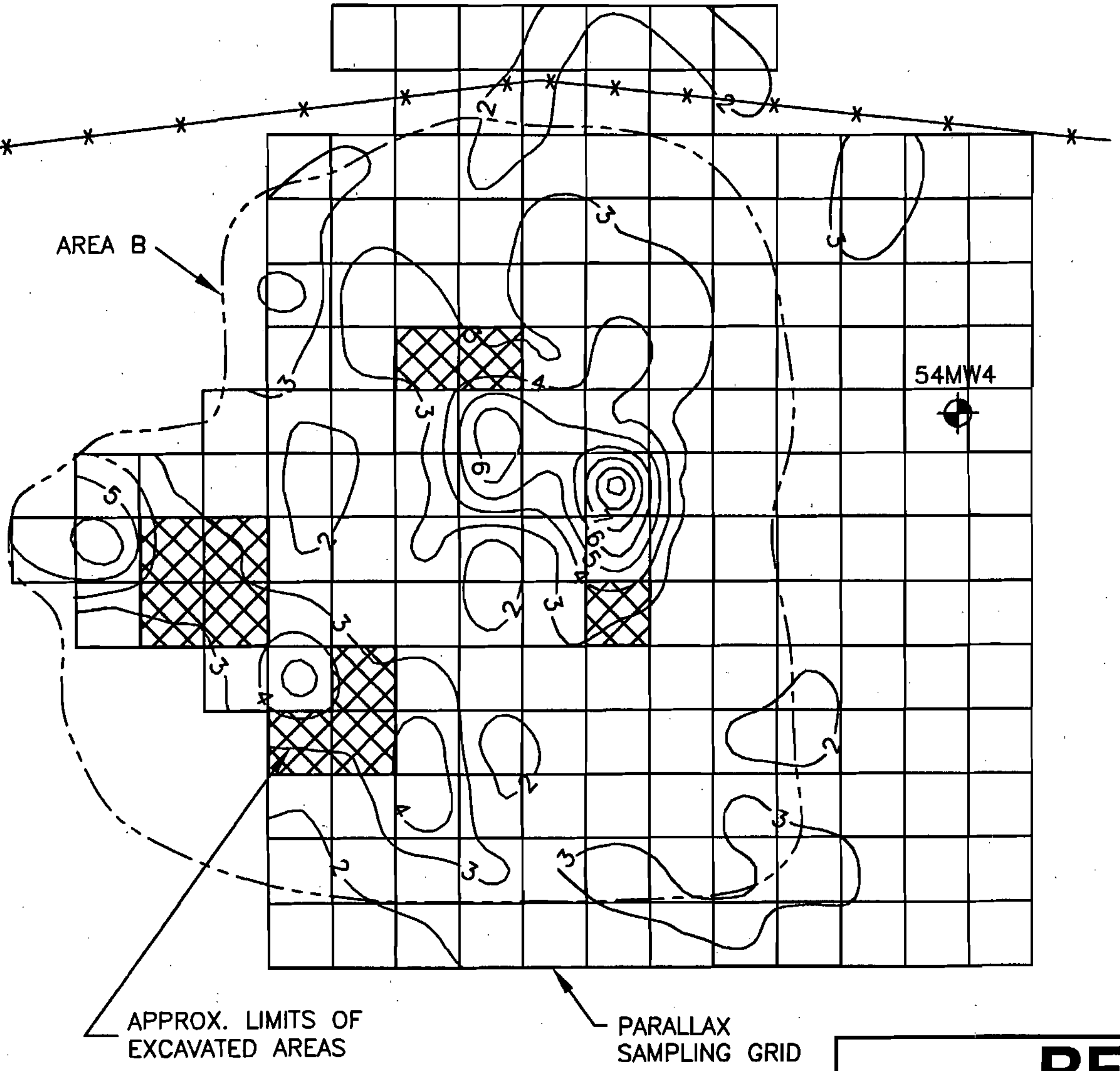
File Name: P:\...\09604-263.WPA.1-46.DWG

FIGURE 1-46

ESTIMATED POST-EXCAVATION ISOCONCENTRATION MAP OF LEAD IN COMPOSITE SAMPLES, AREA B, PARALLAX, 1999

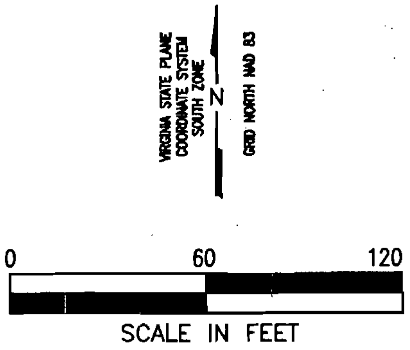
213

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
～ - ～	APPROX. LIMITS OF SWMU
—— 10 ——	ARSENIC ISOCONCENTRATION CONTOUR IN mg/kg
▨	APPROX. LIMITS OF EXCAVATED AREAS
—X—X—	EXISTING FENCELINE



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002
Prepared By: URS Corp./TAC
Scale: AS SHOWN
File Name: P:\...\09604-263.WPA.1-47.DWG

FIGURE 1-47

ESTIMATED POST-EXCAVATION ISOCONCENTRATION MAP OF ARSENIC IN COMPOSITE SAMPLES, AREA B, BASED ON PARALLAX, 1999 arsenic in composite samples. An arsenic concentration of 3.1 mg/kg, the average for backfill sample analysis, has been used for excavated and backfilled cells. Figure 1-48 presents an estimated post-excavation isoconcentration maps of Area B of SWMU 54 for laboratory analysis of 2,4,6-TNT in composite samples. Data for 2,4,6-TNT have been adjusted to zero for excavated and backfilled cells.

A review of the figures indicates that IA excavation and removal in Area A and B of SWMU 54 by Parallax (1999) resulted in an overall reduction of COPCs in soil at the SWMU; however, there was inadequate post-excavation characterization of soils adjacent to most excavated cells. Further site investigation and collection of discrete samples is necessary to assess the concentrations of COPCs remaining in soils at the site.

Groundwater - Parallax collected groundwater samples from each groundwater monitoring well on site (54MW1, 54MW2, 54MW3, and 54MW4). The Parallax groundwater sampling event represents the first time that the four groundwater monitoring wells at the site were sampled during the same event. A review of site photographs taken during the Parallax investigations indicates that a low-flow purge and sample method was likely used.

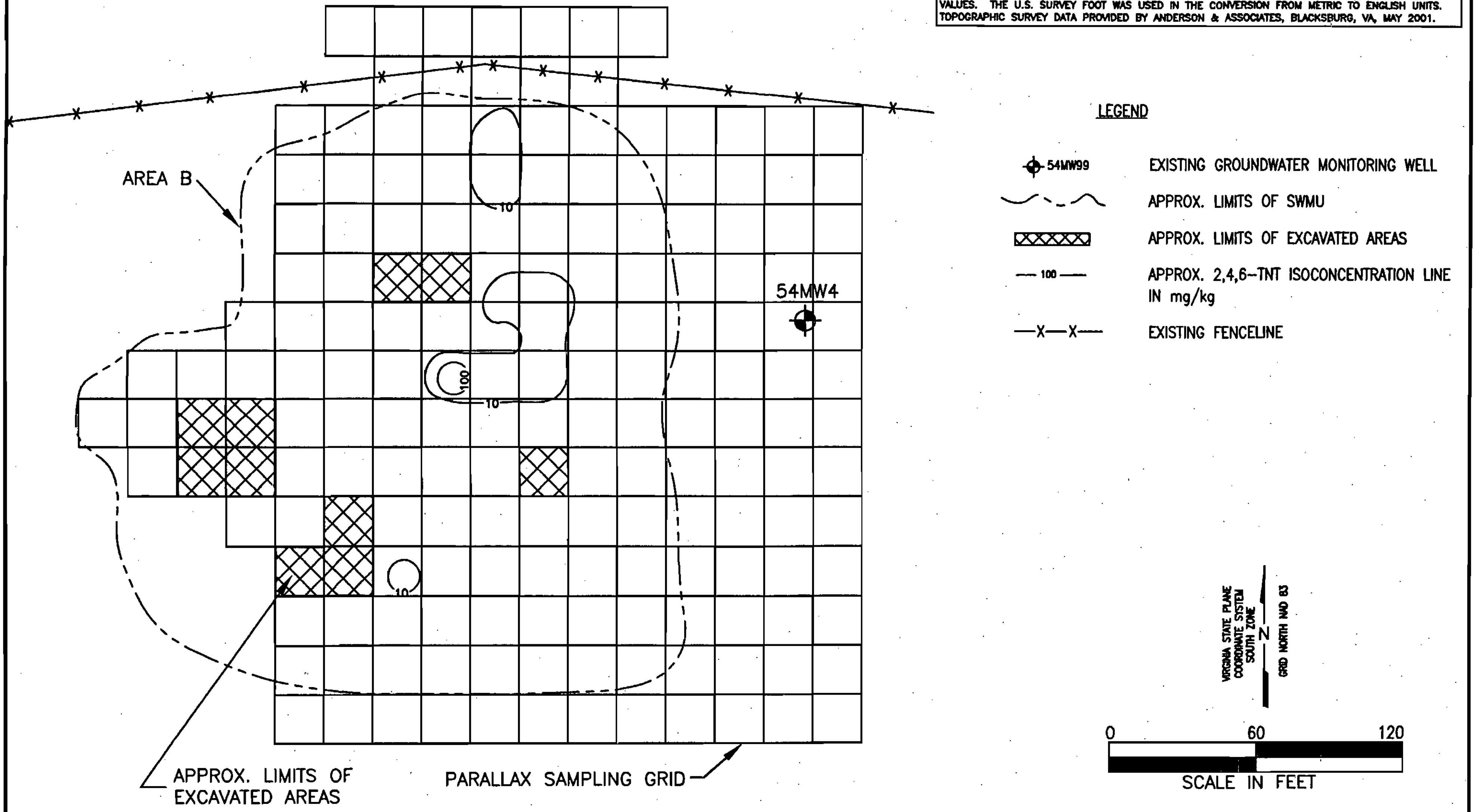
Groundwater samples were analyzed for TAL Metals, SVOCs, VOCs, perchlorate, pesticides, and explosives. Groundwater results are summarized in Table 1-4. Iron was detected above its 2002 Tap Water RBC of 1100 µg/L in wells 54MW3 and 54MW4 (1440 and 1640 µg/L, respectively). Two explosives, 2,4,6-TNT and 2-amino-4,6-dinitrotoluene, were detected above their respective 2002 Tap Water RBCs of 2.2 and 0.22 µg/L in well 54MW3 (7.4 and 5.3 µg/L, respectively). It should be noted that perchlorate, a component in solid rocket propellant, was present in well 54MW3 at 10.7 µg/L. Screening criteria for perchlorates are currently under development by the USEPA (2002). The VOC tetrachloroethene was reported at a concentration above its 2002 Tap Water RBC; however, the detection is a very low, estimated value, below the laboratory limit of quantitation and is flagged as a J-value (indicating that the results are estimated due to a laboratory quality control problem). In addition, methylene chloride was present at significant concentrations in blank samples and should be considered an artifact of sampling and analysis. No other VOCs were reported as present above screening criteria.

Conclusions - Data regarding soils generated by Parallax (1999) was limited to field-screening and composite sampling and was intended for site-screening purposes. As such, the data does not allow for definitive characterization of soil constituent concentrations in Areas A and B within SWMU 54. Data generated by Parallax and presented in Parallax (1999) will be used as site-screening data.

Based on information presented in Parallax (1999) aluminum, arsenic, chromium, iron, lead, manganese, mercury, 2,4,6-TNT, 2-amino-4,6-dinitrotoluene, 4-amino-2,6-dinitrotoluene, 2,6-DNT, RDX, 2,4-DNT are identified as COPCs in soil at Area A of SWMU 54.

The following constituents are identified as COPCs in the Area B soil: aluminum, antimony, arsenic, cadmium, chromium, copper, iron, lead, manganese, thallium, 2,4,6-TNT, 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, and 2,4-DNT. Iron, 2,4,6-TNT and 2-amino-4,6-dinitrotoluene are identified as a COPCs in groundwater at the site. Note that beryllium, previously identified as a COPC in groundwater, was not reported in concentrations greater than 3.0 µg/L. Due to uncertainty of the actual concentration in groundwater (i.e., J-flagged values), tetrachloroethene is not considered a COPC in groundwater.

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-48.DWG

FIGURE 1-48

ESTIMATED POST-EXCAVATION ISOCONCENTRATION MAP OF 2,4,6-TNT IN COMPOSITE SAMPLES, AREA B, BASED ON PARALLAX, 1999

1.2.3.6 Summary

Dames & Moore (1992a) - Data presented are for groundwater in Area A of SWMU 54. Screening of the data against 2002 Tap Water RBCs indicates that 2,4,6-TNT is identified as a COPC in groundwater. Due to the age of the data, they are not suitable for risk assessment use (Table 1-3; Table 1-8).

Parsons (1996) - Data presented are for soil and groundwater in Area A of SWMU 54. The data for shallow soils are adequate for site-screening purposes and for identification of COPCs. Data for deep soils are adequate for both COPC identification and as definitive data for use in a risk assessment (Table 1-3; Table 1-8).

Screening of the data against 2002 Tap Water RBCs and MCLs indicates that arsenic, barium, cadmium, chromium, lead, mercury, 2,4,6-TNT, 2,4-DNT, and 2,6- DNT are identified as COPCs in soil; beryllium is identified as a COPC in groundwater (Table 1-3; Table 1-8).

MSE (1998) - Data presented are for soil and groundwater in Area B of SWMU 54. Due to uncertainties of sample locations and sample depths, they are not deemed suitable for use in a risk assessment (Table 1-3; Table 1-8).

Screening of the data against 2002 Soil RBCs (AL for lead) and MCLs indicates that aluminum, antimony, arsenic, chromium, copper, iron, lead, manganese, mercury, 2,4,6-TNT, 2-amino-4,6-dinitrotoluene, 2,6-DNT, 2,4-DNT, benzo[a]anthracene, BAP, benzo[b]fluoranthene, dibenz[a,h]anthracene, and indeno[1,2,3-cd]pyrene are identified as COPCs in soil.

Parallax (1999) - Data presented are for soil and groundwater in Areas A and B of SWMU 54. Data usability from Parallax (1999) is limited to site screening.

Screening of the data against 2002 Soil RBCs, (AL for lead) and MCLs indicates that, for Area A, aluminum, arsenic, iron, manganese, chromium, lead, mercury, 2,4,6-TNT, 4-amino-2,6-dinitrotoluene, 2,6-DNT, RDX, 2-amino-4,6-dinitrotoluene, and 2,4-DNT are identified as COPCs in soil. Iron, 2,4,6-TNT and 2-amino-4,6-dinitrotoluene are identified as COPCs in groundwater (Table 1-3; Table 1-8; Appendix B).

For Area B, aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, thallium, 2,4,6-TNT, 4-amino-2,6-dinitrotoluene, 2-amino-4,6-dinitrotoluene, and 2,4-DNT identified as COPCs in soil.

1.2.4 Conceptual Site Model

Based on current data available for the site, complete migration pathways of constituents away from SWMU 54 likely include leaching of contaminants through site soils to groundwater and direct contact to potential receptors via ingestion and/or dermal contact.

A site-specific CSM has been developed for SWMU 54 to assess potential contaminant sources, exposure pathways, and human and ecological receptors (Figure 1-49). Potentially affected media include surface soil, subsurface soil, and groundwater. The SWMU 54 area is relatively level and precipitation is expected to infiltrate into the ground. Sufficient data do not exist to establish the existence or absence of a complete pathway resulting from site groundwater discharge to the New River and the possible resultant pathway to surface water and sediment (via ingestion, inhalation, and/or dermal contact). The

Table 1-8
Summary of COPCs
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

COPC	Area A			Area B		
	Soil RBCs		Groundwater	Soil RBCs		Groundwater
	Industrial	Residential	RBC/MCL	Industrial	Residential	RBC/MCL
TAL Metals						
Aluminum		**YES**			**YES**	
Antimony					**YES**	
Arsenic	**YES**	**YES**		**YES**	**YES**	
Barium		**YES**				
Beryllium			**YES**^{1}			
Cadmium		**YES**			**YES**	
Chromium		**YES**			**YES**	
Copper					**YES**	
Iron		**YES**	**YES**^{2}		**YES**	**YES**^{2}
Lead	**YES**	**YES**		**YES**	**YES**	
Manganese		**YES**			**YES**	
Mercury	**YES**	**YES**			**YES**	
Thallium					**YES**	
Explosives						
2,4,6-TNT	**YES**	**YES**	**YES**^{2}	**YES**	**YES**	
2,4-DNT		**YES**			**YES**	
2,6-DNT		**YES**			**YES**	
2-amino-4,6-DNT		**YES**	**YES**^{2}		**YES**	
4-amino-2,6-DNT		**YES**			**YES**	
RDX		**YES**				
SVOCs						
Benzo[a]anthracene					**YES**	
Benzo[a]pyrene				**YES**	**YES**	
Benzo[b]fluoranthene					**YES**	
Dibenz[a,h]anthracene					**YES**	
Indeno[1,2,3-cd]pyrene					**YES**	
PERCHLORATE			**YES**^{3}			

Notes:

TAL = Target Analyte List

SVOCs = Semi-volatile Organic Compounds

COPC = Constituent of Potential Concern

RBC = USEPA Region III Risk-based Concentration

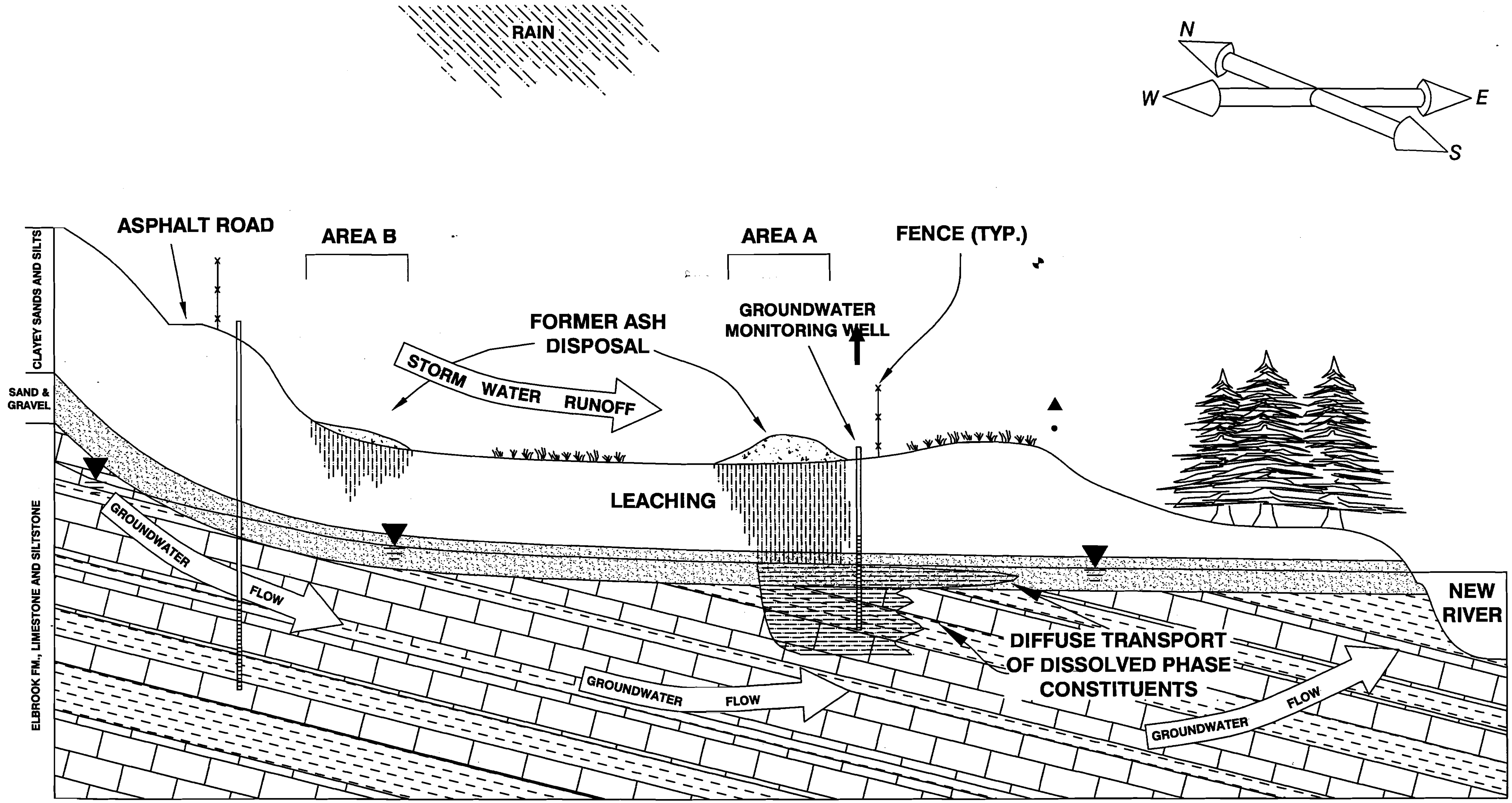
MCL = USEPA National Primary Drinking Water Standards, Maximum Contaminant Level

YES = Exceeds Screening Criteria

1 = Exceedance of MCL

2 = Exceedance of RBC

3 = Perchlorate screening criteria under development; Perchlorate detected in 54MW3



RFAAP RFI WORK PLAN ADDENDUM: SWMU 54		FIGURE 1-49
Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./KDC*	CONCEPTUAL SITE MODEL FIGURE
Scale: *NO SCALE*	**File Name:** *P:\...\09604-263.wpa.1-49*	

results of the investigative activities from the WPA are anticipated to facilitate the definition of the limits of constituent migration in groundwater. The completeness of the surface water and sediment migration pathways at SWMU 54 is considered unknown. Once the constituent migration limits have been assessed, the completeness of the surface water and sediment pathways will be examined.

SWMU 54 is enclosed within a fence, inhibiting entrance by trespassers. Historical ash disposal is indicated on the figure, with subsequent leaching of constituents through site soils and into groundwater. Depth to bedrock is indicated as relatively equal across the site. Subsurface geology is shown as an upper layer of clayey sands and silts underlain by a relatively thin layer of sand and gravel. The Elbrook Formation is shown below the unconsolidated, alluvial deposits. Epikarstic features such as pinnacled bedrock, sinkholes, solution-enhanced conduits or clay-filled voids have not been reported during bedrock drilling (Dames & Moore 1992a; MSE 1998). A lack of nearby macroscopic lineament features on aerial photographs (UESPA 1992) indicates that groundwater flow in the SWMU 54 area likely occurs under diffuse rather than conduit flow conditions. This has been illustrated via constituent plume migration in the upper portions of the Elbrook Formation and in the overlying sand and gravel layer. A higher rate of diffuse flow likely occurs within the sand and gravel, relative to bedrock. The limits of constituent migration are currently unknown.

Constituents have not been detected above screening criteria in well 54MW4, downgradient of Area B in SWMU 54. Consequently, leaching of constituents from Area B has been shown as not reaching groundwater.

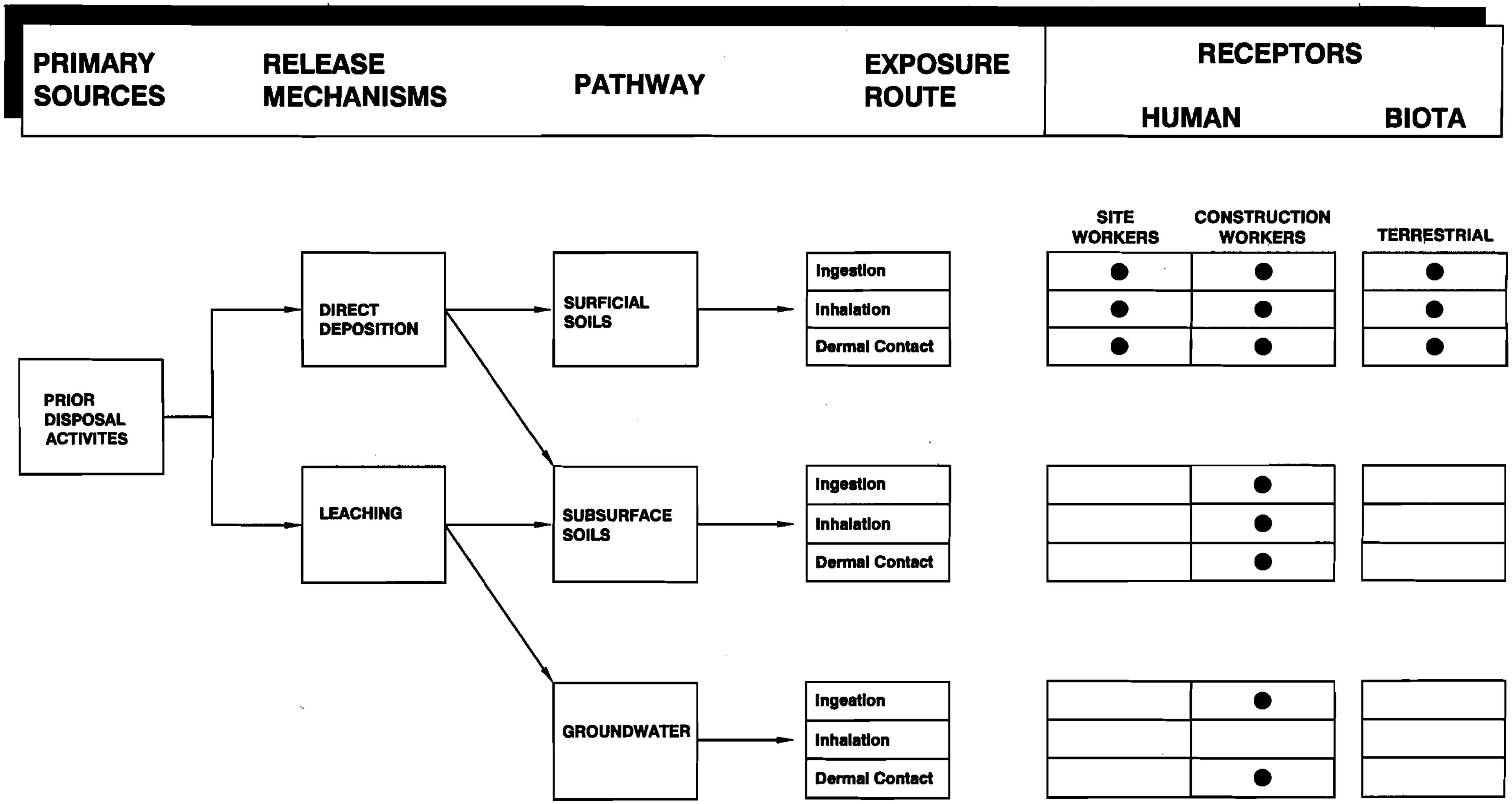
Although current and future land-use scenarios are limited to industrial operations, and the SWMU is enclosed by a fence, both industrial and residential scenarios will be considered. Figure 1-50 presents the potential exposure pathways for each receptor. Direct deposition via surface dumping and burial of materials is considered a release mechanism to surface soil at this site. Site workers, construction workers, hypothetical residents, and terrestrial biota could contact surface soil via incidental ingestion of soil, inhalation of fugitive dust and dermal absorption through direct contact with soil. Direct deposition is also a release mechanism to subsurface soil, potentially leading to exposure by construction workers via incidental ingestion of soil, inhalation of fugitive dust and dermal absorption through direct contact with soil.

Leaching of constituents through site soils is considered a release mechanism to subsurface soil and groundwater at the site. In turn, subsurface soil and groundwater may be received by construction workers via incidental ingestion of soil or groundwater, inhalation of fugitive dust (soil) and dermal absorption through direct contact with soil or groundwater.

1.2.5 Data Gap Analysis

Data are incomplete at SWMU 54 for both physical and chemical information (Table 1-9). In Area A of SWMU 54, useable, definitive data regarding surface and intermediate depth soils do not exist. In addition, relatively high concentrations of constituents in western and southern borings and screening samples indicate a data gap for lateral delineation of constituent concentrations. In Area B of SWMU 54, useable, definitive data regarding soil at surface, intermediate and deep depths do not exist.

The existing upgradient groundwater monitoring well 54MW1 is not adequate for evaluation of site background conditions. It is far from Areas A and B of SWMU 54 and is screened wholly within bedrock, whereas wells downgradient of Area A are screened across the bedrock/overburden interface.



PATHWAY	EXPOSURE ROUTE	HUMAN: SITE WORKERS	HUMAN: CONSTRUCTION WORKERS	BIOTA: TERRESTRIAL
SURFICIAL SOILS	Ingestion	●	●	●
	Inhalation	●	●	●
	Dermal Contact	●	●	●
SUBSURFACE SOILS	Ingestion		●	
	Inhalation		●	
	Dermal Contact		●	
GROUNDWATER	Ingestion		●	
	Inhalation			
	Dermal Contact		●	

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./KDC

Scale: NO SCALE

File Name: P:\...\09604-263.WPA.1-50

FIGURE 1-50

CONCEPTUAL SITE MODEL DIAGRAM

37

Table 1-9
Data Gap Analysis
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

		Media	Sampling Requirements (Gaps)	Data Requirements (Gaps)
SWMU 54	**AREA A**	SWMU Area Soil	Surface Soil Samples	Chemical Data, BRA
			Intermediate Depth Soil Samples	Chemical Data, BRA
		SWMU Area Groundwater	Adequate Background Well	Chemical Data. BRA
	AREA B	SWMU Area Soil	Surface Soil Samples	Chemical Data, BRA
			Intermediate Depth Soil Samples	Chemical Data, BRA
			Deep Soil Samples	Chemical Data, BRA
		SWMU Area Groundwater	Adequate Background Well	Chemical Data, BRA
			Adequate Downgradient Wells	Chemical Data, BRA
	SITE WIDE	Soil	Physical / Geotechnical Properties	Cation Exchange Capacity, Bulk Density, Organic Content, pH
			Fate and Transport Parameters	Pore Volume Analysis, Chemical Mobility, Chemical Characteristics
		Groundwater	Physical/ Geotechnical Properties	Hydraulic Conductivity, Transmissivity, Storativity, Dispersivity

No well monitors upgradient groundwater quality in Area B of SWMU 54. There is one downgradient well in Area B of SWMU 54. Constituent detections in wells 54MW2 and 54MW3 indicate a release to groundwater; however, the downgradient extent of constituents in groundwater is not known.

TCL VOCs - Groundwater samples were collected from Area A (54MW1, 54MW2, and 54MW3) at SWMU 54 during the VI (Dames & Moore 1992a) and analyzed for TCL VOCs. Soil and groundwater samples were collected from Area A at SWMU 54 during the previous RFI (Parsons 1996) and analyzed for TCL VOCs. Additionally, soil and groundwater samples were collected from Area B at SWMU 54 during the Supplemental RFI (MSE 1998) and analyzed for TCL VOCs. In 1999, Parallax analyzed composite soil samples and groundwater samples for TCL VOCs. A review of the data indicates that, with the exception of common laboratory contaminants, TCL VOCs were not reported in soil or groundwater above 2002 Residential Soil, Industrial Soil, or Tap Water RBCs, or MCLs. Therefore, TCL VOCs do not represent a data gap for surface soil, subsurface soil, or groundwater.

TCL SVOCs/PAHs - Groundwater samples were collected from Area A at SWMU 54 during the VI (Dames & Moore 1992a) and analyzed for TCL SVOCs. Soil and groundwater samples were collected from Area A at SWMU 54 during the previous RFI (Parsons 1996) and analyzed for TCL SVOCs. Additionally, soil and groundwater samples were collected from Area B at SWMU 54 during the Supplemental RFI (MSE 1998) and analyzed for TCL SVOCs. A review of the data indicates that select TCL SVOC / polynuclear aromatic hydrocarbons (PAH) are identified as COPCs at the site. Samples were not collected for PAH analysis during the previous investigations. Therefore, adequate characterization of TCL SVOCs / PAHs represents a data gap for surface soil, subsurface soil, and groundwater.

TCL Polychlorinated Biphenyls (PCBs) - Samples were not collected for TCL PCB analysis during the previous investigations. Therefore, TCL PCBs represent a data gap for surface soil and subsurface soil.

TCL Pesticides - Samples were not collected for TCL Pesticide analysis during the previous investigations. Therefore, TCL Pesticides represent a data gap for surface soil and subsurface soil (subsurface soil represents a data gap for TCL Pesticides due to excavation and backfilling associated with previous remedial activities).

Explosives - Groundwater samples were collected from Area A at SWMU 54 during the VI (Dames & Moore 1992a) and analyzed for explosives. Soil and groundwater samples were collected from Area A at SWMU 54 during the previous RFI (Parsons 1996) and analyzed for explosives. Additionally, soil and groundwater samples were collected from Area B at SWMU 54 during the Supplemental RFI (MSE 1998) and analyzed for explosives. In 1999, Parallax analyzed composite soil samples and groundwater samples for explosives. A review of the data identified explosives COPCs in soil and groundwater. Therefore, adequate characterization of explosives represents a data gap for surface, subsurface soil, and groundwater.

TAL Metals - Groundwater samples were collected from Area A at SWMU 54 during the VI (Dames & Moore 1992a) and analyzed for TAL Metals. Soil and groundwater samples were collected from Area A at SWMU 54 during the previous RFI (Parsons 1996) and analyzed for TAL Metals. Additionally, soil and groundwater samples were collected from Area B at SWMU 54 during the Supplemental RFI (MSE 1998) and analyzed for TAL Metals. In 1999, Parallax analyzed composite soil samples and groundwater samples for TAL Metals. A review of the data identified TAL Metal COPCs in soil and groundwater. Therefore, adequate characterization of TAL Metals represents a data gap for surface soil, subsurface soil, and groundwater.

Dioxins/Furans - Dioxin/furans may be formed during combustion of a variety of chlorinated organic compounds. Previous activities documented at the site include disposal of ash from propellant burning operations at the Waste Propellant Burning Grounds. Samples were not collected for dioxin/furans analysis during the previous investigations. Therefore, dioxin/furans represent a data gap for surface and subsurface soil.

Perchlorate – A review of the Parallax (1999) data indicated perchlorate as a potential COPC, pending USEPA determination of screening criteria (USEPA 2002). Therefore, adequate characterization of perchlorate represents a data gap for groundwater.

Other - An analysis of the physical properties of subsurface soil to aid in assessing the nature of possible constituent mobility has not been performed during previous investigations. Site-wide soil physical/geotechnical and chemical properties affecting constituent mobility are unknown. Therefore, the characterization of the physical properties of subsurface soil represents a data gap. Because no BRA has been performed, potential threats to human health and ecological receptors have yet to be identified and therefore, the results of a BRA (including an ecological risk screening) represent a data gap.

Planned activities in support of this RFI Work Plan Addendum, as presented in Section 1.3, are designed to address the data gaps presented above.

1.3 PLANNED FIELD ACTIVITIES

The SWMU 54 field program is designed to fill in the data gaps presented in Section 1.2.5. In designing the field program for SWMU 54, the following has been considered:

- The size and shape of Areas A and B of SWMU 54 and their non-contiguous nature;
- Previous investigative data for SWMU 54;
- Generation of data that can be used to evaluate the leaching potential of constituents from soil to groundwater and the fate and transport of constituents in groundwater;
- Generation of data that can be used to characterize groundwater conditions at SWMU 54 and assess if the migration pathway to the New River from groundwater is complete; and
- Collection of data that can be used to complete a BRA and an evaluation of appropriate corrective measures.

The major components of the field program at SWMU 54 will include the following:

- Collection of surface and subsurface soil samples from Areas A and B for chemical, physical, and geochemical analysis;
- Installation of additional monitoring wells at SWMU 54 and collection of groundwater samples from the newly installed wells and selected existing wells;
- Collection of direct push groundwater samples downgradient of Area A;
- Collection of data for fate-and-transport modeling; and

- Completion of slug testing and aquifer pump testing.

Investigative activities at SWMU 54 will be conducted consistent with the requirements of the MWP, this WPA, and related SOPs included in Appendix A. Table 1-1 identifies the applicable SOPs that will be followed for each element of the field investigation discussed in the following sections.

1.3.1 Soil Borings – Direct Push

The following sections discuss proposed soil investigations to be conducted at Areas A and B of SWMU 54 using the direct push method of drilling, as described in SOP 20.11 in Appendix A. A four-ft, Geoprobe Macro-Core® sampling device will be used to collect soil samples continuously from each of the borings, as described in SOP 20.11 in Appendix A. The location of each soil borings will be established to the nearest meter using Global Positioning System (GPS) equipment.

Table 1-10 summarizes the proposed soil investigative program for Areas A and B of SWMU 54.

1.3.1.1 Area A

As discussed in Section 1.2, sufficient definitive data exist from Parsons (1996) to characterize constituent concentrations in deep soils at Area A that are present at depths immediately above the water table or bedrock. Deep soil samples collected by Parsons (1996) from immediately above the water table are generally in the depth range of 15 to 20 ft bgs. Based on the data gaps identified in Section 1.2 and this information, the objectives of this portion of the investigation will be to accomplish the following:

- Delineate the lateral and vertical extent of constituents that remain in soil at shallow and intermediate depths after IA;
- Further evaluate the physical and geochemical characteristics of surface and intermediate depth soils at Area A and the potential for constituent leaching to deeper soils and groundwater; and
- Provide an appropriate set of definitive data for completion of a BRA.

With consideration of the above objectives, the strategy for selecting boring locations at Area A is based on the:

- Size and shape of Area A;
- Number, locations, and depth of existing boring/sample locations at Area A where definitive chemical data have been collected;
- Lateral and vertical limits of soil excavated during the IA completed by Parallax (1999);
- Inferred distribution of explosives, lead, and mercury in shallow soil and subsurface soil from definitive data collected by Parsons (1996), as shown on Figures 1-9 through 1-11; and
- Inferred distribution of lead and 2,4,6-TNT in soil from screening level data collected by Parallax (1999), as shown on Figures 1-43 and 1-45.

Table 1-10
Summary: Proposed Soil Sampling Plan
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Sample Location	Sample Designation	SAMPLE DEPTH			Analytes	
		0 - 6 inches bgs*	9 - 10 ft bgs	Immediately Above Water Table	Chemical Analytes	Other
AREA A	54SB17A	x			TCL SVOCs, PAHs, TAL Metals (including mercury), Explosives (including nitroglycerin)	Dioxin/Furans, TCL PCBs, and TCL Pesticides (for four samples)
	54SB17B		x			
	54SB18A	x				
	54SB18B		x			
	54SB19A	x				
	54SB19B		x			
	54SB20A	x				
	54SB20B		x			
	54SB21A	x				
	54SB21B		x			
	54SB22A	x				
	54SB22B		x			
	54SB23A	x				
	54SB23B		x			
	54SB24A	x				
	54SB24B		x			
	54SB25A	x				
	54SB25B		x			
	54SB26A	x				
	54SB26B		x			
	54SB27A	x				
	54SB27B		x			
	54SB28A	x				
	54SB28B		x			
	54SB29A	x				
	54SB29B		x			
	54SB30A	x				
	54SB30B		x			
	54SB31A	x				
	54SB31B		x			
	54SB32A	x				
	54SB32B		x			
	54SB33A	x				
	54SB33B		x			
	54SB34A	x				
	54SB34B		x			
	54SB35A	x			TAL metals (including mercury), Explosives (including nitroglycerin)	
	54SB35B		x			
	54SB36A	x				
	54SB36B		x			
	54SB37A	x				
	54SB37B		x			
	54SB38A	x				
	54SB38B		x			

Table 1-10 (Continued)
Summary: Proposed Soil Sampling Plan
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Sample Location	Sample Designation	SAMPLE DEPTH			Analytes	
		0 - 6 inches bgs*	9 - 10 ft bgs	Immediately Above Water Table	Chemical Analytes	Other
AREA B	54SB39A	x			TCL SVOCs, PAHs, TAL Metals (including mercury), Explosives (including nitroglycerin)	Dioxin/Furans, TCL PCBs, and TCL Pesticides (for four samples)
	54SB39B		x			
	54SB40A	x				
	54SB40B		x			
	54SB41A	x				
	54SB41B		x			
	54SB42A	x				
	54SB42B		x			
	54SB43A	x				
	54SB43B		x			
	54SB43C			x		
	54SB44A	x				
	54SB44B		x			
	54SB44C			x		
	54SB45A	x				
	54SB45B		x			
	54SB46A	x				
	54SB46B		x			
	54SB46C			x		
	54SB47A	x				
	54SB47B		x			
	54SB48A	x				
	54SB48B		x			
	54SB49A	x				
	54SB49B		x			
	54SB49C			x		
	54SB50A	x				
	54SB50B		x			
	54SB51A	x				▨
	54SB51B		x			
	54SB51C			x		
	54SB52A	x				
	54SB52B		x			
	54SB53A	x				
	54SB53B		x			
	54SB54A	x				
	54SB54B		x			
	54SB55A	x				
	54SB55B		x			

<u>Notes:</u>

bgs = below ground surface
ft = feet
TCL = Target Compound List
SVOC = Semi-volatile Organic Compound
PAH = Polyaromatic Hydrocarbon
PCB = Polychlorinated Biphenyls
TAL = Target Analyte List
* = 6-12 inches for volatile organic compounds
▨ = not applicable

Systematic Grid Sampling – Area A

Systematic grid sampling has been selected to minimize sample bias and generally provide for complete coverage of the area within and at the periphery of Area A.

- One subsurface sample for chemical analysis will be collected from each boring from a depth of nine to ten ft bgs, which is generally at an intermediate depth between the surface and the water table; and

In Chapter 9 of SW-846, USEPA outlines a method that can be used to estimate the minimum number of samples that should be collected when chemically characterizing a solid waste unit using random grid sampling. The method is a statistical approach (confidence level) that considers the expected distribution of sample observations (number, mean, and variance) and an applicable threshold (RBC, risk-based AL, etc.). Estimates of the sample mean and variance are typically made using existing site data. The goal of this sample estimation method is to provide for a set of sufficiently accurate and precise measurements, which can be used to appropriately characterize the solid waste with respect to regulatory thresholds.

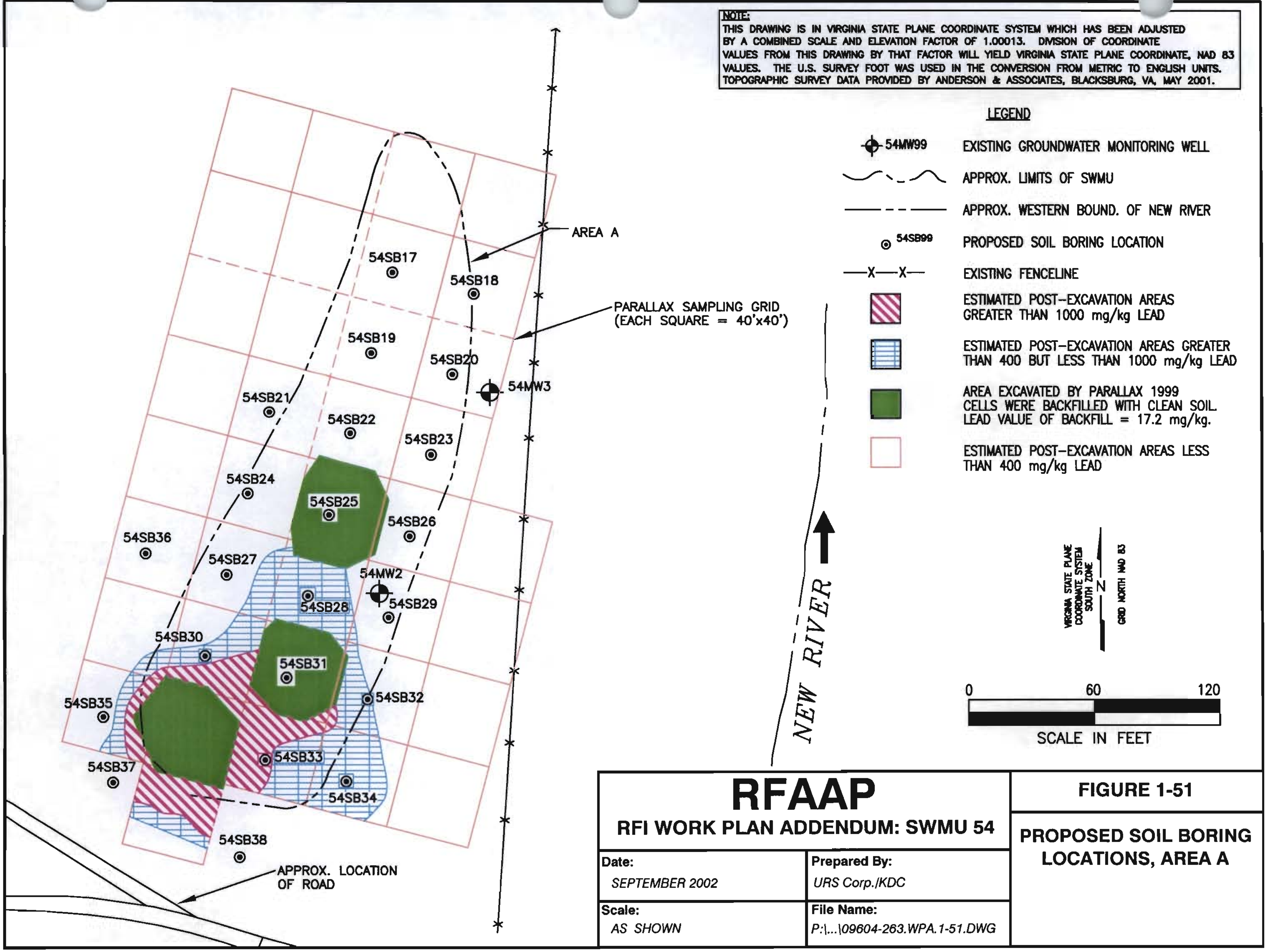
The USEPA method referenced above has been used to provide an initial estimate of the minimum number of samples that should be collected from Area A using the grid sampling strategy. Appendix C of this WPA presents the calculations used to arrive at this estimate. Existing shallow soil data from 14 samples collected by Parsons (1996) for lead were used in the calculations because they:

- Provide adequate coverage across Area A including locations within and surrounding identified waste disposal areas;
- Comprise the largest group of definitive data from a given sample interval;
- Represent the most frequently detected constituent; and
- Exhibit the widest range of concentrations relative to Industrial Soil RBCs.

The resultant calculations in Appendix C indicate that the minimum number of samples that should be collected from surface soil at Area A is 13. Assigning the same minimum number of samples for the intermediate depth is considered appropriate, given that the expected mean and variation of samples likely decreases with depth based on the existing data from Area A.

Upon consideration of the size of Area A and the areal distribution of historical detections, the proposed number of boring locations has been increased from 13 to 18. This will provide for a 40-ft sampling grid covering most of the area within and at the periphery of Area A. The sampling grid for this investigation is composed of a 120-ft by 280-ft section of the 40-ft sample grid used by Parallax during the 1999 IA. Based on existing sample data from Parsons boring 54SB16, which indicated lead concentrations of less than 32 mg/kg and no detected explosive compounds, the northernmost tip of Area A is not covered by the grid of 18 borings.

Appendix C of this WPA includes a figure showing the 475-unit grid (64 square ft per unit) used to randomly select the first boring location at Area A. Seventeen subsequent boring locations selected at fixed intervals of 40 ft from the initial location are also shown on this grid.



NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.

LEGEND

⊕ 54MW99	EXISTING GROUNDWATER MONITORING WELL
⌒–⌒	APPROX. LIMITS OF SWMU
—— – – ——	APPROX. WESTERN BOUND. OF NEW RIVER
⊙ 54SB99	PROPOSED SOIL BORING LOCATION
—X—X—	EXISTING FENCELINE
▨	ESTIMATED POST-EXCAVATION AREAS GREATER THAN 1000 mg/kg LEAD
▤	ESTIMATED POST-EXCAVATION AREAS GREATER THAN 400 BUT LESS THAN 1000 mg/kg LEAD
🟩	AREA EXCAVATED BY PARALLAX 1999 CELLS WERE BACKFILLED WITH CLEAN SOIL. LEAD VALUE OF BACKFILL = 17.2 mg/kg.
☐	ESTIMATED POST-EXCAVATION AREAS LESS THAN 400 mg/kg LEAD

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	Prepared By: URS Corp./KDC
Scale: AS SHOWN	File Name: P:\...\09604-263.WPA.1-51.DWG

FIGURE 1-51

PROPOSED SOIL BORING LOCATIONS, AREA A

241

The 18 boring locations proposed for the 40-ft sampling grid at Area A are shown on Figure 1-51 as borings 54SB17 through 54SB34. The following are proposed to meet the objectives of the soil investigation at Area A above and fill the data gaps discussed in Section 1.2:

- The 18 borings will be completed to a depth of ten ft bgs;
- One surface sample for chemical analysis will be collected from each boring from a depth of zero to six inches bgs, below gravel, vegetative, or organic layers;
- Each of the soil samples will be analyzed for TCL SVOCs, PAHs, explosives (including nitroglycerin), and TAL Metals (including mercury) and four of the soil samples will be analyzed for dioxin/furans, TCL Pesticides, and TCL PCBs consistent with the requirements outlined in the Master Quality Assurance Plan (MQAP) and Section 2.0 of this WPA. Method specifications are included in Section 2.5 of this WPA.

The samples for dioxin/furans, TCL Pesticides, and TCL PCBs analysis will be collected in pairs (surface and subsurface) from boring locations where evidence of residual waste material (including burned material) is observed or where there is historical evidence of residual waste material having been present. If evidence of residual waste material is not observed, then the sample pair(s) having the highest potential to contain organic constituents will be selected for analysis. Physical inspection of the samples and a review of historical site data will be used to make this assessment. Soil sampling will be conducted consistent with the procedures outlined in SOP 30.1 in Appendix A. Table 1-1 identifies other SOPs that will be followed for drilling and soil sampling.

Focused Sampling – Area A

In addition to the 18 borings discussed above, four borings (54SB35 through 54SB38) are proposed at Area A as part of the sampling grid. The locations of the additional borings are shown on Figure 1-51. The four direct push borings will be completed to a depth of ten ft bgs at the following locations:

- Boring 54SB35 is proposed at a location 40 ft southwest of boring 54SB30. This boring is designed to provide additional information on the potential presence of lead, mercury, and explosives in soil at levels of concern; both southwest of Area A and the southwestern limit of the area excavated during the IA, thus filling an identified data gap associated with lateral delineation of these constituents outside the southwestern limit of Area A.
- Boring 54SB36 is proposed at a location 40 ft west of borings 54SB3 (Parsons) and 54SB27 outside of the limits of Area A. This boring is designed to provide additional information on the potential presence of lead, mercury, and explosives in soil west of boring 54SB3 at levels of concern, thus filling an identified data gap associated with lateral delineation of these constituents in the area west of boring 54SB3.
- Boring 54SB37 is proposed at a location 40 ft southwest of boring 54SB33. This boring is designed to provide additional information on the potential presence of lead, mercury, and explosives in soil at levels of concern; both south of Area A and the southernmost area excavated during the IA, thus, filling an identified data gap associated with lateral delineation of these constituents outside the southern limit of Area A.

- Boring 543B38 is proposed at a location 40 ft south of borings 54SB1 (Parsons) and 54SB34, and at a location 80 ft east of boring 54SB37. This boring is designed to provide additional information on the presence of lead, mercury, and explosives in soil at levels of concern, both south of Area A and the southernmost area excavated during the IA, thus filling an identified data gap associated with lateral delineation of these constituents outside the southern limit of Area A.

The following is proposed to meet the objectives of the soil investigation at Area A outlined above and to fill the data gaps identified in Section 1.2:

- One surface sample for chemical analysis will be collected from each boring from a depth of zero to six inches bgs, below gravel, vegetative, or organic layers;

- One subsurface sample for chemical analysis will be collected from each boring from a depth of nine to ten ft bgs, which is generally at an intermediate depth between the surface and the water table; and

- Each of the soil samples will be analyzed for TAL Metals (including mercury) and explosives (including nitroglycerin) because these borings are intended to delineate the extent of metals and explosives in soil within specific areas outside of Area A.

1.3.1.2 Area B

The soil investigation at Area B will focus on the approximate 1.09-acre area identified on Figures 1-52 and 1-53. In general, this area represents the portion of the Parallax grid and certain areas outside of the grid, where, based on screening level data, concentrations of lead and explosives in soil are of potential concern. For lead, the area to be investigated includes locations where screening level samples indicated soil concentrations in the minimum range of ten mg/kg to 100 mg/kg, as shown on Figures 1-52 and 1-53. For explosives, the area to be investigated generally includes locations where screening level samples indicated detectable levels of explosives (see Figure 1-40).

Based on the data gaps identified in Section 1.2, the objectives of this portion of the investigation will be to accomplish the following:

- Delineate the lateral and vertical extent of constituents in soil after the IA;

- Further evaluate the physical and geochemical characteristics of soils at Area B and the potential for constituent leaching to groundwater; and

- Provide an appropriate set of definitive data for completion of a BRA.

With consideration of the above objectives, the strategy for selecting boring locations at Area B is based on the:

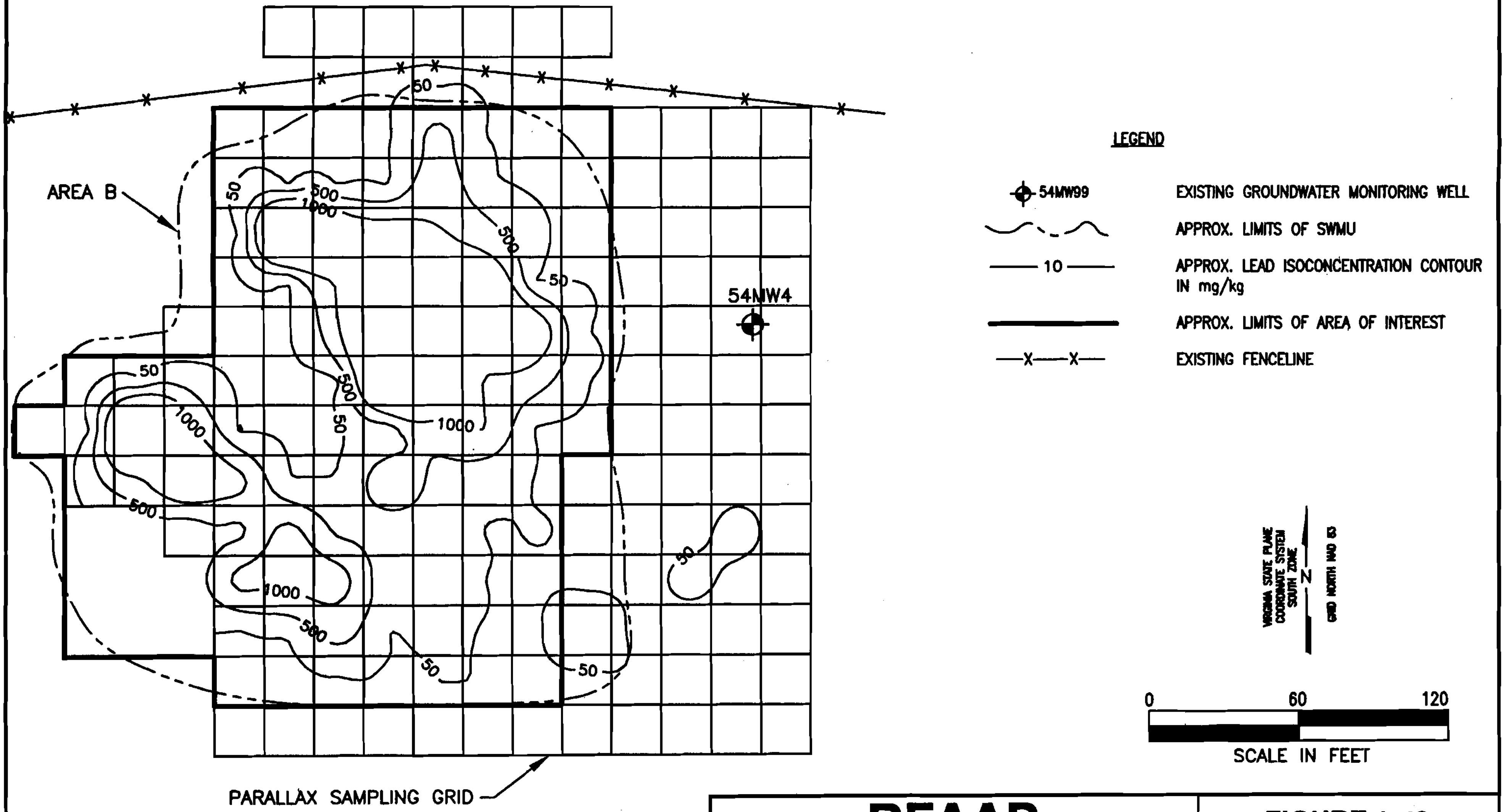
- Size and shape of Area B;

- Lack of definitive data for soil;

- Lateral and vertical limits of soil excavated during the IA completed in 1999; and

- Inferred current distribution of explosives and lead in surface soil and subsurface soil from existing screening level data as shown on Figures 1-33 through 1-42, and 1-46 and 1-47.

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002

Prepared By: URS Corp./TAC

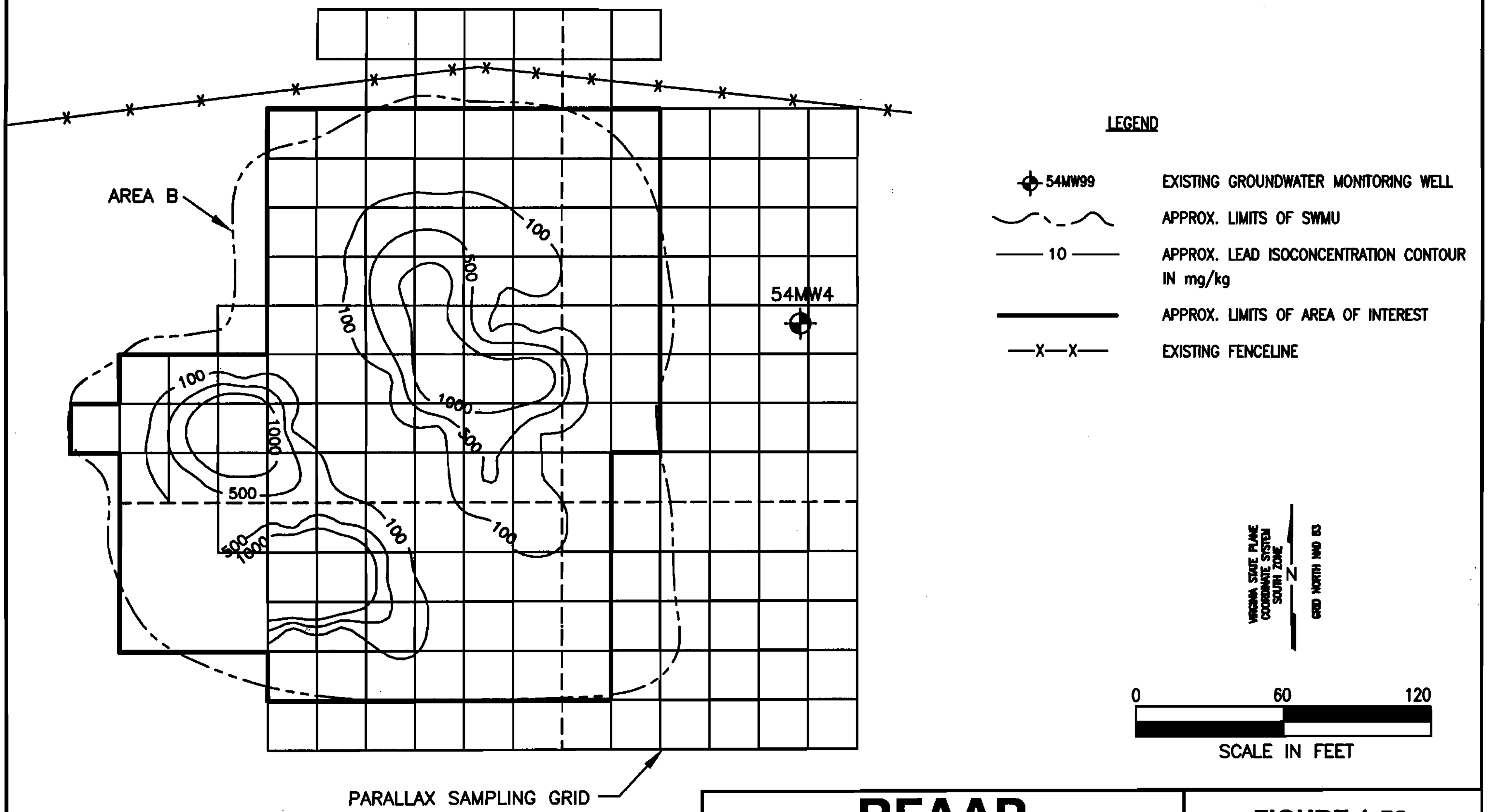
Scale: AS SHOWN

File Name: P:\...\09604-263.WPA.1-53.DWG

FIGURE 1-52

AREA OF INTEREST FOR SOIL INVESTIGATION RELATIVE TO LEAD SCREENING LEVEL DATA FOR SURFACE SOIL (0.5 FT BGS) AREA B, PARALLAX, 1999

NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*

Prepared By: *URS Corp./TAC*

Scale: *AS SHOWN*

File Name: *P:\...\09604-263.WPA.1-54.DWG*

FIGURE 1-53

AREA OF INTEREST FOR SOIL INVESTIGATION RELATIVE TO LEAD SCREENING DATA FOR SOIL (9 FT BGS), AREA B

207

- Two sampling strategies have been used to select the number and location of borings at Area B. Systematic grid sampling will used to provide for complete coverage within the area of interest. Focused sampling (biased) will be used at specific locations to provide lateral and vertical delineation of constituents in soil where data gaps still exist after overlaying the boring grid. SOP 30.7 in Appendix A provides general information on these two sampling strategies. The following sections discuss the proposed boring locations and sampling plan associated with each sampling strategy.

Systematic Grid Sampling – Area B

Systematic grid sampling has been selected to minimize sample bias and generally provide for complete coverage within the area to be investigated at Area B. Complete coverage using a grid approach is appropriate because existing data for Area B are screening level data rather than definitive data.

The USEPA method discussed in Section 1.3.1.1 has been used to provide an initial estimate of the minimum number of samples that should be collected from Area B using the grid sampling strategy. Appendix C of this WPA presents the calculations used to arrive at this estimate. Existing shallow soil data from MSE (1998) for lead concentrations equal to or greater than 100 mg/kg were used in the calculations because the eight associated samples:

- Compose the largest group of discrete data submitted for laboratory analysis;

- Represent the most frequently detected constituent; and

- Exhibit the widest range of concentrations relative to Industrial Soil RBCs.

The resultant calculations in Appendix C indicate that the minimum number of samples that should be collected from surface soil at Area B is 11. Assigning the same minimum number of samples for the intermediate depth is considered appropriate given that the expected mean and variation of samples likely decreases with depth based on existing data from Area B.

Considering the size of Area B, the proposed number of boring locations has been increased from 11 to 12. This will provide for complete coverage of the investigation area shown on Figure 1-54 with a 60-ft spacing between borings.

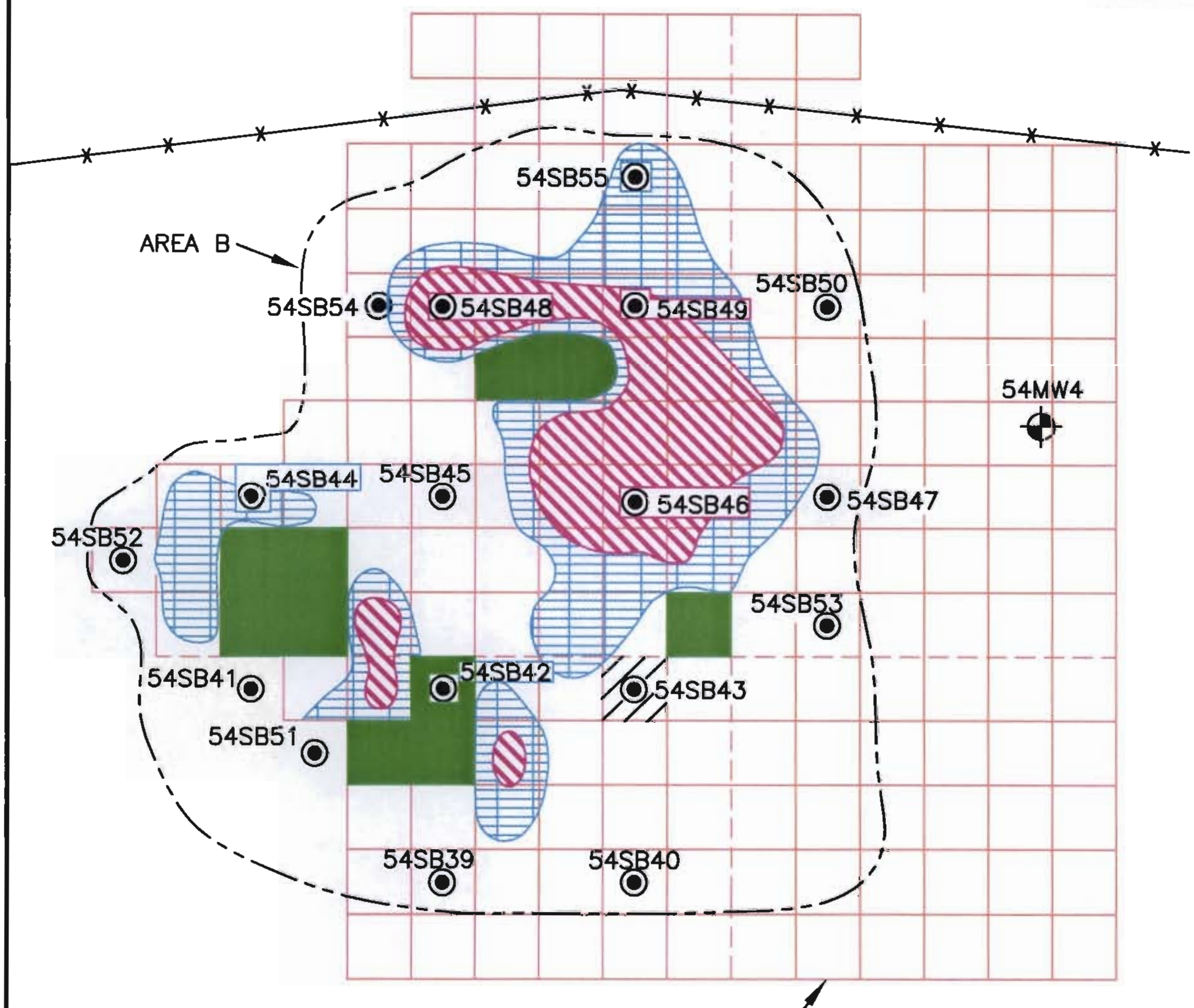
Appendix C of this WPA includes a figure showing the 100-unit grid used to randomly select the first boring location at Area B. Eleven subsequent boring locations selected at fixed intervals of 60 ft from the initial location are also shown on this grid.

Figure 1-54 shows the 12 proposed boring locations at Area B, identified as 54SB39 through 54SB50. The 12 direct push soil borings will be advanced to the following depths:

- Borings 54SB39 through 54BSB42, 54BSB45, 54SB47, 54SB48, and 54SB50 will be advanced to a depth of ten ft bgs. A 10-ft depth is proposed for these borings because screening level data at these locations generally indicated lead concentrations in soil less than 100 mg/kg at a depth of nine ft bgs. In the case of boring 54SB42, the area has been excavated as part of the IA.

Borings 54SB43, 54SB44, 54BSB46, and 54SB49 will be advanced to bedrock, which is expected to be at 18 to 22 ft bgs. These borings will be advanced to bedrock because screening level data at these

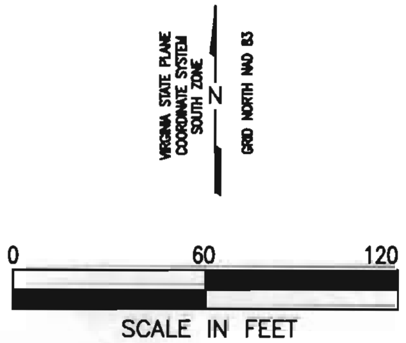
NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.



PARALLAX SAMPLING GRID
(EACH SQUARE = 20'x20')

LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
~ - ~	APPROX. LIMITS OF SWMU
◉ 54SB99	APPROX. LOCATION OF PROPOSED SOIL SAMPLE
—X—X—	EXISTING FENCELINE
▨	INITIAL RANDOMLY SELECTED BORING LOCATION
🟥	ESTIMATED POST-EXCAVATION AREAS GREATER THAN 1000 mg/kg LEAD
▤	ESTIMATED POST-EXCAVATION AREAS GREATER THAN 400 BUT LESS THAN 1000 mg/kg LEAD
🟩	AREA EXCAVATED BY PARALLAX 1999 CELLS WERE BACKFILLED WITH CLEAN SOIL. LEAD VALUE OF BACKFILL = 17.2 mg/kg.
☐	ESTIMATED POST-EXCAVATION AREAS LESS THAN 400 mg/kg LEAD



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: SEPTEMBER 2002	**Prepared By:** URS Corp./TAC
Scale: AS SHOWN	**File Name:** P:\...\09604-263.WPA.1-55.DWG

FIGURE 1-54

PROPOSED SOIL BORING LOCATIONS, AREA B

locations generally indicated lead concentrations in soil greater than 100 mg/kg at a depth of nine ft bgs.

- To meet the objectives of the soil investigation at Area B, the following samples will be collected from the 12 borings for chemical analysis:One surface soil sample for chemical analysis will be collected from each boring from a depth of zero to six inches bgs, below gravel, vegetative, or organic layers;
- One intermediate depth soil sample for chemical analysis will be collected from each boring at a depth of nine to ten ft bgs;
- One deep soil sample for chemical analysis will be collected from borings 54BSB43, 54BSB44, 54BSB45, and 54BSB46 at a depth immediately above the water table or bedrock, whichever is encountered first in a boring; and
- Each of the soil samples will be analyzed for TCL SVOCs, PAHs, explosives (including nitroglycerin), and TAL Metals (including mercury) and four of the soil samples will be analyzed for dioxin/furans, TCL Pesticides, and TCL PCBs consistent with the requirements outlined in the MQAP and Section 2.0 of this WPA; methods of analysis to be used are specified in Section 2.5 of this WPA.

The samples for dioxin/furans, TCL Pesticides, and TCL PCBs analysis will be collected in pairs (surface and subsurface) from boring locations where evidence of residual waste material (including burned material) is observed. If evidence of residual waste material is not observed, then the sample pair(s) having the highest potential to contain organic constituents will be selected for analysis. Physical inspection of the samples and a review of historical site data will be used to make this assessment.

Focused Sampling – Area B

Five additional borings locations (54SB51 through 54SB55) are proposed at Area B as shown on Figure 1-54. These proposed borings will be completed to a depth of ten ft bgs, with the exception of 54SB51, which will be advanced to bedrock refusal. As with the grid borings, the focused borings proposed to be completed to a depth of ten ft bgs are at locations where screening level data indicated lead concentrations in soil less than 100 mg/kg at a depth of nine ft bgs. The five direct push borings will be completed at the following locations:

- Boring 54SB51 is proposed at a location 20 ft west of the southwestern most area excavated during the IA. This boring is designed to fill a data gap in lateral and vertical delineation of lead and other constituents in soil west of this excavation area not addressed by surrounding grid borings 54BSB7, 54BSB9, and 54BSB10.
- Boring 54SB52 is proposed at a location 60 ft west of the westernmost area excavated during the IA. This boring is designed to fill a data gap in lateral delineation of lead and other constituents in soil west of this excavation area not addressed by surrounding grid borings 54BSB9 and 54BSB12.
- Boring 54SB53 is proposed at a location 20 ft east of the easternmost area excavated during the IA. This boring is designed to fill a data gap in lateral delineation of lead and other constituents in soil east of this excavation area not addressed by surrounding grid borings 54SB43, 54SB46, and 54SB47.

Table 1-11
Summary: Proposed Groundwater Investigation Program
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Proposed Monitoring Wells

Proposed Well Identification	Location	Position Relative to SWMU	Proposed Screened Zone	Estimated Proposed Depth (ft bgs)	Estimated Depth to Bedrock (ft bgs)	Proposed Screened Interval (ft bgs)
54MW5	Area A	Upgradient	Soil/Bedrock	28	20	18-28
54MW6	Area B	Upgradient	Soil/Bedrock	28	20	18-28
54MW7	Area B	Downgradient	Soil/Bedrock	28	20	18-28

Proposed Groundwater Samples

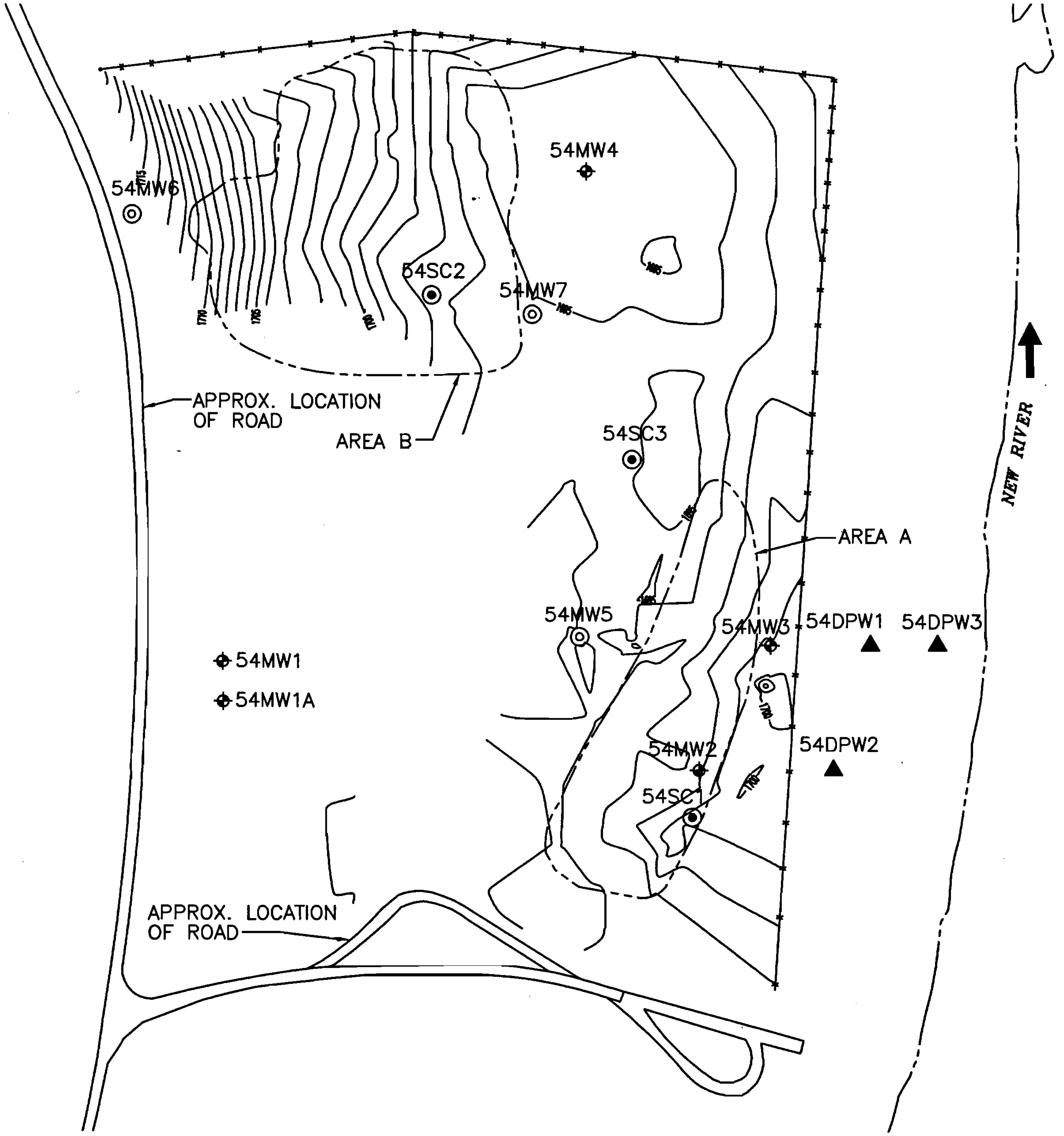
Sample Location	Sample Designation	Type	Position	Sampling Zone	Analytes
Area A	54MW2	Monitoring Well	Downgradient	Soil/Bedrock	TCL SVOCs, PAHs, TAL Metals (including mercury), Explosives (including nitroglycerin), Perchlorate
	54MW3	Monitoring Well	Downgradient	Soil/Bedrock	
	54MW5	Monitoring Well	Upgradient	Soil/Bedrock	
	54DPW1	Direct Push	Downgradient	Soil	TAL Metals, Explosives (including nitroglycerin), Perchlorate
	54DPW2	Direct Push	Downgradient	Soil	
	54DPW3	Direct Push	Downgradient	Soil	
Area B	54MW4	Monitoring Well	Downgradient	Bedrock	TCL SVOCs, PAHs, TAL Metals (including mercury), Explosives (including nitroglycerin), Perchlorate
	54MW6	Monitoring Well	Downgradient	Soil/Bedrock	
	54MW7	Monitoring Well	Downgradient	Soil/Bedrock	

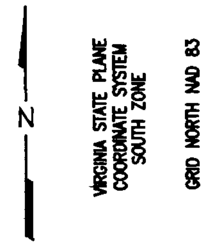
Notes:
TCL = Target Compound List
SVOC = Semi-volatile Organic Compound
PAH = Polyaromatic Hydrocarbon
TAL = Target Analyte List
ft bgs = feet below ground surface
ft = feet

200-

42

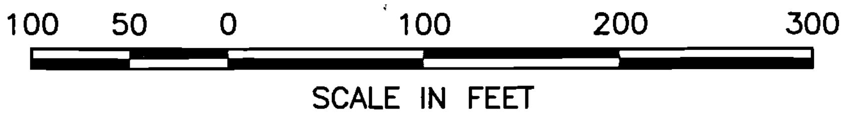
NOTE:
THIS DRAWING IS IN VIRGINIA STATE PLANE COORDINATE SYSTEM WHICH HAS BEEN ADJUSTED BY A COMBINED SCALE AND ELEVATION FACTOR OF 1.00013. DIVISION OF COORDINATE VALUES FROM THIS DRAWING BY THAT FACTOR WILL YIELD VIRGINIA STATE PLANE COORDINATE, NAD 83 VALUES. THE U.S. SURVEY FOOT WAS USED IN THE CONVERSION FROM METRIC TO ENGLISH UNITS. TOPOGRAPHIC SURVEY DATA PROVIDED BY ANDERSON & ASSOCIATES, BLACKSBURG, VA, MAY 2001.





LEGEND

⌖ 54MW99	EXISTING GROUNDWATER MONITORING WELL
—1980—	EXISTING TOPOGRAPHIC CONTOUR LINE IN FEET
‿⁀‿⁀	APPROX. LIMITS OF SWMU AREAS
—— – – ——	APPROX. WESTERN BOUNDARY OF NEW RIVER
—x—x—	EXISTING FENCELINE
◎ 54MW5	PROPOSED GROUNDWATER MONITORING WELL LOCATION
▲ 54DPW1	PROPOSED DIRECT PUSH GROUNDWATER SAMPLE LOCATION
⊙ 54SC1	PROPOSED ROTOSONIC SOIL CORE BORING LOCATION



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *SEPTEMBER 2002*

Prepared By: *URS Corp./DRT:TAL*

Scale: *1" = 100'*

File Name: *P:\...\09604-263.wpa.1-56.DWG*

FIGURE 1-55

PROPOSED MONITORING WELL LOCATIONS, DIRECT PUSH GROUNDWATER SAMPLE LOCATIONS, AND SOIL CORE BORING LOCATIONS

monitoring well will be located at the minimum distance upgradient from Area B that is expected to yield samples representative of background water quality. Monitoring well 54MW6 will be installed to monitor the uppermost portion of the shallow aquifer at Area B, which occurs in the sand and gravel layer immediately overlying bedrock and in weathered rock.

Downgradient monitoring well 54MW7 is proposed immediately east of Area B and south of existing downgradient well 54MW4. This well will function as the second downgradient well for Area B and thereby fill the data gap identified above. Monitoring well 54MW7 will be installed to monitor the same interval of aquifer to be monitored by the proposed upgradient well at Area B.

The direct air rotary method of drilling will be used for completion of the monitoring well borings at SWMU 54, as described in Section 5.2 of the MWP and SOP 20.11 in Appendix A. At a minimum, an eight-inch diameter drill bit will be used. Soil samples will be collected from each boring using a split-barrel sampler as described in SOP 20.11, with the modification that the method of advancing the sampler will be hydraulic push rather the standard penetration test. Samples will be collected continuously from each well boring for the depth interval zero to ten ft bgs and at five-ft intervals thereafter.

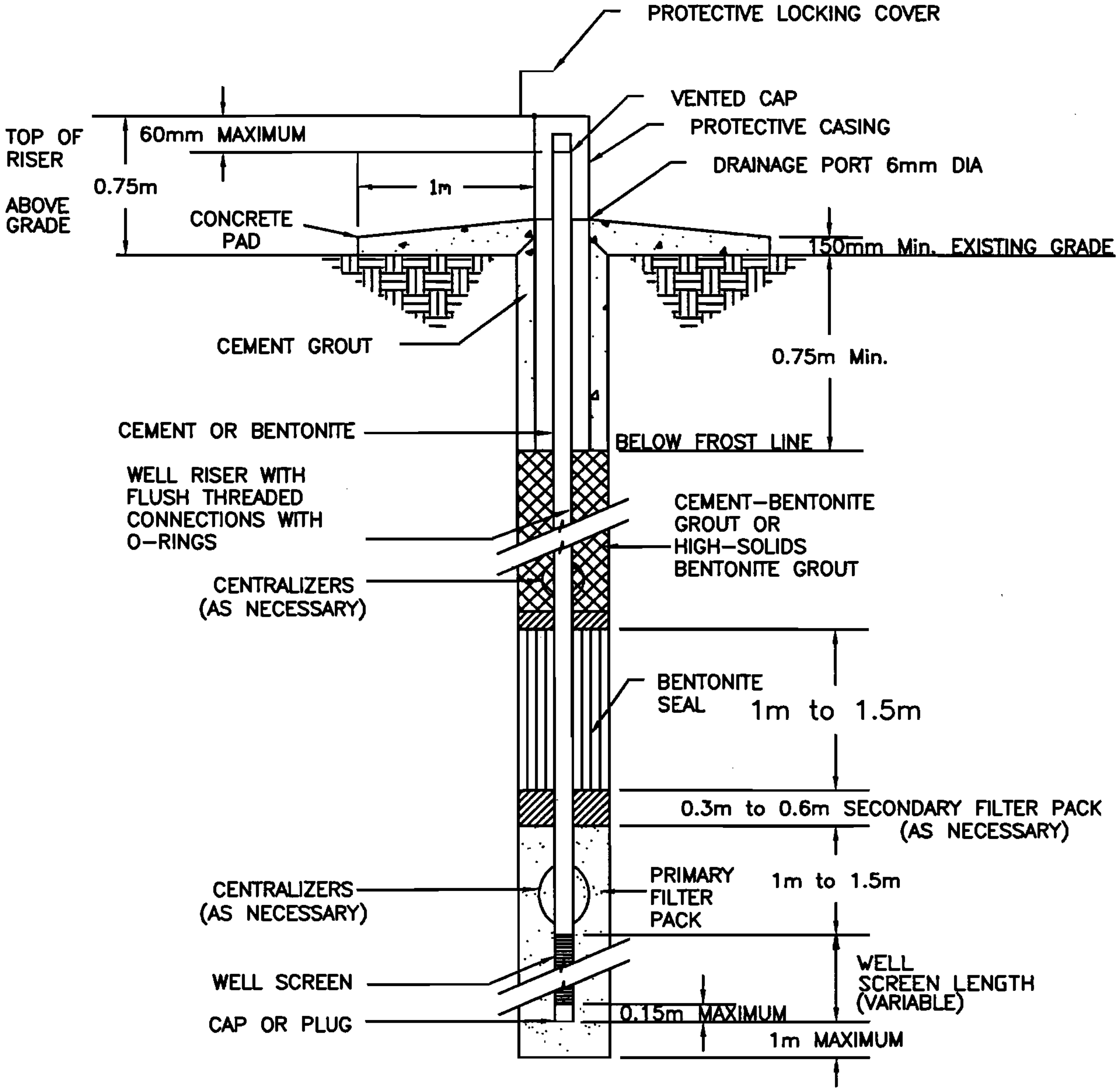
Monitoring well installation procedures and material specifications will follow SOP 20.1 in Appendix A with the following site-specific clarifications:

- Four-inch diameter, Schedule 40 polyvinyl chloride (PVC) well riser and screen will be used for well construction;
- Well screens will be continuously slotted with a 0.02-inch slot size;
- Granular filter pack will consist of Global #7, quartz silica filter pack (effective size 90% retained 0.0188 inch) or equivalent; andA well screen will be positioned across the water table interface so that the top of the screen is approximately two ft above expected seasonally high groundwater levels.

Based on existing subsurface data at SWMU 54, the depth of the proposed monitoring wells at SWMU 54 is expected to be 30 ft bgs or less. This depth assumes that stabilized groundwater levels at the well location will be in the range of 15 to 22 ft bgs, as measured at existing well locations (see Table 1-2). Each monitoring well will be constructed with its screened interval across the soil/bedrock interface so that the uppermost portion of the water table is monitored; thereby, functioning as a detection monitoring well. The type of construction to be used for the proposed monitoring wells is shown on Figure 1-56. Actual depths and thickness of the well elements shown on Figure 1-56 will be dependent on the conditions encountered at each proposed location.

Each monitoring well will be developed after installation consistent with the procedures outlined in SOP 20.2 in Appendix A. Development at a monitoring well will be initiated no sooner than 48 hours after final grouting of the well has been completed. Development will be completed no later than seven days after final grouting of the well has been completed. Other appropriate SOPs that will be followed for drilling, monitoring well installation and well development activities are identified in Table 1-1.

Each newly installed monitoring will be surveyed after completion to establish location coordinates and vertical elevation. Surveying activities will be conducted as outlined in Section 5.10 of the MWP.



ABBREVIATION KEY

DIA = DIAMETER

Min. = MINIMUM

m = METER

mm = MILLIMETER

RFAAP

RFI WORK PLAN ADDENDUM SWMU 54

Date: *SEPTEMBER 2002*	**Prepared By:** *URS Corp./TAC*
Scale: *NO SCALE*	**File Name:** *P:\...\09604-263.WPA.1-57.DWG*

FIGURE 1-56

PROPOSED MONITORING WELL CONSTRUCTION DIAGRAM

1.3.2.2 Groundwater Sampling – Monitoring Wells

The following monitoring wells at SWMU 54 will be sampled as part of this investigation:

- Existing downgradient monitoring wells 54MW2 and 54MW3 at Area A, and 54MW4 at Area B;
- New upgradient monitoring wells 54MW5 at Area A and 54MW6 at Area B; and
- New downgradient monitoring well 54MW7 at Area B.

Existing monitoring well 54MW1 will not be sampled as part of this investigation because the new upgradient monitoring well 54MW5 at Area A will replace this well in the monitoring well network.

Static water levels will be measured at the monitoring wells at SWMU 54 (including existing monitoring wells 54MW1 and 54MW1A, which will not be sampled) prior to purging and sampling. Monitoring wells will be purged and sampled using either the Type I sampling technique (low-flow purging and sampling) or Type II sampling technique (high-flow purge and low-flow sampling), as described in SOP 30.2 in Appendix A. The method to be used at a given well will depend on its recharge characteristics, as the uppermost portion of the surface aquifer does not have a single discrete flow zone. Existing monitoring wells at Area A were noted to have low recharge rates during sampling conducted for the VI at SWMU 54 (Dames & Moore 1992a). In general, if the yield of a well is less than 0.5 liters per minute then the Type I sampling technique will be used to collect groundwater samples; otherwise, the Type II sampling technique will be used. Monitoring well purging will continue until parameters have stabilized as described in SOP 30.2. Other appropriate SOPs that will be followed for well sampling activities are identified in Table 1-1.

Groundwater samples collected from SWMU 54 will be analyzed for TCL SVOCs, PAHs, explosives (including nitroglycerin), total and dissolved TAL Metals (including mercury), and perchlorate consistent with the requirements outlined in the MQAP and Section 2.0 of this WPA. Section 2.5 of this WPA specifies the analytical test methods to be used for this investigation.

1.3.2.3 In Situ Water Quality Testing

Approximately 24 hours after groundwater sampling is complete, each well that is sampled will be logged using a downhole, water quality instrument to obtain *in situ* values for temperature, compensated pH, oxidation-reduction potential (ORP), specific conductance, turbidity, and dissolved oxygen. SOP 40.1 in Appendix A describes the type of instrument that will be used.

Well logs will be prepared presenting the profiled results. This information will be used to evaluate water quality changes with respect to location (upgradient, downgradient, and SWMU area) and depth and will be used along with other data for fate-and-transport analysis.

1.3.2.4 Groundwater Sampling – Direct Push

As indicated in Section 1.2, explosives and iron have been detected in samples that have been collected from monitoring wells 54MW2 and 54MW3, which are located at the downgradient edge of Area A. The highest concentrations of explosives have been detected in samples collected from well 54MW3. In addition, perchlorate has been detected in the latest sample collected from monitoring well 54MW3. Therefore, a data gap exists concerning the downgradient extent of these constituents in groundwater. The collection of three direct push groundwater samples is proposed downgradient (east) of Area A to address this data gap. The area of possible investigation downgradient of Area A is limited by the presence of the New River, which is located approximately 150 ft east of monitoring well 54MW3. Thus, groundwater samples will be located to assess the extent to which these constituents may have migrated from Area A toward the New River via groundwater.

Figure 1-55 shows the proposed locations of the three direct push groundwater samples:

- Groundwater sample 54DPW1 is proposed at a location approximately 75 ft east of monitoring well 54MW3. This sample location is approximately one-half the distance between monitoring well 54MW3 and the New River.

- Groundwater sample 54DPW2 is proposed at a location approximately 100 ft east of monitoring well 54MW2. This sample location is approximately one-half the distance between monitoring well 54MW2 and the New River.

- Groundwater sample 54DPW3 is proposed at a location approximately 50 ft east of sample 54DPW1. This boring will be located as close to the rise overlooking the New River as is practical.

The method to be used for collecting the direct push groundwater sample will be dependent on the conditions encountered at each boring location. Groundwater sampling methods used will follow SOP 20.12 in Appendix A. A four-ft, Geoprobe Macro-Core® sampling device will be used to collect soil samples continuously from each of the borings to the depth of encountered groundwater, as described in SOP 20.11 in Appendix A. Other appropriate SOPs that will be followed for drilling and the collection of groundwater samples are identified in Table 1-1.

Groundwater samples collected from each of the direct push borings will be analyzed for explosives (including nitroglycerin), perchlorate, and TAL Metals (including mercury) consistent with the requirements outlined in the MQAP and Section 2.0 of this WPA. Section 2.4 of this WPA specifies the analytical methods to be used for this investigation.

1.3.3 Aquifer Testing

1.3.3.1 Slug Testing

Slug tests are proposed at SWMU 54 to assess the hydraulic conductivity of the screened unconfined aquifer at selected monitoring well locations. Slug tests will be conducted at existing monitoring well 54MW3 and at newly installed monitoring wells 54MW5, 54MW6, and 54MW7 following the procedures outlined in Section 5.9.1 of the MWP and SOP 40.3 in Appendix A. Rising head tests will be conducted at locations where the well screen extends above the top of the water table. Falling head tests will be conducted at locations where the measured level of water in a well is above the top of the well screen.

Slug test data will be analyzed using a computer-based, model solution appropriate for the type of unconfined aquifer present at SWMU 54. The specific model to be used for analysis will be selected after completion of the tests and a review of monitoring well data, geologic data, and test data. Hydraulic conductivity data generated from the slug tests will be used:

- To evaluate whether an aquifer pumping test is feasible at SWMU 54, and the type of test that should be conducted; and

- As input data for modeling groundwater flow and potential constituent migration at SWMU 54.

1.3.3.2 Aquifer Pumping Test

Existing data from the VI conducted at SWMU 54 indicated apparent low well yields at Area A. This suggests that an aquifer-pumping test may not be an appropriate method of aquifer characterization for the uppermost zone of groundwater flow currently being monitored, which includes the alluvial aquifer. Slug test data and data collected during well development and purging will be used to further evaluate whether an aquifer-pumping test is appropriate, specifically, whether a test can be conducted at one of the existing or newly proposed four-inch diameter monitoring wells located downgradient. In addition to the presence of a sufficient water column for pumping, the main criteria for deciding whether an aquifer-pumping test is appropriate will be the identification of potential zones of high conductivity in bedrock as revealed by:

- Calculation of a relatively high hydraulic conductivity value on the order of 1 x 10^{-3} cm/sec or higher from the slug tests;
- A review of existing and new boring logs (lithology, fluid loss, etc.); and
- Well development and purging data that indicate sustainable pumping rates equal to or more than two gallons per minute.

If it is established that a pump test is appropriate, then the test will be conducted with:

- A single pumping well consisting of one of the four-inch diameter monitoring wells located downgradient of Area A or B; and
- A series of observation points for monitoring changes in water levels during the test, which generally comprise the remaining monitoring wells.

Information from the slug test data, well development data, and purge data will be used to design the aquifer pumping test in terms of type of test (step or constant rate), pumping rate, and duration. As appropriate, computer simulations will be used in the design of the test. The maximum duration of the test is expected to be 12 hours. If a step test is conducted, the maximum duration of a given step will be two hours; each step will be of equal duration.

An electrical submersible pump with an electronic control box will be used to conduct the aquifer-pumping test. This pump will be placed into the pumping well a sufficient time prior to the test to allow for the water in the well to equilibrate. Prior to beginning the aquifer-pumping test, pressure transducers will be used to collect baseline water-level measurements from each well to be monitored in the test (including the pumping well). These transducers will be connected to a multi-channel data logger capable of storing sufficient measurements for the required test. Additional baseline measurements will be collected with an electronic water-level indicator. Water-level measurements will be collected from the pumping well and observations at a logarithmically based measurement frequency, which will generally consist of the following:

Pump Test Start (minutes)	Measurement Frequency
0-0.4	Every 0.083 minutes
0.4-1	Every 0.166 minutes
1-10	Every 0.2 minutes
10-100	Every 2 minutes
100-720	Every 5 minutes

Supplemental water-level measurements will be collected with an electronic water-level indicator during the test. An inline flow meter will be used to measure the discharge rate and volume of water pumped. The discharge rate will be periodically verified by the timing the discharge into a fixed volume container. Groundwater quality parameters, including temperature, specific conductivity, oxidation/reduction potential, and dissolved oxygen will also be measured. Water from the pumping test will be discharged into an appropriate sized container or containers and managed as Investigation-Derived Material (IDM) consistent with the requirements outlined in Section 1.3.6.

A laptop computer will be used to view time and drawdown data during the test to evaluate the data curve and potential anomalies with the test. At the completion of the drawdown test, the pump will be shut off. Recovery measurements will be made with the pressure transducers at the same frequency measured during the drawdown portion of the test. Verification measurements will also be collected with an electronic water-level meter. Recovery monitoring will continue for 60 minutes or less if 90 % recovery to the initial static water level in the pumping well is observed within 60 minutes.

Downhole equipment used for the pumping test will be decontaminated prior to and after use following the procedures outlined in SOP 80.1 in Appendix A. Field activities and data associated with the pumping test will be documented in the field notebook consistent with SOP 10.1 in Appendix A. Field data sheets will also be completed for each well monitored during the pumping test. These data sheets will include time and water-level measurement data obtained using the electronic water-level indicator.

The data generated from the pumping test will be used to calculate:

- Estimated values for aquifer hydraulic conductivity, transmissivity, and storage; and
- Specific capacity and well yield of the pumping well.

In addition, the degree of interconnection of monitoring wells at SWMU 54 to fractures in the bedrock aquifer will be evaluated. This evaluation will be conducted by analyzing the water-level responses to pumping at various points of observation both in space and in time.

1.3.4 Fate and Transport Data Collection

Based on data collected during the RFI, fate-and-transport analysis will be conducted at SWMU 54 to evaluate potential:

- Constituent-specific mobility in the subsurface;
- Leaching of constituents from soil to groundwater; and

- Migration of dissolved phase constituents in groundwater.

Field data will be collected at SWMU 54 to support development of model(s) for fate and transport of organic constituents and metals. The major elements of the field program are:

- Collection of soil samples from Areas A and B for testing of physical and geochemical parameters;
- Completion of slug tests at Areas A and B to provide estimates of hydraulic conductivity;
- The collection of relatively undisturbed soil cores from selected locations at Areas A and B for physical testing, column testing, and batch testing; and
- Completion of an aquifer-pumping test, if appropriate.

Table 1-12 summarizes the proposed laboratory and field-testing programs for fate and transport data collection at SWMU 54.

1.3.4.1 Physical Testing and Geochemical Testing of Soil Samples

Ten soil samples collected during the soil investigation at SWMU 54 that are representative of soil types encountered will be tested for the following parameters by the methods in Section 2.5.4 of this WPA:

- Grain-size analysis (ASTM D-422)
- Atterberg limits (ASTM D-4318);
- Soil moisture content (ASTM-2216);
- Total organic content (ASTM D-2974);
- Soil bulk density (ASTM D-4253);
- Measurement of hydraulic conductivity (ASTM D-5084 and D-5856);
- Soil porosity (ASTM D-854 and D-2973);
- pH (ASTM D-4972);
- Particle-size distribution (ASTM D-422);
- Cation exchange capacity (various methods).

Three of the ten soil samples submitted for testing will be relatively undisturbed core samples to be collected from Areas A and B, as described in Section 1.3.4.2. Data generated from the above tests will be used to:

- Describe the physical and geochemical properties of soil types present at SWMU 54;
- Evaluate various physical and geochemical processes that govern constituent mobility and transport such as adsorption, absorption, ion exchange, desorption, and dispersion;

Table 1-12
Summary: Proposed Fate and Transport Data Collection
Physical/Geochemical Testing and Slug Testing
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Description	Moisture Content	Particle Size Distribution	Atterberg Limits	Total Organic Content	Porosity (Effective)	Bulk Density	pH	Cation Exchange Capacity	Permeability	Column Test for Pb	Column Test for As, Cr, Hg, Pb	Batch Test for Pb	Field Slug Tests on Wells
Seven Representative Soil Samples from Soil Borings/Wells	x	x	x	x	x	x	x	x					
Three Representative Soil Core Samples (Rotosonic)	x	x	x	x	x	x	x	x	x				
One Representative Set of Soil Core Samples (Rotosonic)										x	x	x	
Monitoring Wells 54MW2, 54MW3, 54MW5, 54MW6, 54MW7													x

Notes:

As = Arsenic
Cr = Chromium
Hg = Mercury
Pb = Lead

26p

- Evaluate the potential for constituent leaching from soil to groundwater; and
- Select appropriate input parameters for modeling of constituent leaching to groundwater and migration of dissolved phase constituent in groundwater.

In addition to the testing described above, the three relatively undisturbed soil core samples will be submitted for additional physical and geochemical testing. The proposed testing program is described in the following section.

1.3.4.2 Collection of Soil Cores for Laboratory Testing

Relatively undisturbed core samples of soil will be collected at three proposed boring locations in the SWMU 54 area; these core samples will be collected using the rotosonic drilling technique discussed in Section 5.2 of the MWP (sonic drilling). This method of drilling simultaneously uses a combination of high-frequency vibration and low rotational and downward forces to advance a dual-line casing in the boring. The dual-line casing consists of a large diameter-sampling barrel and override casing. The core barrel is advanced ahead of the outer casing. When the core barrel is ready to be retrieved, the outer casing is driven over the sample barrel to maintain hole stability. Consistent, high-quality core samples of soil, which are relatively undisturbed, can be obtained using this method.

Four- to eight-inch diameter core samples will be collected continuously from the three preliminary locations shown on Figure 1-55:

- Boring 54SC1 is proposed at a location within the defined limits of Area A and will be advanced to bedrock;
- Boring 54SC2 is proposed at a location within the defined limits of Area B and will be advanced to bedrock; and
- Boring 54SC3 is proposed at an intermediate point between Areas A and B and will be advanced to bedrock.

The final boring locations will be selected based on the results of the proposed soil sampling at Areas A and B. Borings will be located within areas where constituent concentrations are generally at background levels, but where representative soil samples can be collected from the types of soil where potential leaching of constituents may be of concern. Appropriate SOPs that will be followed for drilling and soil core sampling are identified in Table 1-1. Core samples will be collected and handled consistent with the procedures described in Section 3.3 of SOP 20.11 in Appendix A, with reference to ASTM Standard Practice 4220-95 (Standard Practice for Preserving and Transporting Soil Samples).

Representative core samples from the borings will be submitted for laboratory testing as described in the following sections.

Column Testing - Column testing is proposed on two core samples to evaluate the sorption of lead, arsenic, chromium, and mercury in soil at SWMU 54. Lead is proposed for column testing based on its frequency of detection and observed concentrations relative to Industrial Soil ALs. Arsenic, chromium, and mercury are proposed for column testing based on their frequency of detection in soil samples. One column test will be conducted for lead and a second column test will be conducted for lead, arsenic, chromium, and mercury to evaluate the potential effects of competing sites for sorption.

The method of column testing to be used is described in the USEPA document *Understanding Variation in Partition Coefficient, K_d, Values* (1999) and will generally consist of the following steps:

- A prepared sample of soil will be packed into a column;
- Reagent free water will slowly be added to the column until effluent from the column is observed;
- At least five pore volumes of water will be added to the column and allowed to pass before the introduction of a solution of non-adsorbing tracer compound and target constituents;
- A pulse or step input of a solution of known concentration containing a non-adsorbing tracer and the target constituents will be introduced into the column;
- Column effluent containing tracer and constituents will be collected into an appropriate container at fixed time intervals;
- Each sample of liquids recovered from the column effluent will be analyzed for the tracer and target constituents by the methods identified in Section 2.5 of this WPA;
- The tracer and constituent pulse will then be followed with a clean water flush;
- Column effluent from the clean water flush will be collected into appropriate containers at fixed time intervals; and
- Each sample of recovered liquid for the clean water flush will be analyzed by the methods identified in Section 2.5 of this WPA.

The tracer data from the column tests will be used to calculate the velocity of pore-water and an estimated dispersion coefficient for the packed column. Data from the column tests will be used to calculate sorption parameters (retardation factors, distribution coefficients, etc.) for lead, arsenic, chromium, and mercury following the methods outlined by USEPA (1999) and Knox et al. (1993). Column testing results along with other RFI data (cation exchange capacity, batch testing, etc.) will be used to evaluate the appropriateness of using the K_d approach or the surface complexion approach to modeling transport of metals in the subsurface, based on the comparison of these two approaches in the context of laboratory column testing presented in Bethke and Brady (2000)

Laboratory Batch Testing - Laboratory batch testing will be conducted on one representative core sample to compare with the results of column testing for lead and provide additional data on lead sorption in soil and confirm the results of the column testing. The batch testing will generally follow the method described by the USEPA (1999) and will consist of the following steps:

- Preparation of soil samples of equal mass for testing and placement of the samples into containers;
- Each sample will be mixed with a solution of known lead concentration;
- Samples will then be shaken and allowed to equilibrate;
- Soil will be separated from the solution by centrifuging;
- Aliquots of the recovered liquids will be obtained; and

- The aliquots of recovered liquids will be analyzed for lead.

A series of four batch tests will be run with varying concentrations of dissolved lead to evaluate the effect of the constituent concentration on adsorption. Data from the batch tests will be used to calculate sorption parameters for lead including an equilibrium partition coefficient following the methods outlined by USEPA (1999) and Knox et al. (1993).

<u>Other Testing of Core Samples</u> - Hydraulic conductivity tests will be performed on three core samples using the test method(s) specified in Section 2.5.4 of this WPA. In addition to these tests, three core samples will be tested for the parameters listed in Section 1.3.4.1 as discussed previously.

1.3.5 Topographic Survey

A topographic field survey will be conducted at SWMU 54 to generate a topographic map with one-ft contours. The survey data will be referenced to RFAAP coordinate system and vertical datum and Virginia State Plane Coordinate System. The topographic map to be prepared for SWMU 54 will include the accurate placement of physical features including:

- SWMU boundaries;
- Buildings, roads, and utilities;
- Monitoring well locations and boring locations; and
- Other information that is appropriate to properly represent the RFI findings.

The existing digital mapping of the Parallax (1999) studies conducted at Areas A and B of SWMU 54 will be overlain on the topographic map on appropriate figures.

1.3.6 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration (OSHA) and Federal regulations regarding the identification, handling, and disposal of hazardous and non-hazardous IDM. IDM related activities at SWMU 54 will be performed in accordance with RFAAP safety rules, protocols, and the guidelines presented in SOP 70.1 included in Appendix A. Specific information on IDM expected to be generated during the field activities at SWMU 54 is presented in Table 1-13; this table includes a description of the IDM, estimated quantities, proposed testing, and expected nature of the IDM.

Table 1-13
Handling, Characterization, and Disposal of Investigation-Derived Material (IDM)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Phase	Matrix	Material	Description	Quantity	Concern	Action	Expected Nature of Material
Soil Investigation	Solid	Soil Cuttings	From 41 Geoprobe Borings	Approx. three 55-gal drums	COPCs	Collect IDM Sample for TCLP SVOCs, TCLP Metals, Ignitability, Corrosivity, Reactivity and Paint Filter Liquids	Non-hazardous. Concentrations in soil cuttings are not expected to exceed regulatory limits.
	Aqueous	Decontamination Water	From Soil Drilling Program	Approx. two 55-gal drums	COPCs	Collect IDM Samples for TCLP SVOCs, TCLP Metals, COD, and pH	Non-hazardous. Concentrations are not expected to exceed regulatory limits.
	Solid	PPE, Plastic Sheeting, Disposable Sampling Equipment	From Drilling and Sampling Activities	Approx. three 55-gal drum	IDM	Confirm Results of Associated Tests for Soil and Liquid IDM	Same as associated Soil and Decontamination Water.
Groundwater Investigation	Solid	Soil Cuttings	From Wells 54MW5, 54MW6, 54MW8 and Soil Core Borings 54SC1, 54SC2, and 54SC3	Approx. ten 55-gal drum	COPCs	Collect IDM Sample for TCLP SVOCs, Ignitability, Corrosivity, Reactivity and Paint Filter Liquids	Non-hazardous. Concentrations in soil cuttings are not expected to exceed regulatory limits.
	Aqueous	Decontamination Water	From Groundwater Drilling Program	Approx. two 55-gal drums	COPCs	Collect IDM Samples for TCLP SVOCs, TCLP Metals, COD, and pH	Non-hazardous. Concentrations are not expected to exceed TCLP limits.
	Aqueous	Well Development and Purge Water	From Wells 54MW2 through 54MW7	Approx. five 55-gal drums	COPCs	Collect IDM Sample for TCLP VOCs, TCLP SVOCs, TCLP Metals, COD, and pH	Non-hazardous. Concentrations in groundwater are not expected to exceed TCLP, COD, or pH limits.
	Solid	PPE, Plastic Sheeting, Disposable Sampling Equipment	From Groundwater Investigation and Sampling	Approx. three 55-gal drums	IDM	Confirm Results of Associated Tests for Soil and Liquid IDM	Same as associated Soil, Decontamination Water, and Well Development/Purge Water.
	Aqueous	Pumping Test Water (if conducted)	From Pumping Test (if conducted)	Approx. 1000 Gallons (Baker Tank)	COPCs	Collect IDM Samples for TCLP SVOCs, TCLP Metals, COD, and pH	Non-hazardous. Concentrations are not expected to exceed TCLP limits.

Notes:

COPC = Constituent of Potential Concern
IDM = Investigation Derived Material
TCLP = Toxicity Characteristic Leaching Procedure
COD = Chemical Oxygen Demand
SVOC = Semi-volatile Organic Compound
PPE = Personal Protective Equipment

Approx. = Approximately
gal = gallon

2.0 QUALITY ASSURANCE PLAN ADDENDUM

2.1 INTRODUCTION

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

Table 2-1
Quality Assurance Measures Discussed in the MQAP
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Quality Assurance Measure	Section in MQAP	SOP Number (MWP Appendix A and Appendix A of WPA No. 13)
Project Organization and Responsibilities	2.0	–
Lines of Authority	2.2	--
Chemical Data Measurements	3.2	–
Levels of Concern	3.3	–
Site Investigation	5.0	20.1, 20.2, 20.3, 20.4, 20.11, 20.12, 30.1, 30.7, 30.9, 40.2, 40.3, 50.3, 70.1, 80.1
Documentation Requirements	5.6	10.1, 10.2, 10.3, 50.1, 50.2
Chain-of-Custody Requirements	5.7	10.4, 50.2
Calibration Procedures	7.0	90.1
Data Reduction, Validation, Reporting and Management	9.0	
Corrective Action	10.0	–
Quality Assessments	11.0	–

The distribution list for submittals associated with the RFI Programs at SWMU 54 is defined in the current Facility Permit (USEPA 2000) and is as follows:

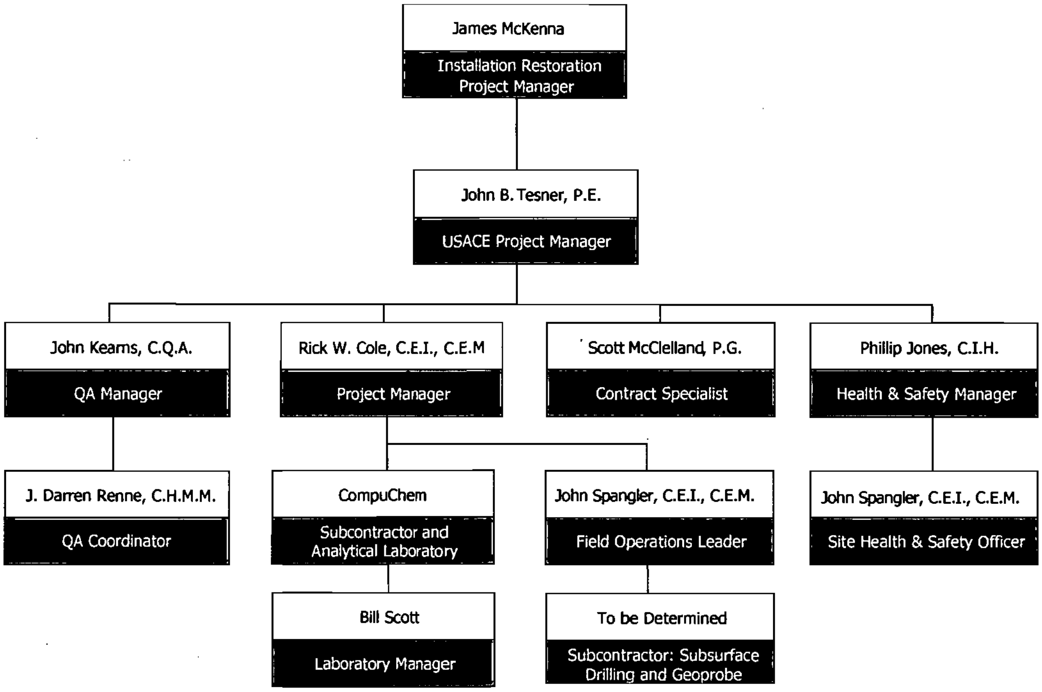
> At least six copies of draft documents and three copies of final plans, reports, notifications or other documents submitted as part of the SWMU 54 RFI are to be submitted to the Regional [USEPA] Administrator, and shall be sent Certified Mail, Return Receipt Requested, overnight mail, or hand-carried to:
>
> Federal Facilities Branch (3HS13)
> USEPA Region III
> 1650 Arch Street
> Philadelphia, Pennsylvania 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, Virginia 23240
>
> And
>
> Commonwealth of Virginia
> Department of Environmental Quality
> West Central Regional Office
> Executive Office Park, Suite D
> 5338 Peters Creek Road
> Roanoke, Virginia 24109

2.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

2.2.1 Contractor and Subcontractor Responsibilities

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

Figure 2-1
Project Organizational Chart
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia



2.2.2 Key Points of Contact

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

The Project Manager (PM) is responsible for ensuring that activities are conducted in accordance with contractual specifications, the Statement of Work (SOW), and approved work plans. The PM will also provide technical coordination with the Installation's designated counterpart. The PM is responsible for management of operations conducted for this project. In addition, the PM will ensure that personnel assigned the project, including subcontractors, will review the technical plans prior to intiation 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 QA Manager is responsible for ensuring that the QA procedures and objectives in the project-specific work plans are met, reviewing field and analytical data to ensure adherence to QA/QC procedures, and approving the quality of data prior to inclusion in associated reports. This may include the performance of field and laboratory audits during the investigation. In addition, the QA Manager will be responsible for the review, evaluation, and validation of analytical data for the project and will participate in interpreting and presenting analytical data. The QC Coordinator is under the technical guidance of the QA Manager to direct the task leaders on a day-to-day or as-needed basis to ensure the application of required QA/QC procedures.

Table 2-2
Contractor and Subcontractor Key Points of Contact
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Contractor	Key Point of Contact
Project Manager, Rick Cole e-mail: rick_cole@urscorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5417; Fax: 804.965.9764
Health and Safety Manager, Phillip Jones e-mail: phillip_l_jones@urscorp.com	URS Group, Inc. 1400 Union Meeting Road, Suite 202 Blue Bell, Pennsylvania 19422-1972 Tel: 215.619.4160; Fax: 215.542.3888
Quality Assurance Manager, Darren Renne e-mail: darren_renne@urscorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5449; Fax: 804.965.9764
Field Operations Leader and Site Health and Safety Officer, John Spangler e-mail: john_spangler@urscorp.com	URS Group, Inc. 5540 Falmouth Street, Suite 201 Richmond, Virginia 23230 Tel: 804.474.5419; Fax: 804.965.9764
Subcontractor	**Key Point of Contact**
Analytical Laboratory Services CompuChem Laboratories, Inc. e-mail: bscott@compuchemlabs.com	Bill Scott 501 Madison Avenue Cary, NC 27513 Tel: 919.379.4024; Fax: 919.379.4050
Subsurface (Drilling and Geoprobe®) Not yet identified	Not Applicable

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

- Preparation of monthly cost reports and invoices;
- Administration of equipment rental, material purchases, and inventory of supplies;
- Administration and negotiation of subcontracts and interaction with the Administrative Contracting Officer and Procurement Contracting Officer on contract and subcontract issues;

- Preparation of project manpower estimates;
- Administration of contract documents.

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 Field Operations Leader will provide management of the field activities during the fieldwork. The Field Operations Leader is responsible for ensuring that technical matters pertaining to the field program are addressed. They will participate extensively in data interpretation, report writing, and preparation of deliverables, and will ensure that work is being conducted as specified in the technical plans. In addition, the Field Operations Leader is responsible for field QA/QC procedures, and for safety-related issues. Prior to initiation of field activities, the Field Operations Leader will conduct a field staff orientation and briefing to acquaint project personnel with the sites and assign field responsibilities

2.3 QUALITY ASSURANCE OBJECTIVES

QA is defined as the overall system of activities for assuring the reliability of data produced. QA objectives are specified for investigation, chemical, and regulatory issues associated with this project and are referenced in Section 2.3. QA objectives will be met through the conformance with appended SOPs. The system integrates the quality planning, assessment, and corrective actions of various groups in the organization to provide the independent QA program necessary to establish and maintain an effective system for collection and analysis of environmental samples and related activities. The program encompasses the generation of complete data with its subsequent review, validation and documentation.

The overall QA objective is to develop and implement procedures for sample and data collection, 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. The DQO process used for developing RFAAP data quality criteria and performance specifications for decision-making is presented in *Guidance For the Data Quality Objectives Process* (USEPA 1994) and *Data Quality Objective Process for Hazardous Waste Sites* (USEPA 2000).

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 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) primary decision-maker, and (3) statement of the problem.

   1) The planning team consists of RFAAP, USACE, USEPA, VDEQ, the RFAAP operating contractor, and URS.

Table 2-3
Summary of Project Data Quality Objectives
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

DQO Element	Project DQO Summary
Problem Statement	• The nature and extent of soil contamination in Area A and Area B is not fully understood. • The nature and extent of groundwater contamination in SWMU 54 is not fully understood. • Risks to Human Health and the Environment are uncertain. • Although IA activities have been completed, it is uncertain that this step was sufficient as a remedial alternative.
Identify Decision/Study Question	• Collect soil samples to complete analysis of nature and extent. • Collect soil samples for analysis of physical properties to aid in assessing the nature of possible routes of migration. • Evaluate nature and extent of groundwater contamination by collection of groundwater samples and by conducting *in situ* testing and laboratory testing to obtain site-specific values for input into groundwater and fate-and-transport models. • Conduct an analysis of chemical mobility and fate-and-transport for inclusion in risk and corrective measures decisions.
Decision Inputs	• Field Investigation Data: Soil borings and samples, monitoring well construction and sampling, *in situ* testing for fate-and-transport modeling. • Chemical Mobility Analysis: Soil cores for testing site-specific physical properties to approved off-site geotechnical laboratory. • Chemical Analyses: Submit soil samples to USACE-approved, off-site analytical laboratory for analyses.
Study Boundaries	• Area A is approximately 0.58 acres and Area B is approximately 1.06 acres. The approximate depth is 20 ft in Area A and ten ft in Area B. • Sample points designed to collect samples representative of constituent distribution representative of each area.
Decision Rule	• Comparison with Industrial Soil and Tap Water RBCs (April 2002) for soil. • Comparison with MCLs for groundwater. • Professional judgment of geologic and hydrologic parameters and industry standards.
Acceptable Decision Error Limits	• Analytical methods USEPA Contract Laboratory Program (CLP) report limits. CLP-like raw data package (Level IV) suitable for validation. • Outcome and effect will be assessed throughout the process.
Optimize Data Design	• Statistical and non-statistical sample locations designed to optimize data collection, complete data gaps, and minimize decision errors. • Document project activities.

    2) Relative to the implementation of this Work Plan, the primary decision-maker is RFAAP, in consultation with USACE, USEPA, VDEQ, and URS.

    3) Assist RFAAP in a) completing an evaluation of the nature and extent of former disposal areas at SWMU 54, including soil and groundwater, b) assessing what risk to human health and the environment exists at SWMU 54, and c) completing a CMS at SWMU 54 and obtaining regulatory closure.

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

    1) Principal study questions include:

        - Has the constituent release in Area A and Area B of SWMU 54 been fully characterized (nature and extent)?
        - Does site contamination pose an unacceptable risk to human health or the environment?
        - Have the routes of migration been fully evaluated?
        - Where do the constituent concentrations exceed applicable regulatory thresholds?
        - Were previous IA activities successful in reducing overall risk by source removal?
        - Are additional corrective measures necessary?

    2) The resultant alternative actions include:

        - Recommend that the site requires no further evaluation;
        - Recommend that the site warrants a possible response action;
        - Recommend that additional remedial alternatives be considered.

3. **Identify Inputs to the Decision**: Identify information inputs required to resolve the decision statement and which inputs require environmental measures. This step of the process includes identification of the data that will be required to make the decision, information source determination, identification of data required for study ALs, and confirmation of appropriate field sampling and analytical methods.

    1) Collection of soil data from SWMU 54:

        - Collect discrete soil samples from continuous undisturbed cores from soil borings. 19 systematic grid borings and three focused borings will be advanced in and around Area A; 12 systematic grid borings and five focused borings will be advanced in and around Area B.

- Advance borings to an approximate depth of ten ft bgs in Area A. In Area B, advance 12 borings to ten ft bgs and advance five borings to bedrock surface to assess stratigraphy and depth to bedrock.
- Collect soil samples from the surface and subsurface and submit for analytical laboratory analysis.
- Prepare boring logs from information gathered during core collection.

2) Collection of groundwater data from SWMU 54:

   - Install two monitoring wells upgradient of Area A and Area B. Construct an upgradient well for Area A that is closer to Area A than the existing upgradient well at Area A and that is appropriate for monitoring upgradient conditions. This well will be screened across the soil/bedrock interface to monitor the uppermost portion of the water table, similar to the downgradient wells at Area A. Construct an upgradient well for Area B that is appropriate for monitoring background conditions. This well will be screened across the soil/bedrock interface to monitor the uppermost portion of the water table similar to the new downgradient well for Area B.
   - Install one monitoring well downgradient of Area B to provide for a second well downgradient of Area B. Construct well as a detection well with a screened interval across the soil/bedrock interface similar to wells downgradient of Area A and the new upgradient well for Area B. This well will be located downgradient of Area B and allow for comparison to background and to Area A.
   - Develop wells and prepare well construction diagrams for each new monitoring well.
   - Collect and analyze six groundwater samples. Collect *in situ* water quality data.

3) Collection of *in situ* field and geotechnical data from SWMU 54 to support fate and transport modeling:

   - Collect three undisturbed, large-diameter soil cores using rotosonic drilling techniques. Analyze cores for parameters needed to assess site-specific chemical mobility.
   - Conduct slug testing on the three new monitoring wells and selected existing wells to evaluate aquifer characteristics.
   - Submit ten soil samples for analytical and geochemical parameters needed to assess soil characteristics and site-specific chemical mobility.

4) Conduct field sampling in accordance with the MWP, attached SOPs, and approved deviation presented herein. Following proper sample collection and handling defined herein, submit samples to an USACE-approved analytical laboratory for evaluation of analytes defined herein using USEPA SW-846 methodologies. Selected laboratory is within the CLP network.

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

    1) Physical lateral boundary of SWMU 54 has been estimated using results from previous investigations. The area estimate of Area A is 0.58 acres and Area B is 1.06 acres. These estimates will be further refined within the scope of the RFI. The estimated vertical boundary of SWMU 54 is 20 ft in Area A and ten ft in Area B.

    2) Soil and groundwater COPCs have been identified from previous investigations and sample points are placed to collect samples representative of each SWMU area and adjacent to SWMU areas. Sample depths have been selected to represent surface and subsurface characteristics.

    3) Collection of *in situ* field data poses constraints. Collection of large diameter undisturbed core samples poses a constraint. Should the soil cores be disturbed during sample collection then a field decision will be made to collect additional cores. Collection of direct push groundwater samples may be constrained by the presence of gravel layers above bedrock and/or potential limited quantities of water present above bedrock.

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

    1) Parameters of interest include:

        - TAL Metals, Mercury, TCL SVOCs, PAHs, Explosives (including nitroglycerin), and Dioxin/Furans. Perchlorate will be analyzed in water samples.

        - Hydraulic conductivity, soil pH, moisture content, cation exchange capacity, bulk density, organic content, effective porosity, and grain size analysis for soil and/or groundwater.

        - *In situ* water quality: pH-Eh, conductivity, oxidation-reduction potential, and dissolved oxygen.

        - Depth to bedrock for soil borings in Area B.

    2) Action levels include:

        - ALs for risk screening will be compared against current Soil RBCs and soil screening levels (SSLs) as well as the Facility-Wide Background Study. Method Detection Limits (MDLs) and Reporting Limits (RLs), as defined herein, will ensure that data quality is sufficient for intended data use. Selected laboratory is within the CLP network and therefore it is assumed that sources of analytical errors are small and known.

        - Bedrock is anticipated to be approximately 20 ft bgs.

        - Industry standards will be applied to geotechnical laboratory test results.

3) Decision rules include:

   - The discrete sample analytical results will be compared to current Soil RBCs, ALs, SSLs and the Facility-Wide Background Study. This will provide an indication of the potential risk of exposure to human health or the environment.

   - *In situ* estimates of site-specific parameters will be compared to geotechnical laboratory generated values. Chemical mobility estimates and fate and transport modeling will be calibrated to field and laboratory results, a sensitivity analysis will be conducted, and the assumptions will be evaluated for applicability to site-specific conditions.

   - The assessment of chemical mobility and fate and transport will provide an indication of the potential risk that may be associated with leaching of metals from soil to groundwater and groundwater flow from the SWMU area.

   - Results of site activities will be used to update the CSM and will be used in remedial alternative decisions.

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

1) Quantitation Limits are established for each analyte within the suites of parameter sought. This will ensure that data quality is appropriate. The Contract Laboratory will provide a CLP-like raw data package (Level IV). Data validation will be conducted based on the MWP QAP, the USACE Shell Document (USACE 2001) and USEPA Region III guidance. Professional judgment for other geologic and hydrologic data will be used.

2) Decision errors include:

   - Deciding that human health or environmental impacts exist when they do not and deciding that human health or environmental impacts do not exist when they actually do. The consequences of deciding that human health or environmental impacts do not exist when they do will result in liabilities associated with future damages and environmental clean-up costs.

   - The true state when the most severe decision error occurs (human health or environmental impacts do not exist when they actually do) is that human health or environmental impacts do exist. The true state when the less severe decision error occurs (human health or environmental impacts exist when they do not) is that human health or environmental impacts do not exist.

   - The null hypothesis (H_o) is: human health or environmental impacts do exist. The alternative hypothesis (H_a) is human health or environmental impacts do not exist.

3) The outcome and effect of decision errors and acceptable probability will be assessed throughout the data collection and analysis process and will be presented in the final report.

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

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

    2) Statistical and non-statistical sampling strategies are proposed. Biased sampling will be performed to verify previous results and complete site characterization. Simple grid sampling will be performed to assess constituent distribution and homogeneity.

    3) This WPA contains the proposed sampling program. A focused approach has been adopted to complete data gaps, optimize resource utilization, and minimize decision errors. Project documentation will be implemented in accordance with the MWP.

2.4 SAMPLE MANAGEMENT

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

2.4.1 Number and Type

The planned number and types of environmental samples proposed during this investigation are included in Tables 1-10 through 1-12.

2.4.2 Sample Containers, Preservation, and Holding Times

Parameter, container and preservation requirements, and holding times are identified in Table 2-4.

2.4.3 Sample Identification

The sample identification number will be similar in manner with past nomenclature at SWMU 54 at RFAAP. The sample identification will consist of an alphanumeric designation related to the sampling location, media type, and sequential order according to the sampling event. The sample identification number will not exceed thirty-two characters for subsequent entry into Environmental Restoration Information System (ERIS). Samples will be coded in the following order to ensure a unique identification.

- **Site Location Code:** The first character will be the site SWMU number (i.e., 54 for SWMU 54);

- **Sample/Media Type:** The second set of characters (two or three) will be the sample/media types. In this case, the characters will be DPW for direct push water, SB for soil boring, SC for soil core, and MW for monitoring well;

- **Sampling Location Number**: The next set of characters (one or two) will be the number of the sampling location (e.g., 3, 4, 5);

Table 2-4
Summary of Sample Containment and Sample Preservation Requirements
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

PARAMETER	SAMPLE CONTAINER		PRESERVATION METHODS	HOLDING TIMES
	Quantity	Type		
SOLID SAMPLES				
Semivolatile Organic Compounds	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Explosives	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Metals*	1	200-g polyethylene or glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	6 months
Mercury*	1	500-mL polyethylene or glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	28 days
Dioxin/Furans	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C, Dark	Extraction: 30 days Analysis: 45 days
Total Organic Carbon	1	100-mL glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	28 days
Reactivity (percent explosive material)	1	250-mL wide-mouth glass container, Teflon®-lined cap	–	–
SOLID WASTE CHARACTERIZATION				
TCLP SVOCs	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 14 days Extraction: 7 days Analysis: 40 days
TCLP Metals	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Leaching: 14 days Analysis: 6 months Mercury analysis: 28 days
Corrosivity, Paint Filter	1	250-mL wide-mouth glass container, Teflon®-lined cap	Cool to 4 ± 2 °C	Corrosivity: 7 days Reactivity: 7 days
Reactivity (percent explosive material)	1	250-mL wide-mouth glass container, Teflon®-lined cap	–	–
AQUEOUS SAMPLES				
Semivolatile Organic Compounds	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Explosives	1	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 7 days Analysis: 40 days
Metals	1	1-liter, polyethylene container	HNO_3 to pH<2, Cool to 4 ± 2 °C	6 months
Perchlorate	1	500-mL, polyethylene bottle	Cool to 4 ± 2 °C	28 days
Dioxin/Furans	2	1-liter, narrow-mouth amber glass, Teflon®-lined cap	Cool to 4 ± 2 °C	Extraction: 30 days Analysis: 45 days
Mercury	1	1-liter, polyethylene container	HNO_3 to pH<2, Cool to 4 ± 2 °C	28 days

Notes:

* = Metals and mercury sample for soil will be combined into one 500 mL bottle
mL = milliliter
g = gram
HNO_3 = Nitric Acid
°C = Degrees Celsius

- **Sample Depth:** Sample that represent zero to six inches bgs will be designated with an "A" after the boring number. Samples collected from intermediate depths of the boring, will be designated with a "B" following the boring number. Samples collected from above the water table or bedrock, at the base of the boring, will be designated with a "C"; and

- **Duplicate:** Duplicate samples will be identified with a "D" designation followed by a numeric designation corresponding to the sequence of duplicates collected (e.g., D-1). A record of the sample that corresponds to the duplicate will be kept in the field logbook. In this manner, duplicates will be submitted as blind duplicates, eliminating the potential for laboratory bias in analysis.

Sample Identification Examples:

1. A subsurface soil sample that collected above the termination depth of boring location four at SWMU 54 would be identified as sample 54SB4C (for SWMU 54, soil boring four, and "C," for the soils above the water table or bedrock at that location).

2. QC samples will be identified by date (month, day, year), followed by QC sample type, and sequential order number at one digit. The QC sample types include:

    - R = Rinse
    - B = Blank;
    - T = Trip Blank;
    - MSD = Matrix Spike; and
    - MS = Matrix Spike Duplicate.

2.4.4 Documentation

Documentation will follow SOPs 10.1 and 10.2 in Appendix A and Section 9.8 of the MQAP.

2.5 ANALYTICAL PROCEDURES

CompuChem Laboratory, Inc., will perform off-site analytical activities. Analytical methods to be used and associated MDLs and RLs are identified in Table 2-5 through 2-11. Laboratory analysis will be in accordance with USEPA SW 846 approved methods for the analysis of the following:

- TAL Metals (including mercury);
- TCL SVOCs;
- TCL Pesticides;
- TCL PCBs;
- PAHs;

Table 2-5

Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TAL Metals (USEPA Method 7000 Series) Soil and Water Samples SWMU 54 RCRA Facility Investigation Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk Based Concentrations						
		Soil		Water									
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
Aluminum	7429-90-5	8.9E-01	1.0E+01	1.7E+01	1.0E+02		N	3.7E+04	3.7E+03	2.0E+06	2.0E+05	7.8E+04	7.8E+03
Antimony	7440-36-0	8.9E-02	1.0E+00	1.3E+00	1.0E+01	6.0E+00	N	1.5E+01	1.5E+00	8.2E+02	8.2E+01	3.1E+01	3.1E+00
Arsenic	7440-38-2	2.7E-01	1.0E+00	3.5E+00	1.0E+01	1.0E+01	C	4.5E-02	4.5E-02	3.8E+00	3.8E+00	4.3E-01	4.3E-01
Barium	7440-39-3	3.2E-02	1.0E+00	2.8E-01	1.0E+01	2.0E+03	N	2.6E+03	2.6E+02	1.4E+05	1.4E+04	5.5E+03	5.5E+02
Beryllium	7440-41-7	3.9E-02	5.0E-01	1.1E-01	5.0E+00	4.0E+00	N	7.3E+01	7.3E+00	4.1E+03	4.1E+02	1.6E+02	1.6E+01
Cadmium	7440-43-9	2.0E-02	5.0E-01	2.3E-01	5.0E+00	5.0E+00	N	1.8E+01	1.8E+00	2.0E+03	2.0E+02	7.8E+01	7.8E+00
Calcium	7440-70-2	3.1E+00	1.0E+02	2.8E+01	1.0E+03	--	--	--	--	--	--	--	--
Chromium (VI)[1]	7440-47-3	4.5E-02	5.0E-01	6.5E-01	5.0E+00	1.0E+02	N	1.1E+02	1.1E+01	6.1E+03	6.1E+02	2.3E+02	2.3E+01
Cobalt	7440-48-4	3.6E-02	5.0E-01	2.8E-01	5.0E+00	--	N	7.3E+02	7.3E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
Copper	7440-50-8	5.0E-02	5.0E-01	3.1E-01	5.0E+00	1.3E+03	N	1.5E+03	1.5E+02	8.2E+04	8.2E+03	3.1E+03	3.1E+02
Iron	7439-89-6	3.6E+00	1.0E+01	1.0E+01	1.0E+02	--	N	1.1E+04	1.1E+03	6.1E+05	6.1E+04	2.3E+04	2.3E+03
Lead[2]	7439-92-1	1.1E-01	3.0E-01	1.2E+00	3.0E+00	1.5E+01	--	--	--	1.0E+03	1.0E+03	4.0E+02	4.0E+02
Magnesium	7439-95-4	6.4E-01	1.0E+02	3.6E+00	1.0E+03	--	--	--	--	--	--	--	--
Manganese (non-food)	7439-96-5	3.7E-02	1.0E+00	2.7E-01	1.0E+01	--	N	7.3E+02	7.3E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
Mercury[3]	7439-97-6	1.1E-01	2.0E-01	3.3E-03	2.0E-02	2.0E+00	N	1.1E+01	1.1E+00	6.1E+02	6.1E+01	2.3E+01	2.3E+00
Nickel	7440-02-0	7.8E-02	5.0E-01	6.3E-01	5.0E+00	--	N	7.3E+02	7.3E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
Potassium	7440-09-7	4.7E+00	1.0E+02	1.8E+01	1.0E+03	--	--	--	--	--	--	--	--
Selenium	7782-49-2	1.7E-01	5.0E-01	3.5E+00	5.0E+00	5.0E+01	N	1.8E+02	1.8E+01	1.0E+04	1.0E+03	3.9E+02	3.9E+01
Silver	7440-22-4	8.2E-02	5.0E-01	5.7E-01	5.0E+00	--	N	1.8E+02	1.8E+01	1.0E+04	1.0E+03	3.9E+02	3.9E+01
Sodium	7440-23-5	1.8E+01	2.0E+02	1.6E+02	2.0E+03	--	--	--	--	--	--	--	--
Thallium	7440-28-0	4.2E-01	1.0E+00	2.1E+00	1.0E+01	2.0E+00	N	2.6E+00	2.6E-01	1.4E+02	1.4E+01	5.5E+00	5.5E-01
Vanadium	7440-62-2	2.8E-02	2.0E+00	2.5E-01	2.0E+01	--	N	2.6E+02	2.6E+01	1.4E+04	1.4E+03	5.5E+02	5.5E+01
Zinc	7440-66-6	3.9E-01	2.0E+00	4.9E+00	2.0E+01	--	N	1.1E+04	1.1E+03	6.1E+05	6.1E+04	2.3E+04	2.3E+03

Notes:

CAS = Chemical Abstract Service
Method Detection and Reporting Limits provided by CompuChem
MDL = Method Detection Limit
mg/kg = milligram per kilogram
µg/L = microgram per liter
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table
C/N = Carcinogenic or Non-carcinogenic status
MCL = Maximum Contaminant Level

C = Carcinogenic
CI = Carcinogen with a hazard quotient of 0.1; see USEPA Region III guidance
N = Noncarcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
TAL = Target Analyte List
(1) = Chromium MCL is for total
(2) = Lead criteria are Action Levels; see USEPA Region III guidance
(3) = Mercuric chloride soil RBC value used
-- = No Criteria available

Table 2-6
Summary by Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL SVOCs (USEPA Method 8270B) Soil and Water Samples
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and ReportingLimits				USEPA MCLs	USEPA Region III Risk-Based Concentrations						
		Soil		Water									
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
1,2,4-Trichlorobenzene	120-82-1	4.2E-02	3.3E-01	1.2	10	7.0E+01	N	1.9E+02	1.9E+01	2.0E+04	2.0E+03	7.8E+02	7.8E+01
1,2-Dichlorobenzene	95-50-1	3.3E-02	3.3E-01	0.96	10	--	N	2.7E+02	2.7E+01	1.8E+05	1.8E+04	7.0E+03	7.0E+02
1,3-Dichlorobenzene	541-73-1	3.4E-02	3.3E-01	1.1	10	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
1,4-Dichlorobenzene	106-46-7	2.9E-02	3.3E-01	0.95	10	--	C	4.7E-01	4.7E-01	2.4E+02	2.4E+02	2.7E+01	2.7E+01
2,2'-oxybis(1-Chloropropane)	106-60-1	4.0E-02	3.3E-01	0.93	10	--	C	2.6E-01	2.6E-01	8.2E+01	8.2E+01	9.1E+00	9.1E+00
2,4,5-Trichlorophenol	95-95-4	5.0E-02	3.3E-01	1.5	10	--	N	3.7E+03	3.7E+02	2.0E+05	2.0E+04	7.8E+03	7.8E+02
2,4,6-Trichlorophenol	88-06-2	6.5E-02	3.3E-01	1.9	10	--	C	6.1E+00	6.1E+00	5.2E+02	5.2E+02	5.8E+01	5.8E+01
2,4-Dichlorophenol	120-83-2	2.2E-02	3.3E-01	0.70	10	--	N	1.1E+02	1.1E+01	6.1E+03	6.1E+02	2.3E+02	2.3E+01
2,4-Dimethylphenol	105-67-9	3.0E-02	3.3E-01	1.5	10	--	N	7.3E+02	7.3E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
2,4-Dinitrophenol	51-28-5	1.6E-01	1.7E+00	3.5	50	--	N	7.3E+01	7.3E+00	4.1E+03	4.1E+02	1.6E+02	1.6E+01
2,4-Dinitrotoluene	121-14-2	1.3E-02	3.3E-01	0.43	10	--	N	7.3E+01	7.3E+00	4.1E+03	4.1E+02	1.6E+02	1.6E+01
2,6-Dinitrotoluene	606-20-2	2.4E-02	3.3E-01	0.73	10	--	N	3.7E+01	3.7E+00	2.0E+03	2.0E+02	7.8E+01	7.8E+00
2-Chloronaphthalene	91-58-7	3.3E-02	3.3E-01	0.74	10	--	N	4.9E+02	4.9E+01	1.6E+05	1.6E+04	6.3E+03	6.3E+02
2-Chlorophenol	95-57-8	3.6E-02	3.3E-01	1.0	10	--	N	3.0E+01	3.0E+00	1.0E+04	1.0E+03	3.9E+02	3.9E+01
2-Methylnaphthalene	91-57-6	3.8E-02	3.3E-01	0.93	10	--	N	1.2E+02	1.2E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
2-Methylphenol	95-48-7	2.9E-02	3.3E-01	0.92	10	--	N	1.8E+03	1.8E+02	1.0E+05	1.0E+04	3.9E+03	3.9E+02
2-Nitroaniline	88-74-4	2.5E-02	6.7E-01	0.46	20	--	--	--	--	--	--	--	--
2-Nitrophenol	88-75-5	3.0E-02	3.3E-01	0.77	10	--	--	--	--	--	--	--	--
3,3'-Dichlorobenzidine	91-94-1	1.6E-02	6.7E-01	1.2	10	--	C	1.5E-01	1.5E-01	1.3E+01	1.3E+01	1.4E+00	1.4E+00
3-Nitroaniline	99-09-2	2.5E-02	6.7E-01	1.1	20	--	--	--	--	--	--	--	--
4,6-Dinitro-2-methylphenol	534-52-1	3.4E-02	6.7E-01	0.86	20	--	N	3.7E+01	3.7E+00	2.0E+03	2.0E+02	7.8E+01	7.6E+00
4-Bromophenyl-phenylether	101-55-3	2.7E-02	3.3E-01	0.84	10	--	--	--	--	--	--	--	--
4-Chloro-3-Methylphenol	59-50-7	3.1E-02	3.3E-01	0.51	10	--	--	--	--	--	--	--	--
4-Chloroaniline	106-47-8	9.5E-03	3.3E-01	1.6	10	--	N	1.5E+02	1.5E+01	8.2E+03	8.2E+02	3.1E+02	3.1E+01
4-Chlorophenyl-phenylether	7005-72-3	2.3E-02	3.3E-01	0.61	10	--	--	--	--	--	--	--	--
4-Methylphenol	106-44-5	2.8E-02	3.3E-01	0.90	5	--	N	1.8E+02	1.8E+01	1.0E+04	1.0E+03	3.9E+02	3.9E+01
4-Nitroaniline	100-01-6	1.9E-02	6.7E-01	0.76	20	--	--	--	--	--	--	--	--
4-Nitrophenol	100-02-7	5.1E-02	6.7E-01	2.7	20	--	N	2.9E+02	2.9E+01	1.6E+04	1.6E+03	6.3E+02	6.3E+01
Acenaphthene	83-32-9	2.2E-02	3.3E-01	0.55	10	--	N	3.7E+02	3.7E+01	1.2E+05	1.2E+04	4.7E+03	4.7E+02
Acenaphthylene (1)	208-96-8	2.6E-02	3.3E-01	0.72	10	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
Anthracene	120-12-7	2.5E-02	3.3E-01	0.61	10	--	N	1.8E+03	1.8E+02	6.1E+05	6.1E+04	2.3E+04	2.3E+03
Benzo(a)anthracene	56-55-3	2.4E-02	3.3E-01	0.46	10	--	C	9.2E-02	9.2E-02	7.8E+00	7.8E+00	8.7E-01	8.7E-01
Benzo(a)pyrene	50-32-8	2.6E-02	3.3E-01	0.58	10	2.0E-01	C	9.2E-03	9.2E-03	7.8E-01	7.8E-01	8.7E-02	8.7E-02
Benzo(b)fluoranthene	205-99-2	2.4E-02	3.3E-01	0.51	10	--	C	9.2E-02	9.2E-02	7.8E+00	7.8E+00	6.7E-01	8.7E-01
Benzo(g,h,i)perylene (1)	191-24-2	3.3E-02	3.3E-01	0.85	10	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
Benzo(k)fluoranthene	207-08-9	3.6E-02	3.3E-01	0.74	10	--	C	9.2E-01	9.2E-01	7.8E+01	7.8E+01	8.7E+00	8.7E+00
Bis(2-chloroethoxy)methane	111-91-1	3.6E-02	3.3E-01	0.79	10	--	--	--	--	--	--	--	--
Bis(2-chloroethyl)ether	111-44-4	3.0E-02	3.3E-01	0.93	10	--	C	9.6E-03	9.6E-03	5.2E+00	5.2E+00	5.8E-01	5.8E-01

Table 2-6 (Continued)
Summary by Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL SVOCs (USEPA Method 8270B) Soil and Water Samples
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and ReportingLimits				USEPA MCLs	USEPA Region III Risk-Based Concentrations						
		Soil		Water									
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
Bis(2-ethylhexyl)phthalate	117-81-7	3.9E-02	3.3E-01	0.65	10	--	C	4.8E+00	4.8E+00	4.1E+02	4.1E+02	4.6E+01	4.6E+01
Butylbenzylphthalate	85-68-7	2.1E-02	3.3E-01	0.52	10	--	N	7.3E+03	7.3E+02	4.1E+05	4.1E+04	1.6E+04	1.6E+03
Carbazole	86-74-8	2.5E-02	3.3E-01	0.78	10	--	C	3.3E+00	3.3E+00	2.9E+02	2.9E+02	3.2E+01	3.2E+01
Chrysene	218-01-9	2.8E-02	3.3E-01	0.65	10	--	C	9.2E+00	9.2E+00	7.8E+02	7.8E+02	8.7E+01	8.7E+01
Dibenz(a,h)anthracene	53-70-3	2.9E-02	3.3E-01	0.80	10	--	C	9.2E-03	9.2E-03	7.8E-01	7.8E-01	8.7E-02	8.7E-02
Dibenzofuran	132-64-9	2.9E-02	3.3E-01	0.66	10	--	N	2.4E+01	2.4E+00	8.2E+03	8.2E+02	3.1E+02	3.1E+01
Diethylphthalate	84-66-2	1.5E-02	3.3E-01	0.58	10	--	N	2.9E+04	2.9E+03	1.6E+06	1.6E+05	6.3E+04	6.3E+03
Dimethylphthalate	131-11-3	2.2E-02	3.3E-01	0.56	10	--	N	3.7E+05	3.7E+04	2.0E+07	2.0E+06	7.8E+05	7.8E+04
Di-n-butylphthalate	84-74-2	2.0E-02	3.3E-01	0.80	10	--	N	3.7E+03	3.7E+02	2.0E+05	2.0E+04	7.8E+03	7.8E+02
Di-n-octylphthalate	117-84-0	1.9E-02	3.3E-01	0.68	10	--	N	7.3E+02	7.3E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
Fluoranthene	206-44-0	1.6E-02	3.3E-01	0.70	10	--	N	1.5E+03	1.5E+02	8.2E+04	8.2E+03	3.1E+03	3.1E+02
Fluorene	86-73-7	1.7E-02	3.3E-01	0.56	10	--	N	2.4E+02	2.4E+01	8.2E+04	8.2E+03	3.1E+03	3.1E+02
Hexachlorobenzene	118-74-1	2.9E-02	3.3E-01	0.75	10	1.0E+00	C	4.2E-02	4.2E-02	3.6E+00	3.6E+00	4.0E-01	4.0E-01
Hexachlorobutadiene	87-68-3	3.3E-02	3.3E-01	1.1	10	--	CI	8.6E-01	8.6E-01	7.3E+01	7.3E+01	8.2E+00	8.2E+00
Hexachlorocyclopentadiene	77-47-4	6.7E-02	3.3E-01	1.0	10	--	N	2.2E+02	2.2E+01	1.2E+04	1.2E+03	4.7E+02	4.7E+01
Hexachloroethane	67-72-1	3.7E-02	3.3E-01	1.4	10	--	CI	4.8E+00	4.8E+00	4.1E+02	4.1E+02	4.6E+01	4.6E+01
Indeno(1,2,3-cd)pyrene	193-39-5	3.0E-02	3.3E-01	0.85	10	--	C	9.2E-02	9.2E-02	7.8E+00	7.8E+00	6.7E-01	8.7E-01
Isophorone	78-59-1	3.0E-02	3.3E-01	0.67	10	--	C	7.0E+01	7.0E+01	6.0E+03	6.0E+03	6.7E+02	6.7E+02
Naphthalene	91-20-3	3.5E-02	3.3E-01	0.90	10	--	N	6.5E+00	6.5E-01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
Nitrobenzene	98-95-3	4.3E-02	3.3E-01	1.0	10	--	N	3.5E+00	3.5E-01	1.0E+03	1.0E+02	3.9E+01	3.9E+00
N-Nitrosodi-n-propylamine	621-64-7	3.3E-02	3.3E-01	0.77	10	--	C	9.6E-03	9.6E-03	8.2E-01	8.2E-01	9.1E-02	9.1E-02
N-Nitrosodiphenylamine	86-30-6	3.2E-02	3.3E-01	0.71	10	--	C	1.4E+01	1.4E+01	1.2E+03	1.2E+03	1.3E+02	1.3E+02
Pentachlorophenol	87-86-5	4.6E-02	6.7E-01	1.2	20	1.0E+00	C	5.6E-01	5.6E-01	4.8E+01	4.8E+01	5.3E+00	5.3E+00
Phenanthrene (1)	85-01-8	2.4E-02	3.3E-01	0.67	10	--	N	1.6E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
Phenol	108-95-2	3.5E-02	3.3E-01	1.2	10	--	N	2.2E+04	2.2E+03	1.2E+06	1.2E+05	4.7E+04	4.7E+03
Pyrene	129-00-0	2.7E-02	3.3E-01	0.59	10	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02

Notes:

CAS = Chemical Abstract Service
Method Detection and Reporting Limits provided by CompuChem
MDL = Method Detection Limit
mg/kg = milligram per kilogram
µg/L = microgram per liter
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table
-- = No RBC available

TCL SVOCs = Target Compound List Semivolatile Compounds
C/N = Carcinogenic or Non-carcinogenic status
C = Carcinogenic
CI = Carcinogen with a hazard quotient of 0.1; see USEPA Region III guidance
N = Noncarcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
MCL = Maximum Contaminant Level
(1) = the RBC for pyrene was used for these compounds

Table 2-7
Summary of Method Detection Limits, Reporting Limits, and Risk-Screening Criteria for PAHs (USEPA Method 8310) Soil and Water Samples
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, VA

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA MCLs	USEPA Region III Risk-Based Concentrations						
		Soil		Water									
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
Acenaphthene	83329	2.2E-02	4.2E-02	0.31	1.25	--	N	3.7E+02	3.7E+01	1.2E+05	1.2E+04	4.7E+03	4.7E+02
Acenaphthylene (1)	208968	6.9E-03	4.2E-02	0.41	1.25	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
Anthracene	120127	5.9E-03	4.2E-02	0.14	1.25	--	N	1.8E+03	1.8E+02	6.1E+05	6.1E+04	2.3E+04	2.3E+03
Benzo(a)anthracene	56553	2.0E-03	8.3E-03	0.02	0.25	--	C	9.2E-02	9.2E-02	7.8E+00	7.8E+00	8.7E-01	8.7E-01
Benzo(a)pyrene	50328	2.7E-03	8.3E-03	0.03	0.25	2.0E-01	C	9.2E-03	9.2E-03	7.8E-01	7.8E-01	8.7E-02	8.7E-02
Benzo(b)fluoranthene	205992	4.0E-03	8.3E-03	0.03	0.25	--	C	9.2E-02	9.2E-02	7.8E+00	7.8E+00	8.7E-01	8.7E-01
Benzo(ghi)perylene (1)	191242	1.7E-03	8.3E-03	0.01	0.25	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
Benzo(k)fluoranthene	205992	1.8E-03	8.3E-03	0.023	0.25	--	C	9.2E-01	9.2E-01	7.8E+01	7.8E+01	8.7E+00	8.7E+00
Chrysene	218019	3.1E-03	8.3E-03	0.23	0.25	--	C	9.2E+00	9.2E+00	7.8E+02	7.8E+02	8.7E+01	8.7E+01
Dibenzo(a,h)anthracene	53703	4.5E-03	8.3E-03	0.05	0.25	--	C	9.2E-03	9.2E-03	7.8E-01	7.8E-01	8.7E-02	8.7E-02
Fluoranthene	206440	6.3E-03	1.7E-02	0.22	0.50	--	N	1.5E+03	1.5E+02	8.2E+04	8.2E+03	3.1E+03	3.1E+02
Fluorene	86737	1.4E-02	4.2E-02	0.97	1.25	--	N	2.4E+02	2.4E+01	8.2E+04	8.2E+03	3.1E+03	3.1E+02
Indeno(1,2,3-cd)pyrene	193395	1.1E-03	8.3E-03	0.089	0.25	--	C	9.2E-02	9.2E-02	7.8E+00	7.8E+00	8.7E-01	8.7E-01
Naphthalene	91203	1.1E-02	4.2E-02	0.60	1.25	--	N	6.5E+00	6.5E-01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
Phenanthrene (1)	85018	5.5E-03	4.2E-02	0.12	0.50	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02
Pyrene	129000	8.3E-03	1.7E-02	0.08	0.50	--	N	1.8E+02	1.8E+01	6.1E+04	6.1E+03	2.3E+03	2.3E+02

Notes:
CAS = Chemical Abstract Service
Method Detection and Reporting Limits provided by CompuChem
MDL = Method Detection Limit
mg/kg = milligram per kilogram
µg/L = microgram per liter
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table
C/N: Carcinogenic or Non-carcinogenic status

C = Carcinogenic
CI = Carcinogen with a hazard quotient of 0.1; see USEPA Region III guidance
N = Noncarcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
-- = No Criteria available
MCL = Maximum Contaminant Level
PAH = Polynuclear aromatic hydrocarbon
(1) = the RBC for pyrene was used for these compounds

Table 2-8
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for Explosives (by USEPA Methods 8330 and 8332) Soil and Water Samples
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant

Compounds by Method 8330	CAS Number	Laboratory-Specific Method Detection and ReportingLimits				USEPA MCLs	USEPA Region III Risk-Based Concentrations						
		Soil		Water									
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	µg/L	C/N	Tap water RBC µg/L	Adjusted Tap Water RBC µg/L	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
1,3,5-Trinitrobenzene	99-35-4	0.18	1.0	1.03	3.0	--	N	1.1E+03	1.1E+02	6.1E+04	6.1E+03	2.3E+03	2.3E+02
1,3-Dinitrobenzene	99-65-0	0.13	1.0	1.04	3.0	--	N	3.7E+00	3.7E-01	2.0E+02	2.0E+01	7.8E+00	7.8E-01
2,4,6-Trinitrotoluene	118-96-7	0.31	1.0	0.61	3.0	--	C!	2.2E+00	2.2E+00	1.9E+02	1.9E+02	2.1E+01	2.1E+01
2,4-Dinitrotoluene	121-14-2	0.30	1.0	0.47	3.0	--	N	7.3E+01	7.3E+00	4.1E+03	4.1E+02	1.6E+02	1.6E+01
2,6-Dinitrotoluene	606-20-2	0.27	1.5	0.59	4.0	--	N	3.7E+01	3.7E+00	2.0E+03	2.0E+02	7.8E+01	7.8E+00
2-Amino-4, 6-dinitrotoluene	355-72-78-2	0.23	1.5	0.86	4.0	--	N	2.2E+00	2.2E-01	1.2E+02	1.2E+01	4.7E+00	4.7E-01
2-Nitrotoluene	88-72-2	0.53	1.5	1.16	3.0	--	N	6.1E+01	6.1E+00	2.0E+04	2.0E+03	7.8E+02	7.8E+01
3-Nitrotoluene	99-08-1	0.53	1.5	0.96	3.0	--	N	1.2E+02	1.2E+01	4.1E+04	4.1E+03	1.6E+03	1.6E+02
4-Amino-2,6-dinitrotoluene	1946-51-0	0.42	1.5	0.78	4.0	--	N	2.2E+00	2.2E-01	1.2E+02	1.2E+01	4.7E+00	4.7E-01
4-Nitrotoluene	99-99-0	0.70	1.5	1.31	3.0	--	N	6.1E+01	6.1E+00	2.0E+04	2.0E+03	7.8E+02	7.8E+01
HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine)	2691-41-0	0.20	1.5	1.07	4.0	--	N	1.8E+03	1.8E+02	1.0E+05	1.0E+04	3.9E+03	3.9E+02
Nitrobenzene	98-95-3	0.20	1.0	0.36	3.0	--	N	3.5E+00	3.5E-01	1.0E+03	1.0E+02	3.9E+01	3.9E+00
RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine)	121-82-4	0.34	1.0	0.88	3.0	--	C	6.1E-01	6.1E-01	5.2E+01	5.2E+01	5.8E+00	5.8E+00
Tetryl (Methyl-2,4,6-trinitrophenylnitramine)	479-45-8	0.55	1.5	0.91	4.0	--	N	3.7E+02	3.7E+01	2.0E+04	2.0E+03	7.8E+02	7.8E+01

Compound by Method 8332													
Nitroglycerin	55-63-0	1.99	10	20.0	60	--	C	4.8E+00	4.8E+00	4.1E+02	4.1E+02	4.6E+01	4.6E+01

Notes:

CAS = Chemical Abstract Service
Method Detection and Reporting Limits provided by CompuChem
MDL = Method Detection Limit
mg/kg = milligram per kilogram
µg/L = microgram per liter
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table
C/N = Carcinogenic or Non-carcinogenic status

C = Carcinogenic
C! = Carcinogen with a hazard quotient of 0.1; see USEPA Region III guidance
N = Noncarcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
-- = No RBC available
MCL = Maximum Contaminant Level

Table 2-9

Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for Dioxins/Furans (USEPA Method 8290) Soil and Water Samples

SWMU 54 RCRA Facility Investigation

Radford Army Ammunition Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and ReportingLimits				USEPA MCLs	USEPA Region III Risk-Based Concentrations						
		Soil		Water									
		MDL	Reporting Limit	MDL	Reporting Limit			Tap water RBC	Adjusted Tap Water RBC	Soil RBC (Industrial)	Adjusted Soil RBC (Industrial)	Soil RBC (Residential)	Adjusted Soil RBC (Residential)
		pg/g	pg/g	ppq	ppq	ppq	C/N	ppq	ppq	pg/g	pg/g	pg/g	pg/g
2,3,7,8-TCDD	1746016	0.072	0.5	1.91	10	3.00E+01	C	4.5E-01	4.5E-01	3.8E+01	3.8E+01	4.3E+00	4.3E+00
1,2,3,7,8-PeCDF	57117416	0.097	2.5	2.18	50	--	--	--	--	--	--	--	--
1,2,3,4,7,8-HxCDD	39227286	0.119	2.5	3.20	50	--	--	--	--	--	--	--	--
1,2,3,6,7,8-HxCDD	57653857	0.131	2.5	4.12	50	--	--	--	--	--	--	--	--
1,2,3,7,8,9-HxCDD	19408743	1.187	2.5	4.67	50	--	--	--	--	--	--	--	--
1,2,3,4,6,7,8-HpCDD	35822394	0.173	2.5	7.86	50	--	--	--	--	--	--	--	--
OCDD	3268879	0.679	5.0	33.7	100	--	--	--	--	--	--	--	--
2,3,7,8-TCDF	51207319	0.146	0.5	0.91	10	--	--	--	--	--	--	--	--
1,2,3,7,8-PeCDF	57117416	0.170	2.5	3.06	50	--	--	--	--	--	--	--	--
2,3,4,7,8-PeCDF	57117314	0.291	2.5	2.00	50	--	--	--	--	--	--	--	--
1,2,3,4,7,8-HxCDF	70648269	0.181	2.5	2.33	50	--	--	--	--	--	--	--	--
1,2,3,6,7,8-HxCDF	57117449	0.251	2.5	2.54	50	--	--	--	--	--	--	--	--
2,3,4,6,7,8-HxCDF	60851345	0.222	2.5	4.90	50	--	--	--	--	--	--	--	--
1,2,3,7,8,9-HxCDF	72918219	0.279	2.5	4.99	50	--	--	--	--	--	--	--	--
1,2,3,4,6,7,8-HpCDF	67562394	0.208	2.5	4.92	50	--	--	--	--	--	--	--	--
1,2,3,4,7,8,9-HpCDF	55673897	0.288	2.5	6.20	50	--	--	--	--	--	--	--	--
OCDF	39001020	0.273	5.0	5.23	100	--	--	--	--	--	--	--	--

Notes:

CAS = Chemical Abstract Service
Method Detection and Reporting Limits provided by Triangle Laboratories
MDL = Method Detection Limit
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table
MCL = Maximum Contaminant Level

pg/g = picogram per gram
ppq = parts per quadrillion
pg/L = picogram per liter
C/N = Carcinogenic or Non-carcinogenic status
C = Cancinogenic
-- = No Criteria Available

Table 2-10
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for TCL Pesticides (by EPA Method 8081A) Soil and Water Samples
SWMU 54 RCRA Facility Investigation
Radford Army Ammuniton Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and				USEPA Region III Risk Based Concentrations				
		Soil		Water						
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	C/N	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
4,4'-DDD	72-54-8	1.2E-03	3.3E-03	0.025	0.10	C	2.4E+01	2.4E+01	2.7E+00	2.7E+00
4,4'-DDE	72-55-9	7.8E-04	1.7E-03	0.014	0.050	C	1.7E+01	1.7E+01	1.9E+00	1.9E+00
4,4'-DDT	50-29-3	1.1E-03	5.0E-03	0.017	0.15	C	1.7E+01	1.7E+01	1.9E+00	1.9E+00
Aldrin	309-00-2	3.9E-04	8.3E-04	0.016	0.025	C	3.4E-01	3.4E-01	3.8E-02	3.8E-02
alpha-BHC	319-84-6	5.9E-04	8.3E-04	0.015	0.025	C	9.1E-01	9.1E-01	1.0E-01	1.0E-01
alpha-Chlordane[1]	5103-71-9	5.4E-04	8.3E-04	0.010	0.050	C	1.6E+01	1.6E+01	1.8E+00	1.8E+00
gamma-Chlordane[1]	5103-74-2	3.7E-04	8.3E-04	0.0069	0.025	C	1.6E+01	1.6E+01	1.8E+00	1.8E+00
beta-BHC	319-85-7	1.4E-03	1.7E-03	0.027	0.050	C	3.2E+00	3.2E+00	3.5E-01	3.5E-01
delta-BHC	319-86-8	7.8E-04	8.3E-04	0.015	0.025	--	--	--	--	--
Dieldrin	60-57-1	7.3E-04	1.7E-03	0.019	0.050	C	3.6E-01	3.6E-01	4.0E-02	4.0E-02
Endosulfan I	959-98-8	3.1E-04	1.7E-03	0.013	0.050	N	1.2E+04	1.2E+03	4.7E+02	4.7E+01
Endosulfan II	33213-65-9	9.4E-04	3.3E-03	0.020	0.10	--	--	--	--	--
Endosulfan sulfate	1031-07-8	1.1E-03	3.3E-03	0.020	0.10	--	--	--	--	--
Endrin	72-20-8	7.4E-04	3.3E-03	0.018	0.10	N	6.1E+02	6.1E+01	2.3E+01	2.3E+00
Endrin aldehyde	7421-93-4	1.6E-03	3.3E-03	0.028	0.10	--	--	--	--	--
Endrin ketone	53494-70-5	9.7E-04	8.3E-03	0.023	0.25	--	--	--	--	--
gamma-BHC (Lindane)	58-59-9	6.3E-04	8.3E-04	0.018	0.025	C	4.4E+00	4.4E+00	4.9E-01	4.9E-01
Heptachlor	76-44-8	4.8E-04	8.3E-04	0.018	0.025	C	1.3E+00	1.3E+00	1.4E-01	1.4E-01
Heptachlor epoxide	1024-57-3	4.4E-04	8.3E-04	0.0067	0.025	C	6.3E-01	6.3E-01	7.0E-02	7.0E-02
Methoxychlor	72-43-5	2.7E-03	8.3E-03	0.078	0.25	N	1.0E+04	1.0E+03	3.9E+02	3.9E+01
Toxaphene	8001-35-2	2.7E-02	1.7E-01	0.70	5.0	C	5.2E+00	5.2E+00	5.8E-01	5.8E-01

Notes:

CAS = Chemical Abstract Service
Method Detection and Reporting Limits provided by CompuChem
MDL = Method Detection Limit
mg/kg = milligram per kilogram
µg/L = microgram per liter
-- = RBC not available
USEPA = U.S. Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table

C/N = Carcinogenic or Non-carcinogenic status
C = Carcinogenic
C! = Carcinogen with a hazard quotient of 0.1; see USEPA Region III guidance
N = Non-carcinogenic
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
(1) = Chlordane value is for sum of isomers
TCL = Target Compound List

Table 2-11
Summary of Analyte Method Detection Limits, Reporting Limits, and Risk Screening Criteria for PCBs (USEPA Method 8082) and Perchlorate (USEPA Method 314.0)
Soil and Water Samples
SWMU 54 RCRA Facility Investigation
Radford Army Ammuniton Plant, Radford, Virginia

Compound	CAS Number	Laboratory-Specific Method Detection and Reporting Limits				USEPA Region III Risk Based Concentrations					
		Soil		Water							
		MDL mg/kg	Reporting Limit mg/kg	MDL µg/L	Reporting Limit µg/L	C/N	Soil RBC (Industrial) mg/kg	Adjusted Soil RBC (Industrial) mg/kg	C/N	Soil RBC (Residential) mg/kg	Adjusted Soil RBC (Residential) mg/kg
Aroclor 1016	12674-11-2	1.4E-02	6.3E-02	0.510	2.0	C!	8.2E+01	8.2E+01	N	5.5E+00	5.5E-01
Aroclor 1221	11104-28-2	1.9E-02	8.3E-02	0.940	3.0	C	2.9E+00	2.9E+00	C	3.2E-01	3.2E-01
Aroclor 1232	11141-16-5	1.3E-02	6.3E-02	0.270	2.0	C	2.9E+00	2.9E+00	C	3.2E-01	3.2E-01
Aroclor 1242	53469-21-9	1.5E-02	4.2E-02	0.420	2.0	C	2.9E+00	2.9E+00	C	3.2E-01	3.2E-01
Aroclor 1248	12672-29-6	1.4E-02	4.2E-02	0.380	2.0	C	2.9E+00	2.9E+00	C	3.2E-01	3.2E-01
Aroclor 1254	11097-69-1	8.3E-03	4.2E-02	0.180	2.0	C	2.9E+00	2.9E+00	C!	3.2E-01	3.2E-01
Aroclor 1260	11096-82-5	6.8E-03	6.3E-02	0.5200	2.0	C	2.9E+00	2.9E+00	C	3.2E-01	3.2E-01
Perchlorate	n/a	n/a	n/a	1.9892	5.0	*USEPA screening criteria under development*					

Notes:

CAS = Chemical Abstract Service

Method Detection and Reporting Limits provided by CompuChem

MDL = Method Detection Limit

mg/kg = milligram per kilogram

µg/L = microgram per liter

USEPA = U.S. Environmental Protection Agency

USEPA Region III Risk-Based Concentration (RBC) values from the April 4, 2002 RBC Table

C/N = Carcinogenic or Non-carcinogenic status

C = Carcinogenic

N = Non-carcinogenic

C! = Carcinogen with a hazard quotient of 0.1; see USEPA Region III guidance

Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens

n/a = Not applicable

- Perchlorate (aqueous);
- Explosives (including nitroglycerin); and
- Dioxin/furans.

Note that Triangle Laboratories will perform analysis of dioxin/furans.

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

- TCLP SVOCs;
- Ignitability;
- Corrosivity;
- Reactivity; and
- Paint Filter Test (solids).

2.5.1 Organics

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

2.5.1.1 Semivolatiles by SW8270C

The samples are prepared for analysis by gas chromatography/mass spectrometry (GC/MS) using SW846 Test Method 3520C for aqueous media and Test Method 3540C for solid media, or other appropriate methods. If necessary, sample cleanup procedures will be used (refer to Method 3600 series). The semivolatile compounds are introduced into the GC/MS by injecting the sample extract into a gas chromatograph with a narrow-bore fused-silica capillary column.

The GC column is temperature-programmed to separate the analytes, which are then identified with a mass spectrometer, connected to the gas chromatograph. Analytes eluted from the capillary column are introduced into the mass spectrometer via a jet separator or a direct connection. Identification of target analytes is accomplished by comparing their mass spectra with the electron impact (or electron impact-like) spectra of authentic standards. Quantitation is accomplished by comparing the response of a major (quantitation) ion relative to an internal standard using a five-point calibration curve.

2.5.1.2 Dioxin and Furans by SW8290

Method 8290 provides procedures for the identification and quantitative measurement of polychlorinated dibenzo-p-dioxins (tetra- though octa-chlorinated homologues; PCDDs) and polychlorinated dibenzofurans (tetra- though octa-chlorinated homologues; PCDFs) in a variety of environmental matrices and at part-per-trillion (ppt) to part-per-quadrillion (ppq) concentrations. A specified amount of sample is spiked with a solution containing specified amounts of each of the nine isotopically ($^{13}C_{12}$) labeled PCDDs/PCDFs. The sample is then extracted according to a matrix-specific extraction procedure.

The samples are prepared for analysis by high-resolution gas chromatography/high-resolution mass spectrometry (HRGC/HRMS) using the matrix specific extraction (refer to Method 8290) and analyte specific cleanup procedures (refer to Method 8290). A high-resolution capillary column (60 m DB-5, J&W Scientific, or equivalent) is used in this method. However, no single column is known to resolve isomers. In order to establish the concentration of the 2,3,7,8-TCDF (if detected on the DB-5 column), the sample extract must be reanalyzed on a column capable of 2,3,7,8-TCDF isomer specificity (e.g., DB-225, SP-2330, SP-2331, or equivalent). Quantitation of the individual congeners, total PCDDs and total PCDFs is achieved in conjunction with the establishment of a multipoint (five points) calibration curve for each homologue, during which each calibration solution is analyzed once. The identification of OCDD and nine of the fifteen 2,3,7,8- substituted congeners, for which a 13C-labeled standard is available in the sample fortification and recovery standard solutions, is based on their elution at their exact retention time (within 0.005 retention time units measured in the routine calibration) and simultaneous detection of the two most abundant ions in the molecular ion region. The remaining six 2,3,7,8-substituted congeners (i.e., 2,3,4,7,8-PeCDF; 1,2,3,4,7,8-HxCDD; 1,2,3,6,7,8-HxCDF; 1,2,3,7,8,9-HxCDF; 2,3,4,6,7,8-HxCDF, and 1,2,3,4,7,8,9-HpCDF), for which no carbon-labeled internal standards are available in the sample fortification solution, and other identified PCDD/PCDF congeners are identified by their relative retention times from the routine calibration data, and the simultaneous detection of the two most abundant ions in the molecular ion region. The identification of OCDF is based on its retention time relative to $^{13}C_{12}$-OCDD and the simultaneous detection of the two most abundant ions in the molecular ion region. Confirmation is based on a comparison of the ratios of the integrated ion abundance of the molecular ion species to their theoretical abundance ratios. A calculation of the toxicity equivalent concentration (TEQ) of each sample is made using international consensus toxicity equivalence factors (TEFs), and the TEQ is used to establish if the concentrations of target compounds in the sample are high enough to warrant confirmation of the results on a second GC column.

2.5.1.3 Polynuclear Aromatic Hydrocarbons by SW8310

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

2.5.1.4 Pesticides by SW8081A

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

2.5.1.5 PCBs by SW8082

A measured volume or weight of sample (approximately one liter for liquids, two grams to 30 grams for solids) is extracted using the appropriate matrix-specific sample extraction technique. Aqueous samples are extracted at neutral pH Method 3520C (continuous liquid-liquid extractor), or other appropriate technique. Solid samples are extracted Method 3540C (Soxhlet) or other appropriate technique. Extracts for PCB analysis may be subjected to a sulfuric acid/potassium permanganate cleanup (Method 3665) designed specifically for these analytes. This cleanup technique will remove (destroy) many single component organochlorine or organophosphate pesticides. Therefore, Method 8082 is not applicable to the analysis of those compounds. Instead, use Method 8081. After cleanup, the extract is analyzed by injecting a two µL aliquot into a gas chromatograph with a narrow- or wide-bore fused silica capillary column and ECD. The chromatographic data may be used to identify the seven Aroclors in Table 2.11, individual PCB congeners, or total PCBs.

2.5.1.6 Explosives by SW8330 and SW8332

Method 8330 and 8332 provide HPLC conditions for the detection of ppb levels of certain explosives residues in water, soil and sediment matrix. Prior to use of these methods, appropriate sample preparation techniques must be used. Two sample preparation techniques are available.

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

(2) High-level Direct Injection Method: Aqueous samples of higher concentration can be diluted 1/1 (v/v) with methanol or acetonitrile, filtered, separated on a C-18 reverse phase column, identified at 254 nm, and confirmed on a CN reverse phase column. If HMX is an important target analyte, methanol is preferred. Soil and sediment samples are extracted using acetonitrile in an ultrasonic bath, filtered and-chromatographed as described above.

2.5.2 Inorganics

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

2.5.2.1 Metals by Inductively Coupled Plasma

Prior to analysis, samples are prepared by Method 3010A for aqueous media and Method 3050B for solid media, or other appropriate methods. When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved prior to analysis. This method describes multi-elemental determinations by Inductively Coupled Plasma (ICP)-Atomic Emission Spectroscopy (AES) using sequential or simultaneous optical systems and axial or radial viewing of the plasma. The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by radio frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and photosensitive devices monitor the intensities of the emission lines.

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

2.5.2.2 Mercury by SW7470 (aqueous samples) and SW7471 (soil/solid samples)

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

2.5.2.3 Perchlorate by USEPA 314.0

This method covers the identification of perchlorate in reagent water, surface water, ground water, and finished drinking water using ion chromatograph. A one-milliliter volume of sample is introduced into an ion chromatograph. The exact volume is not critical since standard and samples will be used the same sample loop. However, the volume should be verified to be within 5% of this volume be weighing the sample loop empty, filling the loop with deionized water and re-weighing the loop. Perchlorate is separated and measured, using a system composed of an ion chromatographic pump, sample injection valve, guard column, analytical column, suppressor device, and conductivity detector. Reagent solutions, samples, and laboratory blanks must be filtered through no larger than a 0.45-micrometer nominal pore size membrane to remove particulate and prevent damage to the instrument, columns, and flow systems.

Sample matrices with high concentrations of common anions such as chloride, sulfate, and carbonate can make the analysis problematic by destabilizing the baseline in the retention time window for perchlorate. This is evidenced by observing a protracted tailing following the initial elution of the more weakly retained anion (chloride, sulfate, and carbonate) that extends into the perchlorate retention time window. These common anion levels can be indirectly assessed by monitoring the conductivity of the matrix. Consequently, sample matrices must be monitored for conductivity prior to analysis. When the laboratory Matrix Conductivity Threshold (MCT) is exceeded, procedures incorporating sample dilution and/or pretreatment must be performed.

2.5.3 Waste Samples

2.5.3.1 TCLP Extraction

For liquid wastes (i.e., those containing less than 0.5% dry solid material), the waste, after filtration through a 0.6 to 0.8 micrometer glass fiber filter, is defined as the TCLP extract. For wastes containing greater than or equal to 0.5% solids, the liquid is separated from the solid phase and stored for later analysis; the particle size of the solid phase is reduced, if necessary. The solid phase is extracted with an amount of extraction fluid equal to 20 times the weight of the solid phase. The extraction fluid employed

9A

is a function of the alkalinity of the solid phase of the waste. A special extractor vessel is used when testing for volatile analytes. Following extraction, the liquid extract is separated from the solid phase by filtration through a 0.6 to 0.8 micrometer glass fiber filter. If compatible (i.e., multiple phases will not form on combination), the initial liquid phase of the waste is added to the liquid extract, and these are analyzed together. If incompatible, the liquids are analyzed separately and the results are mathematically combined to yield a volume-weighted average concentration. Extracts are analyzed using the analytical methods described above.

2.5.3.2 Ignitability

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

2.5.3.3 Corrosivity

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

2.5.3.4 Reactivity

An aliquot of acid is added to a fixed weight of waste in a closed system. The generated gas is swept into a scrubber. The analyte is quantitated for cyanide and sulfide as follows. (1) In the colorimetric measurement, the cyanide is converted to cyanogen chloride CNCl) by reaction of cyanide with chloramine-T at a pH less than eight. After the reaction is complete, color is formed on the addition of pyridine-barbituric acid reagent. The absorbence is read at 578 nm for the complex formed with pyridine-barbituric acid reagent and CNCl. To obtain colors of comparable intensity, it is essential to have the same salt content in both the sample and the standards. The titration measurement uses a standard solution of silver nitrate to titrate cyanide in the presence of a silver sensitive indicator. (2) Sulfide is extracted from the sample by a preliminary distillation procedure and precipitated in a zinc acetate scrubber as zinc sulfide. The sulfide is oxidized to sulfur by adding a known excess amount of iodine. The excess iodine is quantified by titration with a standard solution of phenyl arsine oxide (PAO) or sodium thiosulfate until the blue iodine starch complex disappears. As the use of standard sulfide solutions is not possible because of oxidative degradation, quantitation is based on the PAO or sodium thiosulfate.

2.5.4 Physical/Geotechnical Analysis

As discussed in Section 1.3.4.1, four soil samples will be collected for analysis of physical/geotechnical parameters. A USACE or other approved laboratory will conduct analysis. Analysis will be conducted for:

- Grain-size analysis (ASTM D-422)
- Atterberg limits (ASTM D-4318);
- Soil moisture content (ASTM-2216);
- Total organic content (ASTM D-2974);
- Soil bulk density (ASTM D-4253);
- Measurement of hydraulic conductivity (ASTM D-5084 and D-5856);
- Soil porosity (ASTM D-854 and D-2973);
- pH (ASTM D-4972);
- Particle-size distribution (ASTM D-422);
- Cation exchange capacity (various methods)

2.6 INTERNAL QUALITY CONTROL CHECK

Internal QC components that will be used by URS 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.

2.7 DATA COLLECTION AND VALIDATION

A USACE-approved analytical laboratory will conduct analyses. Level IV CLP-like raw data will be provided along with the Form 1. Data validation will be conducted based on the MQAP (Section 9.5), the USACE Shell Document, and USEPA Region III guidance.

URS will direct the overall data management. Data activity for the sampling program will be divided between URS and CompuChem Laboratories. Each firm has the equipment needed to perform the required data management functions. The laboratory will perform data entry and manipulation operations associated with the analysis of raw analytical data and provisions of chemical analysis results by sampling location. These data will be transmitted to URS for evaluation and interpretation. URS will also code and review boring logs and sample location maps.

3.0 HEALTH AND SAFETY PLAN ADDENDUM

3.1 INTRODUCTION

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

This HSPA addresses project-specific hazards identified in Section 3.2.2 including physical hazards, biological hazards, and chemical hazards. This HSPA 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 MHSP
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

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

URS 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 54 and must be amended if conditions change. A copy of this HSPA will be available at each work site.

The contractor will provide a safe work environment for personnel involved in RFAAP investigative activities. The contractor will emphasize the importance of prevention of personnel injury and illness at the work site.

3.2 TRAINING PLAN

Training will be used to review topics outlined in this HSPA and to inform URS and subcontractor personnel of the hazards and control techniques associated with work locations.

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

3.2.1 Hazard Information Training

Hazard information training will be presented to URS and subcontractor that will include, as a minimum, a description of the Hazardous, Toxic, Radioactive Waste (HTRW) that may be found at SWMU 54. Training will also be provided on the potential biological, chemical, and physical hazards to be found at the Installation. This training will be conducted by the URS SSHO based on information provided by the operating contractor.

3.2.2 Project-Specific Hazard Analysis

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

(1) Physical Hazards

- Cold stress – refer to Section 3.2.2 of the MHSP;
- Manual lifting – refer to Section 3.2.4 of the MHSP;
- Slips, trips and falls associated with walking through heavily vegetated areas – refer to Section 6.1.1 of the MHSP;
- Heavy equipment – refer to Section 6.1.2.1 of the MHSP; and
- Manufacturing Area – overhead power lines.

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

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

(3) Chemical Hazards

- Potential exposure to carcinogenic chemicals; and

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

3.2.3 Hearing Conservation

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

During site field work involving drilling, geoprobing, or other work where the potential exists to encounter noise at levels exceeding 85 dBA eight-hour TWA, field personnel will be required to wear either ear plugs or ear muff hearing protection.

3.2.4 Hazard Communication Training

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

3.2.5 Confined Space Entry Training

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

3.3 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

The minimum and initial level of PPE for these activities will be Level D. The initial selection of PPE is based on a hazard assessment, including the review of existing analytical data and related toxicological information with respect to the proposed field activities. PPE assignments are subject to change based upon site conditions and task variation. The SHSO will review the required level of protection and safety equipment for each task with the sampling crew. The decisions on which protective level is most appropriate will be made by the SHSO.

In accordance with 29 CFR 1910.134, URS personnel working on site will be required to participate in URS' 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.

3.4 MONITORING PLAN

During sampling activities, the SHSO will monitor the site initially and periodically for potentially hazardous airborne constituents or physical hazards. A photoionization detector (PID) will be used to detect organic vapors. The PID will be calibrated on a daily basis in accordance with SOP 90.1. The ALs for volatile organic compounds at sustained concentrations in the general area are identified in Table 3-2.

Table 3-2
Air Monitoring Action Levels
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

PID Readings	Action
Background plus five parts per million (ppm)	Investigate
Five ppm to 25 ppm	Upgrade to Level C (full face air-purifying respirator with organic vapor/acid gas cartridge), investigate
Greater than 25 ppm	Suspend work, depart area, investigate

3.5 EMERGENCY RESPONSE PLAN

Emergency response will follow the protocols set forth in MHSP, Section 10.0. Table 3-3 presents Emergency Telephone Numbers for activities performed at RFAAP.

Table 3-3
Emergency Telephone Numbers
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Emergency Response Services	Telephone Number
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 ATK 2000.

4.0 REFERENCES

Alliant TechSystems (ATK). 2000. *Safety, Security and Environmental Rules for Contractors and Subcontractors.*

Bethke, C.M. and Brady, P.V. 2000. *How the K_d Approach Undermines Ground Water Cleanup. Ground Water* 38(3): 435-443.

Dames & Moore. 1992a. *Draft VI Report for the Radford Army Ammunition Plant, Virginia.* Prepared for the U. S. Army Toxic and Hazardous Materials Agency.

Dames & Moore. 1992b. *SWMU 13 Characterization Report, Radford Army Ammunition Plant, Virginia.* Prepared for the U. S. Army Toxic and Hazardous Materials Agency.

Department of the Army. 1999. Correspondence, August 20, 1999, Subject: SWMU 54 Interim Action.

Department of the Army. 1999. *Decision Document Interim Action, SWMU 54.*

Freeze, R.A., and Cherry, J.A. 1979. *Groundwater.* Prentice Hall, Englewood Cliffs, NJ.

Knox, R.C., Sabanti, D.A., and Canter, L.W. 1993. *Subsurface Transport and Fate Processes.* Lewis Publishers. p. 56-71.

IT Corporation (IT). 2001. *Current Conditions Report, Horseshoe Area: Draft Document.* Prepared for U.S. Army Corps of Engineers Baltimore District.

IT Corporation (IT). 2002. *Facility-Wide Background Study.* Prepared for U.S. Army Corps of Engineers Baltimore District.

Millennium Science and Engineering (MSE). 1998. *Supplemental RFI Report, SWMU 54, Radford Army Ammunition Plant.*

Parsons Engineering Science, Inc. (Parsons). 1996. *RCRA Facility Investigation for Solid Waste Management Units 17, 31, 48, and 54 at Radford Army Ammunition Plant, Virginia.* Prepared for U.S. Army Environmental Center.

Radford Army Ammunition Plant (RFAAP). 2002. *Radford Army Ammunition Plant Installation Action Plan, 2002.*

URS Corporation (URS). 2002. *Master Work Plan, Quality Assurance Plan, Health and Safety Plan: Draft Document, Radford Army Ammunitions Plant, Radford, Virginia.* Prepared for U.S. Army Corps of Engineers Baltimore District.

U.S. Army Corps of Engineers (USACE). 2001. *Engineering and Design – Requirements for the Preparation of Sampling and Analysis Plans.* Publication EM 200-1-0. February.

U.S. Army Toxic and Hazardous Materials Agency (USATHAMA). 1976. *Installation Assessment of Radford Army Ammunition Plant, Records Evaluation Report No. 103.*

U.S. Environmental Protection Agency (USEPA). 1987. *RCRA Facility Assessment for Radford Army Ammunition Plant, Radford, Virginia, VAD-21-002-0730.*

U.S. Environmental Protection Agency (USEPA). 1989. *Draft Permit for Corrective Action and Incinerator Operation, Radford Army Ammunition Plant, Radford, Virginia, VAD-21-002-0730.*

U.S. Environmental Protection Agency (USEPA). 1992. *Installation Assessment, Radford Army Ammunition Plant, Radford, Virginia. Environmental Photographic Interpretation Center (EPIC).*

U.S. Environmental Protection Agency (USEPA). 1994. *Guidance for the Data Quality Objectives Process*. EPA/600/R-96/055. September.

U.S. Environmental Protection Agency (USEPA). 1998. *Test Methods for Evaluating Solid Waste, Physical Chemical Methods* (SW 846), Third Edition. Office of Solid Waste and Emergency Response.

U.S. Environmental Protection Agency (USEPA). 1999. *Understanding Variation in Partition Coefficient, K_d, Values, Volume I: The K_d Model, Methods of Measurement, and Application of Chemical Reaction Codes*. Office of Radiation and Indoor Air Quality, Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency and Office of Environmental Restoration, U.S. Department of Energy, Washington, D.C, August.

U.S. Environmental Protection Agency (USEPA). 2000a. Guidance for Data Quality Objectives for Hazardous Waste Sites. EPA/300/R-00/007. Office of Solid Waste and Emergency Response.

U.S. Environmental Protection Agency (USEPA). 2000b. *Permit for Corrective Action and Waste Minimization; Pursuant to the Resource Conservation and Recovery Act as Amended by the Hazardous and Solid Waste Amendments of 1984, Radford Army Ammunition Plant, Radford, Virginia, VA1210020730.*

U.S. Environmental Protection Agency (USEPA). 2002. *http://www.epa.gov/ogwdw000/ccl/perchlor/perchlo.html*

APPENDIX A
STANDARD OPERATING PROCEDURES

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.

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.

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 10.2
SURFACE WATER, GROUNDWATER, AND SOIL/SEDIMENT FIELD LOGBOOKS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording surface water, groundwater, and soil/sediment sampling information, as well as instrument calibration data in field logbooks.

2.0 MATERIAL

- Applicable field logbook (see attached forms); and
- Indelible ink pen.

3.0 PROCEDURE

All information pertinent to surface water, groundwater, or soil/sediment sampling will be recorded in the appropriate logbook. Each page/form of the logbook will be consecutively numbered. All entries will be made with an indelible ink pen. All corrections will consist of line out deletions that are initialed and dated.

3.1 SOIL/SEDIMENT

3.1.1 Field Parameters/Logbook (Form 10.2-a)

1. HIGH CONCENTRATION EXPECTED?: Answer "Yes" or "No.";
2. HIGH HAZARD?: Answer "Yes" or "No.";
3. INSTALLATION/SITE: Record the complete name of the installation or site;
4. AREA: Record the area designation of the sample site;
5. INST. NAME: Record the two-letter installation name for Radford Army Ammunition Plant – "RD";
6. SAMPLE MATRIX CODE: Record the appropriate sample matrix code. Common codes are "SD" for solid - sediment, "SI" for soil - gas, "SL for solid sludge, "SO" for surface other, "SS" for solid – soil, "SW" for surface wipe, "WD" for water – potable, "WG" for water – ground, "WS" water – surface, "WT" – water treated and "WW" water -waste;
7. SITE ID: Record a code up to 20 characters or numbers that is unique to the site;
8. ENV. FIELD SAMPLE IDENTIFIER: Record a code up to 20 characters specific for the sample;
9. DATE: Enter the date the sample was taken;
10. TIME: Enter the time (12-hour or 24-hour clock acceptable as long as internally consistent) the sample was taken;

11. AM PM: Circle "AM" or "PM" to designate morning or afternoon (12-hour clock);
12. SAMPLE PROG: Record "RFI" (RCRA Facility Investigation) or other appropriate sample program;
13. DEPTH (TOP): Record the total depth sampled;
14. DEPTH INTERVAL: Record the intervals at which the plug will be sampled;
15. UNITS: Record the units of depth (feet, meters);
16. SAMPLE MEASUREMENTS: Check the appropriate sampling method;
17. CHK: Check off each container released to a laboratory;
18. ANALYSIS: Record the type of analysis to be performed on each sample container;
19. SAMPLE CONTAINER: Record the sample container type and size;
20. NO.: Record the number of containers;
21. REMARKS: Record any remarks about the sample;
22. TOTAL NUMBER OF CONTAINERS FOR SAMPLE: Record the total number of containers;
23. SITE DESCRIPTION: Describe the location where the sample was collected;
24. SAMPLE FORM: Record the form of the sample (i.e., clay, loam, etc.) using The Unified Soil Classification System (USCS);
25. COLOR: Record the color of the sample as determined from standard Munsell Color Charts;
26. ODOR: Record the odor of the sample or "none";
27. PID: Record the measured PID values or other similar measurement instrument value;
28. UNUSUAL FEATURES: Record anything unusual about the site or sample;
29. WEATHER/TEMPERATURE: Record the weather and temperature; and
30. SAMPLER: Record your name.

3.1.2 Map File Form (refer to form 10.2-c)

1. SITE ID: Record the Site ID from the field parameter form;
2. POINTER: Record the field sample number for the sample being pointed to;
3. DESCRIPTION/MEASUREMENTS: Describe the location where the sample was taken, along with distances to landmarks;
4. SKETCH/DIMENSIONS: Diagram the surroundings and record the distances to landmarks;
5. MAP REFERENCE: Record which U.S.G.S. Quad Map references the site;
6. COORDINATE DEFINITION: Write the compass directions and the X- and Y-coordinates of the map run;
7. COORDINATE SYSTEM: Write "UTM" (Universal Transverse Mercator);
8. SOURCE: Record the 1-digit code representing the Map Reference;
9. ACCURACY: Give units (e.g., write "1-M" for 1 meter);
10. X-COORDINATE: Record the X-coordinate of the sample site location;

11. Y-COORDINATE: Record the Y-coordinate of the sample site location;
12. UNITS: Record the units used to measure the map sections;
13. ELEVATION REFERENCE: Record whether topography was determined from a map or a topographical survey;
14. ELEVATION SOURCE: Record the 1-digit code representing the elevation reference;
15. ACCURACY: Record the accuracy of the map or survey providing the topographical information;
16. ELEVATION: Record the elevation of the sampling site;
17. UNITS: Write the units in which the elevation is recorded; and
18. SAMPLER: Write your name.

3.2 SURFACE WATER

3.2.1 Field Parameter Logbook (Forms 10.2-b and 10.2-c)

1. CAL REF: Record the calibration reference for the pH meter;
2. pH: Record the pH of the sample;
3. TEMP: Record the temperature of the sample in degrees Celsius;
4. COND: Record the conductivity of the water;
5. Description of site and sample conditions (refer to 10.2-b);
6. Map File Form (refer to Section 3.1.2).

3.3 GROUNDWATER (FORMS 10.2- D)

3.3.1 Field Parameter Logbook (Form 10.2.b)

Refer to Section 3.2.1.

3.3.2 Map File and Purging Forms

1. WELL NO. OR ID: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on pages 18-21 of the IRDMIS User's Guide for chemical data entry;
2. SAMPLE NO.: Record the reference number of the sample;
3. WELL/SITE DESCRIPTION: Describe the location where the sample was taken, along with distances to landmarks;
4. X-COORD AND Y-COORD: Record the survey coordinates for the sampling site;
5. ELEV: Record the elevation where the sample was taken;
6. UNITS: Record the units the elevation was recorded in;
7. DATE: Record the date in the form MM/DD/YY;
8. TIME: Record the time, including a designation of AM or PM;
9. AIR TEMP.: Record the air temperature, including a designation of C or F (Celsius or Fahrenheit);
10. WELL DEPTH: Record the depth of the well in feet and inches;

11. CASING HEIGHT: Record the height of the casing in feet and inches;
12. WATER DEPTH: Record the depth (underground) of the water in feet and inches;
13. WELL DIAMETER: Record the diameter of the well in inches;
14. WATER COLUMN HEIGHT: Record the height of the water column in feet and inches;
15. SANDPACK DIAM.: Record the diameter of the sandpack. Generally, this will be the same as the bore diameter;
16. EQUIVALENT VOLUME OF STANDING WATER: Use one of the following equations to determine one equivalent volume (EV);

    1 EV = volume in casing + volume in saturated sandpack. Or:

    $1\ EV = [\pi R_W{}^2 h_W + 0.30p(R_S{}^2 - R_W{}^2)h_S] * (0.0043)$

Where:

R_S = radius of sandpack in inches
R_W = radius of well casing in inches
h_S = height of sandpack in inches
h_W = water depth in inches

$0.0043 = gal/in^3$
and filter pack porosity is assumed as 30%, or

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

Where:

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

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Wh)(0.30)

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

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Sh)(0.30)

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

where:

Rb = radius of the borehole, and
Sh = length of the sandpack.

Show this calculation in the comments section.

1. PUMP RATE: Record pump rate;
2. TOTAL PUMP TIME: Record total purge time and volume;
3. WELL WENT DRY? Write "YES" or "NO";
4. PUMP TIME: Record pump time that made the well go dry;
5. VOLUME REMOVED: Record the volume of water (gal) removed before the well went dry;
6. RECOVERY TIME: Record the time required for the well to refill;
7. PURGE AGAIN?: Answer "YES" or "NO";
8. TOTAL VOL. REMOVED: Record the total volume of water (in gallons) removed from the well;
9. CAL REF.: Record the calibration reference for the pH meter;
10. TIME: Record time started (INITIAL T(0)), 2 times DURING the sampling and the time sampling ended (FINAL);
11. pH: Record the pH at start of sampling (INITIAL), twice DURING the sampling, and at the end of sampling (FINAL);
12. TEMP: Record the water temperature (Celsius) at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
13. COND: Record the conductivity of the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
14. D.O.: Record the dissolved oxygen level in the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
15. TURBIDITY: Record the readings from the turbidity meter (nephelometer) and units at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
16. ORD: Record the oxidation/reduction (RedOx) potential of the water sample at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
17. HEAD SPACE: Record any positive readings from organic vapor meter reading taken in well headspace before sampling;
18. NAPL: Record the presence and thickness of any non-aqueous phase liquids (LNAPL and DNAPL)
19. COMMENTS: Record any pertinent information not already covered in the form; and
20. SIGNATURE: Sign the form.

3.4 FIELD CALIBRATION FORMS (REFER TO FORM 10.2-E)

1. Record time and date of calibration;
2. Record calibration standard reference number;
3. Record meter ID number;
4. Record initial instrument reading, recalibration reading (if necessary), and final calibration reading on appropriate line;
5. Record value of reference standard (as required);

6. COMMENTS: Record any pertinent information not already covered on form; and
7. SIGNATURE: Sign form.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCE

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

FIELD PARAMETER/LOGBOOK FORM 10.2-a
SOIL AND SEDIMENT SAMPLES

HIGH CONCENTRATION EXPECTED? ____________________ HIGH HAZARD?

INSTALLATION/SITE ____ AREA ____________________

INST NAME ___________ FILE NAME ____

SAMPLE MATRIX CODE _____________ SITE ID _______________________
ENV. FIELD SAMPLE IDENTIFIER ____________________

DATE (MM/DD/YY) __/__/__ TIME ___________ AM PM SAMPLE PROGRAM

DEPTH (TOP) ______ DEPTH INTERVAL ______________ UNIT ______________

SAMPLING METHOD:

SPLIT SPOON ___ AUGER ___ SHELBY TUBE ___ SCOOP ___ OTHER

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE______

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION:____

SAMPLE FORM _____________________ COLOR ________________ ODOR ______________
PID (HNu)______________________ UNUSUAL FEATURES________________________

WEATHER/TEMPERATURE

SAMPLER ____________________

FIELD PARAMETER/LOGBOOK FORM 10.2-b
GROUNDWATER AND SURFACE WATER SAMPLES

HIGH CONCENTRATION EXPECTED? ________________ HIGH HAZARD?

INSTALLATION/SITE ______________________ AREA

INST CODE __________ FILE NAME ____________________ SITE TYPE

SITE ID ___________________ FIELD SAMPLE NUMBER

DATE (MM/DD/YY) __/__/__ TIME __________ AM PM SAMPLE PROG.

DEPTH (TOP) __________ DEPTH INTERVAL ___________ UNITS

SAMPLING MEASUREMENTS

CAL REF. ____ pH _____ TEMPERATURE °C _____ CONDUCTIVITY _____ REDOX _____

DISSOLVED OXYGEN ____ TURBIDITY _____ OTHER

CHK	ANALYSIS	SAMPLE CONTAINER	NO.	REMARKS

TOTAL NUMBER OF CONTAINERS FOR SAMPLE______

DESCRIPTION OF SITE AND SAMPLE CONDITIONS

SITE DESCRIPTION____

SAMPLING METHOD_____________________________________

SAMPLE FORM _________________ COLOR ________ ODOR ________

PID (HNu)____

UNUSUAL FEATURES_______________________________

WEATHER/TEMPERATURE____ SAMPLER _______________

EXAMPLE MAP FILE LOGBOOK FORM 10.2-c
SURFACE WATER, SOIL, AND SEDIMENT SAMPLES

SITE ID________________________ POINTER__________________

DESCRIPTION/MEASUREMENTS____

SKETCH/DIMENSIONS :

MAP REFERENCE______________________________________

COORDINATE DEFINITION (X is ______________ Y is __________)

COORDINATE SYSTEM ______________ SOURCE _______________ ACCURACY__________________

X-COORDINATE ___________ Y-COORDINATE ___________ UNITS_________

ELEVATION REFERENCE_______________________________

ELEVATION SOURCE ________________ ACCURACY ______________ELEVATION_________________

UNITS_______________

SAMPLER_________

EXAMPLE MAP FILE AND PURGING LOGBOOK FORM 10.2-d
GROUNDWATER SAMPLES

WELL COORD. OR ID ____________________ SAMPLE NO.____________

WELL/SITE DESCRIPTION____

____

X-COORD. _______ Y-COORD. _____________ ELEV. ________ UNITS

DATE ___/___/___ TIME _______________ AIR TEMP.

WELL DEPTH ___________ FT. _____ IN. CASING HT. _____ FT. ____ IN.

WATER DEPTH _____ FT. _____ IN. WELL DIAMETER ________ IN.

WATER COLUMN HEIGHT _______ FT. _____ IN. SANDPACK DIAM. ____ IN.

EQUIVALENT VOLUME OF STANDING WATER ____________ (GAL) (L)

VOLUME OF BAILER ______ (GAL) (L) or PUMP RATE ________ (GPM) (LPM)

TOTAL NO. OF BAILERS (5 EV) ________ or PUMP TIME _______ MIN.

WELL WENT DRY? [Yes] [No] NUM. OF BAILERS _______ or PUMP TIME

VOL. REMOVED ____________ (GAL) (L) RECOVERY TIME

PURGE AGAIN? [Yes] [No] TOTAL VOL. REMOVED _________ (GAL) (L)

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color / clarity / odor / partic.)
(before)									
(during)									
(during)									
(during									
(after)									

COMMENTS____

SIGNATURE____________________________

EXAMPLE FIELD CALIBRATION FORM 10.2-e
FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY, ORD, AND DISSOLVED OXYGEN METERS

INITIAL CALIBRATION	FINAL CALIBRATION
DATE:	**DATE:**
TIME:	**TIME:**

pH METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

pH STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
7.0			
10.0			
4.0			

CONDUCTIVITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

COND. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

TEMPERATURE METER CALIBRATION

METER ID__________________

TEMP. STANDARD	INITIAL READING	RECALIB. READING	FINAL READING
ICE WATER			
BOILING WATER			
OTHER ________			

EXAMPLE FIELD CALIBRATION FORM 10.2-e
FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY, ORD, AND DISSOLVED OXYGEN METERS

TURBIDITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

ORD METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

DISSOLVED OXYGEN METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:________________

METER ID__________________

STANDARD	INITIAL READING	RECALIB. READING	FINAL READING

COMMENTS____

SIGNATURE__________________________________

STANDARD OPERATING PROCEDURE 10.3
BORING LOGS

1.0 INTRODUCTION

The purpose of this standard operating procedure (SOP) is to describe the methods to be followed for classifying soil and rock, as well as preparing borehole logs and other types of soil reports.

2.0 MATERIALS

The following equipment is required for borehole logging:

- HTRW ENG Form 5056-R and 5056A-R boring log forms;
- Daily inspection report forms;
- Chain-of-custody forms;
- Request for analysis forms;
- ASTM D 2488 classification flow chart;
- Soil and/or Rock color chart (i.e., Munsell®);
- Grain size and roundness chart;
- Graph paper;
- Engineer's scale;
- Previous reports and boring logs;
- Pocketknife or putty knife;
- Hand lens;
- Dilute hydrochloric acid (10% volume);
- Gloves;
- Personal protective clothing and equipment, as described in work plan addenda health and safety plan;
- Photoionization detector or other appropriate monitoring equipment per site-specific health and safety plan; and
- Decontamination supplies (SOP 80.1).

3.0 PROCEDURE

Each boring log should fully describe the subsurface environment and the procedures used to obtain this description.

Boring logs should be prepared in the field on USACE Engineer Form 5056-R and 5056-R. Logs should be recorded in the field directly on the boring log form and not transcribed from a field book.

A "site geologist" should conduct borehole logging and soil/rock identification and description or other professional trained in the identification and description of soil/rock.

3.1 BORING LOG INFORMATION

As appropriate, the following information should be recorded on the boring log during the course of drilling and sampling activities:

- Project information including name, location, and project number;
- Each boring and well should be uniquely numbered and located on a sketch map as part of the log;
- Type of exploration;
- Weather conditions including events that could affect subsurface conditions;
- Dates and times for the start and completion of borings, with notations by depth for crew shifts and individual days;
- Depths/heights in feet and in decimal fractions of feet;
- Descriptions of the drilling equipment including rod size, bit type, pump type, rig manufacturer and model, and drilling personnel;
- Drilling sequence and descriptions of casing and method of installation;
- Description and identification of soils in accordance with ASTM Standard D 2488;
- Descriptions of each intact soil sample for the parameters identified in Section 3.2;
- Descriptions and classification of each non-intact sample (e.g., wash samples, cuttings, auger flight samples) to the extent practicable;
- Description and identification of rock;
- Description of rock (core(s)) for the parameters identified in Section 3.7;
- Scaled graphic sketch of the rock core (included or attached to log) according to the requirements identified in Section 3.7;
- Lithologic boundaries, with notations for estimated boundaries;
- Depth of water first encountered in drilling, with the method of first determination (any distinct water level(s) below the first zone will also be noted);
- Interval by depth for each sample taken, classified, and/or retained, with length of sample recovery and sample type and size (diameter and length);
- Blow counts, hammer weight, and length of fall for driven samplers;

- Rate of rock coring and associated rock quality designation (RQD) for intervals cored;
- Drilling fluid pressures, with driller's comments;
- Total depth of drilling and sampling;
- Drilling fluid losses and gains should be recorded;
- Significant color changes in the drilling fluid returned;
- Soil gas or vapor readings with the interval sampled, with information on instrument used and calibration;
- Depth and description of any in-situ test performed; and
- Description of other field tests conducted on soil and rock samples.

3.2 SOIL PARAMETERS FOR LOGGING

In general, the following soil parameters should be included on the boring log when appropriate:

- Identification per ASTM D 2488 with group symbol;
- Secondary components with estimated percentages per ASTM D 2488;
- Color;
- Plasticity per ASTM D 2488;
- Density of non-cohesive soil or consistency of cohesive soil;
- Moisture condition per ASTM D 2488 (dry, moist, or wet);
- Presence of organic material;
- Cementation and HCL reaction testing per ASTM D 2488;
- Coarse-grained particle description per ASTM D 2488 including angularity, shapes, and color;
- Structure per ASTM D 2488 and orientation;
- Odor; and
- Depositional environment and formation, if known.

ASTM D 2488 categorizes soils into 13 basic groups with distinct geologic and engineering properties based on visual-manual identification procedures. The following steps are required to classify a soil sample:

1. Observe basic properties and characteristics of the soil. These include grain size grading and distribution, and influence of moisture on fine-grained soil.
2. Assign the soil an ASTM D 2488 classification and denote it by the standard group name and symbol.
3. Provide a written description to differentiate between soils in the same group if necessary.

Many soils have characteristics that are not clearly associated with a specific soil group. These soils might be near the borderline between groups, based on particle distribution or plasticity characteristics. In such a case, assigning dual group names and symbols (e.g., GW/GC or ML/CL) might be an appropriate method of describing the soil. The two general types of soils, for which classification is performed, coarse- and fine-grained soils, are discussed in the following sections.

3.3 COURSE-GRAINED SOIL IDENTIFICATION

For soils in the coarse-grained soils group, more than half of the material in the soil matrix will be retained by a No. 200 sieve (75-µm).

1. Coarse-grained soils are identified on the basis of the following:
   a) Grain size and distribution;
   b) Quantity of fine-grained material (i.e., silt and clay as a percentage); and
   c) Character of fine-grained material.
2. The following symbols are used for classification:

Basic Symbols	Modifying Symbols
G = gravel	W = well graded
S = sand	P = poorly graded
	M = with silty fines
	C = with clayey fines

3. The following basic facts apply to coarse-grained soil classification.

- The basic symbol G is used if the estimated percentage of gravel is greater than that for sand. In contrast, the symbol S is used when the estimated percentage of sand is greater than the percentage of gravel.
- Gravel ranges in size from 3-inch to 1/4-inch (No. 4 sieve) diameter. Sand ranges in size from the No. 4 sieve to No. 200 sieve. The Grain Size Scale used by Engineers (ASTM Standards D 422-63 and D 643-78) is the appropriate method to further classify grain size as specified by ASTM D 2488.
- Modifying symbol W indicates good representation of all particle sizes.
- Modifying symbol P indicates that there is an excess or absence of particular sizes.
- The symbol W or P is used only when there are less than 15% fines in a sample.
- Modifying symbol M is used if fines have little or no plasticity (silty).
- Modifying symbol C is used if fines have low to high plasticity (clayey).

Figure 10.03a is a flowchart for identifying coarse-grained soils by ASTM D 2488.

3.4 FINED-GRAINED SOIL IDENTIFICATON

If one-half or more of the material will pass a No. 200 sieve (75 µm), the soil is identified as fine-grained.

1. Fine-grained soils are classified based on dry strength, dilatancy, toughness, and plasticity.
2. Classification of fine-grained soils uses the following symbols:

Basic Symbols	Modifying Symbols
M = silt (non plastic)	L = low liquid limit (lean)
C = clay (plastic)	H = high liquid limit (fat)
O = organic	
Pt = peat	

3. The following basic facts apply to fine-grained soil classification:
   - The basic symbol M is used if the soil is mostly silt, while the symbol C applies if it consists mostly of clay.
4. Use of symbol O (group name OL/OH) indicates that organic matter is present in an amount sufficient to influence soil properties. The symbol Pt indicates soil that consists mostly of organic material.

- Modifying symbols (L and H) are based on the following hand tests conducted on a soil sample:
  - — Dry strength (crushing resistance).
  - — Dilatancy (reaction to shaking).
  - — Toughness (consistency near plastic limit).
- Soil designated ML has little or no plasticity and can be recognized by slight dry strength, quick dilatency, and slight toughness.
- CL indicates soil with slight to medium plasticity, which can be recognized by medium to high dry strength, very slow dilatancy, and medium toughness.

Criteria for describing dry strength per ASTM D 2488 are as follows:

Description	Criteria
None	Dry sample crumbles into powder with pressure of handling
Low	Dry specimen crumbles into powder with some finger pressure
Medium	Dry specimen breaks into pieces or crumbles with considerable finger pressure
High	Dry specimen cannot be broken with finger pressure but will break into pieces between thumb and a hard surface
Very high	Dry specimen cannot be broken between the thumb and a hard surface stiffness

Criteria for describing dilatancy per ASTM D 2488 are as follows:

None	No visible change in the sample
Slow	Water appears slow on the surface of the sample during shaking and does not disappear or disappears slowly upon squeezing
Rapid	Water appears quickly on the surface of the sample during shaking and disappears quickly upon squeezing

Criteria for describing toughness per ASTM D 2488 are as follows:

Description	Criteria
Low	Only slight pressure is required to roll the thread near the plastic limit and the thread and lump are weak and soft
Medium	Medium pressure is required to roll the thread to near the plastic limit and the thread and lump have medium stiffness
High	Considerable pressure is required to roll the thread to near the plastic limit and the thread and lump have very high stiffness

Figure 10.03b is a flowchart for identifying fine-grained soils by ASTM D 2488.

3.5 DENSITY AND CONSISTENCY

Relative density for coarse-grained soils and consistency for fine-grained soils can be estimated using standard penetration test blow count data (ASTM D 1586). The number of blows required for each 6 inches of penetration or fraction thereof is recorded. If the sampler is driven less than 18 inches, the number of blows per each complete 6-inch interval and per partial interval is recorded.

For partial increments, the depth of penetration should be recorded to the nearest 1 inch. If the sampler advances below the bottom of the boring under the weight of rods (static) and/or hammer, then this information should be recorded on the log.

The following are some "rule-of-thumb" guidelines for describing the relative density of coarse-grained soils:

Blow Count	Relative Density for Sand
0–4	Very loose
4–10	Loose
10–30	Medium dense
30–50	Dense
>50	Very Dense

The following are some "rule-of-thumb" guidelines for describing the consistency of fine-grained soils:

Blow Count	Consistency for Clays	Description
0–2	Very Soft	Sample sags or slumps under its own weight
2–4	Soft	Sample can be pinched in two between the thumb and forefinger
4–8	Medium Stiff	Sample can be easily imprinted with fingers
8–16	Stiff	Sample can be imprinted only with considerable pressure of fingers
16–32	Very Stiff	Sample can be imprinted very slightly with fingers
>32	Hard	Sample cannot be imprinted with fingers; can be pierced with pencil

3.6 OTHER DESCRIPTIVE INFORMATION

The approximate percentage of gravel, sand, and fines (use a percentage estimation chart) should be recorded per ASTM D 2488 as follows:

Modifiers	Descriptions
Trace	Less than 5%
Few	5%–10%
Little	15%–25%
Some	30%–45%
Mostly	50%–100%

Color/discoloration should be recorded and described using a soil color chart, such as the Munsell® Soil Color Charts. A narrative and numerical description should be given from the color chart, such as Brown 10 YR, 5/3 (Munsell®). Odor should be described if organic or unusual.

Plasticity should be described as follows:

Description	Criteria
Non-plastic	A 1/8-inch thread cannot be rolled at any water content
Low	Thread can barely be rolled and lump cannot be formed when drier than plastic limit.
Medium	Thread is easy to roll; plastic limit can be reached with little effort and lump crumbles when drier than plastic limit.
High	Considerable time is required to reach the plastic limit and lump can be formed without crumbling when drier than plastic limit

Moisture condition should be recorded as dry (absence of moisture), moist (damp but no visible water) or wet (visible free water).

Cementation should be recorded (carbonates or silicates) along with the results of HCL reaction testing. The reaction with HCL should be described as none (no visible reaction), weak (some reaction with slowly forming bubbles) or strong (violent reaction with bubbles forming immediately).

Particle description information for coarse-grained soil should be recorded where appropriate per ASTM D 2488 including maximum particle size, angularity (angular, subangular, subrounded, or rounded), shape (flat, elongated or flat and elongated), and color.

Structure (along with orientation) should be reported using the following ASTM D 2488 descriptions:

Description	Criteria
Stratified	Alternating layers of varying material or color with layers greater than 6 millmeters thick
Laminated	Alternating layers of varying material or color with layers less than 6 millimeters thick
Fissured	Breaks along definite planes of fracture with little resistance
Slickensided	Fracture planes that appear polished or glossy, can be striated
Blocky	Inclusion of small pockets of different soils
Homogeneous	Same color and appearance throughout

3.7 ROCK CORE PARAMETERS FOR LOGGING

In general, the following parameters should be included on the boring log when rock coring is conducted:

- Rock type;
- Formation;
- Modifier denoting variety;
- Bedding/banding characteristics;
- Color;
- Hardness;
- Degree of cementation;
- Texture;
- Structure and orientation;
- Degree of weathering;
- Solution or void conditions;
- Primary and secondary permeability including estimates and rationale; and
- Lost core interval and reason for loss.

A scaled graphic sketch of the core should provided on or attached to the log, denoting by depth, location, orientation, and nature (natural, coring-induced, or for fitting into core box) of all core breaks. Where fractures are too numerous to be shown individually, their location may be drawn as a zone.

The RQD values for each core interval (run) should be calculated and included on the boring log. The method of calculating the RQD is as follows per ASTM D 6032:

RQD = [Σ length of intact core pieces > 100 mm (4-inches)] x 100%/total core length.

3.8 PROCEDURES FOR ROCK CLASSIFICATION

For rock classification record mineralogy, texture, and structural features (e.g., biotite and quartz fine grains, foliated parallel to relict bedding oriented 15 to 20 degrees to core axis, joints coated with iron oxide). Describe the physical characteristics of the rock that are important for engineering considerations such as fracturing (including minimum, maximum, and most common and degree of spacing), hardness, and weathering.

1. The following is to be used as a guide for assessing fracturing:

AEG Fracturing	Spacing
Crushed	up to 0.1 foot
Intense	0.1–0.5 foot
Moderate	0.5 foot–10 feet
Slight	1.0 foot–3.0 feet
Massive	>3.0 feet

2. Record hardness using the following guidelines:

Hardness	Criteria
Soft	Reserved for plastic material
Friable	Easily crumbled by finger pressure
Low	Deeply gouged or carved with pocketknife
Moderate	Readily scratched with knife; scratch leaves heavy trace of dust
Hard	Difficult to scratch with knife; scratch produces little powder and is often faintly visible
Very Hard	Cannot be scratched with knife

3. Describe weathering using the following guidelines:

Weathering	Decomposition	Discoloration	Fracture Condition
Deep	Moderate to complete alteration of minerals feldspars altered to clay, etc.	Deep and thorough	All fractures extensively coated with oxides, carbonates, or clay
Moderate	Slight alteration of minerals, cleavage surface lusterless and stained	Moderate or localized and intense	Thin coatings or stains
Weak	No megascopic alteration of minerals	Slight and intermittent and localized	Few strains on fracture surfaces
Fresh	Unaltered, cleavage, surface glistening		

3.9 PROCEDURE FOR LOGGING REFUSE

The following procedure applies to the logging of subsurface samples composed of various materials in addition to soil as may be collected from a landfill or other waste disposal site.

1. Observe refuse as it is brought up by the hollow stem auger, bucket auger, or backhoe.

2. If necessary, place the refuse in a plastic bag to examine the sample.

3. Record observations according to the following criteria:

   - Composition (by relative volume), e.g., paper, wood, plastic, cloth, cement, or construction debris. Use such terms as "mostly" or "at least half." Do not use percentages;
   - Moisture condition: dry, moist, or wet;
   - State of decomposition: highly decomposed, moderately decomposed, slightly decomposed, etc.;
   - Color: obvious mottling and/or degree of mottling;
   - Texture: spongy, plastic (cohesive), friable;

- Odor;
- Combustible gas readings (measure down hole and at surface); and
- Miscellaneous: dates of periodicals and newspapers, ability to read printed materials, degree of drilling effort (easy, difficult, and very difficult).

3.10 SUBMITTAL REQUIREMENTS

Each original boring log should be submitted to the Contracting Officer Representative (CRO) after completion of the boring. When a monitoring well will be installed in a boring, the boring log and well installation diagram should be submitted together.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Not applicable.

6.0 REFERENCES

ASTM Standard D 1586–84 (1992). 1992. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 2488-93. 1993. *Standard Practice for Description and Identification of Soils Visual-Manual Procedure).*

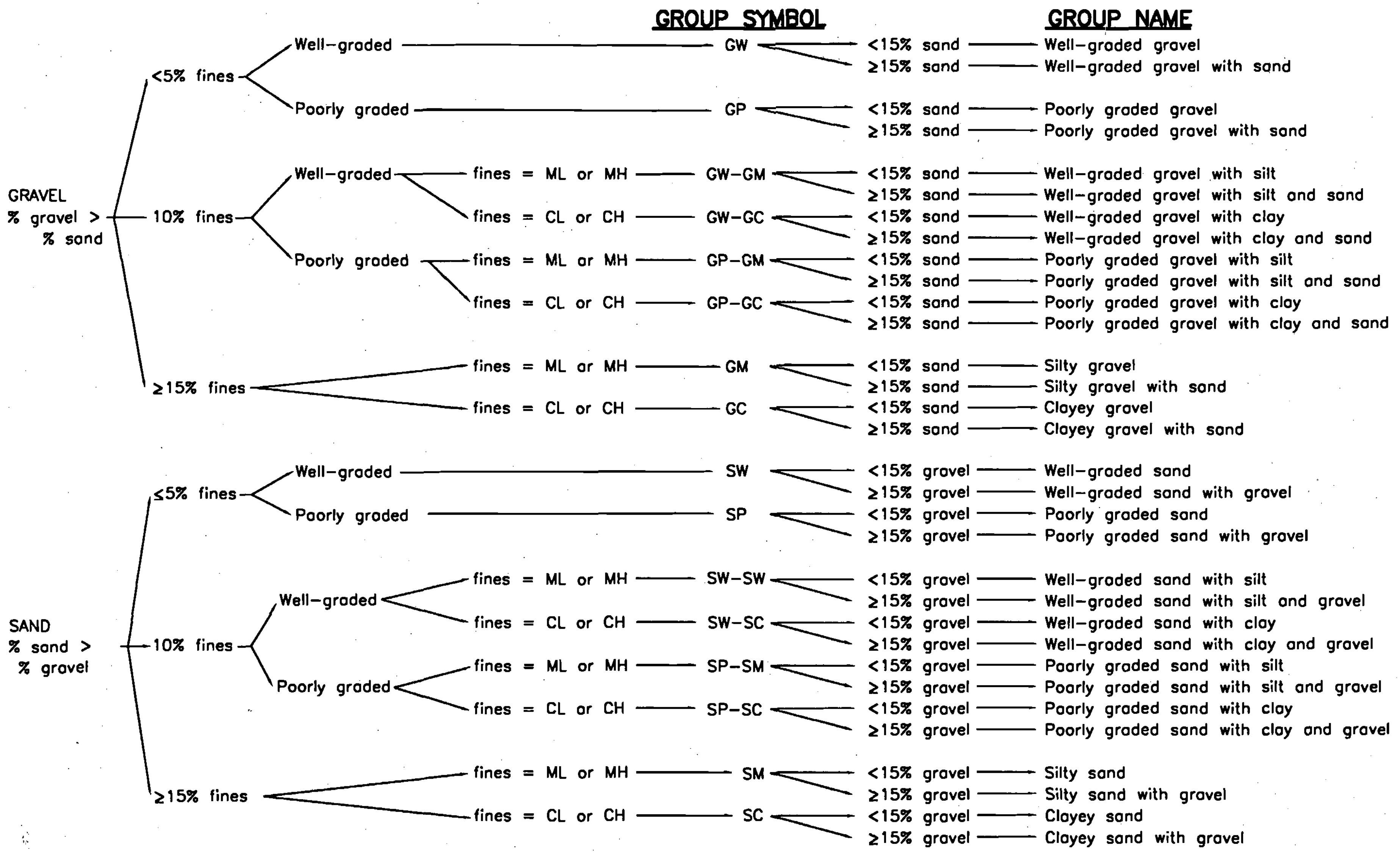
ASTM Standard D 5434-93. 1993. *Guide for Field Logging of Subsurface Explorations of Soil and Rock.*

ASTM Standard D 6032-96. 1996. *Standard Test Method for Determining Rock Quality Designation (RQD) of Rock Core.*

Compton, R. R. 1962. *Manual of Field Geology.* John Wiley & Sons, Inc., New York.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1, November.

U.S. Department of the Interior. 1989. *Earth Manual.* Water and Power Resources Service, Washington, DC.



NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

SOURCE: ASTM D 2488

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: 06/13/01

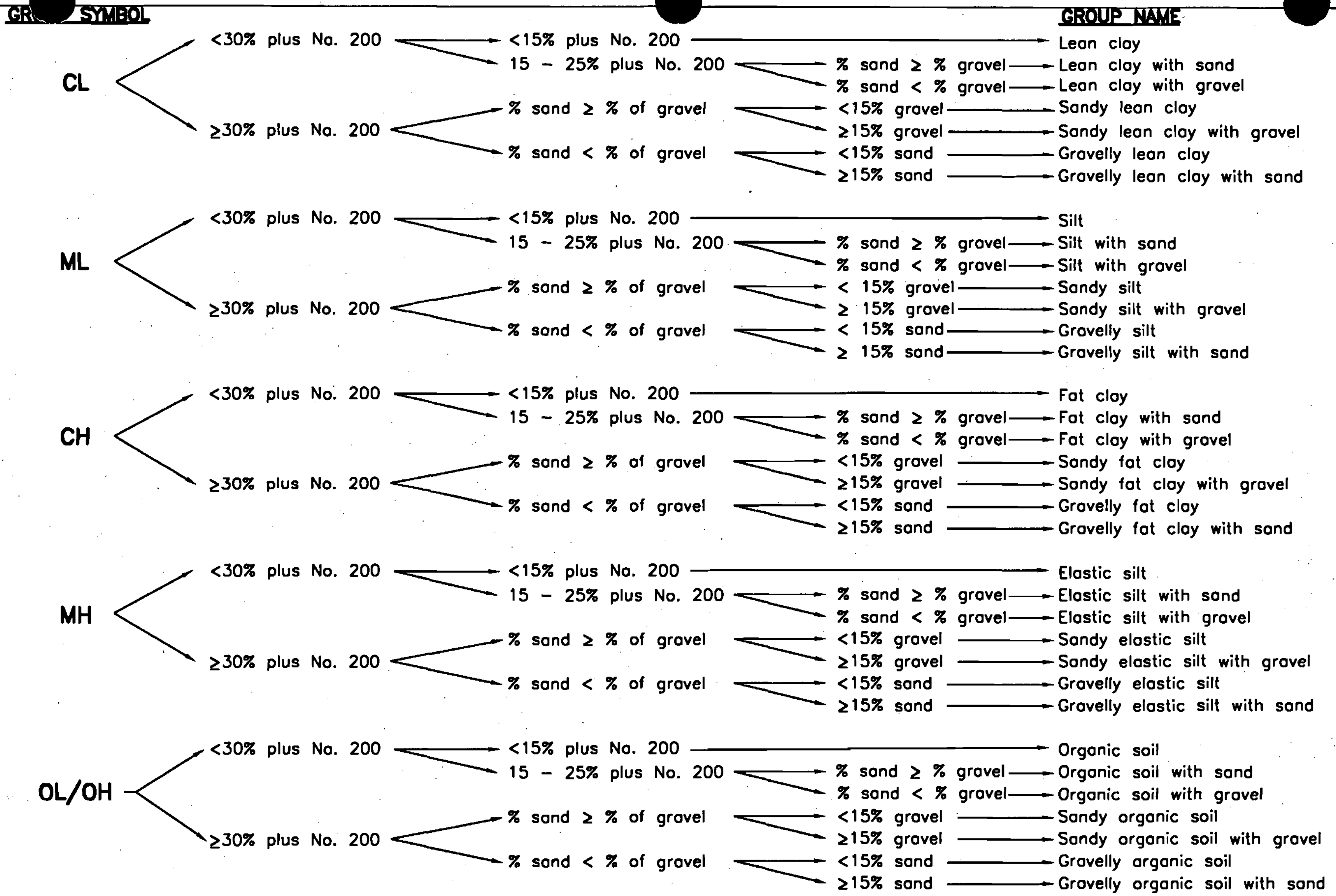
Prepared By: URS Corp./DRT

Scale: NO SCALE

File Name: P:\...\Figure XXXx.

FIGURE 10.03a

FLOW CHART FOR IDENTIFYING COARSE-GRAINED SOILS



NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

SOURCE: ASTM D 2488

RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: 06/13/01	**Prepared By:** URS Corp./DRT
Scale: NO SCALE	**File Name:** P:\...\Figure XXX.x..

FIGURE 10.03b

FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS

STANDARD OPERATING PROCEDURE 10.4
CHAIN-OF-CUSTODY FORM

1.0 SCOPE AND APPLICATION

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

2.0 MATERIALS

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

3.0 PROCEDURE

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

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

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

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

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

FIGURE 10.4-a
EXAMPLE CHAIN-OF-CUSTODY FORM

Project Number	Project Name				Matrix	A	N	A	L	Y	S	E	S		LAB :
Project Contact (Name and Phone Number)															AIRBILL No:
Samplers:															Courier:
Field Sample No.	Date (MM-DD-YY)	Time	Comp	Grab										Subtotal	REMARKS
TOTAL															

Relinquished by:	Date/time	Received by:	Relinquished by:	Date/Time	Received by:
Relinquished by:	Date/time	Received by: (for lab)	Date/Time	Remarks	

STANDARD OPERATING PROCEDURE 20.1
MONITORING WELL INSTALLATION

1.0 SCOPE AND APPLICATION

The installation of monitoring wells is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to delineate the quality control measures required to ensure the accurate installation of monitoring wells. For a particular site investigation, the associated work plan addenda should be consulted for specific installation instructions. The term "monitoring wells", as used herein is defined to denote any environmental sampling well.

2.0 MATERIALS

2.1 DRILLING EQUIPMENT

- Appropriately sized drill rig adequately equipped with augers, bits, drill stem, etc;
- Steam cleaner and approved source water for decontamination of drilling equipment, etc.;
- Source of approved water;
- Photoionization detector or other appropriate monitoring instrument per the site-specific Health and Safety plan;
- Water level indicator (electrical);
- Weighted steel tape measure;
- Steel drums and other appropriate containers for investigation-derived materials (drill cuttings, contaminated PPE, decontamination solutions, etc.);
- Absorbent pads and/or logs;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination supplies, pad with heavy plastic sheeting (SOP 80.1).

2.2 WELL INSTALLATION MATERIALS

Technical information on all installed materials (screens, riser pipe, filter pack, bentonite, cement, etc.) and representative samples of the proposed filter pack will be supplied to the Contracting Officer's Representative (COR) before initiating well installation.

Well screen slot size and filter pack gradation will be determined based on existing site geology before initiating site-specific investigations.

- Well screen :

  Polyvinyl Chloride (PVC): JOHNSON (or equivalent); PVC commercially slotted continuous slot, wire wrapped screen; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage or ASTM

Standard Specification F 480 and bear the appropriate rating logo. PVC should be free of ink markings, cleaned, and prepackaged by manufacturer;

Stainless Steel: JOHNSON (or equivalent); stainless steel Vee-Wire continuous slot, wire wrapped screen; 304 stainless steel (unless the sum concentration of Cl^-, F^-, and Br^- is <1000 ppm, case type 316 should be used); ASTM F 480 flush threads; cleaned, wrapped, and heat-sealed by manufacturer;

- Riser pipe:
  - PVC: JOHNSON (or equivalent); STD. PVC; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to NSF Standard 14 or F 480; free of ink markings; cleaned and prepackaged by manufacturer;
  - Stainless Steel: JOHNSON (or equivalent); SCH 5; 304 stainless steel; ASTM type A312 material; 4-in. diameter.; cleaned, wrapped and heat-sealed by manufacturer;
- Plugs/Caps: JOHNSON (or equivalent); standard PVC or stainless steel;
- Filter pack: MORIE, clean sorted gravel (or equivalent);
- Bentonite seal: BAROID, bentonite pellets (3/8-in. diameter.);
- Cement: Type II Portland Cement; if sulfate concentrations are higher than 1500 ppm, Type IV Portland Cement will be used;
- Bentonite powder: BAROID, Aquagel Gold Seal;
- Steel Protective Casing: BRAINARD-KILMAN (or equivalent) zinc-plated steel, lockable, painted;
- Containers for purged water, as required;
- Submersible pump or bailer of appropriate capacity, and surge block sized to fit well;
- Hach DREL 2000 portable laboratory (or equivalent);
- Multiprobe Electronic Water Quality Recorder (Hydrolab);
- Electric well sounder and measuring tape;
- Portland Type II cement (see footnote); and
- Steel Posts (pickets), painted (see footnote).

2.3 DOCUMENTATION

- Copy of work plans and health and safety plan;
- Copy of USACE EM 110-1-4000 Monitoring Well Requirements.;
- Copies of permits (area entry, hot work, well, and utility clearance);
- Boring log forms;
- Well completion diagram form; and
- Field logbook.

2.4 GEOLOGIST'S PERSONAL EQUIPMENT

- Boring log materials per SOP 10.3; and
- Personal protective equipment and clothing (PPE) as required by the site-specific health and safety plan.

3.0 PROCEDURE

3.1 MATERIALS APPROVAL

3.1.1 Source Water

Water sources for drilling, grouting, sealing, filter pack placement, well installation, and equipment decontamination must be approved by the COR before arrival of the drilling equipment. Information required for the water source includes:

- Water source;
- Manufacturer/owner and their address and telephone number;
- Type of treatment and filtration prior to tap;
- Time of access;
- Cost per gallon (if applicable); and
- Dates and results associated with all available chemical analyses over the past 2 years, and the name and address of the analytical laboratory (if applicable).

3.1.2 Bentonite

Pure sodium bentonite with no additives (bentonite) will be the only drilling fluid additive allowed, and its use must be approved by the COR before the arrival of the drilling equipment. The information required for evaluation includes brand name, manufacturer, manufacturer's address and telephone number, product description, and intended use for the product, and potential effects on chemical analysis of water samples.

3.1.3 Granular Filter Pack

Granular filter pack material must be approved by the COR before drilling. A one-pint representative sample must be supplied to the COR. Information required includes lithology, grain size distribution, brand name, source, processing method, and size of intended screen.

3.1.4 Cement

Portland Type II cement will be used for grout (or Type IV, as noted in Section 2.2).

3.2 DRILLING

The objective of the selected drilling technique used at given site is to ensure that the drilling method provides representative data while minimizing subsurface contamination, cross contamination, and drilling costs.

Drilling methods that are appropriate for boring or monitoring well installation will depend on the subsurface geology most likely to be encountered in the boring. The geology for each site should be determined by reviewing previous investigation data (boring data, geophysics, etc.) from the site or nearby areas. Specific drilling methods that will be used to support site activities will be incorporated into work plan addenda.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of monitoring wells at the Radford Army Ammunition Plant (RFAAP) based on the different types of conditions encountered. The different drilling methods discussed in this section of the Master Work Plan including:

- Hollow Stem Auger (for soil);
- Air Rotary (soil and rock);
- Water Rotary and wire-line casing advancement (soil and rock);
- Drill-Through-Casing Driver (soil and rock); and
- Sonic (soil and rock).

3.2.1 Responsibilities of the Site Geologist

A Site Geologist will be present during all well drilling and installation activities and will fully characterize all tasks performed in support of these activities in the monitoring well logbook. The Site Geologist will be responsible for the logging samples, monitoring drilling operations, recording water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures for one operating rig. The Site Geologist will have sufficient equipment in operable condition on-site to perform efficiently his/her duties.

3.2.2 Additives

No lubricants will be used on down hole drilling equipment. Additives containing either lead or copper will not be allowed. In addition, polychlorinated biphenyls will not be permitted in hydraulic fluids or other fluids used in the drilling rig, pumps, or other field equipment and vehicles.

Surface runoff or other fluids will not be allowed to enter any boring or well during or after drilling/construction.

Antifreeze used to keep equipment from freezing will not contain rust inhibitors and sealants. Antifreeze is prohibited in any areas in contact with drilling fluid. Absorbent pillows will be placed to catch any obvious leaks from the drill rig.

3.2.3 Boring Logs and Field Notes

Borings for monitoring wells will be logged by a geologist as described in SOP 10.3. Logs will be recorded on USACE HTRW ENG Form 5056-R and 5056A-R boring log forms.

Daily investigation activities at the site related to drilling should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

3.3 WELL CONSTRUCTION AND INSTALLATION

Specifications for monitoring well construction and installation for a given site being investigated are to be included in work plan addenda. In case the previously defined criteria have not been met before the depth range for a given hole is reached, the geologist will stop the drilling and confer with the supervisor. The current boring conditions (depth, nature of the stratigraphic unit, and water-table depth) will be compared to those of other wells nearby to decide whether to continue drilling or to terminate and complete the well.

3.3.1 Overburden Wells

Overburden wells at the RFAAP are typically designed as a 4-inch diameter, single cased well (see Figure 20-1a) installed into a surficial aquifer, which is present above bedrock. For this type of well, the well boring would be terminated before penetrating any underlying confining unit and/or bedrock.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of overburden wells.

If dense, non-aqueous liquid (DNAPL) is encountered during drilling, the well boring will be terminated and completed at the base of the overburden aquifer being monitored.

3.3.2 Bedrock Wells

Multi-cased wells or wells with an outer casing installed into competent bedrock should be specified for wells that are designed to monitor groundwater within bedrock (see Figure 20-1c). The installation of a multi-cased well or outer casing will isolate the zone(s) monitored from overburden and will minimize the potential for cross-contamination during and after drilling.

The general procedure to be followed for installation of a multi-cased well is as follows. This procedure assumes the installation of a 4-inch diameter monitoring well. Specific procedures, drilling techniques and design of monitoring wells will be presented in work plan addenda for site-specific investigations.

1. If soil sampling is required within overburden, use appropriate drilling techniques to advance the boring and collect the soil samples.

2. A minimum 10-inch drill bit should be advanced from the surface into competent bedrock a distance not less than 2 feet. A drilling technique appropriate for penetrating overburden and bedrock should be used such as air rotary.

3. After the borehole has been advanced to the target depth within competent bedrock, a 6-inch diameter steel or Schedule 80 PVC outer casing should be lowered to the bottom of the boring.

4. Once the outer casing has been lowered to the bottom of the boring, the casing should be grouted in-place using a decontaminated tremie pipe equipped with a side discharge. The annulus between the outer casing and borehole wall will be injected with grout until undiluted grout reaches the surface.

5. The grouting mixture, specification, and placement should be consistent with the requirements identified in Section 3.3.8.

6. The grout should be allowed to cure a minimum of 24 hours before further drilling.

7. After adequate curing time for outer casing, drilling with a 5-5/8-inch bit until the desired total depth is reached should complete the well boring.

8. Once the well boring is completed, an appropriate bedrock well will be constructed based on site-specific conditions. The types of wells that may be installed may include a constructed well with screen,

casing, filter pack, seal, and grout; an open-bedrock well; or a lined open bedrock well (see Section 3.3.3).

3.3.3 Well Screen Usage

Well screen usage for a given site should be specified in work plan addenda based on expected site conditions.

In general, wells installed within overburden will be installed with a screen as per Figure 20.01-a or 20.01-b. Bedrock wells may be installed with or without a screen depending on site specific conditions such as the depth of water bearing zones, stability of bedrock, occurrence of karst zones, and construction of existing wells at the site being investigated.

In general, bedrock wells installed within karst zones will be completed as open-hole construction (see Figure 20.01c). If evidence of potential or severe borehole collapse (unstable bedrock) is indicated during drilling, casing and screen will be installed in the borehole as a removable lining. If desired, multiple flow zones may be monitored in an open bedrock well by installing a multiport well, which has monitoring/sampling intervals sealed off from the rest of the boring and from each other by packers.

3.3.4 Beginning Well Installation

Schedule

Monitoring well installation should begin within 12 hours of boring completion for holes that are uncased or partially cased with temporary drill casing. In the case where a partially cased hole into bedrock is to be partially developed prior to well insertion, the well installation should begin within 12 hours of this initial development. For holes that are fully cased, installation should begin within 48 hours. Once begun, well installation should not be interrupted.

Placement of Materials

Temporary casing and hollow stem augers may be removed from the boring prior to well installation if the potential for cross contamination is low and if the borehole will remain stable during the time required for installation.

Where borehole conditions are unstable, some or all of the well materials may need to be installed prior to removal of the temporary casing or hollow stem augers. The casing or hollow stem augers should have an inside diameter sufficient to allow the installation of the screen and casing plus annular space for a pipe through which to place filter pack and grout.

Any materials blocking the bottom of the drill casing or hollow stem auger should be dislodged and removed from the casing prior to well insertion.

3.3.5 Screens, Casing, and Fittings

Borehole Specifications

The borehole for each well should be of sufficient diameter to provide for at least 2 inches of annular space between the borehole wall and all sides of the casing.

Well Screens

Material specifications for well screens, casings, and fittings are discussed in Section 2.2.

Screen bottoms should be securely fitted with a threaded cap or plug of the same composition as the screen. The cap/plug should be within 0.5 feet of the open portion of the screen. A sediment trap/sump will not be used.

Screen slot size will be appropriately sized to retain 90%-100% of the filter pack material, the size of which will be determined by sieve analysis of formation material.

Well screen lengths should be specified in work plan addenda and will be based on various site-specific factors such as environmental setting, subsurface conditions, analytes of concern, regulatory considerations, etc.

Assembly and Placement of Well Screen and Casing

Personnel should take precautions to assure that grease, oil, or other contaminants do not contactany portion of the well screen and casing assembly. Clean latex or nitrile gloves should be worn when handling the screen and casing assembly. Flush, threaded joints usually can be tightened by hand. If necessary, steam cleaned wrenches may be used to tighten joints.

In general, each section of the well assembly is lowered into the borehole, one section at a time, screwing each section securely into the section below it. No grease, lubricant, polytetrafluoroethylene (PTFE) tape, or glue may be used in joining the sections of screen and casing.

The assembly should be lowered to its predetermined level and held in position for placement of the filter pack. It is essential that the assembly be installed straight (with centralizers as appropriate) to allow for appropriate sampling. Buoyant forces associated with fluids in the borehole may require that the assembly be installed with the aid of hydraulic rams of the drill rig. When the well assembly is placed to predetermined level, a temporary cap should be place on the well to prevent foreign material from entering the well.

The bottoms of well screens should be placed no more than 3 feet above the bottom of the drilled borehole. If significant overdrilling is required, a pilot boring should be used. Sufficient filter pack should be placed at the bottom of the borehole

The well casing should be pre-cut (square) to extend 2 to 2.5 feet above the ground surface. Before placement of the last piece of well casing, a notch or other permanent reference point will be cut, filed, or scribed into the top edge of the casing.

The tops of all well casing will be capped with covers composed of materials compatible with the products used in the well installation. Caps will be loose fitting, constructed to preclude binding to the well casing caused by tightness of fit, unclean surfaces, or weather conditions. In either case, it should be secure enough to preclude the introduction of foreign material into the well, yet allow pressure equalization between the well and the atmosphere.

The top of each well casing should be level so that the maximum difference in elevation between the highest and lowest points of the casing is less than or equal to 0.02 ft.

3.3.6 Filter Pack

The volume of filter pack that is required to fill the annular between the well screen/casing and borehole should be computed, measured, and recorded.

Granular filter packs will be chemically and texturally clean, inert, and siliceous. The gradation of filter packs will be selected based on the screen size used and will be specified in the work plan addenda for the site being investigated.

Primary Filter Pack

Filter pack material should be placed in the borehole using a decontaminated tremie pipe. An appropriate amount of primary filter pack should be placed in the borehole prior to final positioning of the well screen to provide an appropriate barrier between the bottom of the borehole and the bottom of the screen. Once the initial filter pack has been placed and the well assembly is appropriately positioned and centered in the borehole, the remaining primary filter pack should be placed in increments (and tamped) as the tremie pipe is gradually raised.

As the primary filter pack is placed, approved source water may need to be added to help move the filter pack. A weighted tape should be used to measure the top of the filter pack as it is being placed. If bridging of the filter pack occurs, then this bridging should be broken mechanically prior to adding additional filter pack.

When temporary casing or hollow stem augers are used, the casing or augers should be removed in increments such that lifting of the well assembly is minimal. After removal of each increment, it should be confirmed by direct measurement that the primary filter pack has not been displaced during the removal.
The primary filter pack should extend from the bottom of the borehole to 3 to 5 ft above the top of the screen.

Secondary Filter Pack

The primary filter pack may be capped with 1 to 2 feet of feet of secondary filter pack to prevent the intrusion of the bentonite seal into the primary filter pack The need for this filter pack (and specifications) should be addressed in work plan addenda for the site being investigated. Such factors as the gradation of the primary filter pack, the potential for grout extrusion, and site hydrogeology should be considered when evaluating the need for this filter pack.

3.3.7 Bentonite Seal

A bentonite seal, consisting of hydrated 3/8-inch diameter. bentonite pellets, will be installed immediately above the filter pack. The seal may be installed with a tremie pipe, which is lowered to the top of the filter pack and slowly raised as the pellets fill the annular space. In deep wells, the pellets may bridge and block the tremie pipe; in this case, pellets may be placed by free fall into the borehole. A weighted tape should be used to measure the top of seal as it is installed.

When cement grout is to be used above the bentonite seal, a minimum of 3 to 4 hours should be allowed for hydration of the pellets.

When installing a seal above the water table, water should be added to the bentonite for proper hydration In this case, the seal should be placed in lifts of 0.5 to 1 foot with each lift hydrated for a period of 30 minutes.
If the bentonite seal is to be installed far below the water table, a bentonite slurry seal will be installed. Cement-bentonite grout will not be used below the water table. The slurry will be mechanically blended aboveground to ensure a lump-free mixture. The slurry will consist of bentonite powder and approved water

mixed to a minimum 20 percent solids by weight of pumpable slurry with a density of 9.4 pounds per gallon or greater. The slurry will be pumped into place through a tremie pipe and measured as installed. Bentonite seals should be 3 to 5 ft thick as measured immediately after placement. The final depth to the top of the bentonite seal will be measured and recorded before grouting.

3.3.8 Grout

Cement grout used in construction will be composed of the following:

- Type II Portland Cement (or Type IV as noted in Section 2.2);
- Bentonite (2 to 5% dry bentonite per 94-lb sack of dry cement); and
- A maximum of 6 to 7-gallons of approved water per 94-lb sack of cement

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump before placement. Grout placement should be performed as follows:

1. Grout should be placed from a rigid tremie pipe located just over the top of the bentonite seal. The tremie pipe should be decontaminated prior to use.
2. The tremie pipe should be kept full of grout from start to finish with the discharge end of the pipe completely submerged as it is slowly and continuously lifted.
3. The annulus between the drill casing and well casing should be filled with sufficient grout to allow for the planned drill casing removal. Grout should not penetrate the well screen or filter pack.

- For incremental removal of drill casing, grout should be pumped to maintain at least 10 ft of grout in the drill casing remaining in the borehole after removing the selected length of casing. After each section of casing is removed, the tremie pipe may be reinserted to the base of the casing not yet removed.
- In the case where drill casing will be removed all at once, grout should be pumped from the tremie pipe until undiluted grout flows from the annulus at the ground surface.

4. If the un-grouted portion of a borehole is less than 15 feet and without fluids after drill casing removal, then the un-grouted portion may be filled by pouring grout from the surface.
5. If drill casing was not used for well installation, grouting should proceed to the surface in one continuous operation.
6. For grout placement in a dry and open hole less than 15 ft deep, grout may be manually mixed and poured in from the surface providing that integrity of the bentonite seal is maintained.
7. Protective casing should be installed immediately after completion of grouting.
8. Grout settlement should be checked within 24 hours of the initial grout placement. Additional grout should be added grout should be added to fill any observed depressions.

The following will be noted in the boring logs: (1) exact amounts of cement, bentonite, and water used in mixing grout and (2) actual volume of grout placed in the hole.

3.3.9 Well Protection

The major elements of well protection will include:

- A protective casing;
- Protective concrete pad around the well; and
- Protective steel posts set around the well outside of the concrete pad.

Well Protective Casing

Well protective casings will be installed around all monitoring wells immediately after grouting. The protective casing should consist of a minimum 5-ft long, steel pipe (protective casing) installed over the well casing and into the grout. The protective casing should be installed to a depth of approximately 2.5-feet below ground surface (extending approximately 2.5 feet above ground surface). The internal well casing (riser) and protective casing will not be separated by more than 0.2 feet of height.

An internal mortar collar will be placed within the protective steel casing and outside the well casing to a height of 0.5 above ground surface.

After placement and curing of the mortar collar, an internal drainage hole will be drilled through the protective casing, which is centered no more 1/8 inch above the grout filled annulus between the well riser and the protective casing.

Any annulus formed between the outside of the protective casing and the borehole will be filled to ground surface with cement.

Concrete Pad

After the grout has thoroughly set and the well protective casing has been installed, a protective concrete pad will be installed around the well. This pad will be at least 4 inches thick and 4 feet square and sloped away from the well to provide for adequate drainage.

Protective Posts

Additional protection will be provided at each well location by the installation of four steel posts outside of each corner of the concrete pad. The installation of protective posts should occur before the well is sampled. The posts should have a minimum diameter of 3 inches, be placed 2 to 3 feet below ground surface, and extend at least 3 feet above ground surface. Posts should be painted orange using a brush.

Posts should be set in post holes, which are backfilled with concrete. For additional protection, the posts can be filled with concrete.

3.3.10 Well Construction Diagram and Field Notes

The construction of each well will be depicted as built in a well construction diagram (see Figure 20.1a). The diagram will be attached to the boring log and the following will be graphically denoted:

- Bottom of boring;
- Screen location, length, and size;
- Coupling locations;

- Granular filter pack;
- Seal;
- Grout;
- Cave-in;
- Centralizers;
- Height of riser;
- Protective casing detail;
- Water level 24 hours after completion with date and time of measurement;
- Quantity and composition of materials used; and
- Material between bottom of boring and bottom of screen.

Daily activities at the site related to monitoring well installationshould be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.4 GENERAL SEQUENCE OF MONITORING WELL COMPLETION

The following is a general sequence of monitoring well completion with reference to the specific details included in Section 3.3.

1. Completion of borehole;
2. Assembly and placement of well assembly as described in Section 3.3.5;
3. Placement of the appropriate filter pack(s) as discussed in Section 3.3.6;
4. Installation of an appropriate bentonite seal as discussed in Section 3.3.7;
5. Grouting the remaining annular space of the borehole as discussed in Section 3.3.8;
6. Set the protective casing for the well as discussed in Section 3.3.9;
7. Complete the protective concrete pad as discussed in Section 3.3.9; and
8. Install the protective posts as discussed in Section 3.3.9.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

ASTM Standard D 5092-90. 1990. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

ASTM Standard D 5717-95. 1995. *Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured Rock Aquifers.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1, November.

EXAMPLE WELL DEVELOPMENT FORM

WELL DESIGNATION:________________ DATE(S) OF INSTALLATION:____/____/____

SITE GEOLOGIST:____________________ DEVELOPMENT DATE(S):____/____/____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT * :

BEFORE ____________ DATE ___________ 24 HR. AFTER ___________ DATE___________

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT * :

BEFORE ____________ DATE ___________ 24 HR. AFTER ___________ DATE___________

DEPTH TO WELL BOTTOM *: ________________ SCREEN LENGTH ______________

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: ___________________

QUANTITY OF MUD/WATER:

LOST DURING DRILLING	(+)____________________gallons
REMOVED PRIOR TO WELL INSERTION	(-)____________________gallons
LOST DURING THICK FLUID DISPLACEMENT	(+)____________________gallons
ADDED DURING FILTER PACK PLACEMENT	(+)____________________gallons
TOTAL LOSSES	____________________gallons

(a) Water column ht. (ft.) _____________ (b) Well radius (in.)____________

(c) Screen length (ft.) _____________ (d) Borehole radius (in.)____________

(e) QUANTITY OF FLUID STANDING IN WELL
Install Equation Editor and double-click here to view equation. 1 _________ gallons
(Show Calculation)

(f) QUANTITY OF FLUID IN ANNULUS Install Equation Editor and double-click here to view equation. 1_________gallons
(Show Calculation)

DEVELOPMENT VOLUME = (5 * TOTAL LOSSES) + [5 * (e + f)] = _____________ gallons
(Show Calculation)

*** ALL DEPTHS MEASURED FROM TOP OF WELL CASING**

EXAMPLE WELL DEVELOPMENT RECORD

WELL DESIGNATION ______________ DATE(S) OF DEVELOPMENT: ____/____/____

TYPE AND SIZE OF PUMP: ____

TYPE AND SIZE OF BAILER: ____

DESCRIPTION OF SURGE TECHNIQUE: ____

____

____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/ odor/partic.)
(before)									
(during)									
(during)									
(during									
(after)									

TYPICAL PUMPING RATE________ GAL./HR. EST. RECHARGE RATE______________________

TOTAL QUANTITY OF WATER REMOVED_________ TIME REQUIRED_______________

REMARKS____

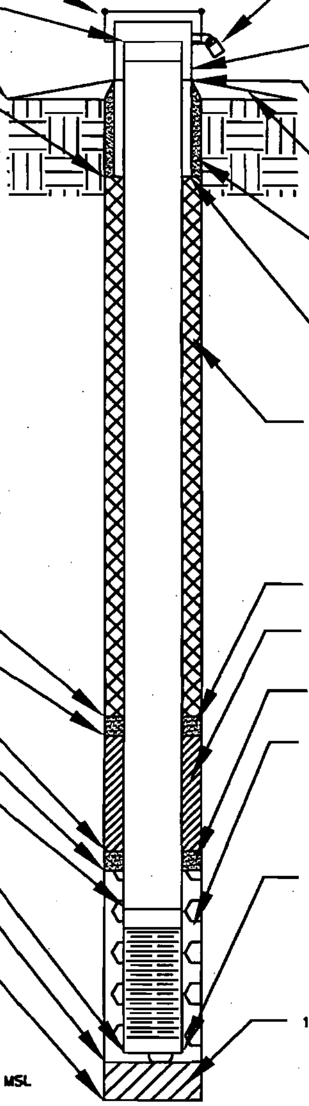
____

____

SIGNATURE OF SITE GEOLOGIST______________________________

Facility/Project Name	Local Grid Location of Well _____ m. ☐N. ☐S. _____ m. ☐E. ☐W.	Well Number
Facility License, Permit or Monitoring Number	Grid Origin Location Lat. ___ ___ ___ Long ___ ___ ___ or St. Plane _______ m. N. _______ m. E.	Date Well Installed (Start)
Type of Protective Cover: Above-Ground ☐ Flush-To-Ground ☐	Section Location of Waste/Source	Date Well Installed (Completed)
Well Distance From Waste/Source Boundary	___1/4 of ___1/4 of Sec. ____T. ____N.R. ____ ☐E. ☐W.	Well Installed By: (Person's Name & Firm) _______________ _______________
Maximum Depth of Frost Penetration (estimated)	Location of Well Relative to Waste/Source u ☐ Upgradient s ☐ Sidegradient d ☐ Downgradient n ☐ Not Known	

Note: Use top of casing (TOC) for all depth measurments.



A. Protective casing, top elevation __________ m. MSL

B. Well casing, Top elevation __________ m. MSL

C. Land surface elevation __________ m. MSL

D. Surface seal, bottom ________ m. TOC or ________ m. MSL

16. USCS classification of soil near screen:
GP ☐ GM ☐ GC ☐ GW ☐ SW ☐ SP ☐
SM ☐ SC ☐ ML ☐ MH ☐ CL ☐ CH ☐
Bedrock ☐

17. Sieve analysis attached? ☐ Yes ☐ No

18. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
______________________ Other ☐

19. Drilling fluid used Water ☐ Air ☐
Drilling mud ☐ None ☐

20. Drilling additives used? ☐ Yes ☐ No
Describe ______________________

21. Source of water (attach analysis):
____

E. Secondary filter, top _______ m. TOC or _______ m. MSL

F. Bentonite seal, top _______ m. TOC or _______ m. MSL

G. Secondary filter, top _______ m. TOC or _______ m. MSL

H. Primary filter, top _______ m. TOC or _______ m. MSL

I. Screen joint _______ m. TOC or _______ m. MSL

J. Well bottom _______ m. TOC or _______ m. MSL

K. Filter pack, botton _____ n. TOC ___ n. MSL

L. Borehole, bottom _____ m. TOC or _____ m. MSL

M. Borehole, diameter __________ mm.

N. O.D. well casing __________ mm.

O. I.D. well casing __________ mm.

P. 24-hr water level after completion ________ m. TOC or ________ m. MSL

1. Cap and Lock? ☐ Yes ☐ No

2. Protective posts? ☐ Yes ☐ No

3. Protective casing:
a. Inside diameter: __________ mm.
b. Length: __________ m.

4. Drainage port(s) ☐ Yes ☐ No

5. Surface seal: Gravel blanket ☐
a. Cap Bentonite ☐
Concrete ☐
______________________ Other ☐

b. Annular space seal: Bentonite ☐
Cement ☐
______________________ Other ☐

6. Material between well casing and protective casing: Bentonite ☐
Cement ☐
______________________ Other ☐

7. Annular space seal: A. Granular Bentonite ☐
b. ______ Lbs/gal mud weight........Bentonite-sand slurry ☐
c. ______ Lbs/gal mud weight..................Bentonite slurry ☐
d. ______ x Bentonite..................Bentonite-cement grout ☐
e. __________ m^3 volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☐
Gravity ☐

8. Centralizers ☐ Yes ☐ No

9. Secondary Filter ☐ Yes ☐ No
a. Volume added ________ m^3 ______________ Bags/Size

10. Bentonite seal: a. Bentonite granules ☐
b. 1/4in. 3/6in. 1/2in. Bentonite pellets ☐
c. ______________________ Other ☐

11 Secondary Filter ☐ Yes ☐ No
a. Volume added ________ m^3 ______________ Bags/Size

12. Filter pack material: Manufacturer, product name & mesh size
a.
b. Volume added __________ m^3 ______________ Bags/Size

13. Well casing: Flush threated PVC schedule 40 ☐
Flush threated PVC schedule 80 ☐
______________________ Other ☐

14. Screen material:
a. Screen type: Factory cut ☐
Continous slot ☐
______________________ Other ☐
b. Manufacturer
c. Slot size: 0. __________ In.
d. Slotted length: __________ In.

15. Backfill material (below filter pack): None ☐
______________________ Other ☐

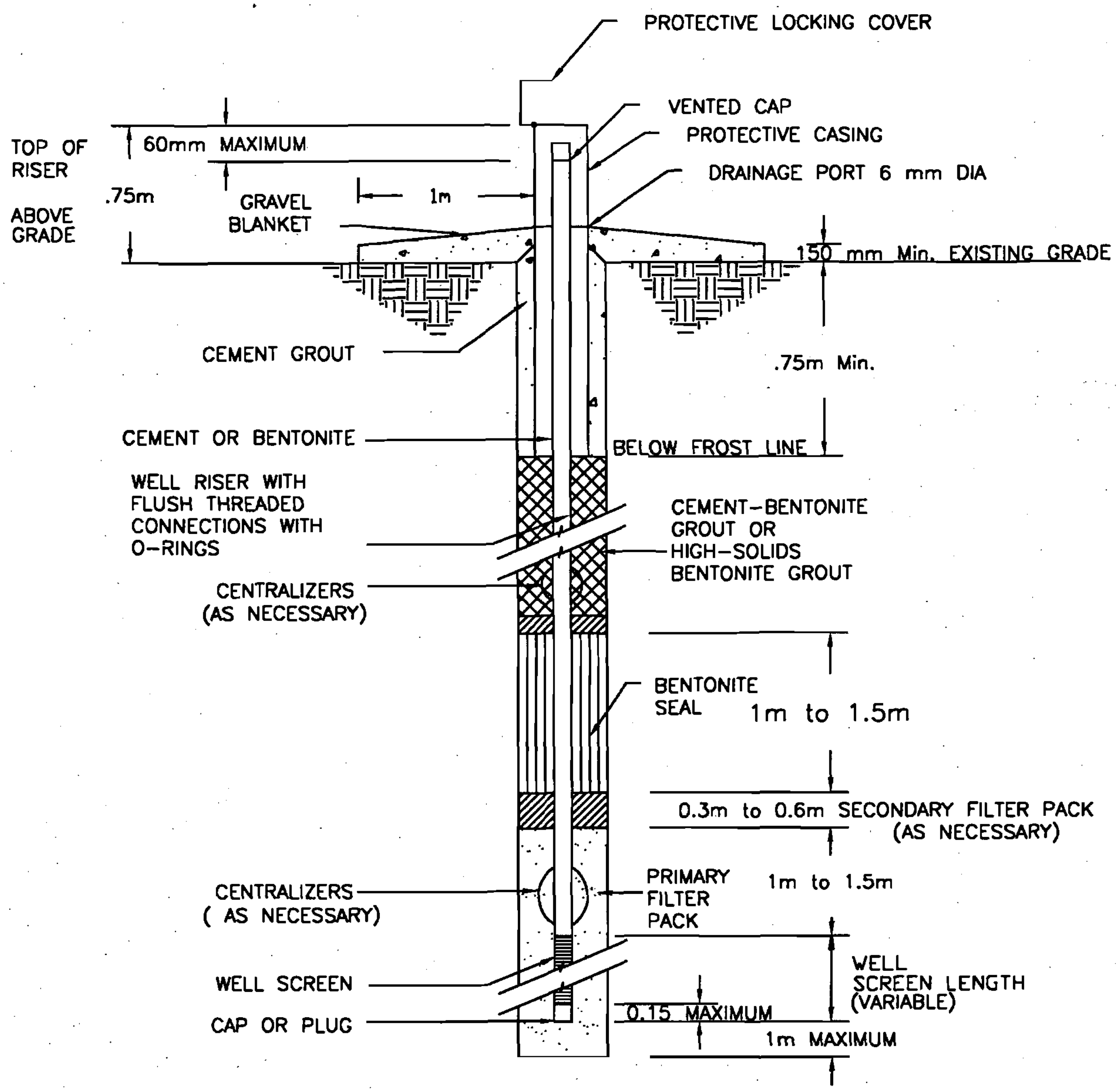
RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: *06/27/01*	**Prepared By:** *URS Corp./TAC*
Scale: *NO SCALE*	**File Name:** *P:\...\Figure XXX.x.*

FIGURE 20-1a

SCHEMATIC CONSTRUCTION DIAGRAM OF MONITORING WELL



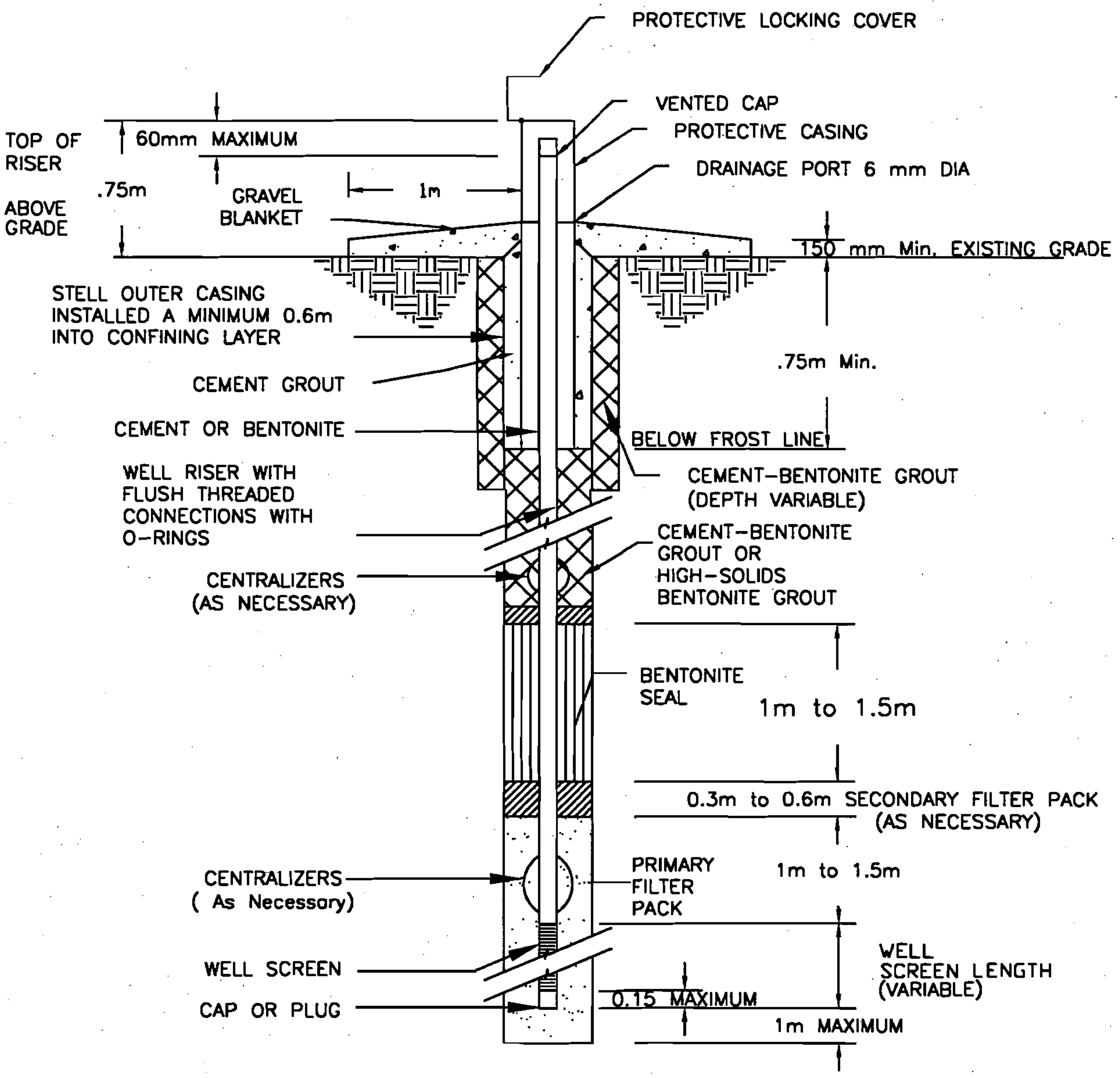
RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

FIGURE 20-1b

SCHEMATIC CONSTRUCTION OF SINGLE-CASED WELL WITH GRAVEL BLANKET

Date: *06/29/01*	**Prepared By:** *URS Corp./TAC*
Scale: *NO SCALE*	**File Name:** *P:\...\Figure 20-1b*



RFAAP

RFI WORK PLAN ADDENDUM: SWMU 54

Date: 06/29/01

Prepared By: URS Corp./TAC

Scale: NO SCALE

File Name: P:\...\Figure XXX.x..

FIGURE 20-1c

SCHEMATIC CONSTRUCTION OF MULTI-CASED WELL WITH CONCRETE PAD

STANDARD OPERATING PROCEDURE 20.2
MONITORING WELL DEVELOPMENT

1.0 SCOPE AND APPLICATION

Well development is the process by which drilling fluids, solids, and other mobile particulates within the vicinity of the newly installed monitoring well are removed, while ensuring proper hydraulic connection to the aquifer. Development stabilizes the formation and filter pack sands around the well screen to ensure aquifer water moves freely to the well.

Well development will be initiated not less than 48 consecutive hours but no longer than 7 calendar days following grouting and/or placement of surface protection.

2.0 MATERIALS

- Work Plans;
- Well Development Form;
- Field Logbook;
- Boring Log and Well Completion Diagram for the well;
- Submersible pump, control box, associated equipment, etc;
- Photoionization detector or other appropriate monitoring instrument as specified in site-specific health and safety plan;
- Personal protective equipment and clothing (PPE) as specified in site-specific health and safety plan;
- Flow-through-cell and probes measuring specific conductance, pH, temperature, oxidation/reduction potential, dissolved oxygen, and turbidity;
- Decontamination supplies (SOP 80.1);
- Electric well level indicator and measuring tape;
- Appropriate containers for purged water and other investigation-derived material, as required; and
- Drilling tools for reverse-air circulation development, as appropriate.

3.0 PROCEDURE

3.1 SELECTING METHOD OF DEVELOPMENT

The type of subsurface conditions encountered should determine the method of well development used at a particular site at the Radford Army Ammunition Plant (RFAAP).

When monitoring wells are installed within overburden material, fractured bedrock or karst aquifers producing little sediment, a combination of mechanical surging and pumping (over pumping) or bailing is generally appropriate for well development. In general, over-pumping is the method of pumping the well at a rate higher than recharge occurs. Moving a tight-fitting surge block along the inside of the well screen to create a vacuum completes surging.

When monitoring wells are installed with solution features containing excessive amounts of sediment, reverse-circulation airlifting should be used as the initial step of development. Because reverse-circulation tools airlift methods avoid forcibly exposing the annular space to air, reverse-circulation tools can be run throughout the entire water column in the wells being developed.

After the excessive sediment has been removed by reverse-circulation airlifting, conventional pumping techniques may be used as appropriate to complete the well development.

3.2 DEVELOPMENT AND SAMPLING TIMING

Final development of monitoring wells should not be initiated any sooner than 48 hours after or more than 7 days beyond the final grouting of the well. Pre-development or preliminary development may be initiated before this 48-hour minimum period. Preliminary development may be conducted for open wells or for screened wells after installation of the well screen, casing, and filter pack but before installation of the annular seal. Pre-development is recommended when the natural formation will be used as a filter pack. Well development should be completed at least 14 days prior to sampling.

3.3 SUMMARY OF PROCEDURES

In general, the following procedure should be followed when developing a well using the pump and surge technique:

1. Prepare the work area outside the well by placing plastic sheeting on the ground to avoid cross-contamination.
2. Calibrate water quality meters (refer to SOP 40.1).
3. Determine the depth to water and total depth of well (refer to SOP 40.2).
4. Calculate the equivalent volume (EV) of water in well to be developed (refer to SOP 30.2).
5. Pump or bail the well to ensure that water flows into it and to remove some of the fine materials from the well. Removal of a minimum of one EV is recommended at this point. The rate of removal should be high enough to stress the well by lowering the water level to approximately one-half its original level.
6. Remove pump or bailer, slowly lower a close-fitting surge block into the well until it rests below the static water level but above the screened interval. (NOTE: The latter is not required in the case of an LNAPL well.)
7. Begin a gentle surging motion along top on-third length of the screen, which will allow any material blocking the screen to break up, go into suspension, and move into the well. Note that development should always begin above or at the top of the screen and move progressively downward to prevent the surge block from becoming sand locked in the well casing. Continue surging for 5-10 minutes, remove surge block, and pump or bail the well, rapidly removing at least one EV.
8. Repeat previous step at successively lower levels within the well screen, until the bottom of the well is reached. As development progresses, successive surging can be more vigorous and of longer duration as long as the amount of sediment in the screen is kept to a minimum.

9. Development should continue until the well development criteria listed in Section 3.1.3 have been achieved.
10. All water removed must be managed as directed by the site investigation plan.

3.3.1 Well Development Criteria

In general, well development should proceed until the following criteria are met:

1. At a minimum, removal of three EV of water from the well.
2. Removal of three times of the amount of fluid (mud and/or water) lost during drilling.
3. Removal of three times the fluid used for well installation.
4. The following indicator parameters should be stabilized as indicated by three successive readings within:
    - ± 0.2 for pH;
    - ±3% for specific conductance;
    - ±10 mV for oxidation/reduction potential;
    - ± 1 degree Celsius for temperature; and
    - ±10% for turbidity and dissolved oxygen (except for wells installed in karst aquifers).
5. Well water is clear to the unaided eye (except for wells installed in karst aquifers).
6. The sediment thickness remaining within the well is less than one percent of the screen length or less than 0.1 ft for screens equal to or less than 10 feet.
7. Site specific factors should be evaluated to determine appropriate well development criteria have been if:
    - Well recharge is so slow that the required volume of water cannot be removed during 48 consecutive hours of development;
    - Water discoloration persists after the required volumetric development; and
    - Excessive sediment remains after the required volumetric development.

3.4 WELL DEVELOPMENT RECORD

Record all data as required on a Well Development Record Form (see example), which becomes a part of the complete Well Record. These data include the following:

- Project name, location;
- Well designation, location;
- Date(s) and time(s) of well installation;
- Static water level from top of well casing before and 24 hours after development;
- Depths and dimensions of the well, the casing, and the screen, obtained from the Well Diagram;
- Water losses and uses during drilling, obtained from the boring log for the well;
- Water contained in the well, obtained from calculations using the depth of the water column and the well radius, plus the radius and height of the filter pack and an assumed 30% porosity;

- Measurements of the following indicator parameters: pH, conductivity, oxidation/reduction potential, temperature, and turbidity before and after development and once during each EV;
- Notes on characteristics of the development water;
- Data on the equipment and technique used for development; and
- Estimated recharge rate and rate/quantity of water removal during development.

Well development records shall be submitted to the COR after the development has been completed.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addendum for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

Aller, Linda, et al. 1989. *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells.* National Water Well Association.

EPA Groundwater Handbook. 1989.

Nielsen, David M. 1993. *Correct Well Design Improves Monitoring,* in "Environmental Protection," Vol. 4, No.7, July, 1993.

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1 November.

ASTM Standard D 5092-90. 1990. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

ASTM Standard D 5717-95. 1995. *Standard Guide for Design of Ground-Water Monitoring Systems in Karst and Fractured Rock Aquifers.*

EXAMPLE WELL DEVELOPMENT FORM

WELL DESIGNATION:________________ DATE(S) OF INSTALLATION:____/____/____

SITE GEOLOGIST:____________________ DEVELOPMENT DATE(S):____/____/____

STATIC WATER LEVELS BEFORE AND AFTER DEVELOPMENT :

BEFORE ____________ DATE __________ 24 HR. AFTER __________ DATE__________

DEPTH TO SEDIMENT BEFORE AND AFTER DEVELOPMENT * :

BEFORE ____________ DATE __________ 24 HR. AFTER __________ DATE__________

DEPTH TO WELL BOTTOM *: _______________ SCREEN LENGTH _____________

HEIGHT OF WELL CASING ABOVE GROUND SURFACE: ________________

QUANTITY OF MUD/WATER:

LOST DURING DRILLING	(+)____________________	gallons
REMOVED PRIOR TO WELL INSERTION	(-)____________________	gallons
LOST DURING THICK FLUID DISPLACEMENT	(+)____________________	gallons
ADDED DURING FILTER PACK PLACEMENT	(+)____________________	gallons
TOTAL LOSSES	____________________	gallons

(a) Water column ht. (ft.) ____________ (b) Well radius (in.)____________

(c) Screen length (ft.) ____________ (d) Borehole radius (in.)____________

(e) QUANTITY OF FLUID STANDING IN WELL

Install Equation Editor and double-click here to view equation. 1 _________ gallons
(Show Calculation)

(f) QUANTITY OF FLUID IN ANNULUS Install Equation Editor and double-click here to view equation. 1_________gallons
(Show Calculation)

DEVELOPMENT VOLUME = (3 * TOTAL LOSSES) + [5 * (e + f)] = ____________ gallons
(Show Calculation)

*** ALL DEPTHS MEASURED FROM TOP OF WELL CASING**

EXAMPLE WELL DEVELOPMENT RECORD

WELL DESIGNATION ____________ DATE(S) OF DEVELOPMENT: ____/____/____

TYPE AND SIZE OF PUMP:____

TYPE AND SIZE OF BAILER:____

DESCRIPTION OF SURGE TECHNIQUE:____

RECORD OF DEVELOPMENT

DATE & TIME	QUANTITY REMOVED	TIME REQ'D	pH	Cond	Temp	ORD	Turb	DO	Character of water (color/clarity/ odor/partic.)
(before)									
(during)									
(during)									
(during									
(after)									

TYPICAL PUMPING RATE_______ GAL./HR. EST. RECHARGE RATE________________

TOTAL QUANTITY OF WATER REMOVED________ TIME REQUIRED____________

REMARKS____

SIGNATURE OF SITE GEOLOGIST________________________

STANDARD OPERATING PROCEDURE 20.3
WELL AND BORING ABANDONMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to establish the protocols by which all borings and wells will be abandoned. The primary objective of boring or well abandonment activities is to permanently abandon the boring or well so that the natural migration of groundwater or soil vapor is not significantly influenced.

2.0 MATERIALS

- Well abandonment equipment including appropriate grout mixing/placement equipment, and heavy equipment as appropriate (drill rig, crane, backhoe, etc.);
- Pure sodium bentonite powder with no additives (bentonite);
- Bentonite pellets (seal);
- Cement (Portland Type II); and
- Approved source water.

3.0 PROCEDURE

The volume of grout required for borehole or well abandonment should be calculated prior to proceeding with abandonment. These calculations should consider loss of material to the formation, changes in borehole diameter, potential zones of washout, and shrinkage of material. Calculations should be recorded on an abandonment record (see Section 3.1.4).

In general, cement grout should be used for boring and well abandonment per the specifications in Section 3.1 and procedures identified in the following sections. Specialized narrow diameter soil borings (3-inches or less) associated with direct push methods or hand augers may be abandoned using bentonite pellets or chips (see Section 3.5).

Any replacement borings or wells associated with the abandonment should be offset at least 20 feet from any abandoned site in a presumed up- or cross-gradient direction.

3.1 GROUT

Grout used in construction will be composed by weight of the following:

- Type II Portland cement (Type IV Portland Cement if sulfate concentrations are greater than 1,500 ppm);
- Bentonite (2 to 5% dry bentonite per 94-lb sack of dry cement); and

- A maximum of 6 to 7 gallons of approved water per 94-lb sack of cement.

Neither additives nor borehole cuttings will be mixed with the grout. Bentonite will be added after the required amount of cement is mixed with the water.

All grout material will be combined in an aboveground container and mechanically blended to produce a thick, lump-free mixture. The mixed grout will be recirculated through the grout pump before placement.

Grout placement will be performed using a commercially available grout pump and a rigid tremie pipe. Removal and grouting will be accomplished in stages, aquifer by aquifer, sealing the boring from the bottom to ground surface. This will be accomplished by placing a grout pipe to the bottom and pumping grout through the pipe until undiluted grout reaches the bottom of the next higher section of casing or, for the top most section, until grout flows from the boring at ground surface.

After 24 hours, the abandoned drilling site will be checked for grout settlement. Any settlement will be filled with grout and rechecked 24 hours later. This process will be repeated until firm grout remains at the ground surface.

3.2 BORINGS

The term "borings" as used in this SOP applies to any drilled hole made that is not completed as a well. This includes soil test borings, soil sampling borings, and deep stratigraphic borings. Whether completed to the planned depth or aborted for any reason before reaching that depth, borings will be grouted and will be normally closed within 12 hours.

To achieve an effective seal, the borehole to be abandoned should be free of debris and foreign matter that may restrict the adhesion of the grout to the borehole wall. Borehole flushing with a tremie pipe may be required to remove such materials prior to grouting.

Each boring to be abandoned should be sealed by grouting from the bottom of the boring to the ground surface. This will be accomplished by placing a tremie pipe to the bottom of the borehole and pumping grout through the pipe at a steady rate. The grouting should be completed slowly and continuously to prevent channeling of material. The tremie pipe should be raised when pumping pressure increases significantly or when undiluted grout reaches the surface.

After 24 hours of completing the abandonment, the abandoned boring or well should be checked for any grout settlement. The settlement depression should be filled with grout and rechecked 24 hours later. Grout should be placed with a tremie pipe if the open hole is 15 feet or deeper or if the hole is not dry. Otherwise, the grout may be poured from the surface.

3.3 NARROW BORINGS

Narrow borings, those with diameter less than 3 inches, advanced by hand auger or direct push methods, may be sealed using bentonite pellets or chips rather than a grout mixture. Often times a grout pump is not available to mix the grout when these methods have been used. Bentonite pellets or chips will be poured into the boring from the ground surface. Then bentonite will hydrate by absorbing moisture from the ground; unapproved water should not be added to the boring. After 24 hours, the abandoned boring will be checked, and any grout settlement will be topped off with more bentonite. The process will be repeated until bentonite remains at ground surface unless site condition indicates otherwise.

3.4 WELLS

The following procedure applies to wells aborted before completion and existing wells determined to be ineffective or otherwise in need of closure.

General Considerations

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

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

The particular method used for abandonment should be specified in the work plan addenda developed for a site-specific investigation. Several factors must be considered when selecting the appropriate abandonment technique including well construction, well condition, and subsurface conditions.
In general the preferred method for abandonment of wells is to remove all existing well materials to:

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

In general, all well materials will be removed during abandonment (including screen and casing) by either pulling out the casing, screen, and associated materials or by overdrilling using a rotary or hollow stem auger drilling procedure.

Abandonment with Well Materials In Place

In the event that it is not possible to remove the casing and screen, the casing and screen will be perforated using a suitable tool. A minimum of four rows of perforations several inches long and a minimum of five perforations per linear foot of casing or screen is recommended.

After the screen and casing have been appropriately perforated, the well should be abandoned by grouting from the bottom of the well to the ground surface using a tremie pipe as described in Section 3.2. The tremie pipe should be raised when pumping pressure increases significantly or when undiluted grout reaches the surface.

After 24 hours of completing the abandonment, the abandoned well should be checked for any grout settlement. The settlement depression should be filled with grout and rechecked 24 hours later. Grout should be placed with a tremie pipe if the open hole is 15 feet or deeper or if the hole is not dry. Otherwise, the grout may be poured from the surface.

Abandonment by Removal

Site conditions permitting, relatively shallow monitoring wells may be successfully abandoned by removal providing that the well is generally good condition and sections of casing (including screen) can be successfully removed with materials intact.

This method of abandonment is generally accomplished by removing (pulling) sections of casing and screen out of the subsurface using a drill rig, backhoe, crane, etc. of sufficient capacity. Materials with lower tensile strength such as polyvinyl chloride (PVC) generally cannot be removed by pulling if they have been appropriately cemented in place.

Once the well materials have been removed from the borehole, the borehole should be abandoned by grouting in the same manner discussed for borings in Section 3.2. If the borehole collapses after removal of well materials, then the borehole should be over drilled to remove all material and then grouted to the surface.

Overdrilling

With this method of abandonment, the well materials are removed by overdrilling (overreaming) the well location. Overdrilling using rotary techniques may be accomplished using an overreaming tool. This tool consists of a pilot bit that is approximately the same size as the inner diameter of well casing and a reaming bit that is slightly larger than the diameter of the borehole. As drilling proceeds, all well materials are destroyed and returned to the surface. After completion of the overdrilling, the borehole should be immediately grouted with a tremie pipe as described in Section 3.2.

In the case of overburden wells, a hollow stem auger may be used for overdrilling providing that this method of drilling appropriate for the subsurface conditions. The hollow stem auger should be equipped with outward facing carbide-cutting teeth with a diameter 2 to 4 inches larger than the well casing. With this method, the casing guides the cutting head and remains inside the auger. When the auger reaches the bottom of the well boring and the well materials have been removed, the borehole may be grouted with a tremie pipe (Section 3.2) through the augers as the augers are gradually withdrawn.

Considerations for Fractured Bedrock and Karst Wells

Multi-cased wells completed into bedrock as screened wells, open wells, or open-lined wells may be abandoned with the outer casing left in place providing that the integrity of this casing and associated annular seal is good. A cement bond log (acoustic amplitude boring geophysical log) may be used to evaluate the integrity of the casing and annular seal, if the outer casing is to be left in place.

Borings or wells completed in karst zones may be difficult to abandon because of the potential presence of large conduits, which may make it difficult to grout. Where large conduits exist or difficulties are encountered when abandoning a boring or well, fill the portion of the borehole penetrating the solution cavity with inert gravel (quartz, claystone, etc.). Packers can be used to isolate critical intervals for filling with grout above and below these zones.

3.5 RESTORATION

All work areas around the borings or wells abandoned should be restored to a condition essentially equivalent to that before the borings and wells were installed.

3.6 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material should be managed in accordance with the requirements of SOP 70.1 and the work plan addenda associated with the site investigation

3.7 DOCUMENTATION

For each abandoned boring or well, a record should be prepared to include the following as appropriate:

- Project and boring/well designation;
- Location with respect to replacement boring well (if any);
- Open depth of well/annulus/boring prior to grouting;
- Casing or items left in hole by depth, description, composition, and size;
- Copy of the boring log;
- Copy of construction diagram for abandoned well;
- Reason for abandonment;
- Description and total quantity of grout used initially;
- Description and daily quantities of grout used to compensate for settlement;
- Disposition of investigation-derived material;
- Water or mud level prior to grouting and date measured; and
- Remaining casing above ground surface, height above ground surface, size, and disposition of each.

Daily investigation activities at the site related to boring and well abandonment should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

4.0 PRECAUTIONS

Refer to the health and safety plan associated with the Work Plan Addenda and the Master Health and Safety Plan.

5.0 REFERENCES

ASTM Standard D 5299-92. 1992. *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1 November.

STANDARD OPERATING PROCEDURE 20.4
TEST PITS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the excavation of test pits and provide general guidelines for sample collection from the test pits.

Test pit excavations are conducted to investigate and identify possible areas of contamination. Thus, samples taken from the excavation will be positively biased according to visual inspection (i.e., soil discoloration, soil staining) and field screening. Areas showing evidence of possible contamination will be sampled directly. If no evidence of contamination is present during excavation, then samples will be collected in two equally spaced intervals or at intervals specified in work plan addenda for site-specific investigations. In either case, no less than two representative samples per excavation site should be collected. Excavation (and sampling) shall terminate if the water table is encountered before terminal depth.

2.0 MATERIALS

- Master Work Plan;
- Work Plan Addenda;
- Field log books;
- Appropriate health and safety equipment for monitoring conditions in the work zone and excavation area including a photoionization detector (PID) or other types of monitoring equipment;
- Personal protective equipment and clothing (PPE) per the site-specific health and safety plan;
- Backhoe and associated equipment;
- Appropriate soil sampling equipment such as stainless steel scoops, trowels, spoons, and bowls/trays SOP 30.1);
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Tarps or plastic sheeting;
- Measuring tape;
- Camera and film; and
- Decontamination equipment and supplies.

3.0 PROCEDURE

3.1 DOCUMENTATION

Field activities and sampling information should be recorded in the field logbooks as outlined in SOPs 10.1 and 10.2.

Cross-sections and sketches of the layout will be prepared upon completion of the excavation. The sketches will indicate soil horizons and geologic observations. Soil horizons will be differentiated based upon variations in soil color (i.e., Munsell Chart), texture, coarse fragment content, structure, and consistence. Refer to SOP 10.3 for boring log completion procedures. In addition, depth and thickness of horizontal depth to bedrock (if encountered) and indicators of seasonal high water table (presence of redoximorphic features) will be recorded. Sketches will also indicate the location of any samples collected. Photographs of the excavation will be taken and locations noted on the field map.

3.2 DECONTAMINATION

Decontamination of the backhoe, trowels or spoons, bowls, field tape measure, and other associated equipment will be carried out before use and between each test pit as outlined in work plan addenda and SOP 80.1.

3.3 SITE PREPARATION

Mark out dimensions of excavation and possible hazards (e.g., utilities, former structures). The backhoe must be equipped with a protective shield and the operator properly trained in the use of level B respiratory and dermal protection. The backhoe bucket and arm must be thoroughly decontaminated by steam cleaning before use and between each test pit location as described in work plan addenda and SOP 80.1. Discuss all hazards with equipment operator before any intrusive activities.

Set up exclusion zone with caution tape and position backhoe upwind of excavation site. All activities must be conducted in accordance with the health and safety plan developed for work plan addenda.

3.4 EXCAVATION AND SAMPLING

The backhoe operator shall be directed to excavate until the sampler indicates the desired depth has been reached. If the pit is less than 3 ft deep, the sampler can enter the pit and collect the samples using a decontaminated stainless steel trowel or spoon as described in SOP 30.1. As the pit becomes deeper, the sampler will collect the soil samples directly from the center of the bucket of the backhoe in an area not in contact with the sides of the bucket. The samples will then be transferred from the bucket into the appropriate sample container following sampling techniques outlined in SOP 30.1. Screening processes and analytical parameters for field screening soil samples will vary from site to site as specified per scope of work.

Begin excavating in increments of 6 to12 inches per pass. Deeper passes may be necessary if the soil is rocky. Total excavation width will be of adequate dimensions to visually characterize the soil profile as observed on the excavation walls, typically not exceeding the width of the backhoe bucket. However, total width of the excavation will be dependent on the depth of the excavation, thus wider dimensions may be necessary for characterization of deeper pits. Excavation will be continuously monitored with health and safety monitoring equipment. Safety measures must be exercised when working near and around the backhoe arm and excavation pit. Health and safety procedures and any installation safety procedures must be strictly followed.

All soil removed during excavation shall be placed on a tarp or plastic sheeting. Soil exhibiting signs of contamination based on visual or olfactory observations, as well as monitoring results, will be separated from uncontaminated soil and containerized for site removal.

Samples will be collected at desired intervals as specified in work plan addenda. Sampling procedures will follow the requirement of work plan addenda and SOP 30.1.

3.5 BACK FILL

Once the terminal depth of the excavation is reached or the water table is encountered and all samples are collected, the trench will be backfilled with certified clean fill. Soils removed during excavation shall be containerized and disposed of at an approved landfill or moved to an approved storage area for subsequent disposal. All backfilled material will be tamped to a proper compacted level to ensure no major settling will occur. After all backfilling and compacting procedures are complete, the area will be raked and seeded or resurfaced with asphalt, as appropriate. When the area is properly secured, decontamination procedures shall begin.

4.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

5.0 REFERENCE

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

STANDARD OPERATING PROCEDURE 20.11
DRILLING METHODS AND PROCEDURES

1.0 SCOPE AND APPLICATION

The use of an appropriate drilling procedure is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to outline procedures for the various methods of soil and rock drilling identified in the Master Work Plan. In addition it provides procedures for using sampling devices commonly used during soil and rock drilling such as split-barrel sampling, thin walled tube sampling, direct push samplers, and rock coring. For a particular site investigation, the associated work plan addendum will identify the appropriate drilling method and method of sampling, along with proposed sampling depths and intervals and any special procedures or methods.

2.0 MATERIALS

The following types of materials are generally appropriate for drilling:

2.1 SPLIT-BARREL SAMPLING

- Split barrel sampler;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.2 THIN WALLED TUBE SAMPLING

- Thin walled tubes;
- Sealing materials for sample such as sealing wax, metal disks, wood disks, tape, cheesecloth, caps, etc;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.3 DIRECT PUSH SAMPLING

- Direct push unit with hydraulic ram, hammer, etc;
- Sample collection devices, associated equipment and expendable supplies such as sample liners, sample retainers, appropriate lubricants, etc;
- Hollow extension rods;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;

- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.4 HOLLOW-STEM AUGER DRILLING

- Drill rig and associated equipment;
- Hollow stem auger assemblies for drilling to appropriate depth including auger heads, drive assembly, pilot assembly, and hollow-stem auger sections;
- Auxiliary devices such as wrenches, auger forks, hoisting hooks, swivels, and adaptors;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.5 DIRECT AIR ROTARY DRILLING

- Drill rig with rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Sampling devices and equipment, as appropriate;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.6 DRILL-THROUGH CASING DRIVER

- Drill rig equipped with a mast-mounted, percussion driver;
- Casing, drill rods, and drill bits or hammers;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Sampling devices and equipment, as appropriate;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Welding equipment and materials for installation of casing;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;

- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.7 DIRECT WATER-BASED ROTARY DRILLING

- Drill rig with derrick, rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, cyclone de-sander(s), drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1.
- Decontamination supplies and equipment per SOP 80.1.

2.8 DIRECT ROTARY WIRELINE-CASING ADVANCEMENT DRILLING

- Drill rig with either hollow spindle or top-head drive;
- Drill rods, coring or casing bits, overshot assembly, pilot bit, and core barrel;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

2.9 DIAMOND CORE DRILLING

- Direct rotary drill rig and associated equipment (see Sections 2.4, 2.5 or 2.6);
- Core barrels and core bits;
- Core lifters;
- Core boxes, engineers scale, permanent marking pen, and camera for photographing cores;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

3.0 PROCEDURES

3.1 PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

The following general procedure may be followed as outlined in ASTM Standard Test Method D 1586-84.

1. Advance the boring to the desired sampling depth using an appropriate drilling method (see sections below) and remove excessive cuttings from the borehole.
2. Attach the split-barrel sampler to the sampling rods and lower into the borehole. Do not allow the sampler to drop onto the soil to be sampled.
3. Position the hammer above and attach the anvil to the top of the drilling rods.
4. Rest the dead weight of the sampler, rods, anvil, and drive weight on the bottom of the boring and apply a seating blow. If excessive cuttings are encountered at the bottom of the borehole, remove the sampler and rods from borehole and remove the cuttings.
5. Mark the drill rods in three successive 6-inch increments so that the advance of the sampler can be observed.
6. Drive the sampler with blow from the 140 pound hammer and count the number of blows applied in each 6-inch increment until:
    a. Fifty (50) blows have been applied during one of the three 6-inch increments.
    b. A total of 100 blows have been applied.
    c. There is no observed advance of the sampler during the application of 10 successive blows of the hammer.
7. The sampler is advanced the complete 18-inches without the limiting blow counts occurring as described above.
8. Record the number of blows that is required to achieve each 6-inch increment of penetration or fraction of this increment on the boring.
    a. The first 6 inches is considered the seating driver.
    b. The sum of the second and third 6-inch penetration intervals is termed the "standard penetration resistance" or "N-value."
    c. If the sampler is driven less than 18 inches as discussed in No. 6, then the number of blow for each partial increment will be recorded.
    d. For partial increments, the depth of penetration should be recorded to the nearest 1-inch on the boring log.
    e. If the sampler advances below the bottom of the boring under the weight of rods (static) and/or hammer, then this information will be recorded on the boring log.
9. The raising and dropping of the 140 pound hammer may be accomplished by:
    a. Using a trip, automatic, or semi-automatic hammer drop system that lifts the hammer and allows it to drop 30± 1 inches.
    b. Using a cathead shall be essentially free of rust, oil, or grease and have a diameter in the range of 6 to 10 inches. The cathead should be operated at a minimum speed of rotation of 100

revolutions per minute. No more than 2-1/4 rope turns on the cathead may be used when conducting the penetration test.

10. For each hammer blow, a 30-inch lift and drop shall be used.
11. After completing the penetration test, retrieve the sampler and open. Record the percent recovery or the length of sample recovered. Following the procedures outlined in SOP 30.1 when collecting environmental soil samples.
12. Borehole logging should be completed per SOP 10.3.
13. Split-barrel samples must be decontaminated before and after each use per the requirements of SOP 80.1.

3.2 THIN WALLED TUBE SAMPLING

The following general procedure may be followed for collection of relatively undisturbed, thin walled tube samples (e.g., Shelby tube) as outlined in ASTM Standard Practice D 1587-94.

1. Clean out the borehole to targeted sampling depth using most appropriate method, which avoids disturbing the material to be sampled. If groundwater is encountered, maintain the liquidlevel in the borehole at or above the groundwater level during sampling.
2. Place the sample tub so that its bottom rests on the bottom of the borehole.
3. Advance the sampler without rotation by a continuous relatively rapid motion.
4. Determine the length of the advance by the resistance and condition of the formation, the length of the advance should never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clay.
5. When the formation is too hard for push type of sampling, the tube may be driven or the practice used for ring-lined barrel sampling may be used per ASTM Standard D 3550-84 (1995). When a sample is driven, the weight and fall of the hammer must be recorded along with the penetration achieved.
6. The maximum length of sample advance will be no longer than the sample-tube length minus an allowance for the sample head and a minimum of 3-inches for sludge-end cuttings.
7. Upon removal of the tube, measure the length of the sample in the tube. Remove the disturbed material in the upper end of the tube and re-measure the sample length.
8. Remove at least one-inch of material from the lower end of the tube for soil description and identification per SOP 10.3. Measure the overall sample length. Seal the lower end of the tube. If directed, the material from the end of the tube will not be removed for soil identification and description; in this case the tube will be sealed promptly.
9. Prepare sample labels and affix (or markings) on the tube.

3.3 DIRECT PUSH SOIL BORING

The following general procedures outlined in this section may be followed as described in ASTM Standard Test Method D 6282-98.

General considerations for this method include the following:

- A variety of direct push drive systems may be used to advance soil borings based on the intended sampling depths and subsurface conditions and include the following:

  Shallower Depths and Less Difficult Conditions

  - Percussive driving systems – use hydraulically operated hammers and mechanically operated hammers.
  - Static push drive systems – use hydraulic rams to apply pressure and exert static pull (e.g., cone penetrometer systems).
  - Vibratory/sonic systems – use a vibratory device, which is attached to the top of the sampler extension rods.

  Greater Depths and More Difficult Conditions

  - Sonic or resonance drilling systems – use a high power vibratory system to advance larger diameter single or dual tube systems.
  - Rotary drilling equipment – use hydraulic system of drill rig for direct push.
- The equipment used for direct push must be capable of apply sufficient static force, or dynamic force, or both, to advance the sampler to the required depth of collection. Additionally, this equipment must have adequate retraction force to remove the sampler and extension/drive rods once the sample has been collected.
- Avoid using excessive down pressure when advancing the drilling tools/sampler. Excessive pressure may cause the direct push unit to offset from the boring location and may damage drilling tools and samplers.
- Sample liners should be compatible with the material being sampled and the type of analysis to be conducted on the sample. Sealing of liners for submittal to the laboratory for physical testing should be accomplished according to ASTM Standard D 4220-95 (Standard Practice for Preserving and Transporting Soil Samples).
- The general procedure for completing direct push soil borings is the following:

1. Stabilize direct push unit and raise mast at desired location.
2. Attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit the position over the borehole, and ready the tools for insertion.
3. Inspect the direct push tools before and after use. Decontaminate all down hole tools before and after use per SOP 80.1.
4. Inspect drive shoes for damaged cutting edges, dents or thread failures and these conditions could cause loss of sample recovery and slow the rate of advancement.
5. Assemble samplers and install where required, install sample retainers where needed, and install and secure sampler pistons to ensure proper operation where needed (see Steps 14 through 20 for the various sampler assembly procedures, etc.).
6. After sampler has been appropriately installed (see Steps 14 through 20 for installation procedures, etc.) advance the boring to the target sampling depth using an appropriate direct push technique, as identified above under general considerations.
7. Collect the soil sample from the target sampling depth using one of the methods identified in Steps 14 through 20.
8. Retrieve the sampler and appropriately process the soil sample as identified in Steps 14 through 20 below and in SOP 30.1.

9. Log the borehole per the requirements of SOP 10.3.
10. If collecting another soil sample, decontaminate the sampler for reuse per the requirements of SOP 80.1 or use another decontaminated sampler.
11. Appropriately manage investigation-derived material (discarded samples, decontamination fluids, etc.) per SOP 70.1.
12. Upon completion of the boring and collection of the desired soil samples, abandon the boring per the requirements of SOP 20.2.
13. The following single tube sampling systems (generally piston rod) may be used to collect soil samples (see Steps 14 through 16 below):
    a. Open Solid Barrel Sampler;
    b. Closed Solid Barrel Sampler (e.g. Geoprobe Macro-Core® Piston Rod Sampler); and
    c. Standard Split Barrel Sampler (see Section 3.1).
14. The following two tube sampling systems may be used to collect soil samples (see Steps 17 through 20 below):
    a. Split Barrel Sampler;
    b. Thin Wall Tubes;
    c. Thin Wall Tube Piston Sampler; and
    d. Open Solid Barrel Samplers.
15. Sampling with the single tube, open solid barrel sampler:
    a. Attach the required liner to the cutting shoe by insertion into the machined receptacle are or by sliding over the machined tube.
    b. Insert the liner and shoe into the solid barrel and attach the shoe.
    c. Attach the sampler head to the sampler barrel.
    d. Attach the sampler assembly to the drive rod and the drive head to the drive rod.
    e. Position the sampler assembly under the hammer anvil and advance the sampler assembly into the soil at a steady rate slow enough to allow the soil to be cut by the shoe and move up into the sample barrel.
    f. At the completion of the sampling interval, removal the sampler from the borehole. Remove the filled sampler liner from the barrel by unscrewing the shoe. Cap the liner for laboratory testing or split open for field processing (see SOP 30.1).
    g. Log the borehole per the requirements of SOP 10.3.
16. Sampling with the closed, solid barrel sampler (e.g., Macro-Core® sampler).
    a. Insert or attach the sample liner to the shoe and insert the assembly into the solid barrel sampler. Install the sample, retaining basket, if desired.
    b. Attach the latch coupling or sampler head to the sampler barrel, and attach the piston assembly with point and "O" rings if free water is present, to the latching mechanism.
    c. Insert the piston or packer into the liner to its proper position so that the point leads the sampler shoe. Set latch, charge packer, or install locking pin, and attach assembled sampler to drive rod.
    d. Add drive head and position under the hammer anvil. Apply down pressure, and hammer if needed, to penetrate the soil strata above the targeted sampling interval.

   e. When the sampling interval is reached, insert the piston latch release and recovery tool, removing the piston, or insert the locking pin removal/extension rods through the drive rods, turn counter clockwise, and remove the piston locking pin so the piston can float on top of the sample, or release any other piston holding device.
   f. Direct push or activate the hammer to advance the sampler the desired interval.
   g. Retrieve the sampler from the borehole by removing the extension/drive rods. Remove the shoe, and withdraw the sample line with sample for processing (see SOP 30.1).
   h. Clean and decontaminate the sampler, reload as described above and repeat the same procedure for collection of addition samples.
   i. Log the borehole per the requirements of SOP 10.3.

17. Sampling with standard split barrel (split spoon) sampler generally consists of the following:
   a. Attach the split barrel sampler to an extension rod or drill rod.
   b. Using a mechanical or hydraulic hammer drive the ampler into the soil the desired interval. The maximum interval that should be driven is equal to the sample chamber length of the split barrel sampler, which is either 18-inches or 24-inches.
   c. Retrieve the sampler from the borehole by removing the extension/drive rods.
   d. Split the sampler open for field processing (see SOP 30.1).
   e. Clean and decontaminate the sampler (SOP 80.1), re-attach and repeat the same procedure for collection of additional samples.
   f. Log the borehole per the requirements of SOP 10.3.

18. Sampling with a two tube, split barrel sampler generally consists of the following:
   a. Assemble the outer casing with the drive shoe on the bottom, attach the drive head to the top of the outer casing, and attach the sampler to the extension rods.
   b. Connect the drive head to the top of the sampler extension rods, and insert the sampler assembly into the outer casing.
   c. The cutting shoe of the sampler should contact the soil ahead of the outer casing to minimize sample disturbance.
   d. The sample barrel should extend a minimum of 0.25 inches ahead of the outer casing.
   e. Mark the outer casing to identify the required drive length, position the outer casing and sampler assembly under the drill head.
   f. Move the drill head downward to apply pressure on the tool string. Advance the casing assembly into the soil at a steady rate, which is slow enough to allow the soil to be cut by the shoe and move up inside the sample barrel.
   g. Occasional hammer action during the push may assist recovery.
   h. If smooth push advancement is not possible because of subsurface conditions, use the hammer to advance the sampler.
   i. Stop the application of pressure or hammering when target interval has been sampled Move the drill head off the drive head. Attach a pulling device to the extension rods or position the hammer bail and retrieve the sampler from the borehole.
   j. At the surface, remove the sampler from the extension rods and process the sample per Section 3.01 and SOP 30.1.
   k. Log the borehole per the requirements of SOP 10.3.

19. Sampling with a two tube, thin wall tube sampler generally consists of the following:
    a. Attach the tube to the tube head using removable screws.
    b. Attach the tube assembly to the extension rods and position at the base of the outer casing shoe protruding a minimum of 0.25 inches to contact the soil ahead of the outer casing.
    c. Advance the tube with or without the outer casing at a steady rate.
    d. After completing the sampling interval, let the tube remain stationary for one minute. Rotate the tube slowly two revolutions to shear off the sample.
    e. Remove the tube from the borehole and measure the recovery, and log the borehole per the requirements of SOP 10.3.
    f. For field processing, extrude the sample from the tube sampler and process per SOP 30.1. Alternatively, the tube may be sealed and shipped to the laboratory.
20. Sampling with two tube, thin wall tube, piston sampler generally consists of the following:
    a. Check the fixed piston sampling equipment for proper operation of the cone clamping assembly and the condition of the "O" rings.
    b. Slide the thin wall tube over the piston, and attach it to the tube head. Position the piston at the sharpened end of the thin wall tube just above the sample relief bend
    c. Attach the tube assembly to the extension rods and lower the sampler into position through the outer casing. Install the actuator rods through the extension rod, and attach to the actuator rod in the sampler assembly.
    d. Attach a holding ring to the to top of the actuator rod string and hook the winch cable or other hook to the holding ring to hold the actuator rods in a fixed position.
    e. Attach the pushing fork to the drill head/probe hammer and slowly apply downward pressure to the extension rods advancing the thin wall tube over the fixed piston into the soil for the length of the sampling interval.
    f. After completing the sampling interval, let the tube remain stationary for one minute. Rotate the tube slowly one revolution to shear off the sample.
    g. Remove the tube sampler from the borehole and measure the recovery, and log the borehole per the requirements of SOP 10.3.
    h. For field processing, extrude the sample from the tube sampler and process per SOP 30.1.
21. Sampling with an two tube, open solid barrel sampler generally consists of the following:
    a. This sampling technique may be used when soil conditions prevent advancement of a split barrel sampler or advancement of an outer casing.
    b. The solid, single, or segmented barrel sampler requires the use of a liner.
    c. Use sampler in advance of outer casing when this casing cannot be advanced.
    d. Follow the procedures outlined for two tube, split barrel sampling.

3.4 HOLLOW-STEM AUGER DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5784.

1. Stabilize drill rig and raise mast at desired location.
2. Attach an initial assembly of hollow-stem auger components (hollow stem auger, hollow auger head, center rod and pilot assembly, as appropriate) to the rotary drive of the drill rig.

3. Push the auger assembly below the ground surface and initiate rotation at a low velocity.
4. Decontamination of auger head may be necessary after this initial penetration if this surface soil is contaminated.
5. Continue drilling from the surface, usually at a rotary velocity of 50 to 100 rotations per minute to the depth where sampling or in-situ testing is required or until the drive assembly is within approximately 6 to 18 inches of the ground surface.
6. As appropriate, collect a soil sample from the required depth interval. The sample may be conducted by
    a. Removing the pilot assembly, if used, and inserting and driving a sampler through the hollow stem auger of the auger column; or
    b. Using a continuous sampling device within the lead auger section, where the sampler barrel fills with material as the auger is advanced.
7. Additional sections of hollow stems augers may be added to drill to a greater depth. After these auger sections are added, rotation of the hollow-stem auger assembly may be resumed.
8. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.

   Monitoring wells or piezometers may be installed using hollow-stem augers by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the pilot assembly, if used, and insertion of the monitoring well (or piezometer) assembly.
    c. The hollow stem auger column should be removed incrementally as the monitoring well (or piezometer) completion materials are placed (see SOP 20.1 for grouting).
9. If materials enter the bottom of the auger hollow stem during the removal of the pilot assembly, it should be removed with a drive sampler or other appropriate device.
10. If sampling or *in-situ* testing is not required during completion of the boring, the boring may be advanced with an expendable knock out plate or plug of an appropriate material instead of a pilot assembly.
11. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1. It may be necessary to drill through a hole of sheet of plywood or similar material to prevent cuttings from contacting the ground surface.
12. The hollow-auger assembly and sampling devices must be decontaminated before and after each use per the methods specified in SOP 80.1.
13. Borehole logging should be completed per SOP 10.3.
14. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.5 DIRECT AIR ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5784-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit, down hole hammer, or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed below the top of the dust collector.

4. Activate the air compressor to circulate air through system.
5. Initiate rotation of bit.
6. Continue with air circulation and rotation of the drill-rod column to the depth where sampling or in-situ testing is required or until the length of the drill rod section limits further penetration.
7. Monitor air pressure during drilling operations. Maintain low air pressure at bit to prevent fracturing of surrounding material.
8. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.
9. Open reaching a desired depth of sampling, stop the air circulation and rest bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
10. When sampling, remove the drill rod column from the borehole or leave the drill rod assembly in place if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 12 should be conducted for each sampling or testing interval.
14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section tothe 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 fromthe borehole annulus.
12. After reaching a desired depth of sampling, stop the air circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
13. When sampling, remove the drill rod column from the borehole. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
14. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
15. The procedure described in Steps 11 through 14 should be conducted for each sampling or testing interval.
16. Drilling to a greater depth may be accomplished by attaching an additional drill rod section and casing section to the top of the previously advanced drill-rod column/casing and resuming drilling operations as described above.
17. Monitoring wells or piezometers may be installed by:
    a. Casing advancement in increments, with or without sampling to the target depth.

   b. Removal of the drill rods and the attached drill bit while the casing is temporarily left in place to support the borehole wall.
   c. Insertion of the monitoring well (or piezometer) assembly.
   d. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).

18. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
19. The drill rod assembly, casing, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
20. Borehole logging should be completed per SOP 10.3.
21. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.7 DIRECT WATER-BASED ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5783-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the mud tub and install surface casing and seal at the ground surface.
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed with the top of the surface casing.
4. Activate the drilling-fluid circulation pump to circulate drill fluid through the system.
5. Initiate rotation of bit and apply axial force to bit.
6. Document drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, etc.) as described in SOP 10.3.
7. Continue with drill fluid circulation as rotation and axial force are applied to the bit until drilling to the depth
   a) Where sampling or in-situ testing is required;
   b) Until the length of the drill rod section limits further penetration; or
   c) Until core specimen has completely entered the core barrel (when coring) or blockage has occurred.
8. Stop rotation and the lift bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue fluid circulation until the drill cuttings are removed from the borehole annulus.
9. After reaching a desired depth of sampling, stop the fluid circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
10. When sampling, drill rod removal is not necessary if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 11 should be conducted for each sampling or testing interval.

14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
15. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
16. Monitoring wells or piezometers may be installed using hollow-stem augers by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the drill rod assembly and insertion of the monitoring well (or piezometer) assembly.
    c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
17. Drill cuttings and fluids should be appropriately controlled and contained as IDM per SOP 70.1.
18. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
19. Borehole logging should be completed per SOP 10.3.
20. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.8 DIRECT ROTARY WIRELINE CASING ADVANCEMENT DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5876-95.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the mud tub (for water based rotary) and install surface casing and seal at the ground surface.
2. Record the hole depth by knowing the length of the rod-bit assemblies and comparing its position relative to the established surface datum.
3. Attach an initial assembly of a lead drill rod and a bit or core barrel below the top-head drive unit, with the bit placed with the top of the surface casing.
4. Activate the drilling-fluid circulation pump to circulate drill fluid through the system.
5. Initiate rotation of bit and apply axial force to bit.
6. Document drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, down feed pressures etc.) as described in SOP 10.3.
7. In general, the pilot bit or core barrel can be inserted or removed at any time during the drilling process and the large inside diameter rods can act as a temporary casing for testing or installation of monitoring devices.
8. Continue with drill fluid circulation as rotation and axial force are applied to the bit until drilling to the depth
    a) Where sampling or in-situ testing is required;
    b) Until the length of the drill rod section limits further penetration; or
    c) Until core specimen has completely entered the core barrel (when coring) or blockage has occurred.
9. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue fluid circulation until the drill cuttings are removed from the borehole annulus.

10. After reaching a desired depth of sampling, stop the fluid circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
11. When sampling, drill rod removal is not necessary if the sampling can be performed through the hollow axis of the drill rods and bit.
12. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
13. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it may be necessary to further clean the hole by rotary recirculation.
14. Continuous sampling may be conducted with a soil core barrel or rock core barrel (see Section 1.7).
15. The pilot bit or core barrel may need to be removed during drilling such as when core barrels are full or there is evidence of core blocking. Before the drill string is reinserted, the depth of the boring should be rechecked to evaluate hole quality and determine whether casing may be required.
16. Water testing may be performed in consolidated deposits by pulling back on the drill rods and passing inflatable packer(s) with pressure fitting to test the open borehole wall (see ASTM Standards D 4630 and D 4631).
17. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
18. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings might be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
19. Monitoring wells or piezometers may be installed by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the pilot bit or core barrel and insertion of the monitoring well (or piezometer) assembly.
    c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
20. Drill cuttings and fluids should be appropriately controlled and contained as IDM per SOP 70.1.
21. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
22. Borehole logging should be completed per SOP 10.3.
23. Borehole abandonment, when required, should be conducted according to SOP 20.3.

3.9 DIAMOND CORE DRILLING

The following general procedure may be followed as outlined in ASTM Standard Practice D 2113-83 (1993).

1. Use core-drilling procedures, such as the water-rotary drilling method outlined in Section 3.6.
2. Seat the casing on bedrock or firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the formation that the casing will be seated on as needed.
3. Begin core drilling using an N-size double-tube, swivel-type core barrel or other approved size or type. Continue core drilling until core blockage occurs or until the net length of the core has been drilled.

4. Remove the core barrel from the borehole, and dis-assemble the core barrel as necessary to remove the core.
5. Reassemble the core barrel and return it to hole.
6. Continue core drilling.
7. Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box. Wrap soft or friable cores, etc. as needed or required. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core that might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.
8. The core within each completed box should be photographed after core surface has been cleaned or peeled, as appropriate, and wetted. Each photo should be in sharp focus and contain a legible scale in feet and tenths of feet (or metric if appropriate). The core should be oriented so that the top of the core is at the top of the photograph. A color chart should be included in the photograph frame as a check on photographic accuracy. The inside lid of the box should also be shown.
9. The inside of the box lid should be labeled at a minimum with the facility name, project name, boring number, box number, and core interval.
10. A preliminary field log of the core must be completed before the core box has been packed for transport (see SOP 10.3). Detailed logging may be conducted at a later time providing the core is appropriately handled and transported.
11. Four levels of sample protection may be used depending on character of the rock and the intended use of the rock core including:
    a. *Routine care* – for rock cored in 5 to 10 foot runs. Consists of placing in structurally sound boxes. Lay flat tubing may be used prior to placing the core.
    b. *Special care* – for rock samples to be tested that are potentially moisture sensitive, such as shale. This care consists of sealing with a tight fitting wrapping of plastic film and application of wax at the ends of the sample.
    c. *Critical care* – for rock samples that may be sensitive to shock and vibration and/or temperature. Protect by encasing each sample in cushioning material, such as sawdust, rubber, polystyrene, foam, etc. A minimum one-inch thick layer of cushioning material should be used. Thermally insulate samples that are potentially sensitiveto changes in temperature.
    d. Soil-Like care – handle per ASTM Standard D 4220-95.
12. Drilling conditions and sequence (fluid loss, circulation pressures, depths of lost circulation, down feed pressures, core blockage etc.) should be documented on the boring log as described in SOP 10.3.
13. Drill cuttings and fluids should be appropriately controlled and contained as investigation-derived material per SOP 70.1.
14. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
15. Borehole logging should be completed per SOP 10.3.
16. Borehole abandonment, when required, should be conducted according to SOP 20.3.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to site-specific health and safety plan included in work plan addenda.

6.0 REFERENCES

ASTM Standard D 2113-83 (1993). 1993. *Standard Practice for Diamond Core Drilling for Site Investigation.*

ASTM Standard D 1586-84 (1992). 1992. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 1587-94. 1994. *Standard Practice for Thin-Walled Tube Geotechnical Sampling of Soils.*

ASTM Standard D 4220-95. 1995. *Standard Practices for Preserving and Transporting Soil Samples.*

ASTM Standard D 5079-90. 1995. *Standard Practices for Preserving and Transporting Rock Core Samples.*

ASTM Standard D 5782-95. 1995. *Standard Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5783-95. 1995. *Standard Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5784-95. 1995. *Standard Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5872-95. 1995. *Standard Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 5876-95. 1995. *Standard Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices.*

ASTM Standard D 6282-98. 1998. *Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000. 1, November.

STANDARD OPERATING PROCEDURE 20.12
DIRECT PUSH GROUNDWATER SAMPLING

1.0 SCOPE AND APPLICATION

The use of direct push groundwater sampling is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to outline procedures for the collecting groundwater samples using direct push sampling. For a particular site investigation, the associated work plan addendum will identify the appropriate drilling method and method of groundwater sampling, along with proposed sampling depths and intervals and any special procedures or methods.

2.0 MATERIALS

The following types of materials are generally appropriate for direct push groundwater sampling with a protected screen sampler:

- Direct push unit with hydraulic ram, hammer, etc;
- Groundwater sampling system consisting of expendable sampling tips, well screen with protective sleeve, connector assembly, probe rods (riser pipe), drive cap, grab sampling devices (bailers, if used), sample tubing and check valve assembly (if used), and sampling pump (if used);
- As needed, soil sampling devices and associated equipment and expendable supplies such as sample liners, sample retainers, appropriate lubricants, etc;
- Auxiliary tools for handling, assembling, and disassembling tools and probe rods;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

3.0 PROCEDURES

Static probing systems, penetrometer systems, or rotary drilling equipment can be used for inserting direct push groundwater sampling devices.

The following general procedures outlined in this SOP may be followed as described in ASTM Standard Test Method D 6001-96.

General considerations for this method include the following:

- A variety of direct push drive systems may be used to advance borings based on the intended sampling depths and subsurface conditions and include the following:

Shallower Depths and Less Difficult Conditions

  - *Percussive driving systems* – use hydraulically operated hammers and mechanically operated hammers;
  - *Static push drive systems* – use hydraulic rams to apply pressure and exert static pull (e.g., cone penetrometer systems); and
  - *Vibratory/sonic systems* – use a vibratory device, which is attached to the top of the sampler extension rods.

Greater Depths and More Difficult Conditions

  - *Sonic or resonance drilling systems* – use a high power vibratory system to advance larger diameter single or dual tube systems; and
  - *Rotary drilling equipment* – use hydraulic system of drill rig for direct push.

- The equipment used for direct push must be capable of apply sufficient static force, or dynamic force, or both, to advance the sampler to the required depth of collection. Additionally, this equipment must have adequate retraction force to remove the sampler and extension/drive rods once the sample has been collected.
- Avoid using excessive down pressure when advancing the drilling tools/sampler. Excessive pressure may cause the direct push unit to offset from the boring location and may damage drilling tools and samplers.
- Direct push sampling materials should be compatible with the material being sampled and the type of analysis to be conducted on the sample. A variety of materials are available including stainless steel, rigid polyvinyl chloride (PVC) and polytetrafluorethylene (PTFE).

The following general procedure involves the advancement of a direct push boring and collection of a groundwater sample using a protected screen sampler:

1. Stabilize direct push unit and raise mast at desired location.
2. Attach the hammer assembly to the drill head if not permanently attached. Attach the anvil assembly in the prescribed manner, slide the direct push unit the position over the borehole, and ready the tools for insertion.
3. Inspect the direct push tools before and after use. Decontaminate all down hole tools before and after use per SOP 80.1.
4. If soil samples will be collected to characterize soil stratigraphy and/or identify zones of groundwater for sampling, the drilling and soil sampling procedures outlined in SOP 20.11 (Section 3.3) should be followed.
5. Connect the sampler assembly (well screen enclosed in sheath), with drive point to probe rods along with any subassemblies such as friction reducers.
6. Prior to driving, measure the length of the sampling assembly and probe rod(s) to determine the depth of sampling.
7. After the sampling assembly has been appropriately installed to the probe rod, advance the assembled sampler using the drill rigs hydraulic rams (smooth quasi static push) or the drill rig hammer (percussive driving), or both.
8. Add additional probe rods as the sampling assembly is advanced and greater depths are reached. As the sampling assembly is advanced, the number of rod sections (riser) added should be recorded to ensure that groundwater sampling occurs at the targeted depth.

9. Once the sampling assembly is advanced to the desired depth check the system for leakage before exposing the screen for sampling. The leakage test does not have to be performed if the sampling system allows for direct connection to the screened sampling area (using a sealed chamber or tubing).
10. If appropriate, the leakage test will be conducted by checking for the presence of water inside the riser with an electronic water level meter. If no leakage is observed, then sampling may proceed. If water is present in the riser pipe from an unknown source, it should be purged before sampling; otherwise the sampling effort should be abandoned.
11. Extension rods are used to hold the screen in position as the casing puller assembly is used to retract the probe rods. The extension rods pass through the sampler to the bottom of the screen.
12. Groundwater sampling may be completed once the well screen is fully exposed. The extension rods are then removed and polyethylene or Teflon tubing with a check valve is then inserted inside the probe rods to the bottom of the screen.
13. The sampling tube assembly may then be oscillated up and down to bring water to the surface for sample collection.
14. Alternatively, if permitted by the sampling plan, a sampling pump (e.g., peristaltic) may be connected to the tubing to draw in the sample.
15. In lieu of using sampling tubing, a small diameter bailer may be lowered inside the probe rods to the interval of the screen to collect a grab sample of groundwater.
16. Collect groundwater samples directly from the end of tubing into clean laboratory-prepared (preserved) containers, as specified in work plan addenda prepared for site-specific investigations. Allowing the discharge from the tubing or bailer to flow gently down the inside of the container with minimal turbulence should fill all samples. Volatile organic compounds (VOCs) and gas sensitive parameter samples should be collected first followed by other parameters.
17. In general, samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is VOCs, extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any well location are site-specific and are specified in work plan addenda.
18. Depending on the screen used and site conditions; samples may contain sediment and may require filtration before placement into containers. Refer to the site-specific sampling and analysis plan for requirements for filtration.
19. After sampling, the boring may be abandoned by incrementally removing the screen assembly and probe rods and pumping grout into the probe through the tubing used for sample collection. Other abandonment methods for direct push borings are described in SOP 20.3.
20. Samples should be handled and shipped as specified in SOPs 50.1 and 50.2 and the work plan addenda prepared for site-specific investigations.
21. Log the borehole per the requirements of SOP 10.3.
22. Appropriately manage investigation-derived material (discarded samples, decontamination fluids, etc.) per SOP 70.1.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to site-specific health and safety plan included in work plan addenda.

6.0 REFERENCES

ASTM Standard D 6001. 1996. *Standard Guide for Direct-Push Water Sampling for Geoenvironmental Investigations.*

ASTM Standard D 6282-98. 1998. Standard Guide for Direct Push Soil Sampling for Environmental Site Characterization.

STANDARD OPERATING PROCEDURE 30.1
SOIL SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for sampling surface and subsurface soils.

2.0 MATERIALS

- Stainless steel scoop, spoon, trowel, knife, spatula, (as needed);
- Split-spoon, Shelby tube, or core barrel sampler;
- Hand auger or push tube sampler;
- Drill rig and associated equipment (subsurface soil);
- Stainless steel bowls;
- Photoionization detector or other appropriate instrument as specified in site-specific health and safety plan;
- Sampling equipment for collection of volatile organic samples;
- Appropriate sample containers;
- Appropriate sample labels and packaging material.;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination equipment and supplies (SOP 80.1).

3.0 PROCEDURE

3.1 DOCUMENTATION

Soil sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

3.2 SURFICIAL SOIL SAMPLES

The targeted depths for surficial soil samples (surface and near surface) will be specified in the work plan addenda developed for site-specific investigations.

1. All monitoring equipment should be appropriately calibrated before beginning sampling according to the requirements of the work plan addenda and SOP 90.1 or 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Use a spade, shovel, or trowel or other equipment (manufactured from material, which is compatible with the soil to be sampled) to remove any overburden material present (including vegetative mat) to the level specified for sampling.
4. Measure and record the depth at which the sample will be collected with an engineers scale or tape.

5. Remove the thin layer that was in contact with the overburden removal equipment using a clean stainless steel scoop or equivalent and discard it.
6. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
7. When a sample will not be collected with a core type of sampler (push tube, split spoon, etc.), the sample for VOC analysis will be collected from freshly exposed soil. The method of collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
8. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
9. Collect a suitable volume of sample from the targeted depth with a clean stainless steel scoop (or similar equipment), push tube sampler, or bucket auger
10. For core type of samplers, rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife. Samples collected with a bucket auger or core type of sampler should be logged per the requirements of SOP 10.3.
11. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
12. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
13. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
14. Return any remaining unused soil to the original sample location. If necessary, add clean sand to bring the subsampling areas back to original grade. Replace the vegetative mat over the disturbed areas.

3.3 SUBSURFACE SAMPLES

All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.

1. All monitoring equipment should be appropriately calibrated before sampling according to the requirement of the work plan addendum and SOP 90.1 or SOP 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Collect split-spoon; core barrel, Shelby tube, sonic core or other similar samples during drilling.

4. Upon opening sampler or extruding sample, immediately screen soil for VOCs using a PID or appropriate instrument. If sampling for VOCs, determine the area of highest concentration; use a stainless steel knife, trowel, or lab spatula to cut the sample; and screen for VOCs with monitoring instrument(s).
5. Log the sample on the boring log before extracting from the sampler per the requirements of SOP 10.3.
6. Any required VOC samples will be collected first followed by the other parameters. VOC samples will not be composited or homogenized and will be collected from the area exhibiting the highest screening level. The method of VOC sample collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
8. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
9. If homogenization or compositing of the sampling location is not appropriate for other parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
10. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
15. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
16. Discard any remaining sample into the drums used for collection of cuttings.
17. Abandon borings according to procedures outlined in SOP 20.2.

3.4 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

NOTES: If sample recoveries are poor, it may be necessary to composite samples before placing them in jars. In this case, the procedure will be the same except that two split-spoon samples (or other types of samples) will be mixed together. The boring log should clearly state that the samples have been composited, which samples were composited, and why the compositing was done. In addition, VOC fraction should be collected from the first sampling device.

When specified, samples taken for geotechnical analysis (e.g., percent moisture, density, porosity, and grain size) will be undisturbed samples, such as those collected using a thin-walled (Shelby tube) sampler, sonic core sampler, etc.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

Soil samples will not include vegetative matter, rocks, or pebbles unless the latter are part of the overall soil matrix.

6.0 REFERENCES

ASTM Standard D 1586-84. 1984. *Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 1587-83. 1983. *Thin Walled Sampling of Soils.*

ASTM Standard D 5633-94. 1994. *Standard Practice for Sampling with a Scoop.*

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

JH

STANDARD OPERATING PROCEDURE 30.2
GROUNDWATER SAMPLING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the collection of groundwater samples from monitoring wells.

2.0 MATERIALS

- Work Plans;
- Field logbooks and field parameter forms;
- Plastic sheeting;
- Decontamination equipment and supplies (SOP 80.1);
- Variable-speed, low-flow submersible pump with safety drop cable;
- Nylon stay-ties;
- Generator;
- Dedicated Teflon tubing or Teflon lined polyethylene tubing;
- Flow-through-cell and probes for measuring pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity (SOP 40.1);
- Electronic water-level indicator;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Cooler with ice;
- Silicone tubing;
- 0.45-micron disposable filters (as appropriate).
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan;
- Photoionization detector (PID) or other appropriate monitoring instrument per the site-specific health and safety plan; and
- Appropriate containers for investigation-derived material.

3.0 PROCEDURE

3.1 DOCUMENTATION

Groundwater sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

The following are general rules for the field parameter logbook for groundwater, as described in SOP 10.2:

- Only information for one site or installation per logbook. The same book maybe used for more than one sampling event.
- The first five pages will be reserved for index, general notes, etc. Sign and date each entry.
- Fill in the forms.
- Duplicate copies, index pages, and calibration sheets remain intact.

3.2 OVERVIEW OF SAMPLING TECHNIQUES

In general, two different techniques may be used to sample groundwater from monitoring wells at Radford Army Ammunition Plant (RFAAP):

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

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

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

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

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

- In a well with potential or documented multiple flow zones and where individual flow zones will not be evaluated;
- In moderately producing wells (> 0.5 liters per minute) where no discrete flow zones were documented during drilling; and
- In wells sampled during seasonal high groundwater conditions with enhanced yield (and potentially additional flow zones).

Groundwater samples should be collected no sooner than 14 days after well development. Information from the boring logs, well completion records, and well development records should be reviewed before sampling a well to determine the most appropriate sampling technique. Pertinent information for each well to be sampled includes:

- Well construction;
- Depth and nature of water producing zones;
- Sustainable pumping rate of the well to be sampled;
- Well recharge characteristics; and
- Baseline turbidity.

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

In general, when using the pumps specified in the following sections, situate any gasoline-powered generator on level ground approximately 15 ft downwind from the well. All generator maintenance (oil and fueling) is to be performed off site. If the hose(s) and/or power cord of the pump is not on a reel, place the pump with its hose and power cord on the plastic sheeting downhill from the well.

3.3 TYPE I SAMPLING PROCEDURES

Type I low flow purging and sampling procedures include the following:

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.
- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.
- Well depth at the time of purging will be obtained from well construction and existing data.
- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the desired depth. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- For wells with very low sustainable pumping rates (≤ 0.5 liters per minute), the pump should be set in the middle of the saturated screen section of the well or middle of the water column for open wells. The pump should be set 12 hours prior to purging so that the depth to water equilibrates and sediments disturbed during pump placement have time to settle.
- For wells with sustainable pumping rates (> 0.5 liters per minute), the pumps will be set at a desired depth prior to purging, allowing for the depth to water to equilibrate before sampling. The desired depth will be specified in work plan addenda based on site-specific conditions and DQOs.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into a appropriate container(s) to collect purge water.
- Immediately prior to purging, the depth to water will be measured and record. Start pumping the water at a rate of 100 to 400 milliliters per minute. Avoid surging. The pumping rate should cause minimal drawdown (less than 0.2 ft). Water level measurements should be collected continuously to document stabilization of the water level. Pumping rates should, if needed, be reduced to the minimal capabilities of the pump to avoid dewatering the screen interval and ensure stabilization of indicator parameters.

- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.
- Continue purging until stabilization of indicator parameters is achieved. Stabilization is defined as three consecutive readings that are within the following criteria:
  - ± 0.1 for pH;
  - ±3% for specific conductance;
  - ±10 mV for oxidation/reduction potential (Eh); and
  - ±10% for turbidity and dissolved oxygen.
- If the parameters have stabilized, but the turbidity is not in the range of 5 to 10 NTU, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-though cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- In general, samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is VOCs, extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any well location are site-specific and are specified in work plan addenda.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well be replacing and locking the lid.

3.4 TYPE II SAMPLING PROCEDURES

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.

- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.
- Well depth at the time of purging will be obtained from well construction and existing data.
- Calculate the standing water column in the well by subtracting the depth to water from the total depth of the well as recorded during completion of the well.
- From the water depth, well diameter, sand pack length, etc., calculate the equivalent volume (1 EV) of water in the well.

  1 EV = volume in casing + volume in saturated sand pack. Therefore; if the water table lies below the top of the sand pack, use the following equation:

  $1\ \mathrm{EV} = (pR_W{}^2h_W) + (0.30p(R_S{}^2 - R_W{}^2)h_W) * (0.0043)$

  If the water table lies above the top of the sand pack use this equation:

  $1\ \mathrm{EV} = [(pR_W{}^2h_W) + (0.30p(R_S{}^2 - R_W{}^2)h_S)] * (0.0043)$

  Where: R_S = radius of sand pack in inches
  R_W = radius of well casing in inches
  h_S = height of sand pack in inches
  h_W = water depth in inches

  0.0043 gal/in^3
  Assumed filter pack porosity = 30%

Tables and graphs showing equivalent volumes for typical well constructions are available.

- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the middle of the saturated screen interval or water column in an open borehole. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into an appropriate container to collect purge water.
- Start purging the well at the minimally achievable pumping rate. Gradually increase the pumping rate to achieve the maximum flow rate of the pump or the maximum sustainable flow rate that does not draw down the static water level to a point below the top of the first water bearing zone, whichever is achieved first.
- During purging, water level measurements should be collected periodically to verify water levels in the well.
- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.
- Note when each indicator parameter stabilizes. Stabilization is defined as three consecutive readings that are within the following criteria:
  - ± 0.1 for pH;
  - ±3% for specific conductance;

  - ±10 mV for oxidation/reduction potential (Eh); and
  - ±10% for turbidity and dissolved oxygen.
- Three calculated eVs of water in the will be purged prior to sampling. It will be documented if stabilization of the indicator parameters has not occurred after three calculated well volumes have been removed and sampling procedures begin.
- If the turbidity is not in the range of 5 to 10 NTU when purging has been completed, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-though cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well be replacing and locking the lid.

3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addendum for the site being investigated and SOP 70.1.

4.0 MAINTENANCE

Refer to manufacturer's requirements for maintenance of pumps and generators.

5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

6.0 REFERENCES

USACE. 2001. R*equirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3, 1 February.

USEPA. 1997. *Recommended Procedure for Low-flow Purging and Sampling of Groundwater Monitoring Wells.* Bulletin No. QAD023, October.

STANDARD OPERATING PROCEDURE 30.7
SAMPLING STRATEGIES

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate sampling strategies for sampling various media.

2.0 MATERIALS

- Historical site data;
- Site topography;
- Soil types; and
- Sampled media.

3.0 PROCEDURE

The primary goal of any investigation is to collect samples representative of existing site conditions. Statistics are generally used to ensure samples are as representative as possible. Sampling plans may employ more than one approach to ensure project data quality objectives are adequately addressed. A comparison of sampling strategies is presented in Table 1.

3.1 CLASSICAL STATISTICAL SAMPLING

Classical statistical sampling strategies are appropriately applied to either sites where the source of contamination is known or small sites where the entire area is remediated as one unit. Primary limitations of this sampling approach include (1) inability to address media variability; (2) inadequate characterization of heterogenous sites; and (3) inadequate characterization of sites with unknown contamination characteristics.

3.1.1 Simple Random Sampling

Simple random sampling is generally more costly than other approaches because of the number of samples required for site characterization. This approach is generally used when minimal site information is available and visible signs of contamination are not evident and includes the following features:

- Sampling locations are chosen using random chance probabilities.
- This strategy is most effective when the number of sampling points is large.

3.1.2 Stratified Random Sampling

This sampling approach is a modification to simple random sampling. This approach is suited for large site investigations that encompass a variety of soil types, topographic features, and/or land uses. By dividing the site into homogenous sampling strata based on background and historical data, individual random sampling techniques are applied across the site. Data acquired from each stratum can be used to detemine the mean or total contaminant levels and provide these advantages:

- Increased sampling precision results due to sample point grouping and application of random sampling approach.

- Control of variances associated with contamination, location, and topography.

3.1.3 Systematic Grid

The most common statistical sampling strategy is termed either systematic grid or systematic random sampling. This approach is used when a large site must be sampled to characterize the nature and extent of contamination.

Samples are collected at predetermined intervals within a grid pattern according to the following approach:

- Select the first sampling point randomly; remaining sampling points are positioned systematically from the first point.
- Determine the grid design: one or two-dimensional. One-dimensional sample grids may be used for sampling along simple man-made features. Two-dimensional grid systems are ideal for most soil applications.
- Determine the grid type: square or triangular. Sampling is usually performed at each grid-line intersection. Other strategies include sampling within a grid center or obtaining composite samples within a grid.
- Each stratum is sampled based on using the simple random sampling approach but determined using a systematic approach.

3.1.4 Hot-Spot Sampling

Hot spots are small, localized areas of media characterized by high contaminant concentrations. Hot-spot detection is generally performed using a statistical sampling grid. The following factors should be addressed:

- Grid spacing and geometry. The efficiency of hot-spot searches is improved by using a triangular grid. An inverse relationship exists between detection and grid point spacing, e.g., the probability of hot-spot detection is increased as the spacing between grid points is decreased.
- Hot-spot shape/size. The larger the hot spot, the higher the probability of detection. Narrow or semicircular patterns located between grid sampling locations may not be detected.
- False-negative probability. Estimate the false negative (β-error) associated with hot-spot analysis.

3.1.5 Geostatistical Approach

Geostatistics describe regional variability in sampling and analysis by identifying ranges of correlation or zones of influence. The general two-stage approach includes the following:

- Conducting a sampling survey to collect data defining representative sampling areas.
- Defining the shape, size, and orientation of the systematic grid used in the final sampling event.

3.2 NON-STATISTICAL SAMPLING

3.2.1 Biased Sampling

Specific, known sources of site contamination may be evaluated using biased sampling. Locations are chosen based on existing information.

3.2.2 Judgmental Sampling

This sampling approach entails the subjective selection of sampling locations that appear to be representative of average conditions. Because this method is highly biased, it is suggested that a measure of precision be included through the collection of multiple samples.

4.0 MAINTENANCE

Not applicable.

5.0 REFERENCES

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM200-1-3. 1 February.

TABLE 1
SAMPLING STRATEGIES

SAMPLING STRATEGY	DESCRIPTION	APPLICATION	LIMITATIONS
Classical Statistical Sampling Strategies			
Simple Random Sampling	Representative sampling locations are chosen using the theory of random chance probabilities.	Sites where background information is not available and no visible signs of contamination are present.	May not be cost-effective because samples may be located too close together. Does not take into account spatial variability of media.
Stratified Random Sampling	Site is divided into several sampling areas (strata) based on background or site survey information.	Large sites characterized by a number of soil types, topographic features, past/present uses, or manufacturing storage areas.	Often more cost-effective than random sampling. More difficult to implement in the field and analyze results. Does not take into account spatial variability of media.
Systematic Grid Sampling	Most common statistical strategy; involves collecting samples at predetermined, regular intervals within a grid pattern.	Best strategy for minimizing bias and providing complete site coverage. Can be used effectively at sites where no background information exists. Ensures that samples will not be taken too close together.	Does not take into account spatial variability of media.
Hot-Spot Sampling	Systematic grid sampling strategy tailored to search for hot spots.	Sites where background information or site survey data indicate that hot spots may exist.	Does not take into account spatial variability of media. Tradeoffs between number of samples, chance of missing a hot spot, and hot spot size/shape must be weighed carefully.
Geostatistical Approach	Representative sampling locations are chosen based on spatial variability of media. Resulting data are analyzed using kriging, which creates contour maps of the contaminant concentrations and the precision of concentration estimates.	More appropriate than other statistical sampling strategies because it takes into account spatial variability of media. Especially applicable to sites where presence of contamination is unknown.	Previous investigation data must be available and such data must be shown to have a spatial relationship.
Non-Statistical Sampling Strategies			
Biased Sampling	Sampling locations are chosen based on available information.	Sites with known contamination sources.	Contaminated areas can be overlooked if background information or visual signs of contamination do not indicate them. Best used if combined with a statistical approach, depending on the project objectives.
Judgmental Sampling	An individual subjectively selects sampling locations that appear to be representative of average conditions.	Homogenous, well-defined sites.	Not usually recommended due to bias imposed by individual, especially for final investigations.

003

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 immedately shipped back to the laboratory for preservation (adding soil sample into methanol and sodium bisulfite 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 inthe field using the disposable samplers, sealed and returned to the laboratory. A separate aliquot of soil is collected in a 125-mL container for dry weight determination.

3.2 SAMPLE CONTAINERS, PRESERVATION, HANDLING AND STORAGE

After sample collection, the disposable samplers must be cooled to and maintained at 4°C. The contents of the samplers will be analyzed using EPA methods 8015, 8021, and/or 8260. The **disposable** sampler is a single use device. It cannot be cleaned and/or reused.

Disposable samplers have a 48 hour holding time from sample collection to sample preparation in the laboratory. Return the samplers to the laboratory immediately after sampling.

3.3 SAMPLE PROCEDURES

Before sampling, the disposable sampler should be prepared as follows:

1. Unpack the cooler/sampling kit received from the laboratory. Disposable samplers are packed in sealed aluminized bags. These should be over packed in plastic zip lock bags. A T-Handle will also be needed to collect samples with the disposable sampler.
2. Hold coring body and push plunger rod down until small 0-ring rests against tabs. This will assure that plunger moves freely.
3. Depress locking lever on the sampler T-Handle (or other extraction device). Place coring body, plungers end first, into the open end of the T-Handle, aligning the two slots on the coring body with the two locking pins in the T-Handle. Twist the coring body clockwise to lock the pins in the slots. Check to ensure the sampler is locked in place. Sampler is ready for use.

The following procedure should be followed when using a disposable sampler to sample for VOCs in soil:

1. After the soil-sampling device (split spoon, corer, etc.) is opened, the sampling process should be completed in a minimum amount of time with the least amountof 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 notto trap air behind the sampler. When full, the small o-ring will be centered in the T-Handle viewing hole. Remove sampler from soil. Wipe excess soil from coring body exterior with a clean disposable paper towel.
5. Cap coring body while it is still on the T-Handle. ***<u>Push</u>*** cap over flat area of ridge ***<u>and twist</u>*** to lock cap in place. ***Cap must be seated to seal sampler.***
6. Remove the capped sampler by depressing locking lever on T-Handle while twisting and pulling sampler from T-Handle.
7. Lock plunger by rotating extended plunger rod fully counterclockwise until wings rest firmly against tabs.

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

3.4 QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

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

3.5 LIMITATIONS IN SAMPLING

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

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

En Novative Technologies, Inc. 2000. Users Manual for En Core® Sampler. February 2001.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3, 1 February.

USEPA. 1997. *Test Methods for Evaluating Solid Waste, Volume IB: Laboratory Manual Physical/Chemical Methods,* Third Edition, (as updated through update IIIA). Office of Solid Waste and Emergency Response, Washington, DC.

STANDARD OPERATING PROCEDURE 40.1
MULTIPARAMETER WATER QUALITY MONITORING INSTRUMENT

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operation with the multiparameter water quality logging system (data transmitter and visual display). This system can monitor up to eleven basic parameters, including dissolved oxygen, percent saturation, temperature, pH, specific conductance, resistivity, salinity, total dissolved solids, redox, level, and depth.

2.0 MATERIALS

- Visual display;
- Data transmitter;
- Underwater cables; and
- Field logbooks.

3.0 PROCEDURE

3.1 CALIBRATION

Calibration will be performed in the field daily before use according to manufacturer's specifications. The following parameters are calibrated to the following standards:

- Temperature—none required;
- Specific conductance—KCl or seawater standards;
- pH—pH 7 buffer plus a slope buffer;
- Dissolved oxygen—saturated air or saturated water;
- Redox—quinhydrone or transfer;
- Depth—set zero in air;
- Level—set zero in air; and
- Salinity—uses calibration for specific conductance.

3.2 OPERATION

1. Attach the cable to the transmitter.
2. Connect the other end of the cable to the display.
3. Press the On/Off key on the display panel. Allow a few seconds for the transmitter to start sending data to the display screen.
4. Calibrate the transmitter.
5. Deploy the sensor into a minimum of 4 in. of water.

6. Write data values from the display screen in the appropriate field logbook.
7. Retrieve sensor and clean the transmitter to prevent cross-contamination.
8. Move to the next sampling location. If travel time is great, turn off display by pressing On/Off key. Check condition of probes after each deployment.
9. Disconnect the transmitter when finished sampling for the day.

4.0 MAINTENANCE

Maintain according to specific manufacturer's specifications.

5.0 PRECAUTIONS

- Check condition of probes frequently between sampling; and
- Don't force pins into the connectors; note the keying sequence.

STANDARD OPERATING PROCEDURE 40.2
WATER LEVEL AND WELL-DEPTH MEASUREMENTS

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for measuring water level and well depth. This procedure is applicable to the sampling of monitoring wells and must be performed before any activities that may disturb the water level, such as purging or aquifer testing.

2.0 MATERIALS

- Work Plans;
- Well construction diagrams;
- Field logbook;
- Photoionization detector (PID) or other monitoring instruments per site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Electric water level indicator (dipmeter) with cable measured at 0.01 ft increments;
- Oil-water interface probe (if non-aqueous phase liquid (NAPLs) are suspected to be present); and
- Plastic sheeting.

3.0 PROCEDURE

3.1 PRELIMINARY STEPS

1. Locate the well and verify its position on the site map. Record whether positive identification was obtained, including the well number and any identifying marks or codes contained on the well casing or protective casing. Gain access to the top of the well casing.
2. Locate the permanent reference mark at the top of the casing. This reference point will be scribed, notched, or otherwise noted on the top of the casing. If no such marks are present, measure to the top of the highest point of the well casing and so note this fact in field logbook. Determine from the records and record in the notebook the elevation of this point.
3. Record any observations and remarks regarding the completion characteristics and well condition, such as evidence of cracked casing or surface seals, security of the well (locked cap), and evidence of tampering.
4. Keep all equipment and supplies protected from gross contamination; use clean plastic sheeting. Keep the water level indicator probe in its protective case when not in use.

3.2 OPERATION

1. Sample the air in the well head for gross organic vapors by lifting the well cap only high enough for an organic vapor meter (PID or FID) probe to be entered into the well casing. This will indicate the presence of gross volatile contaminants as well as indicating potential sampler exposure.

2. Remove cap. Allow well to vent for 60–90 seconds. Resample headspace. Record both readings. If the second reading is lower than the first, use the second reading to determining whether respiratory protection will be required during subsequent water level and well depth determinations and sampling.
3. Note that all headspace sampling must be performed at arm's length and from the upwind side of the well if possible.
4. If NAPL contamination is suspected, use an interface probe to determine the existence and thickness of NAPLs.
   - Open the probe housing, turn the probe on, and test the alarm. Slowly lower the probe into the well until the alarm sounds. A continuous alarm indicates a NAPL, while an intermittent alarm indicates water. If a NAPL is detected, record the initial level (first alarm). Mark the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable sufficiently to record the depth.
   - Continue to slowly lower the probe until it passes into the water phase. Slowly retract the probe until the NAPL alarm sounds and record that level in the manner as described above.
   - Record the thickness of the LNAPL (see Section 3.3.1).
   - Continue to slowly lower the interface probe through the water column to check for the presence of DNAPL.
   - Measure and record the thickness of the DNAPL layer (if any) as described above.
   - Slowly raise the interface probe, recording the depth to each interface as the probe is withdrawn. If there is a discrepancy in depths, clean the probe sensors and re-check the depths.
   - NOTE: Air-liquid interface depth is more reliable if probe is lowered into liquid. NAPL-water depths are more accurate if probe is moved from water into NAPL.
   - Always lower and raise interface probe slowly to prevent undue mixing of media.
   - Always perform NAPL check in wells installed in areas with suspected NAPL contamination. Always perform NAPL check if headspace test reveals presence of volatiles. Always perform NAPL check the first time a well is sampled. If a well has been sampled previously and no NAPLs were present and none of the proceeding conditions are met, the NAPL check may be omitted.
5. If no NAPL is present, use an electronic water level detector as follows.
   - Remove the water level indicator probe from the case, turn on the sounder, and test check the battery and sensitivity scale by pushing the red button. Adjust the sensitivity scale until you can hear the buzzer.
   - Slowly lower the probe and cable into the well, allowing the cable reel to unwind. Continue lowering until the meter buzzes. Very slowly, raise and lower the probe until the point is reached where the meter just buzzes. Marking the spot by grasping the cable with the thumb and forefingers at the top of the casing. If a mark is present on the casing, use the mark as the reference point. If no mark is present, use the highest point on the casing as the reference point. Withdraw the cable and record the depth.

6. To measure the well depth, lower electric water level indicator probe or tape until slack is noted. Very slowly raise and lower the cable until the exact bottom of the well is "felt." Measure (cable) or read the length (tape) and record the depth.
7. Note that if the electric water level indicator is used to determine depth of well, the offset distance between the tip of the probe and the electrode must be added to the reading to determine actual depth.
8. Withdraw the probe or tape.
9. Decontaminate the probe(s) and cable(s), in accordance with SOP 80.1.

3.3 DATA RECORDING AND MANIPULATION

Record the following information in the field logbook and appropriate sampling forms:

- Date and time;
- Weather;
- Method of measurement;
- Casing elevation;
- NAPL surface elevation = casing elevation - depth to NAPL;
- Apparent measured LNAPL thickness = depth to bottom of NAPL - depth to top of NAPL;
- Water level elevation = casing elevation - depth to water; and
- Well bottom elevation = casing elevation - depth to bottom (or read directly from tape).

4.0 CALIBRATION

No calibration is required. Ensure operability of electric water level indicator by testing sounder before use.

5.0 PRECAUTIONS

- Depending upon the device used, correction factors may be required for some measurements;
- Check instrument batteries before each use; and
- Exercise care not to break the seals at the top of the electric water level indicator probe.

6.0 REFERENCES

ASTM Standard D 4750-87. 1987. *Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).*

McAlary, T. A., and Barker, J.F. 1987. "Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials" in *Ground Water Monitoring Review.* Fall 1987.

Thornhill, Jerry T. 1989. *Accuracy of Depth to Groundwater Measurements;* in "EPA Superfund Ground Water Issue" EPA/540/4-89/002.

STANDARD OPERATING PROCEDURE 40.3
SLUG TESTS

1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide information and technical guidance for performing falling- and rising-head *in situ* hydraulic conductivity tests and data analyses. The slug test method involves causing a sudden change in head in a control well and measuring the water level response within that control well. Head change may be induced by suddenly injecting into the well or removing from the well a known quantity of water, rapid removal of a mechanical "slug" from below the water level, increasing or decreasing the air pressure in the well casing, or emplacement of a mechanical slug into the water column.

The water level response in the well is a function of the mass of water in the well and the transmissivity and coefficient of storage of the aquifer. The results of the slug test may be used to determine an estimate of the hydraulic conductivity of the aquifer material near the well.

2.0 MATERIALS

- Work Plans;
- Field logbook;
- Well construction information and boring log;
- Photoionization detector (PID) or other monitoring instruments per site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Aquifer test data sheets;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Slug-inducing equipment (solid slug, line, etc.) large enough to displace groundwater beyond the well filter pack.

3.0 PROCEDURE

Initially, an appropriate test methodology should be chosen. The selection of the appropriate test method (rising or falling head) is dependent primarily on saturated screen length, the well diameter, and the estimated hydraulic conductivity. If the screen extends above the water table, a rising-head test (water removal) should be used. The performance of a falling-head test (water added) in this circumstance would overstate the hydraulic conductivity value, as the measured response would reflect the equilibration rate of previously unsaturated material; unsaturated materials would equilibrate faster than saturated materials. When the measured water level in a monitoring well is above the screened portion of the well, a falling-head test methodology should be employed. A rising-head test may also be performed, but only if the initial water level reading (after the slug is removed) is above the screened interval.

For larger diameter and deeper wells, as a general rule and particularly for high conductivity materials, it is not feasible to remove a large enough slug or water volume to cause a sufficient change in head. In these cases the falling-head test method should be used.

It is recommended that a pressure transducer be used whenever possible to record water levels and time. A pressure transducer is required to record useful data when the hydraulic conductivity is high (greater than 10^{-3} cm/sec). The standard stopwatch and water-level indicator method is adequate for lower conductivity units.

The procedures outlined below assume use of a pressure transducer. Readings should be collected at intervals set on the data logger if used. If manual readings are collected, the following intervals should be applied:

- 0 to 5 minutes, every 10 seconds;
- 5 to 10 minutes, every 30 seconds;
- 10 to 30 minutes, every 1 minute; and
- 30 to 60 minutes, every 2 minutes.

3.1 Falling-Head Tests

1. Install pressure transducer near the total well depth and permit transducer and water levels to equilibrate to ambient conditions. Secure transducer cable to prevent movement during the test. Begin transducer readings.
2. Manually measure the static water level.
3. Insert slug completely below static water level or add a water "slug."
4. Intermittently measure water level and note the time of measurement with reference to the data logger.
5. Continue monitoring until water level is within 90% of the static level.

If a solid slug was used, stop the falling-head test recording at this point and begin a rising-head test by removing the solid slug from the well. If a solid slug was not used, simply end recording by the data logger at the completion of the falling-head test.

3.2 Rising-Head Tests

1. Install pressure transducer near the total well depth and permit transducer and water levels to equilibrate to ambient conditions. Secure transducer cable to prevent movement during testing.
2. Manually measure the static water level.
3. Remove sufficient volume of water to lower the water level a minimum of 1 ft below static water level, or
4. Install the solid slug fully below water level; permit static conditions to return and then remove the solid slug.
5. Begin readings with data logger.
6. Intermittently measure water level and note time of measurement with reference to data logger.
7. Continue monitoring until the water level is within 90% of the static level.

As a check on equipment operation and in the event that test data for a particular well are not usable, the data should be printed out in the field. If there is equipment failure (e.g., a non-attainment of a 1-foot minimum head change, unexplained fluctuations in water levels, etc.), the test can be rerun with minimum time lost.

The well numbers, static and subsequent water levels, programmed test numbers, and general comments should be recorded in the field notebook.

4.0 PRECAUTIONS

Not applicable.

5.0 REFERENCES

ASTM Standard D 4043-91. *Standard Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties of Well Techniques.*

Hvorslev, M.J. 1951. *Time-Lag and Soil Permeability in Ground Water Observations.* U.S. Army Engineers, Bulletin 36 - This method can be applied to both unconfined and confined aquifers but provides only approximate conductivity values (Freezer R.A. and J.A. Cherry, 1979, Groundwater, Prentice-Hall, Inc.).

Cooper, H.H., J.D. Bredehoeft, I.S. Papadopulos. 1967. *Response of a Finite-Diameter Well to an Instantaneous Charge of Water.* Water Resources Division, U.S. Department of the Interior Geological Survey, Vol. 3, No. 1 - This method can be applied to aquifers under confined conditions and requires that the well completely penetrate the aquifer. This method is believed to produce most reliable data when applied to low-permeability materials.

Bouwer, H. 1989. *The Bouwer and Rice Slug Test -- An Update.* Ground Water, Vol. 27, No. 3; and Bouwer, H. and R.C. Rice. 1976. *A Slug Test for Determining Hydraulic Conductivity of Unconfined Aquifers with Completely or Partially Penetrating Wells.* Water Resources Research, Vol. 12, No. 3 - This method takes into account additional well and aquifer configuration data points not considered by Hvorslev's more simplistic method. Computer analyses are available.

Nguyen, V., G.F. Pinder. 1984. *Direct Calculation of Aquifer Parameters in Slug Test Analyses, Groundwater Hydraulics.* American Geophysical Union Water Resources Monograph 9 - This method can be applied to partially penetrating wells in both confined and unconfined aquifers it produces better values for low- to moderate-permeability materials.

STANDARD OPERATING PROCEDURE 50.1
SAMPLE LABELS

1.0 SCOPE AND APPLICATION

Every sample will have a sample label uniquely identifying the sampling point and analysis parameters. The purpose of this standard operating procedure (SOP) is to delineate protocols for the use of sample labels. An example label is included as Figure 50.1-A. Other formats with similar levels of detail are acceptable.

2.0 MATERIALS

- Sample label; and
- Indelible marker.

3.0 PROCEDURE

The use of preprinted sample labels is encouraged and should be requested from the analytical support laboratory during planning activities.
As each sample is collected, fill out a sample label ensuring the following information has been collected:

- Project name;
- Sample ID: enter the SWMU number and other pertinent information concerning where the sample was taken. This information should be included in site-specific work plan addenda;
- Date of sample collection;
- Time of sample collection;
- Initials of sampler(s);
- Analyses to be performed (NOTE: Due to number of analytes, details of analysis should be arranged with lab *a priori*); and
- Preservatives (water samples only).

Double-check the label information to make sure it is correct. Detach the label, remove the backing and apply the label to the sample container. Cover the label with clear tape, ensuring that the tape completely encircles the container.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

None.

6.0 REFERENCES

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

FIGURE 50.1-A
SAMPLE LABEL

PROJECT NAME ______________________

SAMPLE ID _______________________

DATE: ___/___/___ TIME: ____:____

ANALYTES: VOC SVOC P/P METALS CN
PAH D/F HERBs ANIONS TPH
ALK TSS

PRESERVATIVE: [HCl] [HNO_3] [NaOH] [H_2SO_4]

SAMPLER: _________________

STANDARD OPERATING PROCEDURE 50.2
SAMPLE PACKAGING

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the packing and shipping of samples to the laboratory for analysis.

2.0 MATERIALS

- Waterproof coolers (hard plastic or metal);
- Metal cans with friction-seal lids (e.g., paint cans);
- Chain-of-custody forms;
- Chain-of-custody seals (optional);
- Packing material;
- Sample documentation;
- Ice;
- Plastic garbage bags;
- Clear Tape;
- Zip-top plastic bags; and
- Temperature blanks provided by laboratory for each shipment.

3.0 PROCEDURE

1. Check cap tightness and verify that clear tape covers label and encircles container.
2. Wrap sample container in bubble wrap or closed cell foam sheets. Samples may be enclosed in a secondary container consisting of a clear zip-top plastic bag. Sample containers must be positioned upright and in such a manner that they will not touch during shipment.
3. Place several layers of bubble wrap, or at least 1 in. of vermiculite on the bottom of the cooler. Line cooler with open garbage bag, place all the samples upright inside the garbage bag and tie.
4. Double bag and seal loose ice to prevent melting ice from soaking the packing material. Place the ice outside the garbage bags containing the samples.
5. Pack shipping containers with packing material (closed-cell foam, vermiculite, or bubble wrap). Place this packing material around the sample bottles or metal cans to avoid breakage during shipment.
6. A temperature blank (provided by laboratory) will be included in each shipping container to monitor the internal temperature. Samples should be cooled to 4 degrees C on ice immediately after sampling.

7. Enclose all sample documentation (i.e., Field Parameter Forms, Chain-of-Custody forms) in a waterproof plastic bag and tape the bag to the underside of the cooler lid. If more than one cooler is being used, each cooler will have its own documentation. Add the total number of shipping containers included in each shipment on the chain-of-custody form.
8. Seal the coolers with signed and dated custody seals so that if the cooler were opened, the custody seal would be broken. Place clear tape over the custody seal to prevent damage to the seal.
9. Tape the cooler shut with packing tape over the hinges and place tape over the cooler drain.
10. Ship all samples via overnight delivery on the same day they are collected if possible.

4.0 MAINTENANCE

Not applicable.

5.0 PRECAUTIONS

5.1 PERMISSIBLE PACKAGING MATERIALS

- Non-absorbent
  - Bubble wrap; and
  - Closed cell foam packing sheets.
- Absorbent
  - Vermiculite.

5.2 NON-PERMISSIBLE PACKAGING MATERIALS

- Paper;
- Wood shavings (excelsior); and
- Cornstarch “peanuts”.

6.0 REFERENCES

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

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

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

STANDARD OPERATING PROCEDURE 70.1
INVESTIGATION-DERIVED MATERIAL

1.0 SCOPE AND APPLICATION

Management of investigation-derived material (IDM) minimizes the potential for the spread of waste material onsite or offsite through investigation activities. The purpose of this standard operating procedure (SOP) is to provide general guidelines for appropriate management of potentially contaminated materials derived from the field investigations. Specific procedures related to the transportation and disposal of hazardous waste are beyond the scope of this SOP.

2.0 INTRODUCTION

Investigation derived material (IDM) consists of waste materials that are known or suspected to be contaminated with waste substances through the actions of sample collection or personnel and equipment decontamination. These materials include decontamination solutions, disposable equipment, drill cuttings and fluids, and water from groundwater monitoring well development and purging. To the extent possible, the site manager will attempt to minimize the generation of these materials through careful design of decontamination schemes and groundwater sampling programs. Testing conducted on soil and water investigation-derived material will show if they are also hazardous wastes as defined by RCRA. This will determine the proper handling and ultimate disposal requirements.

The criteria for designating a substance as hazardous waste according to RCRA is provided in 40 CFR 261.3. If IDM meet these criteria, RCRA requirements will be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR 262.34. Those materials that are judged potentially to meet the criteria for a regulated solid or hazardous waste will be placed in DOT-approved 55-gallon steel drums or another type of DOT approved container, based on waste characteristics and volume.
Investigation-derived material will be appropriately placed in containers, labeled, and tested to determine disposal options in accordance with RCRA regulations and Virginia Hazardous Waste Management Regulations.

3.0 INVESTIGATION-DERIVED MATERIAL MANAGEMENT

Procedures that minimize potential for the spread of waste material include minimizing the volume of material generated, material segregation, appropriate storage, and disposal according to RCRA requirements.

3.1 WASTE MINIMIZATION

In the development of work plan addenda, each aspect of the investigation will be reviewed to identify areas where excess waste generation can be eliminated. General procedures that will eliminate waste include avoidance of unnecessary exposure of materials to hazardous material and coordination of sampling schedules to avoid repetitious purging of wells and use of sampling equipment.

3.2 WASTE SEGREGATION

Waste accumulation and management procedures to be used depend upon the type of material generated. For this reason, IDM described below are segregated into separate 55-gallon storage drums or other appropriate DOT containers. Waste materials that are known to be free of potential hazardous waste contamination (such as broken sample bottles or equipment containers and wrappings) must be collected separately for disposal to municipal systems. Large plastic garbage or "lawn and leaf" bags are useful for collecting this trash. Even "clean" sample bottles or Tyvek should be disposed of with care. Although they are not legally a problem, if they are discovered by the public they may cause concern. Therefore, items that are known to be free from contamination but are also known to represent "hazardous or toxic waste" to the public must not be disposed of in any public trash receptacle, such as found at your hotel or park.

3.2.1 Decontamination Solutions

Solutions considered investigation-derived materials range from detergents, organic solvents, and acids used to decontaminate small hand samplers to steam-cleaning rinsate used to wash drill rigs and other large equipment. These solutions are to be placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT approved containers. Residual liquid IDM from decontamination pads will be removed and appropriately placed in container(s) at the end of each field day.

3.2.2 Soil Cuttings and Drilling Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities or drilling for the collection of subsurface soil samples or the installation of monitoring wells. Depending on the type of drilling, drilling fluids known as "muds" may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Drill cuttings, whether generated with or without drilling fluids, are to be removed with a flat-bottomed shovel and placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT containers, as conditions or volume of IDM dictate.

3.2.3 Well Development and Purge Water

Well development and purge water is removed from monitoring wells to repair damage to the aquifer following well installation, obtain characteristic aquifer groundwater samples, or measure aquifer hydraulic properties. The volume of groundwater to be generated will determine the appropriate container to be used for accumulation of IDM.

For well development and purging, 55-gallon drums are typically an efficient container for accumulation. When larger volumes of water are removed from wells, such as when pumping tests are conducted, the use of large-volume portable tanks such as "Baker Tanks" should be considered for IDM accumulation.

Analytical data for groundwater samples associated with the well development and purge water will be used to assist in characterizing IDM and evaluating disposal options.

3.2.4 Personal Protective Equipment and Disposable Sampling Equipment

Personal protective equipment and clothing (PPE) may include such items as Tyvek coveralls, gloves, booties, and APR cartridges. Disposable sampling equipment may include such items as plastic sheeting, bailers, disposable filters, disposable tubing and paper towels. PPE and disposable sampling equipment that have or may have contacted contaminated media (soil, water, etc.) will be segregated and placed in 55-gallon drums separate from soil and water IDM. Disposition of this type of IDM will be determined by the results of IDM testing of the media in which the PPE and sampling equipment contacted.

3.3 MATERIAL ACCUMULATION

The IDM in containers must be placed in an appropriate designated RCRA container accumulation area at RFAAP, where it is permissible to accumulate such waste. IDM placed into a designated 90-day accumulation area will be properly sealed, labeled and covered. All drums will be placed on pallets.

A secure and controlled waste staging area will be designated by the installation prior the commencement of field sampling activities. Per the facility's requirements as a RCRA large quantity generator, waste accumulation cannot exceed 90 days for materials presumed or shown to be RCRA-designated hazardous wastes; waste which is known not to be RCRA-designated waste should be promptly disposed to municipal waste systems or appropriate facility.

3.3.1 IDM Accumulation Containers

Containers will be DOT-approved (DOT 17H 18/16GA OH unlined) open-head steel drums or other DOT approved container, as appropriate.

Container lids should lift completely off be secured by a bolt ring (for drum). Order enough containers to accumulate all streams of expected IDM including soil, PPE and disposable sampling equipment, decontamination water, purge water, etc.

Solid and liquid waste streams will not be mixed in a container. PPE and expendable sampling equipment will be segregated from other IDM and placed in different containers than soil. Containers inside containers are not permitted. PPE must be placed directly in a drum not in a plastic bag.

Pallets are often required to allow transport of filled drums to the staging area with a forklift. Normal pallets are 3×4 ft and will hold two to three 55-gallon drums depending on the filled weight. If pallets are required for drum transport or storage, field personnel are responsible for ensuring that the empty drums are placed on pallets before they are filled and that the lids are sealed on with the bolt-tighten ring after the drums are filled. Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move the drums by hand.

3.3.2 Container Labeling

Each container that is used to accumulate IDM will be appropriately labeled at the time of accumulation and assigned a unique identification number for tracking purposes. The following information will be written in permanent marker on a drum label affixed on the exterior side at a location at least two-thirds of the way up from the bottom of the drum.

- Facility name.
- Accumulation start date and completion date.
- Site identifier information (SWMU, boring, well, etc.).
- Description of IDM.
- Drum ID No.

4.0 MATERIAL CHARACTERIZATION AND DISPOSAL

IDM will be characterized and tested to determine whether it is a hazardous waste as defined by 40 CFR Part 261 and to determine what disposal options exist in accordance with RCRA regulations and the Virginia Hazardous Waste Management Regulations (VHWMR).

In general, IDM will be considered a hazardous waste if it contains a listed hazardous waste or if the IDM exhibits a characteristic of hazardous waste.

Work plan addenda will identify the appropriate characterization and testing program for IDM based on the following:

- Site-specific conditions related to chemicals of concern, etc.
- The nature and quantity of expected IDM to be generated during site-specific investigations.
- Applicable Federal, State, and local regulations, such as RCRA, VHWMR regulations and policies and procedures, and Army Regulation 200-1.
- RFAAP specific requirements and policies for IDM characterization and disposal at the time of the investigation.

In general, appropriate USEPA SW 846 Test Methods for Evaluating Solid Waste will be used for testing IDM and will be specified in work plan addenda. Other appropriate test methods may be specified by RFAAP in addition to SW 846 Methods that are specific to installation operations, the site of interest (percent explosive content, reactivity, etc.), or requirements for disposal at RFAAP water treatment facilities or publicly owned treatment works.

Responsibility for the final disposal of IDM will be determined before field activities are begun and will be described in work plan addenda. Off-site disposal of IDM will be coordinated with RFAAP (generator) to ensure appropriate disposition. The contractor will coordinate IDM transportation and disposal activities for RFAAP (generator).

At the direction of RFAAP, appropriate waste manifests will be prepared by the USACE contractor or Alliant Techsystems subcontractor for transportation and disposal. Alliant Techsystems or other appropriate RFAAP entity will be listed as the generator and an appointed representative from RFAAP will review and sign the manifest for offsite disposal.

RFAAP will make the final decision on the selection of the transporter, storage, and disposal facility (TSDFs) or recycling facility. RFAAP will provide the contractor a listing of previously used TSDFs for priority consideration. Proposed facilities that are not included on the listing arerequired to provide a copy of the TSDFs most recent state or federal inspection to the installation. Waste characterization and testing results will be submitted to RFAAP (generator) for review and approval before final disposition of the material.

Hazardous waste: Prior to final disposition, a hazardous waste manifest will be furnished by the TSDF to accompany transport to the disposal facility. Following final disposition, a certificate of disposal will be furnished by the disposal facility. Copies of the manifests and certificates of disposal are to be provided to RFAAP and retained on file by the contractor or subcontractor.

4.0 PRECAUTIONS

- Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move drums by hand.
- Refer to the site-specific health and safety plan when managing IDM.

5.0 REFERENCES

Safety Rules for Contractors and Subcontractors, 1995. Alliant Techsystems, Incorporated, Radford Army Ammunition Plant.

STANDARD OPERATING PROCEDURE 80.1
DECONTAMINATION

1.0 SCOPE AND APPLICATION

Before leaving the site, all personnel or equipment involved in intrusive sampling or having entered a hazardous waste site during intrusive sampling must be thoroughly decontaminated to prevent adverse health effects and minimize the spread of contamination. Equipment must be decontaminated between sites to preclude cross-contamination. Decontamination water will be free of contaminants as evidenced through either chemical analyses or certificates of analysis. This standard operating procedure (SOP) describes general decontamination requirements for site personnel and sampling equipment. Decontamination procedures for contaminants requiring a more stringent procedure, e.g., dioxins/furans, will be included in site-specific addenda.

2.0 MATERIALS

- Plastic sheeting, buckets or tubs, pressure sprayer, rinse bottles, and brushes;
- U.S. Army Corps of Engineers or installation approved decontamination water source;
- Deionized ultra-filtered, HPLC-grade organic free water (DIUF);
- Non-phosphate laboratory detergent;
- Nitric Acid, 0.1 Normal (N) solution;
- Pesticide-grade solvent, Methanol;
- Aluminum foil;
- Paper towels;
- Plastic garbage bags; and
- Appropriate containers for management of investigation-derived material (IDM).

3.0 PROCEDURE

3.1 SAMPLE BOTTLES

At the completion of each sampling activity the exterior surfaces of the sample bottles must be decontaminated as follows:

- Be sure that the bottle lids are on tight.
- Wipe the outside of the bottle with a paper towel to remove gross contamination.

3.2 PERSONNEL DECONTAMINATION

Review the site-specific health and safety plan for the appropriate decontamination procedures.

3.3 EQUIPMENT DECONTAMINATION

3.3.1 Drilling Rigs

Drilling rigs and associated equipment, such as augers, drill casing, rods, samplers, tools, recirculation tank, and water tank (inside and out), will be decontaminated before site entry, after over-the-road mobilization and immediately upon departure from a site after drilling a hole. Supplementary cleaning will be performed before site entry. There is a likelihood that contamination has accumulated on tires and as spatter or dust en route from one site to the next.

1. Place contaminated equipment in an enclosure designed to contain all decontamination residues (water, sludge, etc.).
2. Steam-clean equipment until all dirt, mud, grease, asphaltic, bituminous, or other encrusting coating materials (with the exception of manufacturer-applied paint) has been removed.
3. Water used will be taken from an approved source.
4. When cross-contamination from metals is a concern, rinse sampling components such as split spoons, geo-punch stems, and augers with nitric acid, 0.1N.
5. Rinse with DIUF water.
6. When semi-volatile and non-volatile organics may be present, rinse the sampling components with pesticide-grade solvent methanol.
7. Double rinse the sampling components with DIUF water.
8. Decontamination residues and fluids will be appropriately managed as IDM per work plan addenda and SOP 80.1.

3.3.2 Well Casing and Screen

Prior to use, well casing and screen materials will be decontaminated. This activity will be performed in the leak proof, decontamination pad, which will be constructed prior to commencement of the field investigation. The decontamination process will include:

- Steam cleaning with approved source water.
- Rinse with DUIF water.
- Air-dry on plastic sheeting.
- Wrap in plastic sheeting to prevent contamination during storage/transit.

3.3.3 Non Dedicated Submersible Pumps Used for Purging and Sampling

1. Scrub the exterior of the pump to remove gross (visible) contamination using appropriate brushes, approved water, and non-phosphate detergent (steam cleaning may be substituted for detergent scrub).
2. Pump an appropriate amount of laboratory detergent solution (minimum 10 gallons) to purge and clean the interior of the pump.
3. Rinse by pumping no less than 10 gallons of approved water to rinse.
4. Rinse the pump exterior with approved decontamination water.
5. When cross-contamination from metals is a concern, rinse the pump exterior with approved nitric acid 0.1N solution.

6. Rinse the pump exterior with DIUF water.
7. When semi-volatile and non-volatile organics may be present, rinse the pump exterior with pesticide-grade solvent methanol.
8. Double rinse the pump exterior with DIUF water.
9. Air-dry on aluminum foil or clean plastic sheeting.
10. Wrap pump in aluminum foil or clean plastic sheeting, or store in a clean, dedicated PVC or PTFE storage container.
11. Solutions and residuals generated from decontamination activities will be managed appropriately as IDM per work plan addenda and SOP 80.1.

3.3.4 Sample Equipment and Measuring Water Level Devices

1. Scrub the equipment to remove gross (visible) contamination using appropriate brush (es), approved water, and non-phosphate detergent.
2. Rinse with approved source water.
3. When cross-contamination from metals is a concern, rinse the sampling equipment with approved nitric acid 0.1N solution.
4. Rinse equipment with DIUF water.
5. When semi-volatile and non-volatile organics may be present, rinse the sampling equipment with pesticide-grade solvent methanol.
6. Double rinse the sampling equipment with DIUF water.
7. Air-dry on aluminum foil or clean plastic sheeting.
8. Wrap in aluminum foil, clean plastic sheeting, or zip top bag or store in a clean, dedicated PVC or PTFE storage container.
9. Solutions and residuals generated from decontamination activities will be managed appropriately as IDM per work plan addenda and SOP 80.1.

3.3.5 Other Sampling and Measurement Probes

Temperature, pH, conductivity, Redox, and dissolved oxygen probes will be decontaminated according to manufacturer's specifications. If no such specifications exist, remove gross contamination and triple-rinse probe with DIUF water.

4.0 PRECAUTIONS

- Manage IDM appropriately according to the requirements specified in work plan addenda.
- Follow appropriate procedures as specified in the site-specific health and safety plan.

5.0 REFERENCES

USACE. 2001. Requirements for the Preparation of Sampling and Analysis Plans. EM 200-1-3. 1 February.

STANDARD OPERATING PROCEDURE 90.1
PHOTOIONIZATION DETECTOR (HNu Model PI–101 and HW–101)

1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for field operations with a photoionization detector (HNu Systems Model PI–101 or HW–101). The photoionization detector (PID) detects total ionizables; hence it is used to monitor both organic and inorganic vapors and gases to determine relative concentrations of air contaminants. This information is used to establish level of protection and other control measures such as action levels. The PID cannot effectively detect compounds having ionization potentials above the photon energy level of the lamp used; therefore, methane, which has an ionization potential of 12.98 eV, is undetectable by PIDs because the lamps produce 9.5, 10.2, or 11.7 eV.

Use of brand names in this SOP is in not intended as an endorsement or mandate that a given brand be used. Alternate equivalent brands of detectors, sensors, meters, etc., are acceptable. If alternate equipment is to be used, the contractor shall provide applicable and comparable SOPs for its maintenance and calibration.

2.0 MATERIALS

- HNu Systems Model PI–101 or HW–101 survey probe with 9.5, 10.2, or 11.7 eV lamp;
- Lead-acid gel-cell battery;
- Calibration gas (e.g., isobutylene, 101 ppm) with regulator;
- Tygon tubing;
- Tedlar bag (optional);
- Instrument logbook; and
- Field logbook.

3.0 PROCEDURE

These procedures are to be followed when using the HNu in the field.

3.1 STARTUP

1. Before attaching the probe, check the function switch on the control panel to ensure that it is in the off position. Attach the probe by plugging it into the interface on the top of the readout module.
2. Turn the function switch to the battery check position. The needle on the meter should read within or above the green battery arc on the scale; if not, recharge the battery. If the red indicator light comes on, the battery needs recharging or service may be indicated.
3. Turn the function switch to any range setting. Listen for the hum of the fan motor. Check meter function by holding a solvent-based marker pen near the sample intake. If there is no needle deflection, look briefly into the end of the probe (no more than 1 or 2 sec) to see if the lamp is on; if it is on, it will give a purple glow. Do not stare into the probe any longer than 2 sec. Long-term exposure to UV light can damage the eyes. (See further information in Section 5.)

4. To zero the instrument, turn the function switch to the standby position and rotate the zero adjustment until the meter reads zero. A calibration gas is not needed since this is an electronic zero adjustment. If the span adjustment setting is changed after the zero is set, the zero should be rechecked and adjusted if necessary. Allow the instrument to warm up for 3–5 min to ensure that the zero reading is stable. If necessary, readjust the zero.

3.2 OPERATIONAL CHECK

Follow the startup procedure in Section 3.1.
With the instrument set on the 0–20 range, hold a solvent-based marker near the probe tip. If the meter deflects upscale, the instrument is working.

3.3 FIELD CALIBRATION PROCEDURE

1. Follow the startup procedures in Section 3.1 and the operational check in Section 3.2.
2. Set the function switch to the range setting for the concentration of the calibration gas.
3. Attach a regulator HNu P/N 101-351 or equivalent (flow = 200 to 300 ml/min) to a disposable cylinder of isobutylene (HNu 101-351 or equivalent). Connect the regulator to the probe of the HNu with a piece of clean Tygon tubing. Turn on the valve of the regulator.
4. After 5 sec, adjust the span dial until the meter reading equals the benzene concentration of the calibration gas used, corrected to its equivalence, which should be marked on the canister (Isobutylene ~0.7X benzene).
5. Record in the field log the instrument ID No., serial No., initial and final span settings, date, time, location, concentration and type of calibration gas used, and the signature of the person who calibrated the instrument.
6. If the HNu does not function or calibrate properly, the project equipment manager is to be notified as soon as possible. Under no circumstances is work requiring monitoring with a PI–101 or HW–101 to be done with a malfunctioning instrument.

3.4 CALIBRATION TO A GAS OTHER THAN ISOBUTYLENE

The HNu may be calibrated to any certified calibration gas. However, after calibration, all subsequent instrument readings will be relative to the calibration gas used. General procedures include the following:

1. Calibrate according to procedure 3.3.
2. Partially fill and flush one-to-two times a gas bag (Tedlar recommended) with the certified National Institute of Standards and Technology (NIST) (formerly NBS) traceable calibration gas. Then fill the bag with 1–3 L of the calibration gas. If the gas is toxic, this must be done in a fume hood.
3. Feed the calibration gas into the probe with the range set for the value of the gas. After 5 sec, adjust the span control until the meter reads the value of the calibration gas.
4. Record the results of the calibration on the calibration/maintenance log and attach a new calibration sticker (if available) or correct the existing sticker to reflect the new calibration data. All subsequent readings will be relative to the new calibration gas.

3.5 OPERATION

1. Follow the startup procedure, operational check, and calibration check (refer to Section 3.1).

2. Set the function switch to the appropriate range. If the concentration of gas vapors is unknown, set the function switch to 0-20 ppm range. Adjust if necessary.
3. Prevent exposing the HNu to excessive moisture, dirt, or contaminant while monitoring the work activity as specified in the Site Health and Safety Plan.
4. When the activity is completed, or at the end of the day, carefully clean the outside of the HNu with a damp disposable towel to remove all visible dirt. Return the HNu to a secure area and place on charge. Charge after each use; the lead acid batteries cannot be ruined by over charging.
5. With the exception of the probe's inlet and exhaust, the HNu can be wrapped in clear plastic to prevent it from becoming contaminated and to prevent water from getting inside in the event of precipitation. If the instrument becomes contaminated, make sure to take necessary steps to decontaminate it. Call the Equipment Administrator if necessary; under no circumstances should an instrument be returned from the field in a contaminated condition.

4.0 MAINTENANCE

Calibration/maintenance logs are to be filled in completely whenever a PI-101 or HW-101 receives servicing. This is true of both contractor-owned and rental instruments.

The equipment manager should be called to arrange for a fresh instrument when necessary. The contractor's equipment facility is responsible for arranging all repairs that cannot be performed by the project equipment manager.

4.1 ROUTINE SERVICE

The PID's performance is affected by a number of factors. These include but are not limited to the decay of the UV lamp output over time and the accumulation of dust and other particulate material and contaminates on the lamp and in the ion chamber. Because of these factors, the PID should not be left in the field for a period of more than 2 weeks before being replaced with a fresh instrument. If a site is going to be inactive for a period of more than a week, all monitoring instruments are to be returned to the project equipment manager or his trained designee for servicing and/or reassignment. The following procedures are to be performed at the designated intervals for routine service.

Procedure	Frequency
Operational check	Before use and at instrument return
Field calibration	Before use and at instrument return
Full calibration	Bi-weekly (return instrument to equipment manager for replacement with a fresh unit)
Clean UV lamp and	Bi-weekly or as needed ion chamber
Replace UV Lamp	As needed

4.1.1 UV Lamp and Ion Chamber Cleaning

During periods of analyzer operation, dust and other foreign materials are drawn into the probe forming deposits on the surface of the UV lamp and in the ion chamber. This condition is indicated by meter readings that are low, erratic, unstable, non-repeatable, or drifting and show apparent moisture sensitivity. These deposits interfere with the ionization process and cause erroneous readings. Check for this condition regularly to ensure that the HNu is functioning properly. If the instrument is malfunctioning, call your equipment manager to arrange to have a fresh replacement.

4.1.2 Lamp eV Change

If different applications for the analyzer would require different eV lamps, separate probes, each with its own eV lamp, must be used. A single readout assembly will serve for any of the probes (9.5, 10.2, and 11.7 eV). A change in probe will require resetting of the zero control and recalibrating the instrument. The 11.7 eV lamp will detect more compounds than either of the two lower eV lamps. However, the 11.7 eV probe needs more frequent calibration; it burns out much faster than the lower eV lamps.

5.0 PRECAUTIONS

- The HNu PI–101 and HW–101 are designed to sample air or vapors only. *Do not allow any liquids or low boiling vapors to get into the probe or meter assembly.*
- High concentrations of any gas can cause erroneous readings. High humidity can also cause the instrument readings to vary significantly from the actual concentration of gases or vapors present. This is true even through the HNu cannot react to water vapor.
- High humidity, dust, and exposure to concentrations of low boiling vapors will contaminate the ion chamber, causing a steady decrease in sensitivity.
- Continued exposure to ultraviolet light generated by the light source can be harmful to eyesight. If a visual check of the UV lamp is performed *do not look at the light source from a distance closer than 6 inches with unprotected eyes.* Use eye protection (UV-blocking sunglasses or safety glasses). Only look briefly—never more than about 2 sec.

Place the instrument on charge after each use; the lead batteries cannot be ruined by over charging.

- If at any time the instrument does not check out or calibrate properly in the field, the equipment manager is to be notified immediately and a replacement obtained for the malfunctioning instrument. Under no circumstances should fieldwork requiring continuous air monitoring for organic vapors and/or gases be done with a malfunctioning Hnu or without a HNu or an approved comparable instrument.

6.0 REFERENCES

Manufacturer's Equipment Manual.

APPENDIX B

SOIL COMPOSITE DATA, PARALLAX (1999)

Appe[illegible]B-1: Metals
Summary o[illegible]Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in mg/kg

Sample ID	Excavated Cell	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
54SC-A-003		Jun-99	12400	<1.1	1.6 B	124	<0.67	<0.67	1640	20.0	6.1 B	9.8	17000	10.7	2910	447	<0.03	12.6	1370	<1.1	<0.67	<223	<2.2	25.5	64.8
54SC-A-004		Jun-99	17000	<1.1	2.2 B	160	0.85	<0.67	2150	24.2	10.2 B	12.8	21200	17	3510	627	<0.03	18	1710	<1.1	<0.87	<223	<2.2	33.4	89.1
54SC-A-005		Jun-99	15400	<1.3	2.5 B	156	0.9 B	<0.78	1940	23.5	10.1 B	12.6	21200	11.9	3310	566	<0.04	15.2	1530	<1.3	<0.76	<253	<2.5	32.6	79.1
54SC-A-006		Jun-99	14000	<1.0	2.6	172	0.81 B	<0.62	4970	22.0	8.3 B	10.8	19500	19.7	4780	477	<0.04	14.4	1480	<1.0	<0.62	<207	<2.1	28.2	83.2
54SC-A-007		Jun-99	13200	<1.1	2.4	158	0.84 B	0.96 B	9740	23.8	8.7 B	27.2	21100	160	8010	575	0.18	15.8	1310	<1.1	<0.65	<217	<2.2	27.8	146
54SC-A-008		Jun-99	13400	<1.1	2.1 B	136	0.85	<0.65	2030	22.6	9.1 B	16.2	20100	78.5	3520	462	0.05	14.3	1370	<1.1	<0.65	<218	<2.2	28.7	77.0
54SC-A-009	yes	no data provided																							
54SC-A-010*		Jun-99	14400	<0.80	1.9	143	0.87	<0.48	1760	22.1	9.6	11.9	21300	10.2	3270	540	<0.04	14.4	1350	<0.80	<0.48	<160	<1.6	31.8	70.0
54SC-A-011		Jun-99	12700	<1.1	1.8 B	140	0.77 B	<0.84	1830	20.5	8.4 B	10.9	18000	12.2	2820	516	<0.04	13	1470	<1.1	<0.64	<212	<2.1	28	75.1
54SC-A-012		Jun-99	13600	<1.1	2.0 B	148	0.79 B	<0.66	1920	21.9	9 B	12.6	19000	9.9	3330	534	<0.03	13.6	1450	<1.1	<0.66	<220	<2.2	29.4	71.7
54SC-A-013		Jun-99	17500	<0.98	2.0	181	0.96	<0.59	2150	24.5	10.2	13.5	21600	12.1	3380	666	0.04	18.8	1690	<0.98	<0.59	<198	<2.0	33.1	78.6
54SC-A-014		Jun-99	18900	<1.1	2.9	185	1 B	0.8 B	2160	27.4	11.1	15.7	27900	59.3	3500	832	<0.04	17.6	1730	<1.1	<0.69	<229	<2.3	39.7	215
54SC-A-019		Jun-99	15400	<1.2	2.2 B	148	0.77	<0.72	1970	23.2	9.7 B	12	20200	15.3	3450	563	<0.04	15.2	1600	<1.2	<0.72	<240	<2.4	30.5	84.4
54SC-A-020		Jun-99	9780	<0.79	2.0	114	0.85 B	<0.48	1890	16.8	7.2 B	8.9	16100	10.9	2850	423	<0.03	11.1	1120	<0.79	<0.48	<159	<1.6	22.3	68.8
54SC-A-021		Jun-99	9020	<1.1	2.0 B	102	<0.88	<0.68	1080 B	18.0	8 B	8.8	16700	10.1	2630	492	<0.04	10.5	1110 B	<1.1	<0.68	<227	<2.3	22.2	63.1
54SC-A-022		Jun-99	12800	<0.85	2.0	134	0.79 B	<0.51	1520	21.4	9	11.4	19800	14.5	3260	530	<0.04	14	1410	<0.85	<0.51	<169	<1.7	28.9	85.4
54SC-A-023		Jun-99	11100	<1.0	2.4	118	0.87 B	<0.62	1280	18.6	7.8 B	9.5	17400	21.6	2700	513	<0.04	11.6	1230	<1.0	<0.62	<208	<2.1	24.5	101
54SC-A-024		Jun-99	9970	<1.1	1.6 B	100	<0.68	<0.68	1350	18.1	7.2 B	8.4	15300	18.6	2880	399	<0.04	10.8	1280	<1.1	<0.68	<227	<2.3	21.2	77.1
54SC-A-025		Jun-99	11400	<1.1	2.4	133	0.71 B	<0.68	1880	19.8	7.7 B	18.9	20200	126	2730	596	0.14	12.4	1600	<1.1	<0.68	<226	<2.3	24.7	190
54SC-A-026	yes	Jun-99	13600	<0.65	2.4	138	0.63 B	1.9	3680	27.7	6.6 B	53.2	17700	556	2930	424	0.44	13.7	1540	<0.85	<0.51	1130	<1.7	23.8	701
54SC-A-027		Jun-99	16900	<1.1	2.3	155	0.97 B	<0.66	2410	24.2	10.8 B	19.3	23200	64.2	3710	654	<0.03	18.8	1790	<1.1	<0.66	<219	<2.2	36.0	95.2
54SC-A-028		Jun-99	12800	<1.1	2.0 B	109	<0.64	<0.64	1700	20.0	8.3 B	9.3	17100	9.2	2940	395	<0.04	12.5	1520	<1.1	<0.64	<213	<2.1	27.6	59.2
54SC-A-029		Jun-99	11800	<0.93	1.4 B	190	0.56 B	<0.56	47300	19.0	7.5	7.0	18400	9.0	9970	456	<0.04	16.4	1330	<0.93	<0.56	<185	<1.9	20.6	50.7
54SC-A-030		Jun-99	10600	<1.2	1.3 B	105	<0.74	<0.74	1400	19.2	7.9 B	9.0	17100	6.1	2800	369	<0.04	11.0	1370	<1.2	<0.74	<246	<2.5	25.3	55.6
54SC-A-031		Jun-99	12700	<0.90	1.5 B	120	0.67 B	<0.54	1670	20.5	8.5 B	9.7	18200	9	2980	449	<0.04	12.4	1360	<0.90	<0.54	<160	<1.8	28	60.1
54SC-A-032		Jun-99	12200	<0.97	1.3 B	103	0.63 B	<0.56	1520	16.4	7.9 B	9.2	16500	7.4	2700	420	<0.04	11.5	1420	<0.97	<0.58	<193	<1.9	26.7	54.5
54SC-A-033		Jun-99	9910	<0.97	1.1 B	78.9	<0.56	<0.56	1460	15.8	6 B	7.2	13500	7.2	2200	307	<0.04	9.3	1150	<0.97	<0.58	<194	<1.9	21.3	43.3
54SC-A-034		Jun-99	8330	<1.1	1.8	67.9	<0.64	<0.64	1110	13.9	5.2 B	6.2	12200	10.6	1820	278	<0.04	8.1 B	1030 B	<1.1	<0.64	<212	<2.1	19	50.3
54SC-A-040		Jun-99	9600	<1.0	1.8 B	102	<0.61	<0.61	1370	15.8	6.6 B	8.2	14400	11.2	2390	375	<0.03	10	1180	<1.0	<0.61	<204	<2.0	21.4	63
54SC-A-041		Jun-99	9620	<0.95	1.7 B	101	0.6 B	<0.57	1290	15.8	6.6 B	8.0	15000	12.8	2420	383	<0.04	10.2	1070	<0.95	<0.57	<190	<1.9	20.6	64.8
54SC-A-042		Jun-99	10200	<0.88	1.4 B	94.5	0.56	<0.53	1450	16.4	6.7	6.1	14800	13.0	2440	362	<0.04	10.5	1260	<0.88	<0.53	<177	<1.8	21.4	66.3
54SC-A-043		May-99	9130	<1.1	<1.1	91.2	<0.64	<0.64	1270	14.9	8.2 B	7.7	13200	12.6	2250	336	<0.04	9.5	1140	<1.1	<0.64	<213	<2.1	19.8	56.4
54SC-A-044		May-99	12400	<1.1	1.2 B	123	0.74 B	<0.68	1850	21.6	8.1 B	26	17000	132	3000	447	<0.04	12.8	1460	<1.1	<0.68	<225	<2.3	25.6	152
54SC-A-045		May-99	11900	<0.95	1.7 B	173	0.84 B	0.76 B	4360	21.0	6 B	37.7	17800	705	3500	532	4.1	12.4	1330	<0.95	<0.57	521 B	<1.9	24.8	231
54SC-A-046	yes	May-99	13600	<0.93	1.9 B	185	0.76 B	1.8	9180	38.6	7.6 B	75	17200	1000	5410	447	0.18	13.5	1680	<0.93	<0.56	363 B	<1.9	25.6	433
54SC-A-047		May-99	14100	<0.96	1.4 B	132	0.8 B	<0.57	1600	20.9	9.1 B	11.1	19500	22.9	3100	504	<0.04	13.7	1500	<0.96	<0.57	<192	<1.9	30.3	75.6
54SC-A-061		Jun-99	11600	<0.81	1.6	91.9	0.54	<0.49	1330	16.1	6.7 B	9	15100	22.4	2350	412	<0.04	10.6	1330	<0.81	<0.49	<163	<1.6	23.5	73.7
54SC-A-042 dup.		Jun-99	7300	<0.87	1.3	81.3	<0.52	<0.52	1120	13.4	5.7 B	7.2	12700	12.5	2050	320	<0.04	8.3	976	<0.87	<0.52	<173	<1.7	17.0	60.8
54SC-A-040 dup.		Jun-99	10600	<0.99	1.6 B	115	0.63 B	<0.59	1530	17.4	7.3 B	9.3	16000	13	2710	428	<0.04	11.1	1220	<0.99	<0.59	<198	<2.0	23.6	72.7
54SC-A-004 dup.		Jun-99	18900	<1.1	2.5	171	0.94 B	<0.65	2300	26.1	10.8	13.8	23000	14.8	3800	635	<0.04	17.4	1760	<1.1	<0.65	<216	<2.2	36.5	86.2
54SC-B-001	yes	May-99	17400	<0.88	4.0	190	0.9	0.58 B	2490	38.5	10.8	50.4	26400	556	3740	666	0.64	17.4	1930	<0.88	<0.53	<176	<1.8	39.1	282
54SC-B-002		May-99	19700	<0.91	2.4	190	1	<0.55	2080	28.6	11.5	15.6	25500	34.7	3840	748	<0.04	18.3	2210	<0.91	<0.55	<182	<1.8	41.3	122
54SC-B-003		May-99	18400	<1.1	1.9 B	183	0.99 B	<0.64	2010	26.9	11.4	15.9	24800	29.8	3870	738	<0.03	18.1	2140	<1.1	<0.64	<215	<2.1	39.7	98.8
54SC-B-004		May-99	1820	<1.1	2.5	202	0.98 B	<0.65	2360	27.3	11.4	22.9	26100	146	3770	755	0.35	17.2	2260	<1.1	<0.65	<215	<2.2	39.1	202
Industrial RBC			200000	82	3.8	14000	410	100	---	610 (1)	4100	8200	61000	1000 (2)	---	4100	61 (3)	4100	---	1000	1000	---	14	1400	61000
Residential RBC			7800	3.1	0.43	550	16	3.9	---	23 (1)	160	310	2300	400 (2)	---	160	2.3 (3)	160	---	39	39	---	0.55	55	2300

Appendix B-1: Metals
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in mg/kg

Sample ID	Excavated Cell	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
54SC-B-005		May-99	14200	3.7 B	2.8	159	0.78 B	<0.52	2350	23.7	10.2	34.1	23900	555	8910	679	0.68	14.8	1740	<0.86	<0.52	<173	<1.7	31.2	284
54SC-B-006		May-99	15600	1.3 B	6.7	272	0.96 B	1.1 B	3550	39.0	10.6 B	616	29100	1050	3690	987	0.09	17.7	2030	<1.1	<0.65	<218	<2.2	32.7	544
54SC-B-007		May-99	16200	<0.82	2.0	146	0.81 B	<0.49	1800	23.3	10.2	12.2	21800	17.2	3410	527	<0.03	15.4	1750	<0.82	<0.49	<164	<1.6	35.7	85.7
54SC-B-008		May-99	20800	<0.99	2.3	206	1.1	<0.59	2260	29.9	13.7	15.3	27000	16.3	4180	853	<0.04	19.8	2130	<0.99	<0.59	<197	<2.0	43.5	96.1
54SC-B-009		May-99	20800	<1.1	2.3	206	1.1	<0.67	2260	29.9	13.7	15.3	27000	16.3	4180	853	<0.04	19.8	2130	<1.1	<0.67	<223	<2.2	43.5	96.1
54SC-B-010		May-99	21600	<1.1	2.8	243	1.3	<0.64	2490	31.7	14.4	16.9	28600	18.3	4260	1030	<0.04	21.5	2060	<1.1	<0.64	<214	<2.1	44.8	101
54SC-B-011		May-99	17900	<0.88	1.6 B	199	1.1	<0.53	2010	26.4	11.4	14.3	24000	17.3	3710	720	<0.04	17.9	1910	<0.88	<0.53	<175	<1.8	38.0	90.9
54SC-B-012		May-99	21000	<1.0	2.7	226	1.2	<0.63	2260	31.6	13.5	18.5	28300	22.4	4450	980	<0.04	21.2	2430	<1.0	<0.63	<210	<2.1	45.2	105
54SC-B-013		May-99	17900	<1.1	2.7	179	0.96 B	<0.66	1790	26.7	12.2	14.9	25800	31.7	3890	741	<0.04	17.2	2080	<1.1	<0.66	<220	<2.2	41	117
54SC-B-014		May-99	19300	<1.1	2.2 B	194	1 B	<0.68	2260	29.3	13.2	19.4	27100	75.5	4160	720	0.14	18.7	1890	<1.1	<0.68	<226	<2.3	43.7	112
54SC-B-015		May-99	20600	<0.66	3.0	243	1.2	<0.53	3010	31.1	12.8	24.3	27700	135	4310	1040	0.76	20.4	2370	<0.88	<0.53	<177	<1.8	42.4	157
54SC-B-016		May-99	20200	<0.83	3.1	260	1.2	0.66 B	3270	33.2	11.7	43.2	30400	1090	4220	625	0.16	20.4	2550	<0.83	<0.50	<165	<1.7	40.2	436
54SC-B-017		Apr-99	18300	5.2 B	6.2	223	<0.72	1 B	12800	34.0	8.4 B	136	25300	2610	7090	491	0.41	19.2	1680	<1.2	<0.72	353 B	<2.4	37.1	544
54SC-B-018		Apr-99	19100	5.7 B	5.2	209	0.76 B	1 B	9150	35.8	11.8 B	193	26700	2560	6100	676	0.45	20.6	1980	<1.2	<0.73	<244	<2.4	44.4	511
54SC-B-018 (4)		Jun-99	10600	<0.92	3.5	134	0.59 B	1.3	3120	19.2	8.8 B	47	21800	855	4470	633	1.1	13.6	1680	<0.92	<0.55	<163	<1.8	24.2	311
54SC-B-019		Apr-99	12700	4.2 B	16.5	333	0.81 B	2.1	6930	66.1	9 B	459	27300	2140	4300	858	1.1	17.7	1800	<1.1	<0.68	264 B	<2.3	27.8	970
54SC-B-019 (4)		Jun-99	14600	<0.85	3.6	175	0.84 B	1.1	2620	27.1	10.1	50.1	23600	467	3380	633	0.26	15.4	1910	<0.85	<0.51	<171	<1.7	32.1	271
54SC-B-020		Apr-99	18100	<1.2	2.8	186	0.95 B	<0.74	2380	27.0	11.5 B	30.1	24600	182	3670	745	0.06	16.3	2110	<1.2	<0.74	<247	<2.5	39.2	142
54SC-B-021		Apr-99	16100	<1.0	2.1	131	0.78 B	<0.63	1620	24.5	9.8 B	11.9	22400	18.3	3430	491	<0.03	14.8	1770	<1.0	<0.63	<209	<2.1	37.2	82.1
54SC-B-022		Apr-99	19600	<1.1	3.2	192	1 B	<0.67	2160	27.8	12.1	14.8	26900	24.2	3790	764	<0.04	17.8	1850	<1.1	<0.67	<223	<2.2	42.4	109
54SC-B-023		May-99	19400	<1.2	2.4 B	205	1.2 B	<0.73	2220	28.5	12.8	15.1	26400	17.5	4060	806	<0.04	19.0	1940	<1.2	<0.73	<243	<2.4	41.8	95.4
54SC-B-024		May-99	18800	<1.0	2.4	179	1.0	<0.61	1800	27.8	12.0	14.5	25700	18.0	3990	707	<0.04	17.6	2240	<1.0	<0.61	<204	<2.0	41.9	90.5
54SC-B-025		May-99	16900	<1.1	1.9 B	179	1.0 B	<0.64	1990	26.4	11.9	12.6	25100	14.9	3870	678	<0.04	16.8	1620	<1.1	<0.64	<214	<2.1	39.0	84.8
54SC-B-026		May-99	16600	<1.2	1.5 B	184	1 B	<0.74	1960	26.2	11.6 B	14.4	24400	19.7	3750	713	<0.04	16.7	1830	<1.2	<0.74	<245	<2.4	37.9	93.9
54SC-B-027		May-99	23700	<1.0	2.7	259	1.5	0.65 B	2800	35.7	16.6	20.1	33300	23.6	5190	1040	<0.04	24.1	2380	<1.0	<0.60	<200	<2.0	51.2	129
54SC-B-028		May-99	21800	<0.87	3.3	210	1.3	0.54 B	2290	33.2	15.0	22.1	32500	128	5250	890	0.04	20.6	2510	<0.87	<0.52	<174	<1.7	52.3	137
54SC-B-029		May-99	21500	<0.97	2.4	233	1.2	<0.58	2260	31.6	13.1	17.7	28000	32.8	4220	914	<0.04	20.7	2410	<0.97	<0.58	<194	<1.9	45	109
54SC-B-030		May-99	19500	<1.1	2.1 B	165	0.9 B	<0.65	1820	28.1	12	17.8	26900	28.2	4600	647	0.05	17.8	2450	<1.1	<0.65	<218	<2.2	45.2	95.8
54SC-B-031		May-99	19400	<0.95	2.5	179	0.92 B	<0.57	2040	28.1	11.5	22.3	25500	77.1	4100	711	0.05	18.1	2320	<0.95	<0.57	<169	<1.9	42.3	137
54SC-B-032		May-99	17600	<1.1	2.0 B	163	0.64 B	<0.68	1820	25.7	11.1 B	15.1	23800	26.2	3820	678	<0.04	16.4	2190	<1.1	<0.68	<227	<2.3	40	89.5
54SC-B-033		May-99	17900	<1.1	1.4 B	149	0.66 B	<0.65	1710	27.6	10.8 B	15.6	24100	51.1	3820	509	<0.04	16.7	2350	<1.1	<0.65	<216	<2.2	40.7	87.3
54SC-B-034		May-99	16400	<0.98	2.4	158	0.8 B	<0.59	5260	25.3	10.5	19.1	23000	97.1	5440	585	0.08	15.5	2040	<0.98	<0.59	<195	<2.0	37.9	116
54SC-B-035		May-99	16300	<0.97	1.7 B	145	0.76 B	<0.58	2050	24.8	10.2	21.8	22700	179	3680	559	0.08	14.9	2150	<0.97	<0.58	<193	<1.9	37.4	121
54SC-B-036		May-99	16600	<1.1	1.3 B	119	0.73	<0.67	1720	25.3	9.6 B	16.6	23200	38.2	4090	424	<0.04	15.2	2130	<1.1	<0.67	<224	<2.2	41	79.3
54SC-B-037		Mar-99	17000	<0.98	2.8	127	1.6	<0.59	2290	27.1	11	26.9	25400	170	51100	472	0.14	16	2240	1.1	<0.59	<196	<2.0	42.3	154
54SC-B-038		Mar-99	14700	5.6	7.0	269	1.1	0.75	11800	42.9	8.8	183	25600	2840	6670	778	0.36	19.7	1690	1.5	<0.67	433	<2.2	32.5	818
54SC-B-039		Mar-99	14800	2.1 B	5.0	211	1.1 B	1.1 B	9760	28.2	7.4	176	22900	1400	6240	569	1.5	15.5	1880	<1.1	<0.69	<229	<2.3	31.0	516
54SC-B-040		Mar-99	17300	1.5 B	3.9	195	1.3	0.82 B	3770	29.3	10 B	79.5	27700	593	3900	739	0.34	15.8	2050	<1.1	<0.64	<213	<2.1	37	279
54SC-B-041		Mar-99	18400	<1.0	2.7	180	1.5	0.63 B	3120	26.3	10.3 B	49.3	24800	668	3960	676	0.24	16.6	2370	<1.0	<0.63	<209	<2.1	37.8	205
54SC-B-042		Mar-99	23600	<0.90	3.0	203	1.9	<0.54	2420	32.3	13.0	17.0	30100	32.6	4610	767	<0.04	20.3	2580	<0.90	<0.54	<179	<1.8	50.2	131
54SC-B-043		Mar-99	21700	<0.86	2.4	206	1.8	<0.52	2290	30.8	12.7	15.6	27800	17.7	4540	705	0.04	20.1	2390	<0.86	<0.52	<172	<1.7	46.2	99.1
54SC-B-044		Mar-99	21300	<0.94	2.3	220	1.7	<0.56	2520	29.5	13.3	15.7	26000	17.4	4210	788	0.05	18.8	2090	<0.94	<0.56	<188	<1.9	43	96.7
54SC-B-045		Mar-99	23100	<1.2	2.6	199	1.8	<0.74	2410	30.9	13.0	15.7	27400	14.0	4370	693	<0.03	19.9	2130	<1.2	<0.74	<246	<2.5	46.9	87.8
Industrial RBC			200000	82	3.8	14000	410	100	---	610 (1)	4100	8200	61000	1000 (2)	—	4100	61 (3)	4100	---	1000	1000	---	14	1400	61000
Residential RBC			7800	3.1	0.43	550	16	3.9	---	23 (1)	160	310	2300	400 (2)	---	160	2.3 (3)	160	---	39	39	---	0.55	55	2300

Appe[illegible]B-1: Metals
Summary o[illegible]Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in mg/kg

Sample ID	Excavated Cell	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
54SC-B-046		Mar-99	20900	<0.97	2.0	189	1.7	<0.58	2180	27.9	11.8	15.3	24900	16.1	4850	677	<0.03	18.1	2440	<0.97	<0.58	<194	<1.9	42.3	85.8
54SC-B-047		Mar-99	26100	<0.91	3.2	206	1.8	<0.55	2220	30.7	12.3	16.7	28300	16.6	4110	684	<0.03	19.8	2310	<0.91	<0.55	<182	<1.8	51.1	95.4
54SC-B-048		Mar-99	20000	<1.1	2.2 B	167	1.8	<0.69	2080	26.2	10.9 B	13.7	23300	10.7	3900	592	<0.04	17.2	2050	<1.1	<0.69	<229	<2.3	40.4	73.9
54SC-B-049		Mar-99	19500	<1.1	2.8	197	1.5	<0.66	2220	28.5	12.1	15.3	24600	22.2	3900	720	<0.04	18.8	2170	<1.1	<0.68	<222	<2.2	40.3	107
54SC-B-050		Mar-99	20200	<1.0	2.8	198	1.6	0.61 B	2210	29.9	12.3	16.3	25700	19.5	4080	774	<0.04	20	2230	<1.0	<0.60	<201	<2.0	42.2	103
54SC-B-051		Mar-99	21000	<1.3	2.9	209	1.7	<0.76	2550	30.3	13.2	16.2	26300	13.2	4320	792	<0.04	20.3	2190	<1.3	<0.78	<252	<2.5	42.4	90.4
54SC-B-052		Mar-99	21700	<0.96	3.4	194	1.5	0.62 B	1920	28.7	11.8	16.4	26300	45.7	3830	846	0.04	19.3	2390	<0.96	<0.57	<191	<1.9	44.5	140
54SC-B-053		Mar-99	22300	<1.1	2.9	175	1.5	<0.67	1780	30.3	12.7	16.2	27500	18.0	4620	752	<0.04	19.0	2770	<1.1	<0.67	<222	<2.2	49.4	91.4
54SC-B-054		Mar-99	20400	<1.1	2.9	210	1.6	<0.66	2030	28.7	12.0	19.7	24800	32.3	3900	771	<0.04	18.7	2560	<1.1	<0.66	<221	<2.2	43.7	101
54SC-B-055		Mar-99	22500	<1.1	3.6	260	1.8	0.74 B	2550	32.5	12.7	18.1	26900	23.6	4220	962	<0.04	21.2	2730	<1.1	<0.65	<216	<2.2	45.7	117
54SC-B-056		Mar-99	20500	<1.0	3.0	183	1.5	0.64 B	1850	29.9	13.4	15.5	26100	28.2	4180	794	<0.04	18.7	2850	<1.0	<0.61	<205	<2.0	46.7	100
54SC-B-057		Mar-99	22300	<0.94	3.2	221	1.7	0.71 B	2140	34.6	13.3	17.5	28400	21.5	4760	838	<0.03	20.9	2900	<0.94	<0.58	<188	<1.9	49.6	99.9
54SC-B-058		Apr-99	15900	<1.0	2.5	115	1.2	<0.62	1310	24.2	10 B	12.4	22400	12.4	3920	482	<0.04	15	2260	<1.0	<0.62	<207	<2.1	38.9	71.1
54SC-B-059		Apr-99	15100	2.6 B	5.3	169	1.1	1.7	3800	42.6	10.1	75.2	27500	1070	4380	690	0.24	17.3	2090	<0.95	<0.57	<190	<1.9	35.5	504
54SC-B-060		Apr-99	14900	<1.0	4.8	208	1.2	1.4	6020	34.3	9.5 B	98.8	28200	1050	4440	921	0.61	16.3	1690	<1.0	<0.61	<202	<2.0	30.3	585
54SC-B-061		Apr-99	17000	<0.62	3.4	116	1.2	<0.49	1640	25.0	10.6	17	25500	54.9	4980	474	0.08	16.7	2360	<0.82	<0.49	<163	<1.6	41.1	101
54SC-B-062		Apr-99	15200	<0.88	2.6	101	1.1	<0.53	1420	22.7	9.6	18.5	23000	18.4	4460	369	<0.04	14.8	2040	<0.88	<0.53	<176	<1.8	38.1	59.4
54SC-B-063		Apr-99	18900	<0.96	3.3	113	1.2	<0.57	1440	26.6	11.2	14.9	27600	13.8	5020	426	<0.03	16.9	2490	<0.96	<0.57	<192	<1.9	47.3	69.8
54SC-B-064		Apr-99	15600	<0.95	2.8	98.9	1.1	<0.57	1500	23.5	10.2	13.5	23800	13.4	4710	409	<0.04	15.3	1970	<0.95	<0.57	<190	<1.9	39.6	61.7
54SC-B-065		Apr-99	16600	<1.0	3.4	120	0.77 B	<0.81	1300	23.6	9.9 B	15.8	28500	15.9	3970	888	<0.03	14.3	2300	<1.0	<0.61	<202	<2.0	44.9	64.4
54SC-B-066	yes	Apr-99	20100	1.1 B	8.9	262	1.4	1.4	10400	44.0	13	233	32400	3260	7810	924	0.41	27.9	2320	<1.0	<0.61	305 B	<2.0	42.4	710
54SC-B-067	yes	Apr-99	13700	10.1 B	5.7	403	1.1	1.9	16200	35.7	8.1 B	1040	27000	3410	8680	624	0.47	20.4	1880	<0.88	<0.53	375 B	<1.8	27.5	1270
54SC-B-068		Apr-99	13200	<0.87	2.8	162	1.1	0.59 B	2360	25.3	8.9	48.9	20400	322	3120	598	0.46	14.2	1910	<0.87	<0.52	<174	<1.7	30.6	191
54SC-B-069		Apr-99	18300	<0.99	4.8	253	1.5	20.8	5260	43.2	11.6	83.2	29600	558	4190	935	0.26	21.8	2000	1.4	<0.60	229 B	<2.0	36.8	1150
54SC-B-070		Apr-99	21100	<1.2	3.5	275	1.8	<0.70	2700	31.8	13.5	17.6	27700	27.3	4210	1010	<0.03	22.2	2300	1.2	<0.70	<232	<2.3	43.5	114
54SC-B-071		Apr-99	17300	<0.88	2.5	155	1.3	<0.53	1940	27.2	11	13	24400	22.8	3850	588	<0.04	17.2	1690	<0.88	<0.53	<177	<1.8	39.1	93.1
54SC-B-072		Apr-99	16800	<0.92	2.4	172	1.3	<0.55	1930	26.0	11.5	12.1	24100	15.6	3650	641	<0.04	18.7	1560	<0.92	<0.55	<184	<1.8	38	83.7
54SC-B-073		Apr-99	20500	<1.0	3.0	231	1.6	<0.60	2410	29.1	12.1	15.8	27200	29.2	4060	893	<0.03	20.5	1880	<1.0	<0.60	<201	<2.0	41.5	135
54SC-B-074		Apr-99	20300	<1.1	2.9	219	1.5	0.95 B	2520	29.1	12.6	16.2	27200	35.4	3840	921	<0.03	19.2	1910	<1.1	<0.64	<213	<2.1	40.9	138
54SC-B-075		Apr-99	19000	<1.2	2.3 B	180	1.6	<0.71	2100	25.9	10.9 B	14.5	23300	17.7	3780	674	<0.04	16.8	2230	<1.2	<0.71	<236	<2.4	38.7	94.7
54SC-B-076		Apr-99	18600	<1.1	3.3	209	1.4	0.91 B	2100	27.3	11.8	16.3	27100	52.6	3600	972	<0.03	18.0	1860	<1.1	<0.66	<219	<2.2	39.2	173
54SC-B-077		Apr-99	14200	<0.98	2.0 B	146	1.1	0.67 B	1740	22.5	8.9 B	12.2	20000	11.7	3330	568	<0.04	14.2	1450	<0.98	<0.59	<196	<2.0	30.6	69.2
54SC-B-078		Apr-99	14900	<1.0	2.3	152	1.2	0.83 B	1780	22.8	10.5	13	22600	11.9	3440	637	<0.04	14.8	1530	<1.0	<0.63	<208	<2.1	34.1	74.2
54SC-B-079		Apr-99	20600	<1.3	2.9	214	1.6	0.97 B	2480	29.7	13.2 B	16.9	27800	29.2	4260	876	<0.04	20.0	2010	<1.3	<0.80	<268	<2.7	42.1	113
54SC-B-080		Apr-99	19300	<0.93	2.5	187	1.5	0.84 B	2290	27.6	12.2	14.5	25300	17.2	3950	784	<0.04	18.4	1920	<0.93	<0.56	<185	<1.8	38.9	91.9
54SC-B-081		Apr-99	21300	<1.3	2.9	251	1.7	1.1 B	2600	32.3	13.6	17.5	29500	31.6	4220	997	0.04	21.2	2030	<1.3	<0.77	<258	<2.8	43.7	143
54SC-B-082		Apr-99	11900	<1.0	2.1	133	0.73	<0.61	1520	19.8	9.3	10.9	19900	24	3100	529	<0.04	12.2	1310	<1.0	<0.61	<202	<2.0	29.3	74.8
54SC-B-083		Apr-99	16300	<1.1	2.3	191	1	<0.65	2020	25.1	10.8	13.9	23800	21.5	3520	736	<0.04	16.4	1870	<1.1	<0.65	<217	<2.2	35.5	105
54SC-B-084		Apr-99	18900	<1.0	3.0	202	1.1	<0.61	2230	27.0	11.8	14.9	25900	33.1	3640	843	<0.04	17.9	1900	<1.0	<0.61	<205	<2.0	39.4	140
54SC-B-085		Apr-99	14700	<1.1	2.6	173	0.92	<0.64	1920	23.7	10.9	13	23000	24.5	3340	700	0.04	14.9	1490	<1.1	<0.64	<212	<2.1	34.1	107
54SC-B-086		Apr-99	17200	<1.1	3.1	169	0.93 B	<0.69	1710	25.8	12.1	15.7	27200	29.4	4020	716	<0.04	16.2	1920	<1.1	<0.69	<229	<2.3	44.3	97.1
54SC-B-087		Apr-99	17700	<1.1	3.0	239	1.2	<0.63	2400	29.6	12.5	20.5	26100	55.4	3910	905	<0.04	18.9	2340	<1.1	<0.63	<211	<2.1	40.9	138
54SC-B-088		Apr-99	15200	<1.1	2.7	221	1.1 B	<0.67	1930	26.2	12.5	15.8	25800	27.7	3810	781	<0.04	16.5	2060	<1.1	<0.67	<224	<2.2	39.2	107
Industrial RBC			200000	82	3.8	14000	410	100	---	610 (1)	4100	8200	61000	1000 (2)	---	4100	61 (3)	4100	—	1000	1000	---	14	1400	61000
Residential RBC			7800	3.1	0.43	550	16	3.9	---	23 (1)	160	310	2300	400 (2)	---	160	2.3 (3)	160	---	39	39	---	0.55	55	2300

Appendix B-1: Metals
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in mg/kg

Sample ID	Excavated Cell	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
54SC-B-089		Apr-99	14800	<1.1	2.1 B	182	0.89 B	<0.65	1580	22.9	10.1 B	13.8	22000	16.6	[illegible]	747	0.04	15.1	2140	<1.1	<0.65	<217	<2.2	35.4	79.2
54SC-B-090		Apr-99	14900	<1.0	2.4	155	0.82 B	<0.63	1580	23.6	9.9 B	13	22400	24	3500	649	<0.04	14.3	2050	<1.0	<0.63	<211	<2.1	36.1	97.4
54SC-B-091		Apr-99	17100	<1.0	1.9 B	106	0.68 B	<0.63	1520	24.5	9.7 B	13.8	24100	12.1	4100	417	0.04	14.5	1860	<1.0	<0.63	<209	<2.1	43.3	66.8
54SC-B-094		May-99	15500	<1.0	2.5	111	0.71 B	<0.60	1400	23.4	11.0	15.8	25100	25.5	4430	434	<0.04	14.8	2150	<1.0	<0.60	<199	<2.0	42.2	72.3
54SC-B-095	yes	May-99	14200	2.3 B	6.3	278	0.74 B	1.4	3540	39.8	9.7	162	25600	2570	4170	730	0.39	17.1	1820	<0.85	<0.51	215 B	<1.7	34.9	696
54SC-B-095 (4)		Jun-99	15900	<0.93	2.5	116	<0.56	<0.56	2750	24.2	9 B	16	20300	26.9	4980	394	<0.04	13.8	1970	<0.93	<0.56	<185	<1.9	36.7	66.2
54SC-B-096	yes	May-99	13300	<0.97	4.2	192	0.92 B	1.2	6170	25.2	9 B	79.0	27800	4320	4400	925	0.5	21.1	1610	<0.97	<0.58	352 B	<1.9	26.6	550
54SC-B-096 (4)		Jun-99	11900	<1.1	2.1	95.4	<0.68	<0.68	1850	18.6	8.2 B	10.5	17900	7.9	3390	206	<0.04	11.3	1620	<1.1	<0.66	<221	<2.2	31.3	45.9
54SC-B-097		May-99	17200	<0.88	2.2	107	0.78 B	<0.53	1440	25.0	10.9	14.4	25800	18.2	4680	447	<0.03	15.3	2190	<0.88	<0.53	<177	<1.8	44.8	89.7
54SC-B-098		Apr-99	17300	<0.95	2.4	124	0.71 B	<0.57	1520	24.6	10.5	14.3	24800	10.6	4510	461	<0.04	15.3	2500	190	<0.57	190	<1.9	43.3	87.2
54SC-B-099		Apr-99	16000	<0.99	2.1	111	0.65 B	<0.60	1250	46.0	10.3	15.3	23900	14.2	4170	441	<0.03	27.7	2560	<0.99	<0.60	<199	<2.0	41.2	141
54SC-B-100		Apr-99	15100	<1.1	2.1 B	106	<0.66	<0.68	1280	22.3	9.5 B	13.9	22800	23.1	3950	451	<0.04	13.2	2200	<1.1	<0.66	<221	<2.2	39	75.7
54SC-B-101		May-99	11300	<1.2	<1.2	102	<0.73	<0.73	1150 B	18.6	8.9 B	11.2	20600	15.8	3460	429	<0.04	11.2	1730	<1.2	<0.73	<243	<2.4	33.7	60.1
54SC-B-102		Apr-99	15000	<1.0	4.2	195	0.71 B	1.1	8030	33.1	10.3 B	63.7	25300	1040	6130	636	0.22	14.5	2000	<1.0	<0.62	<207	<2.1	38.3	360
54SC-B-111		Apr-99	16900	<1.1	2.1 B	176	1.3	0.74 B	2060	25.1	11.3	13.7	23500	16.7	3590	676	<0.03	18.8	1640	<1.1	<0.65	<218	<2.2	35.6	87.1
54SC-B-112		Apr-99	19100	<0.95	2.5	198	1.1	<0.57	2130	27.3	11.7	14.9	26100	24.4	3760	801	<0.04	18.3	1880	<0.95	<0.57	<189	<1.9	39.3	115
54SC-B-113		Apr-99	19000	<0.94	2.8	211	1.1	<0.56	2150	27.3	12	15.3	27200	33.8	3750	891	0.04	18.2	1720	<0.94	<0.56	<187	<1.9	40.3	142
54SC-B-114		Apr-99	17600	<1.2	2.5	232	1.1	<0.71	2300	26.0	11.1	14.4	23800	17.5	3540	868	0.04	18.1	1660	<1.2	<0.71	<237	<2.4	35.8	98.6
54SC-B-115		Apr-99	17100	<1.2	2.8	191	0.95	<0.73	2100	25.0	10.4	14.1	23100	20.1	3510	722	<0.04	18.7	1850	<1.2	<0.73	<242	<2.4	35.2	99
54SC-B-118		Apr-99	18200	<1.2	2.3	182	0.98	<0.70	1990	25.7	11.4	13.9	24300	12.1	3800	659	<0.04	17.6	1900	<1.2	<0.70	<233	<2.3	38.1	79.4
54SC-B-117		Apr-99	16000	<0.96	2.3	180	0.97	<0.57	1940	24.8	11.6	14.2	24300	27	3660	788	<0.04	18.5	1710	<0.96	<0.57	<191	<1.9	36.5	113
54SC-B-118		Apr-99	17900	<0.94	2.3	173	0.97	<0.56	1660	26.8	10.9	14.5	24000	13.9	3710	554	<0.04	17.4	2000	<0.94	<0.56	<187	<1.9	37.7	89.1
54SC-B-119		Apr-99	16100	<1.1	2.9	165	0.87	<0.64	1650	23.5	10.2	13.4	22700	24	3390	658	<0.04	15.7	1740	<1.1	<0.64	<212	<2.1	34.5	106
54SC-B-120		Apr-99	12500	<1.0	1.7	113	<0.63	<0.63	1410	18.9	8	10.1	17700	11.3	2950	432	<0.04	12.3	1480	<1.0	<0.63	<211	<2.1	27.4	63.5
54SC-B-121		Apr-99	12400	<1.1	2.5	107	<0.67	<0.67	1450	18.3	7.8	9.6	17800	12.3	2850	442	<0.03	11.8	1530	<1.1	<0.67	<224	<2.2	27.8	68.4
54SC-B-122		Apr-99	12000	<1.1	1.6	91	<0.64	<0.64	1340	17.5	7.3	8.9	16600	10.9	2710	373	<0.04	11	1550	<1.1	<0.64	<213	<2.1	26.1	60
54SC-B-137		May-99	12800	<1.3	2.0 B	139	<0.78	<0.76	1160	22.5	10.5	12.8	24300	15.5	4010	602	<0.04	12.5	2160	<1.3	<0.76	<253	<2.5	40.1	72.4
54SC-B-138	yes	May-99	12800	15.6	11.6	799	0.77 B	5.6	11200	67.1	9 B	755	28400	3660	6320	812	0.76	25.5	1650	<1.1	7	605 B	<2.3	25.9	1880
54SC-B-138 (4)		Jun-99	13200	<0.93	2.5	92.8	<0.56	0.65 B	1740	22.1	8.5 B	18.2	20600	65.6	4260	319	<0.04	12.6	2670	<0.93	<0.56	<187	<1.9	33.5	71
54SC-B-139		May-99	11400	2.9 B	5.9	212	0.81 B	1.4	3590	34.7	9.6	117	28200	1210	3290	886	0.46	14.3	1600	1.1	<0.56	<188	<1.9	27	640
54SC-B-140		May-99	9390	<1.0	3.5	154	0.81 B	1.0 B	2460	19.1	8.8 B	38.9	26100	657	2580	948	0.43	12.5	1380	<1.0	<0.63	<210	<2.1	23.9	435
54SC-B-141		May-99	12500	<1.0	1.9 B	95.1	0.66 B	<0.60	1080	18.9	9.4 B	12.9	22300	9.1	3630	477	<0.04	12.1	1900	<1.0	<0.60	<201	<2.0	35.8	54
54SC-B-142		May-99	11200	<0.87	1.7 B	112	0.62 B	<0.52	954	19.1	8.8	10.5	19000	11.2	3190	541	<0.04	11.1	1740	<0.87	<0.52	<175	<1.7	31.1	55.6
54SC-B-143		May-99	13200	<0.85	2.0	94.1	0.7 B	<0.51	1090	20.5	11.4	13.1	23600	15.8	4200	477	<0.03	12.7	1950	<0.85	<0.51	<170	<1.7	39.2	61.1
54SC-B-144		May-99	14900	<0.93	2.0	103	0.72 B	<0.58	1170	25.3	10.7	12.3	25000	11.5	4350	433	<0.04	12.9	1940	<0.93	<0.56	<186	<1.9	43.5	66.5
54SC-B-146		May-99	12400	<0.89	1.7 B	110	0.69 B	<0.54	1220	19.2	9.5	13.6	21100	36.5	3660	491	<0.04	12.1	1730	<0.89	<0.54	<179	<1.8	34.3	75.6
54SC-B-147		Apr-99	16500	<1.0	2.7	107	0.69 B	<0.62	1150	23.7	10.4	14	24400	13.1	4370	481	<0.04	14.2	2550	<1.0	<0.62	<206	<2.1	42.2	67.6
54SC-B-148		Apr-99	15300	<0.91	2.4	107	1.1	<0.55	1140	22.9	9.9	12.4	23100	14.3	4160	450	<0.04	14.6	2270	<0.91	<0.55	<182	<1.8	38.6	69.6
54SC-B-149		Apr-99	16100	<0.97	2.1	117	1.2	<0.58	1350	24.2	9.7	13.2	23500	11.9	4300	403	<0.04	15.7	2500	<0.97	<0.58	<193	<1.9	41.1	65.2
54SC-B-150		Apr-99	94600	3.5 B	4.5	269	0.97	2.2	6060	86.9	10.3	156	20800	508	3960	459	1.4	21.5	2200	<0.90	<0.54	384 B	<1.8	33.2	564
54SC-B-151		Apr-99	17300	<1.0	3.0	247	1.5	<0.61	2310	27.1	11	15.3	23300	38.7	3460	947	<0.04	18	2130	<1.0	<0.61	<203	<2.0	35.8	117
54SC-B-152		Apr-99	19600	<1.1	2.8	241	1.6	<0.64	2360	29.7	12.3	15	26500	24.4	3920	874	<0.04	20.1	2200	<1.1	<0.64	<215	<2.2	41.4	120
Industrial RBC			200000	82	3.8	14000	410	100	---	610 (1)	4100	8200	61000	1000 (2)	---	4100	61 (3)	4100	---	1000	1000	---	14	1400	61000
Residential RBC			7800	3.1	0.43	550	16	3.9	---	23 (1)	160	310	2300	400 (2)	---	160	2.3 (3)	160	---	39	39	---	0.55	55	2300

Appe[illegible]B-1: Metals
Summary o[illegible]nalytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in mg/kg

Sample ID	Excavated Cell	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
54SC-B-153		Apr-99	15100	<0.93	2.5	157	1.3	<0.56	1620	24.4	10.1	13.5	22900	13.5	[illegible]	546	<0.04	15.6	1830	<0.93	<0.56	<186	<1.9	36.4	78.9
54SC-B-154		Apr-99	15600	<1.2	2.8	124	1.2	<0.73	1610	22.8	9.6	11.7	21700	16.1	3210	477	<0.04	15.1	1620	<1.2	<0.73	<243	<2.4	38.1	65.4
54SC-B-155		Apr-99	23600	<1.0	3.3	250	1.6	0.66 B	2650	31.4	13	17.3	28300	35.8	3850	1050	0.04	21.2	2220	<1.0	<0.63	<210	<2.1	45.1	149
54SC-B-156		Apr-99	20000	<1.3	2.5 B	201	1.5	0.91 B	2310	28.5	13.2	15.0	27100	24.3	3840	836	<0.04	18.7	1870	<1.3	<0.78	<261	<2.6	42.1	111
54SC-B-157		Apr-99	15600	<0.97	2.0	139	0.81	<0.58	1770	22.9	10.1	11	21700	9.7	3490	587	<0.04	15	1470	<0.97	<0.58	<195	<2.0	34	67.4
54SC-B-190		May-99	11600	2 B	3.1	180	0.78 B	1 B	2100	25.6	10 B	36.8	22600	504	3330	724	<0.04	13.5	1790	<1.2	<0.69	<230	<2.3	34.3	305
54SC-B-191	yes	May-99	13600	10.2 B	7.4	311	0.82 B	2.7	7520	50.0	10.4	279	30100	2930	5170	832	0.76	21.3	2040	1.1	<0.59	574B	<2.0	31.1	1020
54SC-B-192	yes	May-99	8100	<1.0	1.9 B	144	0.7 B	1 B	7080	18.1	7.6 B	82.3	21100	3160	4290	899	0.44	12.4	1230	<1.0	<0.63	<208	<2.1	19.0	447
54SC-B-192 (4)		Jun-99	18200	<0.96	3.1	145	0.74 B	0.85 B	1680	25.9	13.3	18.2	28300	25.6	4970	565	<0.04	16.7	2880	<0.96	<0.57	<192	<1.9	45.9	76.8
54SC-B-193		May-99	18900	<1.0	3.0	150	0.9 B	<0.62	1650	27.3	12	20.2	27600	120	4270	649	<0.04	16.1	2470	<1.0	<0.62	<208	<2.1	43.8	143
54SC-B-199		May-99	12600	<.84	1.4 B	103	0.72 B	<0.50	845	21.0	9.1	11.9	21600	12.5	3740	444	<0.03	12.2	2040	<0.84	<0.50	<168	<1.7	36.1	66.2
54SC-B-200		Apr-99	15100	<0.99	1.9 B	105	0.96 B	<0.59	1110	22.2	9.4 B	11.6	21800	10.0	4050	420	<0.04	13.7	2140	<0.99	<0.59	<197	<2.0	37.0	62.3
54SC-B-201		Apr-99	15700	<1.2	2.4	95.2	0.96 B	<0.71	1300	22.7	9.4 B	13.6	22400	9.5	4330	395	<0.04	14.7	2410	<1.2	<0.71	<236	<2.4	36.1	60.8
54SC-B-202		Apr-99	12500	<0.88	1.8	90.7	0.86 B	<0.53	1100	19.4	8.2 B	12.0	20000	10.9	3580	368	<0.04	12.3	1950	<0.88	<0.53	<178	<1.8	33.2	58.3
54SC-B-203		Apr-99	31300	<1.3	2.2 B	376	1 B	1.3	3530	35.2	9.3 B	78.0	19600	364	3560	637	0.79	17.9	2350	<1.3	<0.77	<256	<2.6	31.4	275
54SC-B-204		Apr-98	15900	<1.1	2.2	207	1.3	0.69 B	1920	24.9	10.6 B	12.6	22000	14.2	3240	774	<0.04	16.1	2040	<1.1	<0.66	<220	<2.2	33.3	84.2
54SC-B-205		Apr-99	19200	<0.85	1.9	216	1.4	0.65 B	2380	38.4	12.4	14.3	25100	19.1	3680	812	<0.04	30.4	2010	<0.85	<0.51	<169	<1.7	39.0	97.1
54SC-B-206		Apr-99	17000	<0.99	2.1	166	1.2	0.67 B	1900	25.3	10.8	12.5	23000	17.7	3450	646	<0.04	16.2	1630	<0.99	<0.59	<196	<2.0	36.7	91.7
54SC-B-207		Apr-99	18600	<1.2	2.4	145	1.3	<0.70	1880	26.7	11.1 B	12.5	23600	13.8	3560	601	<0.04	18.8	1990	<1.2	<0.70	<233	<2.3	39.0	83.6
54SC-B-208		Apr-99	24700	<1.3	3.8	225	1.6	0.95 B	2230	31.9	13 B	17.8	30500	32.4	3820	961	0.05	20.4	2080	<1.3	<0.80	<266	<2.7	50.3	133
54SC-B-209		Apr-99	22400	<0.95	2.8	200	1.4	0.81 B	2030	29.3	12.0	16.1	27500	31.0	3600	857	<0.04	19.2	1950	<0.95	<0.57	<169	<1.9	44.2	123
54SC-B-210		Apr-99	16800	<0.96	2.3	170	0.96	<0.58	1980	25.1	11.2	12.8	23300	12.3	3600	645	<0.04	16.6	1650	<0.96	<0.58	<192	<1.9	35.9	78.9
54SC-B-250	yes	May-99	18700	<1.0	5.1	198	0.92 B	0.8 B	2220	32.0	12.4	54.3	26500	570	4200	830	0.05	18.4	2320	<1.0	<0.63	<210	<2.1	42.6	327
54SC-B-251	yes	May-99	15800	2.8 B	5.7	361	0.82 B	3.3	7480	64.9	10.3 B	195	25000	101000	4830	869	0.24	21	1860	<1.1	6.2	361 B	2.2	29.6	790
54SC-B-251 (4)		Jun-99	16900	<1.0	3.3	132	<0.61	<0.61	1740	24.7	10.3	15.2	24000	10.5	4260	521	<0.04	14.5	2400	<1.0	<0.61	<203	<2.0	42.8	55.5
54SC-B-252		May-99	12600	<0.62	2.9	142	0.84	<0.49	1100	29.6	10.2	12.6	22600	60.9	2290	713	<0.04	11.5	1400	<0.82	<0.49	<163	<1.6	35.7	86.8
54SC-B-262		Apr-99	14200	<0.61	2.8	91.3	0.95	<0.49	1300	22.5	9.6	13.0	22900	8.5	4370	351	<0.04	13.6	2330	<0.81	<0.49	<162	<1.6	36.0	56.9
54SC-B-263		Apr-99	15200	<0.76	1.9	102	0.99	<0.47	1340	21.9	9.4	12.8	22300	10.7	4190	385	<0.04	14.3	2320	<0.76	<0.47	<157	<1.8	37.6	63.0
54SC-B-264		Apr-99	14800	<1.0	2.0	129	0.64	<0.63	1350	22.8	9.2	11.8	20800	15.4	3290	501	<0.04	13.6	2220	<1.0	<0.63	<209	<2.1	36.2	74.9
54SC-B-265		Apr-99	14400	<1.1	2.5	181	0.76	<0.64	1660	22.0	8.9	11.9	20100	21.1	2800	665	<0.04	13.4	1930	<1.1	<0.64	<214	<2.1	32.4	93.4
54SC-B-266		Apr-99	18800	<1.0	2.3	236	1.1	<0.60	2520	28.0	12	14.6	25100	13.8	3700	861	<0.03	18.6	2140	<1.0	<0.60	<200	<2.0	38.8	90.2
54SC-B-317		Jun-99	16100	<0.76	2.5	176	0.8	0.71 B	2590	23.3	12.8	11.9	23000	10.9	3340	993	<0.04	16.2	2030	<0.76	<0.45	<151	<1.5	40	66.9
54SC-B-318		May-99	18000	5.4 B	7.1	321	0.94 B	1.8	4190	64.4	13.2	93.3	42900	1500	4330	956	0.14	29.5	2250	<1.1	<0.68	<226	<2.3	41	512
54SC-B-319		Jun-99	14600	<0.85	2.5	145	0.72 B	0.59 B	1240	21.5	10.5	11.5	20000	9.7	2820	672	<0.04	12.3	1820	<0.85	<0.51	<171	<1.7	38.3	52.4
54SC-B-330		Jun-99	18300	<0.84	2.9	108	0.71 B	0.72 B	1370	26.3	10.2	14.4	25100	11.1	4370	440	<0.04	16.4	2620	<0.84	<0.50	<168	<1.7	44.4	69.0
54SC-B-331		Jun-99	15700	<0.89	2.2	97.7	0.6 B	0.65 B	1280	22.2	9.8	13.4	23000	10.3	4260	392	<0.04	14.9	2620	<0.89	<0.54	<178	<1.8	40.0	61.3
54SC-B-332		Jun-99	12000	<0.85	1.9	81.9	<0.51	0.58 B	1310	20.2	8.1 B	11	19300	8.4	3510	296	<0.03	11.6	1790	<0.85	<0.51	<171	<1.7	32.4	52.9
54SC-B-333		Jun-99	14000	<0.99	2.1	107	0.62 B	0.62 B	1350	22.8	9.1 B	12.8	21300	10	3500	400	<0.04	14	1950	<0.99	<0.59	<198	<2.0	36.9	60.1
54SC-B-334		Jun-99	13600	<0.89	1.9	131	0.72 B	0.6 B	1490	23.9	8.8 B	11.7	21600	10	3240	439	<0.03	13.4	1790	<0.89	<0.53	<178	<1.8	35	62.2
54SC-B-335		Jun-99	13500	<0.91	1.5 B	151	0.78 B	0.62 B	1760	22.6	9 B	11.3	20000	9.8	3240	481	<0.04	13.5	1760	<0.91	<0.55	<182	<1.8	32.3	67.3
54SC-B-336		Jun-99	14600	<0.87	1.9	135	0.73 B	0.63 B	1810	22.5	10.4	11.3	22000	10.5	3400	479	<0.04	14.1	1650	<0.87	<0.52	<175	<1.7	36	66.9
Industrial RBC			200000	82	3.8	14000	410	100	---	610 (1)	4100	8200	61000	1000 (2)	---	4100	61 (3)	4100	---	1000	1000	---	14	1400	61000
Residential RBC			7800	3.1	0.43	550	16	3.9	---	23 (1)	160	310	2300	400 (2)	---	160	2.3 (3)	160	---	39	39	---	0.55	55	2300

Appendix B-1: Metals
Summary of Soil Analytical Results
Modified from: *Interim Action* (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in mg/kg

Sample ID	Excavated Cell	Date	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Mercury	Nickel	Potassium	Selenium	Silver	Sodium	Thallium	Vanadium	Zinc
54SC-B-393		Jun-99	22100	<0.86	8.8	146	0.99	0.99	3380	30.0	11	18.5	33200	16.5	[illegible]	1230	<0.04	28.3	5240	<0.86	<0.52	<173	<1.7	47.9	91.2
54SC-B-018 dup.		Jun-99	13900	<0.95	8.4	257	0.74 B	1.8	6400	39.6	9.2 B	171	24800	1050	4870	753	0.4	15.8	1730	<0.95	<0.57	<190	<1.9	30.7	593
54SC-B-019 dup.		Jun-99	12200	<0.93	4.0	160	0.66 B	1.3	2770	24.6	8.4 B	52	21900	551	5010	753	0.14	15.8	1720	<0.93	<0.56	<186	<1.9	27.9	301
54SC-B-251 dup.	(4)	Jun-99	15900	<1.1	2.5	135	<0.64	0.66 B	1540	24.4	11.2	14.7	25000	13.1	4320	643	<0.04	14.2	2370	<1.1	<0.64	<213	<2.1	42.8	59.7
54SC-B-192 dup.	(4)	Jun-99	20000	<1.1	3.3	141	0.67 B	0.7 B	1810	26.5	11.6	18.6	28500	24.8	4990	532	<0.04	17.1	3060	<1.1	<0.66	<220	<2.2	48	74.4
54SC-B-096 dup.	(4)	Jun-99	11800	<0.84	2.1	98.7	0.52 B	0.54 B	1530	19.9	8.5	10.8	19300	9.7	3350	270	<0.04	11.3	1570	<0.84	<0.50	<167	<1.7	32.8	51.6
54SC-B-138 dup.	(4)	Jun-99	12700	<0.97	2.3	86.9	<0.58	<0.58	1530	19.3	6 B	15	19500	60.6	3610	342	0.05	11.5	2440	<0.97	<0.58	<194	<1.9	32.6	69.6
54SC-B-095 dup.	(4)	Jun-99	16000	<0.89	1.9	119	0.56 B	<0.54	1840	26.6	8.7 B	13.1	21200	20.5	4500	360	<0.04	14.1	2010	<0.89	<0.54	<178	<1.8	37.1	60.7
54SC-B-317 dup.		Jun-99	17000	<0.91	2.6	175	0.82 B	0.6 B	5640	22.4	10.8	11.6	20500	11.1	3870	916	<0.04	13.7	2010	<0.91	<0.55	<182	<1.8	39.5	59.7
54SC-B-393 dup.		Jun-99	22200	<0.94	7.0	120	0.91 B	0.69 B	2200	29.4	10.8	16.5	32300	15	7920	570	<0.03	20.6	4290	<0.94	<0.57	<188	<1.9	51.8	84.6
54SC-B-319 dup.		Jun-99	15800	<0.84	2.4	151	0.71 B	0.62 B	1340	22.7	10.5	12.2	22000	10.5	3000	614	<0.04	13	1900	<0.84	<0.50	<167	<1.7	41	55.3
54SC-B-330 dup.		Jun-99	13200	<0.78	2.0	102	0.84 B	0.82 B	1010	21.7	9.1	11.5	21600	12.2	3580	448	<0.03	12.5	2000	<0.78	<0.47	<156	<1.6	36.1	66.1
54SC-B-331 dup.		Jun-99	12300	<0.75	1.9	87.6	0.56 B	0.6 B	993	19.4	9.2	12.2	21300	9.2	3820	366	<0.04	12.2	2210	<0.75	<0.45	<149	<1.5	34.9	55.8
54SC-B-332 dup.		Jun-99	13800	<0.83	1.7	89.4	0.51 B	0.6 B	1610	21.2	8.9	11.8	21200	8.0	3960	327	<0.04	12.8	2020	<0.83	<0.50	<167	<1.7	36.2	53.7
54SC-B-333 dup.		Jun-99	17700	<0.97	2.5	116	0.71 B	0.72 B	1580	26.2	10.4	14.3	24500	10.5	4030	438	<0.03	15.9	2430	<0.97	<0.58	<195	<2.0	44.7	66.3
54SC-B-334 dup.		Jun-99	19600	<0.83	2.6	145	0.89	0.73 B	1780	29.4	10.7	14.4	27400	11.7	3930	462	<0.03	17.4	2320	<0.83	<0.50	<166	<1.7	48.8	72.1
54SC-B-335 dup.		Jun-99	18400	<1.1	1.7 B	185	0.81 B	0.76 B	2200	27.7	11.5	13.3	23700	11.3	3910	622	<0.04	16.9	2330	<1.1	<0.64	<215	<2.2	39.5	76.3
54SC-B-336 dup.		Jun-99	17300	<1.2	2.2 B	218	1.1 B	0.81 B	2020	27.3	11.8	13.8	24600	18.7	3620	811	<0.04	17.4	1980	<1.2	<0.70	<234	<2.3	38.1	102
Total Detects		Count	240	29	238	240	207	96	231	240	231	240	240	230	231	240	64	230	231	6	2	15	1	230	231
Total Analyses		Count	240	230	230	230	231	230	231	230	231	230	230	230	231	230	230	231	231	231	231	231	231	231	231
Average Result		Average	20153	1.048	2.82	466	0.916	0.67	2752	39	10.77	214.8	23935	697	4174.6	696	0.12	16.12	1965	0.033	0.057	28.07	0.01	36.36	167.56
Maximum Detect		Max	200000	82	16.5	14000	1.9	100	47300	610	102	8200	61000	101000	51100	4100	4.1	30.4	5240	1.5	7	1130	2.2	52.3	1880
Minimum Detect		Min	1620	1.1	0.43	67.9	0.51	0.54	845	13.4	5.2	6.2	2300	7.2	1820	160	0.04	8.1	976	1.1	6.2	215	2.2	17	43.3
54BF-01		Aug-99	18300	<1.0	3.6	115	0.87	<0.62	3560	28.9	14.1	16.3	28600	20.7	2880	840	0.06	11.2	1410	<1.0	<0.62	<207	<2.1	59.7	57.7
54BF-02		Sep-99	18600	<.90	2.6	95.7	0.81	<.54	1700	29.4	12.9	17.4	30400	13.7	4440	539	<.03	14.9	1750	<.90	<.54	<180	<1.8	55	71.6
Industrial RBC			200000	82	3.8	14000	410	100	---	610 (1)	4100	8200	61000	1000 (2)	---	4100	61 (3)	4100	---	1000	1000	---	14	1400	61000
Residential RBC			7800	3.1	0.43	550	16	3.9	---	23 (1)	160	310	2300	400 (2)	---	160	2.3 (3)	160	---	39	39	---	0.55	55	2300

Notes:

ID = Identification

mg/kg = milligram per kilogram

RBC = Risk-Based Concentration, USEPA Region III, April 4, 2002 (Non-carcanogenic constituents have been adjusted for a hazard quotient of 0.1.)

dup. = duplicate sample

bgs. = below ground surface

B = Analyte detected in laboratory blank, result is estimated and biased high

(1) = Chromium VI value used from RBC table.

(2) = Lead screening value (Action Level).

(3) = Mercuric chloride value used from RBC table.

(4) = Analytical results for Cells Requiring Increased Sampling Depths (Sample collected from 12 feet bgs.)

* = Indicates samples that could not be reviewed

☐ = Reported value exceeds Industrial RBC.

⧈ = Reported value exceeds Residential RBC.

Appendix B-2: TCLP Metals
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in µg/L

Sample ID	Excavated Cell	Sample Date	Arsenic	Barium		Cadmium	Chromium	Lead	Mercury	Selenium	Silver
54SC-A-003		Jun-99	<50.0	1510	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-004		Jun-99	<50.0	1090	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-005		Jun-99	<50.0	747	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-006		Jun-99	<50.0	1480	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-007		Jun-99	<50.0	1270	B	<30.0	<50.0	222	<2.0	<50.0	<30.0
54SC-A-008		Jun-99	<50.0	1140	B	<30.0	<50.0	304	<2.0	<50.0	<30.0
54SC-A-009	yes	no data provided									
54SC-A-010		Jun-99	<50.0	644	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-011		Jun-99	<50.0	711	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-012		Jun-99	<50.0	869	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-013		Jun-99	<50.0	1210	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-014		Jun-99	<50.0	943	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-019		Jun-99	<50.0	820	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-020		Jun-99	<50.0	764	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-021		Jun-99	<50.0	708	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-022		Jun-99	<50.0	1090	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-023		Jun-99	<50.0	719	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-024		Jun-99	<50.0	856	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-025		Jun-99	<50.0	975	B	<30.0	<50.0	300	<2.0	<50.0	<30.0
54SC-A-026	yes	Jun-99	<50.0	1310	B	<30.0	<50.0	1090	<2.0	<50.0	<30.0
54SC-A-027		Jun-99	<50.0	929	B	<30.0	<50.0	72.7	<2.0	<50.0	<30.0
54SC-A-028		Jun-99	<50.0	650	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-029		Jun-99	<50.0	2250		<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-030		Jun-99	<50.0	897	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-031		Jun-99	<50.0	892	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-032		Jun-99	<50.0	616	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-033		Jun-99	<50.0	849	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-034		Jun-99	<50.0	566	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-040		Jun-99	<50.0	793	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-041		Jun-99	<50.0	908	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-042		Jun-99	<50.0	806	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-043		May-99	<50.0	924	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-044		May-99	<50.0	954	B	<30.0	<50.0	567	<2.0	<50.0	<30.0
54SC-A-045		May-99	<50.0	1130	B	<30.0	<50.0	1300	<2.0	<50.0	<30.0
54SC-A-046	yes	May-99	<50.0	1890	B	<30.0	<50.0	5110	<2.0	<50.0	<30.0
54SC-A-047		May-99	<50.0	774	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-061		Jun-99	<50.0	850	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-042 dup.		Jun-99	<50.0	726	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-040 dup.		Jun-99	<50.0	776	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-A-004 dup.		Jun-99	<50.0	1010	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-001	yes	May-99	<50.0	2030		<30.0	<50.0	63700	<2.0	<50.0	<30.0
54SC-B-002		May-99	<50.0	801	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-003		May-99	<50.0	945	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-004		May-99	<50.0	1320	B	<30.0	<50.0	347	<2.0	<50.0	<30.0
54SC-B-005		May-99	<50.0	1450	B	<30.0	<50.0	916	<2.0	<50.0	<30.0
54SC-B-006		May-99	<50.0	1300	B	<30.0	<50.0	611	<2.0	<50.0	<30.0
54SC-B-007		May-99	<50.0	963	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-008		May-99	<50.0	901		<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-009		May-99	<50.0	963		<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-010		May-99	<50.0	796		<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-011		May-99	<50.0	832	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-012		May-99	<50.0	963	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-013		May-99	<50.0	1040	B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-014		May-99	<50.0	1060	B	<30.0	<50.0	84.7	<2.0	<50.0	<30.0
54SC-B-015		May-99	<50.0	977	B	<30.0	<50.0	48.3	<2.0	<50.0	<30.0
54SC-B-016		May-99	<50.0	969	B	<30.0	<50.0	382	<2.0	<50.0	<30.0
54SC-B-017		Apr-99	<50.0	890	B	<30.0	<50.0	4790	<2.0	<50.0	<30.0
54SC-B-018		Apr-99	<50.0	1100	B	<30.0	<50.0	2390	<2.0	<50.0	<30.0
54SC-B-018 (1)		Jun-99	<50.0	1520	B	<30.0	<50.0	2200	<2.0	<50.0	<30.0
54SC-B-019		Apr-99	<50.0	1460	B	<30.0	<50.0	654	<2.0	<50.0	<30.0
54SC-B-019 (1)		Jun-99	<50.0	1630	B	<30.0	<50.0	391	<2.0	<50.0	<30.0
54SC-B-020		Apr-99	<50.0	598	B	<30.0	<50.0	44.6	<2.0	<50.0	<30.0

Appendix B-2: TCLP Metals
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in µg/L

Sample ID	Excavated Cell	Sample Date	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
54SC-B-021		Apr-99	<50.0	494 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-022		Apr-99	<50.0	499 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-023		May-99	<50.0	1000 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-024		May-99	<50.0	988 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-025		May-99	<50.0	1630 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-026		May-99	<50.0	928 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-027		May-99	<50.0	896 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-028		May-99	<50.0	1290 B	<30.0	<50.0	258	<2.0	<50.0	<30.0
54SC-B-029		May-99	<50.0	1670 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-030		May-99	<50.0	1750 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-031		May-99	<50.0	1460 B	<30.0	<50.0	50.5	<2.0	<50.0	<30.0
54SC-B-032		May-99	<50.0	1010 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-033		May-99	<50.0	1030 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-034		May-99	<50.0	1120 B	<30.0	<50.0	65.7	<2.0	<50.0	<30.0
54SC-B-035		May-99	<50.0	1050 B	<30.0	<50.0	279	<2.0	<50.0	<30.0
54SC-B-036		May-99	<50.0	936 B	<30.0	<50.0	31.1	<2.0	<50.0	<30.0
54SC-B-049		Mar-99	<50.0	961 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-050		Mar-99	<50.0	1130 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-051		Mar-99	<50.0	958 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-052		Mar-99	<50.0	812 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-053		Mar-99	<50.0	930 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-054		Mar-99	<50.0	1100 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-055		Mar-99	<50.0	1320 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-056		Mar-99	<50.0	1040 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-057		Mar-99	<50.0	909 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-058		Apr-99	54.5 B	680 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-059		Apr-99	<50.0	1570 B	<30.0	<50.0	3120	<2.0	<50.0	<30.0
54SC-B-060		Apr-99	<50.0	1540 B	<30.0	<50.0	3460	<2.0	<50.0	<30.0
54SC-B-061		Apr-99	<50.0	854 B	<30.0	<50.0	77.2	<2.0	<50.0	<30.0
54SC-B-062		Apr-99	<50.0	740 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-063		Apr-99	<50.0	654 B	<30.0	<50.0	<30	<2.0	<50.0	<30.0
54SC-B-064		Apr-99	130	552 B	<30.0	<50.0	<30	<2.0	<50.0	<30.0
54SC-B-065		Apr-99	<50.0	411 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-066	yes	Apr-99	<50.0	1560 B	<30.0	<50.0	12400	<2.0	<50.0	<30.0
54SC-B-067	yes	Apr-99	<50.0	1970 B	34.1 B	<50.0	37400	<2.0	<50.0	<30.0
54SC-B-068		Apr-99	138	1050 B	<30.0	<50.0	389	<2.0	<50.0	<30.0
54SC-B-069		Apr-99	<50.0	1400 B	<30.0	<50.0	742	<2.0	<50.0	<30.0
54SC-B-070		Apr-99	<50.0	825 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-071		Apr-99	<50.0	631 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-072		Apr-99	<50.0	840 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-073		Apr-99	<50.0	1210 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-074		Apr-99	<50.0	913 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-076		Apr-99	<50.0	855 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-077		Apr-99	<50.0	915 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-078		Apr-99	<50.0	826 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-079		Apr-99	<50.0	885 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-080		Apr-99	<50.0	881 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-081		Apr-99	<50.0	882 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-082		Apr-99	<50.0	684	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-083		Apr-99	<50.0	1120	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-084		Apr-99	<50.0	1010	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-085		Apr-99	<50.0	905	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-086		Apr-99	<50.0	1030 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-087		Apr-99	<50.0	1040 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-088		Apr-99	<50.0	1430 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-089		Apr-99	<50.0	987 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-090		Apr-99	<50.0	456 B	<30.0	<50.0	63.7	<2.0	<50.0	<30.0
54SC-B-091		Apr-99	<50.0	491 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-094		May-99	<50.0	884 B	<30.0	<50.0	42.8	<2.0	<50.0	<30.0
54SC-B-095	yes	May-99	<50.0	2790	35 B	<50.0	38900	<2.0	<50.0	<30.0
54SC-B-095 (1)		Jun-99	<50.0	879 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-096	yes	May-99	<50.0	2040	<30.0	<50.0	141000	<2.0	<50.0	<30.0

Appendix B-2: TCLP Metals
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in µg/L

Sample ID	Excavated Cell	Sample Date	Arsenic	Barium		Cadmium		Chromium	Lead	Mercury	Selenium	Silver
54SC-B-096 (1)		Jun-99	<50.0	620	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-097		May-99	<50.0	872	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-098		Apr-99	<50.0	677	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-099		Apr-99	<50.0	462	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-100		Apr-99	<50.0	440	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-101		May-99	<50.0	652	B	<30.0		<50.0	35.4	<2.0	<50.0	<30.0
54SC-B-102		Apr-99	<50.0	1070	B	<30.0		<50.0	2210	<2.0	<50.0	<30.0
54SC-B-111		Apr-99	<50.0	842	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-112		Apr-99	<50.0	868		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-113		Apr-99	<50.0	1120		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-114		Apr-99	<50.0	925		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-115		Apr-99	<50.0	928		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-116		Apr-99	<50.0	830		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-117		Apr-99	<50.0	893		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-118		Apr-99	<50.0	1160		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-119		Apr-99	<50.0	1290		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-120		Apr-99	<50.0	841		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-121		Apr-99	<50.0	764		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-122		Apr-99	<50.0	654		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-137		May-99	<50.0	1270	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-138	yes	May-99	<50.0	4350		31.5	B	<50.0	24200	<2.0	<50.0	<30.0
54SC-B-138 (1)		Jun-99	<50.0	1110	B	<30.0		<50.0	276	<2.0	<50.0	<30.0
54SC-B-139		May-99	<50.0	2620		<30.0		<50.0	2700	<2.0	<50.0	<30.0
54SC-B-140		May-99	<50.0	1490	B	<30.0		<50.0	3360	<2.0	<50.0	<30.0
54SC-B-140		May-99	<50.0	1490	B	<30.0		<50.0	3360	<2.0	<50.0	<30.0
54SC-B-141		May-99	<50.0	792	B	<30.0		<50.0	62.6	<2.0	<50.0	<30.0
54SC-B-142		May-99	<50.0	691	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-143		May-99	<50.0	967	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-144		May-99	<50.0	800	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-146		May-99	<50.0	836	B	<30.0		<50.0	4070	<2.0	<50.0	<30.0
54SC-B-147		Apr-99	<50.0	416	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-148		Apr-99	<50.0	610	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-149		Apr-99	<50.0	694	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-150		Apr-99	<50.0	1970	B	<30.0		<50.0	784	<2.0	<50.0	<30.0
54SC-B-151		Apr-99	<50.0	955	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-152		Apr-99	<50.0	1010	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-153		Apr-99	<50.0	944	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-154		Apr-99	<50.0	809	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-155		Apr-99	<50.0	842	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-156		Apr-99	<50.0	825	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-157		Apr-99	<50.0	824		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-190		May-99	<50.0	1010	B	<30.0		<50.0	56.3	<2.0	<50.0	<30.0
54SC-B-191	yes	May-99	<50.0	2600		39.1	B	<50.0	22500	<2.0	<50.0	<30.0
54SC-B-192	yes	May-99	<50.0	1940	B	<30.0		<50.0	22200	<2.0	<50.0	<30.0
54SC-B-192 (1)		Jun-99	<50.0	1290	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-193		May-99	<50.0	782	B	<30.0		<50.0	50.2	<2.0	<50.0	<30.0
54SC-B-199		May-99	<50.0	558	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-200		Apr-99	<50.0	604	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-201		Apr-99	<50.0	582	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-202		Apr-99	<50.0	532	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-203		Apr-99	<50.0	1360	B	<30.0		<50.0	281	<2.0	<50.0	<30.0
54SC-B-204		Apr-99	<50.0	920	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-205		Apr-99	<50.0	1070	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-206		Apr-99	<50.0	876	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-207		Apr-99	<50.0	778	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-208		Apr-99	<50.0	947	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-209		Apr-99	<50.0	886	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-210		Apr-99	<50.0	880		<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-250	yes	May-99	<50.0	1780	B	<30.0		<50.0	17500	<2.0	<50.0	<30.0
54SC-B-251	yes	May-99	<50.0	2900		50	B	<50.0	72100	<2.0	<50.0	<30.0
54SC-B-251 (1)		Jun-99	<50.0	886	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-252		May-99	<50.0	1010	B	<30.0		<50.0	<30.0	<2.0	<50.0	<30.0

Appendix B-2: TCLP Metals
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in µg/L.

Sample ID	Excavated Cell	Sample Date	Arsenic	Barium	Cadmium	Chromium	Lead	Mercury	Selenium	Silver
54SC-B-262		Apr-99	<50.0	696 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-263		Apr-99	<50.0	659 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-264		Apr-99	<50.0	676	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-265		Apr-99	<50.0	960	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-266		Apr-99	<50.0	957	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-317		Jun-99	<50.0	1650 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-318		May-99	<50.0	1930 B	<30.0	<50.0	2820	<2.0	<50.0	<30.0
54SC-B-319		Jun-99	<50.0	878 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-330		Jun-99	<50.0	642 B	<30.0	<50.0	2390	<2.0	<50.0	<30.0
54SC-B-331		Jun-99	<50.0	729 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-332		Jun-99	<50.0	975 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-333		Jun-99	<50.0	864 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-334		Jun-99	<50.0	873 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-335		Jun-99	<50.0	776 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-336		Jun-99	<50.0	852 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-393		Jun-99	<50.0	1070 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-018 dup.		Jun-99	<50.0	1770 B	<30.0	<50.0	3630	<2.0	<50.0	<30.0
54SC-B-019 dup.		Jun-99	<50.0	1320 B	<30.0	<50.0	3050	<2.0	<50.0	<30.0
54SC-B-251 dup.	(1)	Jun-99	<50.0	908 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-192 dup.	(1)	Jun-99	<50.0	1150 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-096 dup.	(1)	Jun-99	<50.0	620 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-138 dup.	(1)	Jun-99	<50.0	1000 B	<30.0	<50.0	266	<2.0	<50.0	<30.0
54SC-B-095 dup.	(1)	Jun-99	<50.0	1070 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-317 dup.		Jun-99	<50.0	1520 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-393 dup.		Jun-99	<50.0	869 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-319 dup.		Jun-99	<50.0	923 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-330 dup.		Jun-99	<50.0	834 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-332 dup.		Jun-99	<50.0	678 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-333 dup.		Jun-99	<50.0	608 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-334 dup.		Jun-99	<50.0	758 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-335 dup.		Jun-99	<50.0	970 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54SC-B-336 dup.		Jun-99	<50.0	793 B	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54BF-01		Aug-99	<50.0	1060	<30.0	<50.0	<30.0	<2.0	<50.0	<30.0
54BF-02		data not available								
TCLP Criteria			5000	100000	1000	5000	5000	200	1000	5000

Notes:

ID = Identification

TCLP = Toxicity Characteristic Leaching Procedure

B = Analyte detected in laboratory blank, result is estimated and biased high

µg/L = micrograms per liter

dup. = duplicate sample

bgs. = below ground surface

(1) = Analytical results for cells requiring increased sampling depths (sample collected from approximately 12 feet bgs.)

☐ = Reported value exceeds TCLP Criteria

Appendix B-2: Explosives
Summary of So[illegible]tical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results and RBCs reported in μg/kg

Sample ID	Excavated Cells	Sample Date	HMX	1,3,5-TNB	Tetryl	2,4,6-TNT	4-Amino-2,6-DNT	2,6-DNT	4-NT	RDX	1,3-DNB	NB	2-Amino-4,6-DNT	2,4-DNT	2-NT	3-NT
54SC-A-003		Jun-99	380 J	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-004		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-A-005		Jun-99	<400	<200	<400	<200	<200	<200	<400	<400	<200	<200	<200	<200	<400	<400
54SC-A-006		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-007		Jun-99	3100	9400	<480	760000 D	<240	<240	<480	<480	<240	<240	2400	11000	2000	<460
54SC-A-008		Jun-99	<500	<250	<500	350	<250	<250	<500	<500	<250	<250	<250	550	<500	<500
54SC-A-009	yes		<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-A-010		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-A-011		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-A-012		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-013		Jun-99	<400	<200	<400	<200	<200	<200	<400	<400	<200	<200	<200	<200	<400	<400
54SC-A-014		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-A-019		Jun-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-A-020		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-021		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-022		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-A-023		Jun-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-A-024		Jun-99	<480	<240	<480	<240	<240	<240	<460	<460	<240	<240	<240	<240	<480	<480
54SC-A-025		Jun-99	<500	4200	<500	200000 D	4300	<250	<500	730	<250	<250	2600	3900	<500	<500
54SC-A-026	yes	Jun-99	6500	14000	<480	1900000 D	<240	<240	4000	16000	550	1700	4100	21000	6500	1800
54SC-A-027		Jun-99	1700	460	<500	120000 D	2000	<250	<500	660	<250	<250	1200	14000	<500	<500
54SC-A-028		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-A-029		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-A-030		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-031		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-032		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-033		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-A-034		Jun-99	<420	<210	<420	<210	<210	<210	<420	<420	<210	<210	<210	<210	<420	<420
54SC-A-040		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-041		Jun-99	<500	<250	<500	8700	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-A-042		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-043		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-A-044		May-99	<500.0	<250.0	<500.0	11752	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-A-045		May-99	<952.4	<476.2	<952.4	6753.9	<476.2	<476.2	<952.4	<952.4	<476.2	<476.2	<476.2	3852.8	<952.4	<952.4
54SC-A-046	yes	May-99	<500.0	2552.7	<500.0	18878.8	4134	10040.6	<500.0	<500.0	<250.0	<250.0	7129.9	<250	<500.0	<500.0
54SC-A-047		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-A-061		Jun-99	<380	<190	<380	<190	<190	<190	<380	<380	<190	<190	<190	<190	<380	<380
54SC-A-004 dup.		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-A-040 dup.		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-042 dup.		Jun-99	<500	<250	<500	8700	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-001	yes	May-99	2518.2	649.2	<500.0	16719.4	4128.4	<250.0	<500.0	<500.0	<250.0	<250.0	3267.7	7965.7	<500.0	<500.0
54SC-B-002		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-003		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-004		May-99	598.3	<238.1	<476.2	1599	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	230.9 J	467.3	<476.2	<476.2
54SC-B-005		May-99	926.2	<236.1	<476.2	134.2 J	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-006		May-99	507.3	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-007		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-008		May-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-009		May-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-010		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-011		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
Industrial RBC			1.0E+07	6.1E+06	2.0E+06	1.9E+05	1.2E+04 (2)	2.0E+05	2.0E+06	5.2E+04	2.0E+04	1.0E+05	1.2E+04 (2)	4.1E+05	2.0E+06	4.1E+06
Residential RBC			3.9E+05	2.3E+05	7.8E+04	2.1E+04	4.7E+02	7.8E+03	7.8E+04	5.8E+03	7.8E+02	3.9E+03	4.7E+02	1.6E+04	7.8E+04	1.6E+05

Appendix B-3: Explosives
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results and RBCs reported in μg/kg

Sample ID	Excavated Cells	Sample Date	HMX	1,3,5-TNB	Tetryl	2,4,6-TNT	4-Amino-2,6-DNT	2,6-DNT	4-NT	RDX	1,3-DNB	NB	2-Amino-4,6-DNT	2,4-DNT	2-NT	3-NT
54SC-B-012		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-013		May-99	<500.0	<250.0	<500.0	<250	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-014		May-99	234.2 J	<250.0	<500.0	223.2 J	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-015		May-99	213.3 J	<250.0	<500.0	476.9	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-016		May-99	47333.2 D	<500.0	<1000.0	32131.6 D	4626.8 D	<500.0	<1000.0	<1000.0	<500.0	<500.0	4521 D	4248.6 D	<1000.0	<1000.0
54SC-B-017		Apr-99	101551.4 D	5475.2 D	<4761.9	177752.4 D	15840 D	<2381.0	<4761.9	<4761.9	<2381.0	<2381.0	14874.3 D	59067.6 D	<4761.9	<4761.9
54SC-B-018		Apr-99	20111 D	<2500.0	<5000.0	56991 D	10168 D	<2500.0	<5000.0	<5000.0	<2500.0	<25000.0	<2500.0	154726 D	<5000.0	<5000.0
54SC-B-018 (1)		Jun-99	<360 J	<220	<430	710	230	<220	<430	<430	<220	<220	580	330	<430	<430
54SC-B-019		Apr-99	15460 D	1544.3 D	<2381.0	91746.7 D	4661.4 D	<1190.5	<2381.0	<2381.0	<1190.5	<1190.5	5549 D	9946.2 D	<2361.0	<2381.0
54SC-B-019 (1)		Jun-99	6200	<250	<500	4100	1100	<250	<500	<500	<250	<250	970	<250	<500	<500
54SC-B-020		Apr-99	616	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-021		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-022		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-023		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-024		May-99	<476.2	<238.1	<476.2	<238.1	<236.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-025		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-026		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-027		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-028		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-029		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-030		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-031		May-99	428.3 J	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-032		May-99	<500.0	<250.0	<500.0	583.8	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-033		May-99	775.2	<238.1	<476.2	310.1	<238.1	<238.1	<476.2	<476.2	<238.1	<236.1	<238.1	<238.1	<476.2	<476.2
54SC-B-034		May-99	889.4	<250.0	<500.0	185.7 J	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-035		May-99	400 J	<238.1	<476.2	238.5 J	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	335.9	<476.2	<476.2
54SC-B-036		May-99	268.5 J	<250.0	<500.0	154 J	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54-SC-B-037		Mar-99	2731.8	<250.0	<500.0	2276.8	198.3 J	<250.0	<500.0	<500.0	<250.0	<250.0	197.8 J	676.2	<500.0	<500.0
54-SC-B-038		Mar-99	46430.6 D	918.2 D	<1000.0	29137.8 D	6861 D	<500.0	788.8 JD	<1000.0	<500.0	<500.0	4787.2 D	16888.8 D	<1000.0	<1000.0
54SC-B-039		Mar-99	15117.6	<238.1	<476.2	5866.5	6387.7	<238.1	<476.2	<476.2	<238.1	<238.1	8572.2	2090.3	<476.2	<476.2
54SC-B-040		Mar-99	7679.6 D	2768.6 D	<1000.0	32829.6 D	2896.8 D	<500.0	<1000.0	<1000.0	<500.0	<500.0	2621.8 D	3305.6 D	<1000.0	<1000.0
54SC-B-041		Mar-99	3385	119 J	<476.2	537.8	206.7 J	<238.1	<476.2	<476.2	<238.1	<238.1	331.2	707.6	<476.2	<476.2
54SC-B-042		Mar-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-043		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-044		Mar-99	<500.0	<250.0	<500.0	11752	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-045		Mar-99	<500.0	<250.0	<500.0	6753.9 D	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	3852.8 D	<500.0	<500.0
54SC-B-046		Mar-99	<500.0	2552.7	<500.0	18876.8	4134	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	5142.7	<500.0	<500.0
54SC-B-047		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-048		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-049		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-050		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-051		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	2166	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-052		Mar-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-053		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-054		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-055		Mar-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-056		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-057		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-058		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-059		Apr-99	9951.6	<250.0	<500.0	2167.6	788.4	<250.0	<500.0	<500.0	<250.0	<250.0	904.1	911.7	<500.0	<500.0
Industrial RBC			1.0E+07	6.1E+06	2.0E+06	1.9E+05	1.2E+04 (2)	2.0E+05	2.0E+06	5.2E+04	2.0E+04	1.0E+05	1.2E+04 (2)	4.1E+05	2.0E+06	4.1E+06
Residential RBC			3.9E+05	2.3E+05	7.8E+04	2.1E+04	4.7E+02	7.8E+03	7.8E+04	5.8E+03	7.8E+02	3.9E+03	4.7E+02	1.6E+04	7.8E+04	1.6E+05

Appendix B[illegible]xplosives
Summary of So[illegible]ytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results and RBCs reported in μg/kg

Sample ID	Excavated Cells	Sample Date	HMX	1,3,5-TNB	Tetryl	2,4,6-TNT	4-Amino-2,6-DNT	2,6-DNT	4-NT	RDX	1,3-DNB	NB	2-Amino-4,6-DNT	2,4-DNT	2-NT	3-NT
54SC-B-060		Apr-99	168302 D	<1250.0	<2500.0	13726 D	1661 D	<1250.0	<2500.0	<2500.0	<1250.0	<1250.0	2660 D	1423.5 D	<2500.0	<2500.0
54SC-B-061		Apr-99	1516	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-062		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-063		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-064		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-065		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-066	yes	Apr-99	10330.2	<238.1	<476.2	1415.9	876.9	<238.1	<476.2	<476.2	<238.1	<238.1	1304.6	484.6	<476.2	<476.2
54SC-B-067	yes	Apr-99	118580 D	<50000.0	<100000.0	1019260 D	<50000	<50000.0	<100000	<100000	<50000.0	<50000.0	<50000.0	<50000.0	<100000	<100000
54SC-B-068		Apr-99	2952.3	513.2	<476.2	15589	3241.3	<238.1	<476.2	<476.2	<238.1	<238.1	4053.5	1467	<476.2	<476.2
54SC-B-069		Apr-99	8517.6 D	2526 D	<1000.0	31501.6 D	3455 D	<500.0	<1000.0	<1000.0	<500.0	<500.0	4329.6 D	9364 D	<1000.0	<1000.0
54SC-B-070		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-071		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-072		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-073		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-074		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-075		Mar-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-076		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-077		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-078		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-079		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-080		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-081		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-082		Jun-99	<476	<238	<476	<238	<238	<238	<476	<476	<238	<238	<238	<238	<476	<476
54SC-B-083		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-084		Apr-99	<476	<238	<476	<238	<238	<238	<476	<476	<238	<238	<238	<238	<476	<476
54SC-B-085		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-086		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-087		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-088		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-089		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-090		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-091		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-094		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-095	yes	May-99	16452.4 D	2176.8 D	<1000.0	17724.6 D	5187 D	<500.0	<1000.0	<1000.0	<500.0	<500.0	<500.0	34933 D	<1000.0	<1000.0
54SC-B-095 (1)		Jun-99	430 J	180 J	<480	3900	350	<240	<480	<480	<240	<240	290	150 J	<480	<480
54SC-B-096	yes	May-99	3295	<250.0	<500.0	703.6	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	4468	<500.0	<500.0
54SC-B-096 (1)		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-097		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-098		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-099		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-100		Apr-99	522.8	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-101		May-99	522.8	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-102		Apr-99	21708.3	<238.1	<476.2	7416.4	969.9	<238.1	<476.2	<476.2	<238.1	<238.1	932	962.1	<476.2	<476.2
54SC-B-111		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-112		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-113		Apr-99	<476	<238	<476	<238	<238	<238	<476	<476	<238	<238	<238	<238	<476	<476
54SC-B-114		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-115		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-116		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-117		Apr-99	<476	<238	<476	<238	<238	<238	<476	<476	<238	<238	<238	<238	<476	<476
Industrial RBC			1.0E+07	6.1E+06	2.0E+06	1.9E+05	1.2E+04 (2)	2.0E+05	2.0E+06	5.2E+04	2.0E+04	1.0E+05	1.2E+04 (2)	4.1E+05	2.0E+06	4.1E+06
Residential RBC			3.9E+05	2.3E+05	7.8E+04	2.1E+04	4.7E+02	7.8E+03	7.8E+04	5.8E+03	7.8E+02	3.9E+03	4.7E+02	1.6E+04	7.8E+04	1.6E+05

Appendix B-3: Explosives
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results and RBCs reported in µg/kg

Sample ID	Excavated Cells	Sample Date	HMX	1,3,5-TNB	Tetryl	2,4,6-TNT	4-Amino-2,6-DNT	2,6-DNT	4-NT	RDX	1,3-DNB	NB	2-Amino-4,6-DNT	2,4-DNT	2-NT	3-NT
54SC-B-116		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-119		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-120		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-121		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-122		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-137		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-138	yes	May-99	41802.6 D	2650 D	<1000.0	34434.2 D	4930.4 D	<500.0	<1000.0	<1000.0	<500.0	<500.0	<500.0	32402.6 D	<1000.0	<1000.0
54SC-B-138 (1)		Jun-99	6800	<240	<480	1200	280	<240	<480	<480	<240	<240	330	170 J	<480	<480
54SC-B-139		May-99	4311.3	<238.1	<476.2	346.2	316.9	<238.1	<476.2	<476.2	<238.1	<238.1	518.1	1199.1	<476.2	<476.2
54SC-B-140		May-99	552.7	<250.0	<500.0	397.6	163.5 J	<250.0	<500.0	<500.0	<250.0	<250.0	206.7 J	416.1	<500.0	<500.0
54SC-B-141		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-142		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-143		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-144		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-146		May-99	267 J	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-147		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-148		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-149		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<236.1	<476.2	<476.2
54SC-B-150		Apr-99	1121.7	1516.2	<500.0	4929.5	882	<250.0	<500.0	629.3	<250.0	<250.0	908.5	454.7	<500.0	<500.0
54SC-B-151		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-152		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-153		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-154		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-155		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-156		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-157		Apr-99	<476	<238	<476	<238	<238	<238	<476	<476	<238	<238	<238	<238	<476	<476
54SC-B-190		May-99	<476.2	<238.1	<476.2	247	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-191	yes	May-99	29114.8 D	<500.0	<1000.0	24738.4 D	4773.2 D	<500.0	<1000.0	<1000.0	<500.0	<500.0	3251.4 D	22406 D	<1000.0	<1000.0
54SC-B-192	yes	May-99	2702.6	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	8151.5	<500.0	<500.0
54SC-B-192 (1)		Jun-99	440	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-B-193		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-199		May-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<236.1	<476.2	<476.2
54SC-B-200		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-201		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-202		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-203		Apr-99	161.9 J	3047	<476.2	9144.7	1137.3	<238.1	2117.9	<476.2	<238.1	<238.1	697.1	3056.9	1588.9	385.4 J
54SC-B-204		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-205		Apr-99	<454.5	<227.3	<454.5	<227.3	<227.3	<227.3	<454.5	<454.5	<227.3	<227.3	<227.3	<227.3	<454.5	<454.5
54SC-B-206		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<236.1	<476.2	<476.2
54SC-B-207		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-208		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-209		Apr-99	<476.2	<238.1	<476.2	<238.1	<238.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-210		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-250	yes	May-99	942.3	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-251	yes	May-99	19988 D	<476.2	<952.4	10716.5 D	<476.2	<476.2	<952.4	<952.4	<476.2	<476.2	<476.2	32971.8 D	952.4	952.4
54SC-B-251 (1)		Jun-99	550	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-B-252		May-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
54SC-B-262		Apr-99	<476.2	<238.1	<476.2	<238.1	<236.1	<238.1	<476.2	<476.2	<238.1	<238.1	<238.1	<238.1	<476.2	<476.2
54SC-B-263		Apr-99	<500.0	<250.0	<500.0	<250.0	<250.0	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	<250.0	<500.0	<500.0
Industrial RBC			1.0E+07	6.1E+06	2.0E+06	1.9E+05	1.2E+04 (2)	2.0E+05	2.0E+06	5.2E+04	2.0E+04	1.0E+05	1.2E+04 (2)	4.1E+05	2.0E+06	4.1E+06
Residential RBC			3.9E+05	2.3E+05	7.8E+04	2.1E+04	4.7E+02	7.8E+03	7.8E+04	5.8E+03	7.8E+02	3.9E+03	4.7E+02	1.6E+04	7.8E+04	1.6E+05

Appendix B[illegible]Explosives
Summary of So[illegible]lytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results and RBCs reported in μg/kg

Sample ID	Excavated Cells	Sample Date	HMX	1,3,5-TNB	Tetryl	2,4,6-TNT	4-Amino-2,6-DNT	2,6-DNT	4-NT	RDX	1,3-DNB	NB	2-Amino-4,6-DNT	2,4-DNT	2-NT	3-NT
54SC-B-264		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-265		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-266		Apr-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-317		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-318		May-99	2801.4	<250.0	<500.0	1422.3	125.2 J	<250.0	<500.0	<500.0	<250.0	<250.0	<250.0	529.6	<500.0	<500.0
54SC-B-319		Jun-99	760	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-330		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-331		Jun-99	<420	<210	<420	<210	<210	<210	<420	<420	<210	<210	<210	<210	<420	<420
54SC-B-332		Jun-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-B-333		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-334		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-335		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-336		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-393		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-018 dup.		Jun-99	160000 D	730	<450	6600	2100	<230	<450	<450	<230	<230	2500	1300	<450	<450
54SC-B-019 dup.		Jun-99	9700	<240	<480	5100	1800	<240	<480	<480	<240	<240	2300	1200	<480	<480
54SC-B-251 dup. (1)		Jun-99	810	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-192 dup. (1)		Jun-99	400 J	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-096 dup. (1)		Jun-99	350 J	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-B-138 dup. (1)		Jun-99	4000	240	<480	1900	560	<240	<480	<480	<240	<240	590	760	<480	<480
54SC-B-095 dup.		Jun-99	400 J	440	<420	4600	240	<210	<420	<420	<210	<210	400	360	<420	<420
54SC-B-317 dup.		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54SC-B-393 dup.		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-B-319 dup.		Jun-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-B-330 dup.		Jun-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-B-331 dup.		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	1400
54SC-B-332 dup.		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-333 dup.		Jun-99	<430	<220	<430	<220	<220	<220	<430	<430	<220	<220	<220	<220	<430	<430
54SC-B-334 dup.		Jun-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
54SC-B-335 dup.		Jun-99	<500	<250	<500	<250	<250	<250	<500	<500	<250	<250	<250	<250	<500	<500
54SC-B-336 dup.		Jun-99	<480	<240	<480	<240	<240	<240	<480	<480	<240	<240	<240	<240	<480	<480
54BF-01		Aug-99	<4900	<2400	<4900	<2400	<2400	<2400	<4900	<4900	<2400	<2400	<2400	<2400	<4900	<4900
54BF-02		Sep-99	<450	<230	<450	<230	<230	<230	<450	<450	<230	<230	<230	<230	<450	<450
Industrial RBC			1.0E+07	6.1E+06	2.0E+06	1.9E+05	1.2E+04 (2)	2.0E+05	2.0E+06	5.2E+04	2.0E+04	1.0E+05	1.2E+04 (2)	4.1E+05	2.0E+06	4.1E+06
Residential RBC			3.9E+05	2.3E+05	7.8E+04	2.1E+04	4.7E+02	7.8E+03	7.8E+04	5.8E+03	7.8E+02	3.9E+03	4.7E+02	1.6E+04	7.8E+04	1.6E+05

Abbreviations:

ID = Identification

B = Analyte detected in laboratory blank, result is estimated and biased high

J = The analyte value is imprecise due to QC problems

D = The analyte concentration results from a required dilution of the sample

RBC = Risk-Based Concentration, USEPA Region III, April 4, 2002 (Non-carcenogenic constituents have been adjusted for a hazard quotient of 0.1.)

dup. = duplicate sample

μg/kg - micrograms per kilograms

Notes:

(1) = Analytical results for Cells Requiring Increased Sampling Depths (Sample collected from 12 feet bgs.)

(2) = Aminodinitrotoluenes value used from the RBC table.

☐ = Reported value exceeds the Industrial RBC

▣ = Reported value exceeds the Residential RBC

Appendix B-4: VOCs
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in µg/kg

Sample Identification	Excavated Cell	Sample Date	Chloromethane	Bromomethane	Vinyl Chloride	Chloroethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloroethene	1,1-Dichloroethane	1,2-Dichloroethene (total)	Chloroform	1,2-Dichloroethane	2-Butanone	1,1,1-Trichloroethane	Carbon Tetrachloride	Bromodichloromethane	1,2-Dichloropropane	cis-1,3-Dicloropropene	Trichloroethene	Benzene	Dibromochloromethane	trans-1,3-Dichloropropene	1,1,2-Trichloroethane	Bromo-form	4-Methyl-2-pentanone	2-Hexanone	Tetrachloroethene	1,1,2,2-Tetrachloroethane	Toluene	Chlorobenzene	Ethylbenzene	Styrene	Xylene (total)
54SC-A-003		Jun-99	<12	<12	<12	<12	26	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-004		Jun-99	<12	<12	<12	<12	14 B	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-005		Jun-99	<13	<13	<13	<13	11 B	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-006		Jun-99	<12	<12	<12	<12	13	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-007		Jun-99	<13	<13	<13	<13	10	<13	<6	<6	<6	<6	1 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	1 JB	<6	<6	<6
54SC-A-008		Jun-99	<12	<12	<12	<12	30 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-009	yes	no data available																																	
54SC-A-010		Jun-99	<12	<12	<12	<12	35 B	<12	1 JB	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-011		Jun-99	<13	<13	<13	<13	15	<13	<6	<6	<6	<6	2 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-A-012		Jun-99	<12	<12	<12	<12	9 B	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-018		Jun-99	<13	<13	<13	<13	49	<13	<6	<6	<6	<6	1 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-A-014		Jun-99	<13	<13	<13	<13	14 B	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-019		Jun-99	<13	<13	<13	<13	30	<13	<6	<6	<6	<6	2 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-A-020		Jun-99	<13	<13	<13	<13	9 B	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-021		Jun-99	<13	<13	<13	<13	6 B	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-022		Jun-99	<13	<13	<13	<13	14	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-023		Jun-99	<12	<12	<12	<12	10	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	1 JB	<6	<6	<6
54SC-A-024		Jun-99	<13	<13	<13	<13	25 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-025		Jun-99	<13	<13	<13	<13	7 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-026	yes	Jun-99	<13	<13	<13	<13	7 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-027		Jun-99	<13	<13	<13	<13	7 JB	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-028		Jun-99	<12	<12	<12	<12	5 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-029		Jun-99	<13	<13	<13	<13	23 B	<13	3 J	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-A-030		Jun-99	<13	<13	<13	<13	85 B	<13	2 J	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-031		Jun-99	<13	<13	<13	<13	13	<13	<7	<7	<7	<7	1 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	2 JB	<7	<7	<7
54SC-A-032		Jun-99	<13	<13	<13	<13	15	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-033		Jun-99	<12	<12	<12	<12	11 B	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-034		Jun-99	<12	<12	<12	<12	41	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-040		Jun-99	<11	<11	<11	<11	9	<11	<6	<6	<6	<6	1 JB	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	<6
54SC-A-041		Jun-99	<12	<12	<12	<12	25 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-042		Jun-99	<13	<13	<13	<13	6 JB	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-043		May-99	<13	<13	<13	<13	33 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-A-044		May-99	<13	<13	<13	<13	51 B	47	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	4 J	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-045		May-99	<12	<12	<12	<12	40 B	17	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-046	yes	May-99	<12	<12	<12	<12	76 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	4 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-047		May-99	<13	<13	<13	<13	25 B	54	<6	<6	<6	<6	<6	<6	9 J	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-A-061		Jun-99	<12	<12	<12	<12	38	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-A-042 dup.		Jun-99	<13	<13	<13	<13	7 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-A-040 dup.		Jun-99	<13	<13	<13	<13	14	<13	<7	<7	<7	<7	2 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	1 JB	<7	<7	<7
54SC-A-004 dup.		Jun-99	<13	<13	<13	<13	12 B	<13	<6	<6	<6	<6	2 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-001	yes	May-99	<11	<11	<11	<11	14 B	<11	<6	<6	<6	<6	<6	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	<6
54SC-B-002		May-99	<13	<13	<13	<13	8 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	4 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-003		May-99	<11	<11	<11	<11	5 JB	<11	<6	<6	<6	<6	<6	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	<6
54SC-B-004		May-99	<12	<12	<12	<12	11 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-005		May-99	<12	<12	<12	<12	12 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-006		May-99	<12	<12	<12	<12	12 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-007		May-99	<12	<12	<12	<12	10 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-008		May-99	<12	<12	<12	<12	10 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-009		May-99	<12	<12	<12	<12	10 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-010		May-99	<12	<12	<12	<12	6 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-011		May-99	4 J	<12	<12	<12	17 B	<12	<6	<6	<6	<6	5 J	<6	<12	<6	<6	<6	<6	<6	3 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-012		May-99	<12	<12	<12	<12	7 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-013		May-99	<12	<12	<12	<12	5 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-014		May-99	<12	<12	<12	<12	10 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-015		May-99	<13	<13	<13	<13	9 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-016		May-99	<13	<13	<13	<13	17 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	2 J	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-017		Apr-99	<13	<13	<13	<13	3 JB	560	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-018		Apr-99	<12	<12	<12	<12	3 JB	<1500	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-019		Apr-99	<13	<13	<13	<13	7 B	<1600	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-020		Apr-99	<13	<13	<13	<13	<7	<1600	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-021		Apr-99	<12	<12	<12	<12	1 JB	<1500	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-022		Apr-99	<12	<12	<12	<12	2 JB	<1600	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-023		May-99	<13	<13	<13	<13	23 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-024		May-99	<12	<12	<12	<12	16 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-025		May-99	<13	<13	<13	<13	15 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-026		May-99	<14	<14	<14	<14	27 B	<14	1 J	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	6 J	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-027		May-99	<13	<13	<13	<13	15 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	2 B	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-028		May-99	<13	<13	<13	<13	20 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	3 J	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-029		May-99	<12	<12	<12	<12	6 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-030		May-99	<12	<12	<12	<12	6 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-031		May-99	<12	<12	<12	<12	3 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-032		May-99	<12	<12	<12	<12	8 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-033		May-99	<12	<12	<12	<12	7 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-034		May-99	<12	<12	<12	<12	9 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-035		May-99	<13	<13	<13	<13	11 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-036		May-99	<12	<12	<12	<12	7 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-037		Mar-99	<12	<12	<12	<12	5 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-038		Mar-99	<13	<13	<13	<13	11 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-039		Mar-99	<13	<13	<13	<13	22	19921 E	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-040		Mar-99	<13	<13	<13	<13	8	277 E	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-041		Mar-99	<12	<12	<12	<12	<6	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-042		Mar-99	<14	<14	<14	<14	6 J	630 E	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-043		Mar-99	<14	<14	<14	<14	21	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-044		Mar-99	<14	<14	<14	<14	15	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-045		Mar-99	<13	<13	<13	<13	25	9289 E	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
Industrial RBC	(µg/kg)		4.4E+05	2.9E+05	7.9E+03	2.0E+06	7.6E+05	2.0E+07	2.0E+07	9.5E+03	2.0E+07	1.8E+06	2.0E+06	6.3E+04	1.2E+08	5.7E+07	4.4E+04	9.2E+04	8.4E+04	5.7E+04	1.4E+04	1.0E+05	6.8E+04	5.7E+04	1.0E+05	7.2E+05	1.6E+07	8.2E+06	1.1E+05	2.9E+04	4.1E+07	4.1E+06	2.0E+07	4.1E+07	4.1E+08
Residential RBC	(µg/kg)		4.9E+04	1.1E+04	9.0E+01	2.2E+05	8.5E+04	7.8E+05	7.8E+05	1.1E+03	7.8E+05	7.0E+04	7.8E+04	7.0E+03	4.7E+06	2.2E+06	4.9E+03	1.0E+04	9.4E+03	6.4E+03	1.6E+03	1.2E+04	7.6E+03	6.4E+03	1.1E+04	8.1E+04	6.3E+05	3.1E+05	1.2E+04	3.2E+03	1.6E+06	1.6E+05	7.8E+05	1.6E+06	1.6E+07

Appendix E-4: VOCs
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reporied in µg/kg

Sample Identification	Excavated Cell	Sample Date	Chloromethane	Bromomethane	Vinyl Chloride	Chloroethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloroethane	1,1-Dichloroethane	1,2-Dichloroethene (total)	Chloroform	1,2-Dichloroethane	2-Butanone	1,1,1-Trichloroethene	Carbon Tetrachloride	Bromodichloromethane	1,2-Dichloropropene	cis-1,3-Dicloropropene	Trichloroethene	Benzene	Dibromochloromethane	trans-1,3-Dichloropropene	1,1,2-Trichloroethene	Bromo-form	4-Methyl-2-pentanone	2-Hexanone	Tetrachloroethene	1,1,2,2-Tetrachloroethene	Toluene	Chlorobenzene	Ethylbenzene	Styrene	Xylene (total)
54SC-B-046		Mar-99	<12	<12	<12	<12	17	279 E	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-047		Mar-99	<13	<13	<13	<13	14	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-048		Mar-99	<13	<13	<13	<13	19	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-049		Mar-00	<12	<12	<12	<12	9	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-050		Mar-99	<12	<12	<12	<12	6 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-051		Mar-99	<13	<13	<13	<13	5 JB	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-052		Mar-99	<13	<13	<13	<13	13 JB	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-053		Mar-99	<12	<12	<12	<12	4 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-054		Mar-99	<13	<13	<13	<13	16 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-055		Mar-99	<13	<13	<13	<13	9 B	5284 E	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-056		Mar-99	<13	<13	<13	<13	6 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-057		Mar-99	<13	<13	<13	<13	4 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-058		Apr-99	<13	<13	<13	<13	3 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-059		Apr-99	<14	<14	<14	<14	3 J	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-060		Apr-99	<13	<13	<13	<13	2 J	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-061		Apr-99	<13	<13	<13	<13	3 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-062		Apr-99	<13	<13	<13	<13	5 JB	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-063		Apr-99	<12	<12	<12	<12	3 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-064		Apr-99	<12	<12	<12	<12	4 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-065		Apr-99	<12	<12	<12	<12	<6	130	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-066	yes	Apr-99	<13	<13	<13	<13	8 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-067	yes	Apr-99	<13	<13	<13	<13	6	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-068		Apr-99	<12	<12	<12	<12	7	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-069		Apr-99	<13	<13	<13	<13	6	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-070		Apr-99	<13	<13	<13	<13	4	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-071		Apr-99	<12	<12	<12	<12	5 J	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-072		Apr-99	<13	<13	<13	<13	6 J	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	15 B	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-073		Apr-99	<12	<12	<12	<12	5 J	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-074		Apr-99	<12	<12	<12	<12	270 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	17 B	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-075		Mar-99	<13	<13	<13	<13	20	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	5
54SC-B-076		Apr-99	<13	<13	<13	<13	200 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	19 B	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-077		Apr-99	<12	<12	<12	<12	390 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	11 B	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-078		Apr-99	<13	<13	<13	<13	74 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	7	<7	<6	<7	<7	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-079		Apr-99	<14	<14	<14	<14	360 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	10 B	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-080		Apr-99	<14	<14	<14	<14	360 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	15 B	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-081		Apr-99	<14	<14	<14	<14	360 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	20 B	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-082		Apr-99	<10	<10	<10	<10	9	<10	<5	<5	<5	<5	<5	<5	<10	<5	<5	<5	<5	<5	9	<5	<5	<5	<5	<5	<10	<10	<5	<5	<5	<5	<5	<5	<10
54SC-B-083		Apr-99	<12	<12	<12	<12	10	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	10	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-084		Apr-99	<12	<12	<12	<12	9	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	7	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-085		Apr-99	<12	<12	<12	<12	11	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	10	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-086		Apr-99	<12	<12	<12	<12	10	<12	<6	<6	<6	<6	<6	<6	12 J	<6	<6	<6	<6	<6	4 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-087		Apr-99	<12	<12	<12	<12	11	<12	<6	<6	<6	<6	<6	<6	16	<6	<6	<6	<6	<6	5 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-088		Apr-99	<12	<12	<12	<12	12	<12	<6	<6	<6	<6	<6	<6	21	<6	<6	<6	<6	<6	17	<6	<6	<6	<6	<6	<12	<12	<6	<6	2 J	<6	<6	<6	<6
54SC-B-089		Apr-99	<12	<12	<12	<12	9	<12	<6	<6	<6	<6	<6	<6	22	<6	<6	<6	<6	<6	15	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	1 J
54SC-B-090		Apr-99	<12	<12	<12	<12	2 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-091		Apr-99	<12	<12	<12	<12	6	550	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-094		May-99	<12	<12	<12	<12	9 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	4 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-095	yes	May-99	<12	<12	<12	<12	18 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	7	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-095 (1)		Jun-99	<12	<12	<12	<12	15	<12	9	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-096	yes	May-99	<13	<13	<13	<13	22 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	3 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-096 (1)		Jun-99	<13	<13	<13	<13	14 B	<13	<6	<6	<6	<6	2 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-097		May-99	<13	<13	<13	<13	16 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-098		Apr-99	<12	<12	<12	<12	<6	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-099		Apr-99	<12	<12	<12	<12	<6	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-100		Apr-99	<12	<12	<12	<12	<6	33	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-101		May-99	<12	<12	<12	<12	6 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-102		Apr-99	<12	<12	<12	<12	3 JB	73	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-111		Apr-99	<12	<12	<12	<12	$\boxed{220}$ B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	7 B	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-112		Apr-99	<12	<12	<12	<12	23 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	9 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-113		Apr-99	<12	<12	<12	<12	25 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	7	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-114		Apr-99	<13	<13	<13	<13	44 B	<13	<6	<6	<6	<6	<6 J	<6	<13	<6	<6	<6	<6	<6	14	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-115		Apr-99	<12	<12	<12	<12	31 B	<12	9	<6	<6	<6	1 J	<6	<12	<6	<6	<6	<6	<6	6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-116		Apr-99	<12	<12	<12	<12	34 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	7	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-117		Apr-99	<13	<13	<13	<13	8	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	4	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-118		Apr-99	<12	<12	<12	<12	20	<12	<6	<6	<6	<6	1 J	<6	<12	<6	<6	<6	<6	<6	16	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-119		Apr-99	<12	<12	<12	<12	17	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	10	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-120		Apr-99	<12	<12	<12	<12	10	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	18	<6	<6	<6	<6	<6	<12	<12	<6	<6	6	<6	<6	<6	8
54SC-B-121		Apr-99	<11	<11	<11	<11	10	<11	<6	<6	<6	<6	<6	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	<6
54SC-B-122		Apr-99	<12	<12	<12	<12	11	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	11	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-137		Apr-99	<11	<11	<11	<11	7	<11	<6	<6	<6	<6	<6	<6	<11	<6	<6	<6	<6	<6	6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	<6
54SC-B-137		May-99	<13	<13	<13	<13	30 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-138	yes	May-99	<13	<13	<13	<13	16 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-138 (1)		Jun-99	<13	<13	<13	<13	35 B	<13	<6	<6	<6	<6	3 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-139		May-99	<12	<12	<12	<12	19 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-140		May-99	<13	<13	<13	<13	14 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	4 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-141		May-99	<12	<12	<12	<12	34 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-142		May-99	<12	<12	<12	<12	22 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-143		May-99	<12	<12	<12	<12	11 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-144		May-99	<12	<12	<12	<12	11 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-146		May-99	<12	<12	<12	<12	6 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-147		Apr-99	<12	<12	<12	<12	<6	240	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-148		Apr-99	<12	<12	<12	<12	3 J	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-149		Apr-99	<13	<13	<13	<13	6 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-150		Apr-99	<13	<13	<13	<13	9	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-151		Apr-99	<14	<14	<14	<14	8	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
Industrial RBC	(µg/kg)		4.4E+05	2.9E+05	7.9E+03	2.0E+06	7.6E+05	2.0E+07	2.0E+07	9.5E+03	2.0E+07	1.8E+06	2.0E+06	6.3E+04	1.2E+08	5.7E+07	4.4E+04	9.2E+04	8.4E+04	5.7E+04	1.4E+04	1.0E+05	6.8E+04	5.7E+04	1.0E+05	7.2E+05	1.6E+07	8.2E+06	1.1E+05	2.9E+04	4.1E+07	4.1E+06	2.0E+07	4.1E+07	4.1E+08
Residential RBC	(µg/kg)		4.9E+04	1.1E+04	9.0E+01	2.2E+05	8.5E+04	7.8E+05	7.8E+05	1.1E+03	7.8E+05	7.0E+04	7.8E+04	7.0E+03	4.7E+06	2.2E+06	4.9E+03	1.0E+04	9.4E+03	6.4E+03	1.6E+03	1.2E+04	7.6E+03	6.4E+03	1.1E+04	8.1E+04	6.3E+05	3.1E+05	1.2E+04	3.2E+03	1.6E+06	1.6E+05	7.8E+05	1.6E+06	1.6E+07

Appendix B-4: VOCs
Summary of Soil Analytical Results
Modified from: Interim Action (Parallax 1999)
SWMU 54 RCRA Facility Investigation
Radford Army Ammunition Plant, Radford, Virginia

Results reported in µg/kg

Sample Identification	Excavated Cell	Sample Date	Chloro-methane	Bromo-methane	Vinyl Chloride	Chloro-ethane	Methylene Chloride	Acetone	Carbon Disulfide	1,1-Dichloro-ethene	1,1-Dichloro-ethane	1,2-Dichloro-ethene (total)	Chloro-form	1,2-Dichloroethane	2-Buta-none	1,1,1-Trichloro-ethane	Carbon Tetra-chloride	Bromodi-chloro-methane	1,2-Dichloro-propane	cis-1,3-Dicloro-propene	Trichloro-ethene	Benzene	Dibromo-chloro-methane	trans-1,3-Dichloro-propene	1,1,2-Trichloro-ethane	Bromo-form	4-Methyl-2-penta-none	2-Hexa-none	Tetra-chloro-ethene	1,1,2,2-Tetra chloro-ethane	Toluene	Chloro-benzene	Ethyl-benzene	Styrene	Xylene (total)
54SC-B-152		Apr-99	<13	<13	<13	<13	6 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-153		Apr-99	<13	<13	<13	<13	6 J	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-154		Apr-99	<14	<14	<14	<14	3 J	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-155		Apr-99	<14	<14	<14	<14	13 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	2 JB	<7	<7	<7	<7	<7	<14	<14	<7	<7	7	<7	<7	<7	<7
54SC-B-156		Apr-99	<14	<14	<14	<14	190 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	13 B	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-157		Apr-99	<12	<12	<12	<12	22 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-190		May-99	<12	<12	<12	<12	6 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-191	yes	May-99	<12	<12	<12	<12	9 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-192	yes	May-99	<12	<12	<12	<12	9 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-192 (1)		Jun-99	<12	<12	<12	<12	48 B	<12	<6	<6	<6	<6	3 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-193		May-99	<12	<12	<12	<12	17 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-199		May-99	<12	<12	<12	<12	4 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	1 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-200		Apr-99	<11	<11	<11	<11	3 JB	<11	<6	<6	<6	<6	<6	<6	<11	<6	<6	<6	<6	<6	1 JB	<6	<6	<6	<6	<6	<11	<11	<6	<6	5 J	<6	<6	<6	<6
54SC-B-201		Apr-99	<13	<13	<13	<13	13 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	7	<6	<6	<6	<6
54SC-B-202		Apr-99	<13	<13	<13	<13	13 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	<6	2 JB	<6	<6	<6	<6	<13	<13	9	<6	6 J	<6	<6	<6	<6
54SC-B-203		Apr-99	<14	<14	<14	<14	150 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	4 JB	<7	<7	<7	<7	<7	<14	<14	<7	<7	6	<7	<7	<7	<7
54SC-B-204		Apr-99	<12	<12	<12	<12	42 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 JB	<6	<6	<6	<6	<6	<12	<12	<6	<6	6	<6	<6	<6	<6
54SC-B-205		Apr-99	<12	<12	<12	<12	19 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	4	<6	<6	<6	<6	<6	<12	<12	<6	<6	3	<6	<6	<6	<6
54SC-B-206		Apr-99	<12	<12	<12	<12	4 JB	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-207		Apr-99	<13	<13	<13	<13	6 JB	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	2 JB	<7	<7	<7	<7	<7	<13	<13	<7	<7	1 J	<7	<7	<7	<7
54SC-B-208		Apr-99	<14	<14	<14	<14	7 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	1 JB	<7	<7	<7	<7	<7	<14	<14	<7	<7	2 J	<7	<7	<7	<7
54SC-B-209		Apr-99	<13	<13	<13	<13	13 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	2 JB	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-210		Apr-99	<13	<13	<13	<13	19 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	5 J	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-250	yes	May-99	<12	<12	<12	<12	22 B	20	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-251	yes	May-99	<12	<12	<12	<12	65 B	152	<6	<6	<6	<6	<6	<6	15	<6	<6	<6	<6	<6	5 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-251 (1)		Jun-99	<12	<12	<12	<12	14 B	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-252		May-99	<12	<12	<12	<12	22 B	36	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-262		Apr-99	<12	<12	<12	<12	180 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	2 JB	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-263		Apr-99	<12	<12	<12	<12	210 B	22	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	4 JB	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-264		Apr-99	<12	<12	<12	<12	36 B	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	6 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-265		Apr-99	<13	<13	<13	<13	24 B	<13	<7	<7	<7	<7	<7	<7	<13	<7	<7	<7	<7	<7	8	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-266		Apr-99	<13	<13	<13	<13	19 B	<13	<6	<6	<6	<6	<6	<6	<13	<6	<6	<6	<6	<6	10	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-317		Jun-99	<12	<12	<12	<12	37 B	<12	<6	<6	<6	<6	4 JB	<6	<12	<6	<6	<6	<6	<6	2 J	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-318		May-99	<14	<14	<14	<14	34 B	<14	<7	<7	<7	<7	<7	<7	<14	<7	<7	<7	<7	<7	2 J	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	<7
54SC-B-319		Jun-99	<12	<12	<12	<12	36 B	<12	<6	<6	<6	<6	3 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-330		Jun-99	<14	<14	<14	<14	24 B	<14	<7	<7	<7	<7	2 JB	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	4 J
54SC-B-331		Jun-99	<14	<14	<14	<14	27 B	<14	<7	<7	<7	<7	2 JB	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	4 J
54SC-B-332		Jun-99	<11	<11	<11	<11	15 B	<11	<6	<6	<6	<6	4 JB	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	1 J
54SC-B-333		Jun-99	<12	<12	<12	<12	14 B	<12	<6	<6	<6	<6	4 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	1 J
54SC-B-334		Jun-99	<12	<12	<12	<12	12 B	<12	<6	<6	<6	<6	3 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	1 J
54SC-B-335		Jun-99	<12	<12	<12	<12	14 B	<12	<6	<6	<6	<6	4 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	1 J
54SC-B-336		Jun-99	<13	<13	<13	<13	24 B	<13	<6	<6	<6	<6	2 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	4 J
54SC-B-393		Jun-99	<12	<12	<12	<12	42 B	<12	<6	<6	<6	<6	3 J	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-018 dup.		Jun-99	<13	<13	<13	<13	39 B	<13	<7	<7	<7	<7	3 JB	<7	<13	<7	<7	<7	<7	<7	<7	2J	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	<7
54SC-B-019 dup.		Jun-99	<12	<12	<12	<12	16 B	<12	<6	<6	<6	<6	4 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	2 J
54SC-B-251 dup.	(1)	Jun-99	<12	<12	<12	<12	<6	<12	<6	<6	<6	<6	4 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	2 J
54SC-B-192 dup.	(1)	Jun-99	<12	<12	<12	<12	4 JB	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	3 J	<6	16 B
54SC-B-096 dup.	(1)	Jun-99	<13	<13	<13	<13	25 B	<13	<7	<7	<7	<7	5 JB	<7	<13	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<13	<13	<7	<7	<7	<7	<7	<7	3 J
54SC-B-138 dup.	(1)	Jun-99	<12	<12	<12	<12	12 B	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-095 dup.	(1)	Jun-99	<12	<12	<12	<12	4 JB	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	3 J	<6	17 B
54SC-B-317 dup.		Jun-99	<12	<12	<12	<12	<6	<12	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-393 dup.		Jun-99	<12	<12	<12	<12	10 B	<12	<6	<6	<6	<6	2 JB	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
54SC-B-319 dup.		Jun-99	<13	<13	<13	<13	40 B	<13	<6	<6	<6	<6	3 JB	<6	<13	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<13	<13	<6	<6	<6	<6	<6	<6	<6
54SC-B-330 dup.		Jun-99	<11	<11	<11	<11	9 B	<11	<6	<6	<6	<6	3 JB	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	1 J
54SC-B-331 dup.		Jun-99	<11	<11	<11	<11	10 B	<11	<6	<6	<6	<6	4 JB	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	<6	<6	<6	<6	2 J
54SC-B-332 dup.		Jun-99	<14	<14	<14	<14	25 B	<14	<7	<7	<7	<7	2 JB	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	5 J
54SC-B-333 dup.		Jun-99	<14	<14	<14	<14	23 B	<14	<7	<7	<7	<7	2 JB	<7	<14	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<14	<14	<7	<7	<7	<7	<7	<7	5 J
54BF-01(2)		Aug-99	<11	<11	<11	<11	38 B	<11	<6	<6	<6	<6	<6	<6	<11	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<11	<11	<6	<6	4 B	<6	<6	<6	<6
54BF-02 (2)		Sep-99	<12	<12	<12	<12	126 B	22 B	<6	<6	<6	<6	<6	<6	<12	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<12	<12	<6	<6	<6	<6	<6	<6	<6
Industrial RBC	(µg/kg)		4.4E+05	2.9E+05	7.9E+03	2.0E+06	7.6E+05	2.0E+07	2.0E+07	9.5E+03	2.0E+07	1.8E+06	2.0E+06	6.3E+04	1.2E+08	5.7E+07	4.4E+04	9.2E+04	8.4E+04	5.7E+04	1.4E+04	1.0E+05	6.8E+04	5.7E+04	1.0E+05	7.2E+05	1.6E+07	8.2E+06	1.1E+05	2.9E+04	4.1E+07	4.1E+06	2.0E+07	4.1E+07	4.1E+08
Residential RBC	(µg/kg)		4.9E+04	1.1E+04	9.0E+01	2.2E+05	8.5E+04	7.8E+05	7.8E+05	1.1E+03	7.8E+05	7.0E+04	7.8E+04	7.0E+03	4.7E+06	2.2E+06	4.9E+03	1.0E+04	9.4E+03	6.4E+03	1.6E+03	1.2E+04	7.6E+03	6.4E+03	1.1E+04	8.1E+04	6.3E+05	3.1E+05	1.2E+04	3.2E+03	1.6E+06	1.6E+05	7.8E+05	1.6E+06	1.6E+07

Notes:

E = Analyte exceeds detection limit.

J = The analyte value is imprecise due to quality control problems

B = Analyte detected in laboratory blank, result is estimated and biased high

dup. = duplicate sample

RBC = Risk-Based Concentration, USEPA Region III, April 4, 2002 (Non-carcenogenic constituents have been adjusted for a hazard quotient of 0.1.)

µg/kg = Micrograms per kilogram

bgs = below ground surface

(1) = Analytical results for Cells Requiring Increased Sampling Depths (Sample collected from 12 feet bgs.)

(2) = Sample from backfill soil

APPENDIX C

STATISTICAL ANALYSIS OF MINIMUM SAMPLE SIZES

Table C-1
Calculation for Minimum Number of Samples to Collect from Systematic Grid at Area A
Using Parsons (1996) Data for Lead - 0-2 ft bgs

Count of Observations	Lead Concentration (mg/kg)
1	716.80
2	2354.26
3	321.84
4	84.26
5	39.90
6	3789.73
7	50.29
8	229.75
9	205.56
10	91.13
11	21.22
12	134.97
13	36.56
14	31.82

number of observations	$n =$	14
degrees of freedom (df)	$n-1 =$	13
tabulated student's t value for two-tailed confidence interval and probability of 0.20 (t.20)	t_{20} for df of 13 =	1.350
t value squared	$t_{20}^2 =$	1.823
Mean of observations	$x =$	579.15
Variance of observations	$s^2 =$	1227828.01
Standard deviation of observations	$s =$	1108.07
Regulatory threshold for lead - industrial	$RT_I =$	1000
Difference regulatory threshold and mean	=	Δ
Difference between regulatory threshold and mean for industrial lead (Δ)	$RT - x =$	420.85
Delta value squared	$\Delta^2 =$	177115.32
Equation 8 in SW 846 Chapter 9, Table 9-1 (p. 9-2)	$n_s =$	$t^2_{.20}s^2/\Delta^2$
	where $n_s =$	Appropriate No. of samples to collect from a solid waste
	number of samples =	13

Reference: USEPA 1998 . *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Chapter 9.

Table C-2
Calculation for Minimum Number of Samples to Collect from Systematic Grid at Area B
Using MSE (1997) Data for Lead => 100 mg/kg

Count of Observations	Lead Concentration (mg/kg)
1	562
2	2340
3	600
4	1060
5	2660
6	196
7	5560
8	1090

number of observations	n =	8
degrees of freedom (df)	n-1 =	7
tabulated student's t value for two-tailed confidence interval and probability of 0.20 (t.20)	$t_{.20}$ for df of 7 =	1.415
t value squared	$t_{.20}^2$ =	2.002
Mean of observations	x =	1758.50
Variance of observations	s^2 =	3107454.6
Standard deviation of observations	s =	1762.80
Regulatory threshold for lead - industrial	RT_I =	1000
Difference regulatory threshold and mean	=	Δ
Difference between regulatory threshold and mean for industrial lead (Δ)	RT - x =	-758.50
Delta value squared	Δ^2 =	575322.25
Equation 8 in SW 846 Chapter 9, Table 9-1 (p. 9-2)	n_s =	$t^2_{.20}s^2/\Delta^2$
	where n_s =	Appropriate No. of samples to collect from a solid waste
	number of samples =	11

Reference: USEPA 1998. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, Chapter 9.