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08-4

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

January 4, 2008

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

P.W. Holt
Environmental Manager
Alliant Techsystems, Inc.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24141-0100

Re: Radford Army Ammunition Plant, Va.
Master Work Plan Addendums 020 & 021
Review of the Army's RCRA Work Plan Addendums

Dear Mr. McKenna and Ms. Holt:

The U.S. Environmental Protection Agency (EPA) and the Virginia Department of Environmental Quality (VDEQ) have reviewed the U.S. Army's (Army's) November, 2007 submittals of the Final Work Plan Addendum 020 for Solid Waste Management Units (SWMU) 25, 37, 38, and Area of Concern Q, and the Final Work Plan Addendum 021 for SWMU 57. Based upon our review, the Work Plans are approved, and in accordance with Part II. (E) (5) of RFAAP's Corrective Action Permit, they can now be considered final.

If you have any questions, please call me at 215-814-3413, or Jim Cutler at 804-698-4498. Thanks.

Sincerely,

William Geiger
RCRA Project Manager
General Operations Branch (3WC23)

cc: Jim Cutler, VDEQ

ATK
ALLIANT TECHSYSTEMS

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

November 6, 2007

Mr. William Geiger
RCRA General Operations Branch, Mail Code: 3WC23
Waste and Chemicals Management Division
U. S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Mr. James L. Cutler, Jr.
Virginia Department of Environmental Quality
629 East Main Street
Richmond, VA 24143-0100

Subject: With Certification, Work Plan Addendum 020, RCRA Facility Investigation for Solid Waste Management Units 35, 37, 38 and Area of Concern Q, Final October 2007 and Work Plan Addendum 021, RCRA Facility Investigation at Solid Waste Management Unit 57, Final October 2007
Radford Army Ammunition Plant, EPA ID# VA1 210020730

Dear Mr. Geiger and Mr Cutler:

Enclosed is the certification for the subject documents that were sent to you on November 5, 2007. Also enclosed is a copy of the transmittal email message and respective response to comments.

Please coordinate with and provide any questions or comments to myself at (540) 639-8658, Jerry Redder of my staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 639-8641.

Sincerely,

P.W. Holt, Environmental Manager
Alliant Techsystems Inc.

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

E. A. Lohman
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West Central Regional Office
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07-815-213
JMcKenna

Rich Mendoza
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bc: Administrative File
J. McKenna, ACO Staff
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M.A. Miano
P.W. Holt
J. J. Redder
Env. File

Coordination: J. McKenna
J. McKenna

MMMiano
M. A. Miano

07-815-213
JMcKenna

Concerning the following:

*Radford Army Ammunition Plant*
*Work Plan Addendum 020,*
*RCRA Facility Investigation for Solid Waste Management Units 35, 37, 38 and Area of Concern O,*
*Final October 2007*
*and*
*Work Plan Addendum 021,*
*RCRA Facility Investigation at Solid Waste Management Unit 57, Final October 2007*

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: Jon R. Drushal
TITLE: Lieutenant Colonel, US Army
Commanding

SIGNATURE:
PRINTED NAME: Kent Holiday
TITLE: Vice President and General Manager
ATK Energetics Systems Division

07-815-213
JMcKenna

## Greene, Anne

**From:** McKenna, Jim
**Sent:** Monday, November 05, 2007 3:13 PM
**To:** Greene, Anne; beth lohman; dennis.druck@us.army.mil; durwood willis2; Geiger.William@epamail.epa.gov; Redder, Jerome; jim spencer; jlcutler@deq.virginia.gov; Mendoza, Richard R Mr CIV USA SA; Parks, Jeffrey N; Timothy.Leahy@shawgrp.com; Tina_Devine@URSCorp.com; Tom.Meyer@nab02.usace.army.mil
**Subject:** Work Plan Addenda 20 & 21 and response to comments. (UNCLASSIFIED)

**Importance:** High

**Attachments:** RTC_EPA_DEQ WPA 20 comment 7_6_07.doc; RTC_EPA_DEQ WPA 21 comment 7_26_07.doc

RTC_EPA_DEQ PA 20 comment 7_6 RTC_EPA_DEQ PA 21 comment 7_2

Classification: UNCLASSIFIED
Caveats: NONE

All:

Note the contractor will ship the subject documents with a copy of this email and attachments to the POCs and tracking numbers below.

Certification letter will follow from Radford AAP under separate cover.

Thank you for support of the Radford AAP Installation Restoration Program.

Jim

Will Geiger - 7992 1664 7563
Jim Cutler - 7914 2706 8729
Durwood Willis - 7983 0213 8061
Tom Meyer - 7997 4621 1178
Rich Mendoza - 7997 4621 3089
Dennis Druck - 7914 2708 9304
Elizabeth Lohman - 7924 4958 0507

Classification: UNCLASSIFIED
Caveats: NONE

**Response to Comments (8/24/2007)**
**EPA and VDEQ Comments Received via e-mail 07/06/07**
**Draft Work Plan Addendum 020, RCRA Facility Investigation for Solid Waste Management Units 35, 37, 38, and Area of Concern Q, Radford Army Ammunition Plant, Virginia, April 2007**

**GENERAL COMMENTS**

**Comment 1:** Groundwater monitoring wells are proposed for several sites, but the specific methods for installation of these wells have not been specified. Although Standard Operating Procedures (SOPs) 20.1 and 20.11, included in Appendix A, are referenced, these SOPs address several types of drilling methods (hollow stem auger, air rotary, etc.). The drilling method for installation of each monitoring well should be indicated in the Work Plan Addendum.

Additionally, the above mentioned SOPs indicate that the proposed well screen length, screen slot size, and filter pack should be specified in the work plan addenda. However, theses details have not been specified for the proposed wells. Please revise the Work Plan Addendum to address these omissions.

> **RFAAP Response:** The work plan addendum will be revised to indicate that the air rotary drilling method will be used for installation of monitoring wells given that well installation into bedrock is anticipated. A 6-inch diameter, roller bit will be used to drill within soil overburden and a 6-inch diameter, air hammer bit will be used to drill in bedrock. If unstable conditions are encountered in the borehole, then a 6-inch temporary casing will be set in the borehole to allow for boring completion and monitoring well installation. A minimum 8-inch diameter roller bit will be used in the overburden if temporary casing is required. The casing sections are fitted with auger couples to allow for incremental removal during well construction.
>
> The work plan addendum will be revised to include proposed monitoring well construction information and specifications including: well diameter, screen and riser pipe material, screen slot size, filter pack material, bentonite seal, cement-bentonite grout, surface seal, protective casing, and surface completion details. A proposed well construction diagram will be included in the work plan addendum. Monitoring wells will be constructed using 2-inch diameter (nominal), Schedule 40 polyvinyl chloride (PVC) threaded screen and riser pipe. A 0.010-inch screen slot size and No. 2 sand filter pack will be used to construct the wells.
>
> The uppermost zone of groundwater at the site is expected to occur near the overburden and bedrock interface. Monitoring wells be installed with a 15 ft long screen so that the top of the screen is above the seasonally high water table. It is anticipated that the monitoring wells will screened across the overburden and bedrock interface.

**Comment 2:** All of the sites described in this Work Plan Addendum are located in close proximity to the New River. It has been noted that site groundwater may be hydraulically connected to the New River, but surface water and sediment sampling have not been proposed at any of the sites. Instead, it is stated that if site-related groundwater impacts are identified, "the surface water pathway will be qualitatively assessed" (Page 2-5 and 3-4). The Work Plan Addendum has not described this qualitative analysis, so it is not clear that the surface water and sediment pathway will be adequately characterized. Please revise the Work Plan Addendum to address this concern. Additional investigation of the New River surface water and sediment may be necessary, depending on the results of the proposed groundwater sampling.

> **RFAAP Response:** Text will be changed to read "If site-related groundwater impacts are identified, an assessment of the potential impacts to the New River will be conducted via screening

the groundwater data for COPCs against Virginia Water Quality Criteria and EPA Region III freshwater ecological screening values. If the screening indicates potential impacts to the New River at levels of concern, additional investigation of the New River may be necessary."

**SPECIFIC COMMENTS**

**Comment 3:** Section 2.6.1.1, Inside Drying Bed Areas, Page 2-8: One of the six proposed soil borings is identified as 35SB57. This sample could not be located on Figure 2-8 (RFI Proposed Sampling Locations SWMU 35). Figure 2-8 does include a sample identified as 35SB5, so it appears a typographical error may have been made in the text of the document. Please resolve this discrepancy.

**RFAAP Response:** The first sentence of Section 2.6.1.1 contains a typographical error. The boring listed as 35SB57 should be 35SB5. The text will be changed from 35SB57 to 35SB5.

**Comment 4:** Section 2.6.1.1, Inside Drying Bed Areas, Page 2-8: The Work Plan Addendum proposes the collection of a subsurface soil sample at the boring completion depth immediately above encountered groundwater or above boring refusal. If boring refusal is encountered, the boring should be moved within 5 feet of the original borehole in an attempt to collect a soil sample just above the water table (as noted on Page 4-10 of Section 4.3 – Quality Assurance Objectives). Please revise the Work Plan Addendum to include this contingency should refusal be encountered in a borehole.

**RFAAP Response:** Text will be changed to read "A subsurface soil sample at the boring completion depth immediately above groundwater. If boring refusal is encountered, the boring will be moved within 5 feet of the original borehole in an attempt to collect the soil sample just above the water table."

**Comment 5:** Section 2.6.1.1, Inside Drying Bed Areas, Page 2-8: It is stated that "based on the presence/absence of sludge in the direct push borings, additional borings will be advanced using direct push and/or hand augers within the drying bed to more completely characterize the volume and nature and extent of sludge." However, no chemical analysis of soil from these borings is proposed. The Work Plan Addendum does not provide a contingency for additional chemical analyses should visual observation or results of field screening indicate potentially elevated levels of contamination. In order to properly characterize the nature and extent of contamination, please revise the Work Plan Addendum to provide a contingency for additional chemical analyses should visual observation or field screening results warrant the collection of additional samples for chemical analysis.

**RFAAP Response:** Previous investigations conducted at SWMU 35 indicated the presence of approximately eight feet of $CASO_4$ sludge at locations tested in the western, central, and eastern parts of the drying bed. Given these results, the proposed investigation program (borings 35SB5 through 35SB10 and 18 chemical samples) has been designed to collect data across the drying bed area and therefore is considered appropriate to characterize waste present and associated impacts to soil within the well-defined drying bed area. In addition to discrete testing of sludge samples for TCL and TAL parameters, a composite sample of $CASO_4$ sludge from the drying bed will be submitted for waste characteristics testing.

As a contingency, if sludge is not encountered in any of the borings (35SB5 through 35SB10), then a minimum of six additional borings will be completed in the drying bed area to evaluate for the presence of sludge. If sludge is encountered in one or more of these borings, then chemical samples will be substituted from nearest original boring or borings (i.e., 35SB5 through 35SB10) to the additional boring or borings where sludge is encountered.

The proposed investigation plan for the drying bed area is consistent with EPA and VDEQ approved investigations implemented by URS at $CASO_4$ sludge drying beds at SWMU 8 and SWMU 36.

**Comment 6:** Section 2.6.1.1, Inside Drying Bed Areas, page 2-8: There appears to be a discrepancy between the text in sections 2.6.1.1 and 2.6.1.2, and Table 4-4 and Figure 2-8. Section 2.6.1.1 indicates that three samples will be collected from each of the six borings (35SB1 through 35SB6) for chemical analysis. However, Table 4-4 which is referenced in this section lists only one surface sample (0-1 ft bgs) each from boring locations 35SB1 through 35SB4. Table 4-4 appears to match boring locations depicted on Figure 2-8. Likewise, section 2.6.1.2 indicates that one surface soil sample (0-1 ft bgs) will be collected from each of the four borings (35SB7 through 35SB10) for chemical analysis. However, Table 4-4 appears to indicate that three samples will be collected from each boring for chemical analysis. Please resolve this discrepancy. One way would be to change the listing in the text (Section 2.6.1.1) for the borings inside the Drying Bed Areas to 35SB5, 35SB6, 35SB7, 35SB8, 35SB9 and 35SB10, and change the listing in the text (Section 2.6.1.2) for the borings outside of the Drying Bed Areas to 35SB1, 35SB2, 35SB3 and 35SB4.

**RFAAP Response:** The correct boring locations and identifications are shown on Figure 2-8 and Table 4-4. To resolve the identified discrepancies, the following text changes will be made:

- Section 2.6.1.1 – the first line of text in Section 2.6.1.1 will be changed to "Six soil borings (35SB5, 35SB6, 35SB7, 35SB8, 35SB9, and 35SB10) will be advanced within the drying bed area to the depth of encountered groundwater or refusal, whichever is shallower."
- Section 2.6.1.2 – the first line of text in Section 2.6.1.2 will be changed to "Four soil borings (35SB1, 35SB2, 35SB3, and 35SB4) will be advanced outside the perimeter/berm of the drying bed to a depth of 10 ft bgs to assess for the presence or absence of sludge outside the drying bed (Figure 2-8)."

**Comment 7:** Section 2.6.1.2, Outside Drying Bed Areas, Page 2-8: It appears that only surface soil sampling is proposed for outside of the drying bed areas. It is not clear that this limited sampling will be adequate to assess the presence or absence of sludge. Previous investigations have encountered a sludge thickness of up to 8 feet within the bermed area; however, areas outside of the berm do not appear to have been assessed (Page 2-3). Please revise the Work Plan Addendum to propose subsurface investigation and sampling outside the drying beds, or provide justification for not assessing subsurface conditions outside the presumed limit of the drying beds.

**RFAAP Response:** The text of Section 2.6.1.2 will be revised as follows:

Four soil borings (35SB1, 35SB2, 35SB3, and 35SB4) will be advanced outside the perimeter/berm of the drying bed to a minimum depth of 10 ft bgs to assess for the presence or absence of sludge outside the drying bed (Figure 2-8). If sludge is encountered at a location, then additional borings will be completed to assess the horizontal and vertical extent of sludge outside of the drying bed. If sludge is encountered to depths of 10 ft, then borings will be extended deeper until the vertical extent of sludge has been delineated.

If sludge is not encountered in the borings completed outside the drying bed, then one surface sample (0-1 ft bgs) will be collected from each boring for chemical analysis (0.5 to 1 ft bgs for

VOCs) to assess for potential surface releases due to previous waste management activities associated with the drying beds. If sludge is encountered outside the drying bed, then surface soil samples will be collected downgradient of the areas containing sludge to evaluate for potential migration via overland runoff. Additional chemical testing of sludge and/or subsurface soil is not proposed outside of the drying beds due to the extensive chemical sampling of sludge and subsurface soil inside the drying bed where primary waste management activities occurred.

**Comment 8:** Section 2.6.2.1, Monitoring Well Installation, Page 2-9: Two-inch diameter wells are proposed at Solid Waste Management Unit (SWMU) 35; however, Section 3.3.1 of SOP 20.1, included in Appendix A, indicates that overburden wells are typically designed as 4-inch diameter wells at RFAAP. Please explain the rationale for proposing 2-inch diameter wells when the SOP indicates that 4-inch diameter wells are typically designed at this site. This comment also applies to the proposed wells at SWMUs 37 and 38 (Section 3.6.2.1).

**RFAAP Response:** As indicated in the RFAAP Response to Comment 1, the air rotary drilling method will be used for installation of monitoring wells at the site given that well installation into bedrock is anticipated, and therefore, 2-inch diameter monitoring wells will be installed at the site.

**Comment 9:** Section 2.6.2.2, Groundwater Sampling, Page 2-10: The Work Plan Addendum proposes to collect additional groundwater samples from upgradient wells D-2 and D-4, if necessary, to obtain sufficient data to establish site-specific background concentrations. During previous sampling at these wells in 1991 and 1993, chromium, lead, and/or nitrite/nitrate were detected above screening levels (Page 2-3). It is not clear that these wells will best represent background conditions. The Work Plan Addendum has not indicated whether these wells may be located downgradient of another SWMU or source area. Please revise the Work Plan Addendum to address this concern.

**RFAAP Response:** The results for chromium and lead discussed for wells D-2 and D-4 in Section 2.3.4 on Page 2-3 are for the total fractions of these metals. Chromium and lead were not detected in the corresponding dissolved fractions of these samples. The elevated levels in the total fraction were attributed to sample turbidity, given that the samples were collected using a high flow purge and bailer. Sample results for the total and dissolved fractions of lead and chromium are summarized in the following table and with nitrite/nitrate results.

| Units: µg/L | **D-2 (1993)** | **D-4 (1991)** | **D-4 (1993)*** |
|---|---|---|---|
| Total Lead | 23.4 | 100 | 71.75 |
| Dissolved Lead | <1.26 | <1.26 | <1.26 |
| Total Chromium | 73.2 | 92.1 | 214 |
| Dissolved Chromium | <6.02 | <6.02 | <6.02 |
| Nitrate/Nitrite | 11,100 | 110 | 1,250 |

Note: * = Results is an average of the sample and its duplicate

Proposed upgradient monitoring wells D-2 and D-4 are positioned approximately 200 ft topographically and hydrogeologically upgradient of the SWMU 35 drying bed area. These wells monitor groundwater flowing into the site area from the plant production area, which includes the finishing area located approximately 400 ft south of the wells. The A-B Line Acid Neutralization Plant area is located approximately 400 ft southwest of the well D-2 and may be upgradient from well D-2.

The proposed background monitoring wells D-2 and D-4 are considered appropriately positioned to monitor groundwater flow into the site area and they are at sufficient distance upgradient of the calcium sulfate areas that they will not be impacted by waste disposal activities in these areas.

**Comment 10:** Section 3.2, Site Background – History, Page 3-2: The description of the site history does not identify the time period when SWMUs 37 and 38 and Area of Concern (AOC) Q were used. Please revise the Work Plan Addendum to describe the approximate dates and/or period of use of SWMUs 37 and 38, and AOC Q.

**RFAAP Response:** The following text will be added "As discussed in Section 3.3.2, based on aerial photographs the drying beds were in use from sometime after 1949, likely in the early 1950's due to the use of the drying beds for sludge from SWMU 9 which began operation during the Korean War (1950-1953) (Dames and Moore 1992). SWMU 37 and SWMU 38 have been inactive since the 1980's. Activity at AOC Q appeared to cease in 1971 based on aerial photographic analysis (EPA 1992) and observations during conduct of the RFA and VI confirmed that this disposal unit area was not in use."

**Comment 11:** Section 3.2, Site Background – History, Page 3-2: It is noted that sludge was pumped from SWMU 38 to AOC Q via pipes that ran through a depression in the berm. The Work Plan Addendum does not indicate whether these pipes still exist. Additionally, the exact location and construction of these pipes is unknown. Please provide further information on the pipes that connected SWMU 38 and AOC Q. If the integrity of the pipes was compromised at any point, the Work Plan Addendum should propose sampling along these pipelines. Additionally, please show the location of the pipes on a site map, if known.

**RFAAP Response:** Information regarding the use of pipes to transfer sludge between SWMU 38 and AOC Q was originally included in Verification Investigation (VI) conducted by Dames & Moore 1992 based on interviews with plant personnel. However, specific diagrams or site maps were not available at the time of VI to verify this information. The presence of pipes was not noted during the site inspection conducted for the RFA in 1987 (EPA 1987), during the VI investigation conducted at the site in 1992 (Dames & Moore), or during subsequent SSP investigations. Any pipes used may have been removed at the time that use of AOC Q ceased; these pipes would have been of limited length given that AOC Q is located immediately adjacent to SWMU 38.

**Comment 12:** Section 3.3.2, Installation Assessment (Air Photo Interpretation), Page 3-2: This section references only three photographs (1962, 1971, and 1986). It is not clear that any earlier photographs (prior to 1962) were reviewed. Additionally, only the 1962 and 1986 photographs appear to have been attached as figures (Figure 3-3 and Figure 3-4). Please clarify whether photographs prior to 1962 were reviewed, and document the findings of that review, if applicable. Additionally, please revise the Work Plan Addendum to include a copy of the 1971 photograph.

**RFAAP Response:** A 1949 and a 1971 aerial photograph will be included. The following text will be added "The 1949 photograph indicates the drying beds were not in use at this time as the area is tree covered and no depressions are evident. "

**Comment 13:** Section 3.3.3, Site Screening Process Investigation – 2007, Page 3-4: It is noted that Table 3-4 provides a summary of conclusions and recommendations from the site screening process (SSP) report. Table 3-4 appears to show that additional groundwater sampling was recommended for AOC Q. However, it does not appear that a monitoring well has been proposed for the area downgradient of AOC Q (Figure

3-8). Please revise the Work Plan Addendum to address the adequacy of the proposed network of monitoring wells to assess potential groundwater impacts associated with AOC Q. An additional well located downgradient of AOC Q may be necessary.

> **RFAAP Response:** Two downgradient monitoring wells were intended to evaluate potential releases from SWMU 38 and AOC Q. Monitoring well 38MW3 will be relocated approximately 100 ft north of the location shown on Figure 3-8 to a position outside and west of the berm to evaluate potential releases from this disposal unit. Monitoring well 38MW2 will be moved slightly to the north of the location shown on Figure 3-8 to be closer the middle of the SWMU 38 disposal unit.

**Comment 14:** Section 3.5, Data Gap Analysis, Page 3-5: Additional investigation of AOC Q has not been proposed since it passed the SSP. However, it is not clear that a sufficient number of surface samples were collected from this AOC as part of the site screening process. Only three surface samples were collected from this site, two of which were located within the bermed area. Of the three samples, only one was analyzed for polychlorinated biphenyls (Appendix D). Additionally, the boring logs for the two samples collected within the bermed area (QSB1 and QSB3) reported sludge at less than a 1-foot depth. Please consider collecting additional surface soil/sludge samples from AOC Q to assure a sufficient number of samples for risk characterization of potential contaminants of concern. Additional samples could also be used to better determine the volume of sludge at AOC Q in consideration of a future remedy at the site.

> **RFAAP Response**: AOC Q passed the SSP process, but due to the proximity to SWMU 38 it was included in the RFI for SWMUs 37 and 38. Due to the small size of AOC Q (0.076 acres), the use of AOC Q as an overflow unit for SWMU 38, and the number of sample collected within the SWMU based on its size, one additional sludge sample will be collected and analyzed for PCBs and two additional site characterization borings will be completed to further assess potential sludge volume.

**Comment 15:** Section 3.6.1.1, Inside Drying Bed Areas, Page 3-7: This section indicates that the soil borings will only be advanced to a depth of 8 feet below grade. The rationale for terminating the borings at this depth has not been provided. The SSP data presented in Appendix D show that several inorganic constituents were detected above screening levels at depths greater than 8 feet. It is not clear that the vertical extent of contamination will be properly characterized. Please revise the Work Plan Addendum to provide the rationale for terminating soil borings at SWMUs 37 and 38 at 8 feet below grade, or propose to advance the soil borings to the top of the groundwater table.

> **RFAAP Response:** Although some naturally occurring inorganic compounds (metals) were detected in subsurface soil samples collected from inside the drying bed at concentrations above their risk-based screening levels, the concentrations detected were below background. Organics were also detected in subsurface soil samples at concentrations below their risk-based screening concentrations; the exception was for trichloroethene (TCE), which was detected in two subsurface samples collected from boring 37SB2 at concentrations above the soil-to-groundwater screening level. This boring was completed to the depth of groundwater and therefore, the detections of TCE will be further evaluated in the RFI by monitoring well installation and groundwater sampling. Based on the above data, the vertical extent of impact inside the drying beds is considered appropriately characterized, and additional investigations will therefore focus on further characterization of sludge and refining the vertical extent of releases and impacts to surface and subsurface soil at depths of 8 ft bgs or less.

A maximum target boring and sampling depth of 8 ft below grade was established within the drying beds based on the above data and the 4 to 8 ft depth of the dry-bed depressions; this will provide data from the same soil strata for samples collected inside and outside the SWMUs.

**Comment 16:** Section 3.6.2.2, Groundwater Sampling, Page 3-9: The proposed analyses for groundwater samples include only those soil contaminants of potential concern identified during the SSP. Specifically, groundwater samples will not be analyzed for Target Compound List (TCL) semi-volatile organic compounds (SVOCs). However, the proposed analyte list for soil samples includes SVOCs. Please revise the Work Plan Addendum to include a contingency to sample groundwater for SVOCs should these constituents be detected in soil above soil migration to groundwater soil screening levels.

> **RFAAP Response:** SVOCs were not proposed for groundwater analysis given that they were not identified as COPCs in sludge or soil at SWMU 37, SWMU 38, or AOC Q. The text of Sections 3.6.1.1 and 3.6.1.2 inadvertently listed SVOCs as target analytes for additional sludge samples and soil samples to be collected for the RFI. These text sections will be revised to remove SVOCs as target analytes for soil.

**Comment 17:** Section 4.3, Quality Assurance Objectives, Define the Boundaries, Page 4-9: It is stated that the media that will be investigated include surface soil, subsurface soil and surface water. However, it does not appear that surface water sampling has been proposed in Sections 2 or 3. Additional media to be sampled also include groundwater and sludge. Please revise the Work Plan Addendum to address this discrepancy.

> **RFAAP Response:** Surface water sampling has not been proposed for the RFI, and therefore, the text in Section 4.3 on Page 9 will be changed to read "The media that will be investigated include sludge, surface soil, subsurface soil, and groundwater within the SWMUs and AOC"

**Comment 18:** Table 4-4, Summary, Proposed Sample Identifiers, Depths, and Analytical Methods. There appear to be several discrepancies between the proposed analyses presented on Table 4-4 and those described in Sections 2 and 3. For example, Table 4-4 shows that all of the SWMU 35 soil samples will be analyzed for herbicides. Sections 2.6.1.1 and 2.6.1.2 have not included herbicides in the list of proposed analyses for the SWMU 35 soil samples. Additionally, Table 4-4 does not include TCL SVOCs for soil samples at SWMUs 37 and 38; however, Sections 3.6.1.1 and 3.6.1.2 indicate that soil samples will be analyzed for TCL SVOCs. Please revise the Work Plan Addendum to resolve these discrepancies.

> **RFAAP Response:** The text of Sections 2.6.1.1 and 2.6.1.2 correctly indicated that herbicides are not target analytes for the RFI and therefore, the RFI tables will be revised to resolve this discrepancy. As indicated in the response to Comment 18, SVOCs were not identified as COPCs in soil and the text of Sections 3.6.1.1 and 3.6.1.2 inadvertently listed SVOCs as target analytes for additional sludge samples and soil samples to be collected for the RFI. These text sections will be revised to remove SVOCs as target analytes for soil.

**Comment 19:** Section 4.6, Internal Quality Control Check, Page 4-29. This section references Table 4-13 for guidelines for collection of QC samples, and Table 4-14 for field QC acceptance criteria. It appears that the actual table references should be Table 4-12 and Table 4-13, respectively. It also appears that references to subsequent Section 4 tables are also misnumbered. Please revise the Work Plan Addendum to provide the correct table references in the text of the document.

**RFAAP Response:** The references to tables in Section 4.6 on Page 4-29 will be changed to Table 4-12 and 4-13, respectively. The first sentence in Section 4.6.1 on Page 4-30 will be changed to reference Table 4-14 rather than 4-15 and the second sentence will be changed to reference Tables 4-15 through 4-22.

**Response to Comments (8/24/2007)**
**EPA and VDEQ Comments Received via e-mail 07/26/07**
**Draft Work Plan Addendum 021, RCRA Facility Investigation for Solid Waste Management Unit 57, Radford Army Ammunition Plant, Virginia, April 2007**

## GENERAL COMMENTS

**Comment 1:** Several important site features do not appear to have been identified on the site figures. For example, Figure 1-2 (Topographic Map) does not label Building 4931 even though a terra cotta pipe connects this building to Solid Waste Management Unit (SWMU) 57. Additionally, the drainage swale that surrounds SWMU 57 and then connects to a drainage way to the northwest has not been labeled. Please revise the Work Plan Addendum to include a site figure which includes these important site features.

> **RFAAP Response:** Figure 2-1 will be revised to identify the location of Building 4931, the location of the drainage ditch that surrounds SWMU 57, and the location of the drainage way extending to the northwest of SWMU 57.

**Comment 2:** Groundwater monitoring wells are proposed for SWMU 57, but the specific method for installation of these wells has not been specified. Although Standard Operating Procedures (SOPs) 20.1 and 20.11, included in Appendix A, are referenced, these SOPs address several types of drilling methods (hollow stem auger, air rotary, etc.). The drilling method for installation of each monitoring well should be indicated in the Work Plan Addendum.

Additionally, the above mentioned SOPs indicate that the proposed well diameter, well screen length, screen slot size, and filter pack should be specified in the work plan addenda. However, theses details have not been specified for the proposed wells. Please revise the Work Plan Addendum to address these omissions.

> **RFAAP Response:** The work plan addendum will be revised to indicate that the air rotary drilling method will be used for installation of monitoring wells given that well installation into bedrock is anticipated. A 6-inch diameter, roller bit will be used to drill within soil overburden and a 6-inch diameter, air hammer bit will be used to drill in bedrock. If unstable conditions are encountered in the borehole, then a 6-inch temporary casing will be set in the borehole to allow for boring completion and monitoring well installation. A minimum 8-inch diameter roller bit will be used in the overburden if temporary casing is required. The casing sections are fitted with auger couples to allow for incremental removal during well construction.
>
> The work plan addendum will be revised to include proposed monitoring well construction information and specifications including: well diameter, screen and riser pipe material, screen slot size, filter pack material, bentonite seal, cement-bentonite grout, surface seal, protective casing, and surface completion details. A proposed well construction diagram will be included in the work plan addendum. Monitoring wells will be constructed using 2-inch diameter (nominal), Schedule 40 polyvinyl chloride (PVC) threaded screen and riser pipe. A 0.010-inch screen slot size and No. 2 sand filter pack will be used to construct the wells.
>
> The uppermost zone of groundwater at the site is expected to occur near the overburden and bedrock interface. Monitoring wells be installed with a 15 ft long screen so that the top of the screen is above the seasonally high water table. It is anticipated that the monitoring wells will screened across the overburden and bedrock interface.

**Comment 3:** Appendix D (Site Screening Process Report Text and Screening Tables for SWMU 57) notes that samples were not collected from within the bermed area of SWMU 57 at depths greater than 1.5 feet (ft) because the fence located outside of the berm prevented the Geoprobe rig from gaining access to that area. Since several samples at depths greater than 1.5 ft are proposed for SWMU 57 in this Work Plan Addendum, please clarify what actions will be implemented to assure that access inside the fenced area will be granted in order to obtain the proposed samples.

> **RFAAP Response:** A portable tripod mounted gas powered soil sampling system with a flotation system will be used to access the area inside the fence and collect the soil samples. This system can be setup inside SWMU 57 without removal of the fence. In the event that access difficulties are still encountered, a portion of the fence will be temporarily removed to allow for access.

**Comment 4:** Surface soil sampling for volatile organic compounds (VOCs) is proposed for several areas of this SWMU. The depth interval for these surface soil samples is identified as 0 to 1 ft below ground surface (bgs) (as shown in Table 2-4). The RFAAP Master Work Plan indicates that surface soil samples for VOCs should be collected within the depth interval of 6 to 12 inches bgs (Section 5.2). Please revise the Work Plan Addendum to address this deviation from the Master Work Plan. Alternatively, please revise the Work Plan Addendum to propose that surface soil samples collected for VOC analysis be collected from the 6- to 12-inch depth interval.

> **RFAAP Response:** Text will be added to Section 1.6.1 and a note will be added to Table 2-4 to clarify a sample collection depth for VOCs of 6-12 inches bgs.

**Comment 5:** Figure 1-3 (Verification Investigation Sampling Locations, SWMU 57) shows SWMUs 68 and 69 in close proximity to SWMU 57. A description of these SWMUs has not been provided. Given their close proximity to SWMU 57 and the associated drainage swale, please identify these SWMUs and the status of the investigations at these sites.

> **RFAAP Response:** The following text will be added to Section 1.2.2.
>
> SWMU 68 (chromic acid treatment tanks) is 0.023-acre area located west of SWMU 57 as shown on Figure 1-3. Drainage from this area was engineered to flow into a former settling pond (SWMU 69). In 1958, RFAAP started reconditioning "Nike" and "Honest John" rocket motors utilizing a rinse of chromic acid with rust inhibitors (Hercules 1958). RFAAP operated a Virginia State Water Control Board-approved waste treatment plant (SWMU 68) in the Cast Propellant Area to treat chromic-acid wastewater prior to discharge to the New River (Hercules 1958, SWCB 1958). SWMU 68 consisted of two 4,000-gallon aboveground, open top tanks (ASTs) with associated pumps, piping, and appurtenances. Tanks in the nearby building were used prior to 1974 to treat spent chromic acid generated from the cleaning of rocket encasements (USEPA 1987). Treated wastewater was then discharged to a 12,000-gallon settling pond (SWMU 69) where chromium-hydroxide sludge precipitated (Hercules 1958). In July 1997, the site underwent closure including removal of the two treatment ASTs, appurtenances, and impacted soil (ICF Kaiser 1998). SWMU 68 was also investigated as part of the site screening process investigation conducted in 2003 by URS. SWMU 68 passed the SSP resulting in a recommendation of no further action (URS 2007).
>
> SWMU 69 (pond by chromic acid tanks) is 0.012-acre depressed, grassed area located west of the site as shown on Figure 1-3. This area was once a shallow settling pond that collected treated wastewater containing chromium-hydroxide sludge from SWMU 68, the Chromic Acid Treatment

Tanks (Hercules 1958). The pond was bermed and approximately 1 to 2 feet deep. The supernatant from SWMU 69 discharged to a perennial stream that flows to the New River (Hercules 1958). In accordance with the recommendations included in the 1992 VI Report for SWMU 69, interim measures were implemented and SWMU 69 underwent closure including removal of impacted soil (Dames & Moore 1994). The SWMU 69 Closure Report was prepared by Dames & Moore and submitted by RFAAP to the USEPA Region III and the VDEQ. Approximately 700 cubic yards of material were excavated during the closure and investigation activities and disposed of at RFAAP Fly Ash Landfill #2. After confirmatory sampling, the excavation(s) were backfilled with clean fill supplied and graded to reestablish the pre-existing drainage way. SWMU 69 was also investigated as part of the site screening process investigation conducted in 2003 by URS. SWMU 69 passed the SSP resulting in a recommendation of no further action (URS 2007).

SPECIFIC COMMENTS

**Comment 6:** Section 1.6.1.1, Inside Pond Area, Page 1-9: The Work Plan Addendum proposes to analyze samples from within the pond area for target compound list (TCL) VOCs and target analyte list (TAL) metals. However, only limited sampling has been conducted within the bermed area of SWMU 57 during previous investigations. During the Site Screening Process, only two samples were collected (from a single boring), and no samples were collected beneath the asphalt liner. It is not clear that the proposed sampling will adequately characterize the pond area since prior sampling has been limited. Please revise the Work Plan Addendum to propose the full suite of CLP constituents for several of the samples collected within the bermed area.

**RFAAP Response:** Additional sample analysis will be performed on soil samples collected from boring locations 57SB5, 57SB6, 57SB7, and 57SB8 to further characterize the pond area. The proposed additional analysis will include: TCL semi-volatile organic compounds (SVOCs) by SW-846 Method 8270C, TCL polychlorinated biphenyls (PCBs) by SW-846 Method 8082, TCL pesticides by SW-846 Method 8081A, and explosives by SW-846 Methods 8330/8332. The following samples identified in the work plan addendum will be analyzed for these parameters:

- Surface samples ("A" samples) 57SB5A, 57SB6A, 57SB7A, and 57SB8A from 0 to 0.5 ft below ground surface;
- Subsurface samples ("AB" samples) 57SB4AB, 57SB5AB, 57SB6AB, 57SB7AB, and 57SB8AB to be collected immediately below the pond asphalt liner:
- Intermediate depth samples ("B" samples) 54SB4B, 57SB5B, 57SB6B, 57SB7B, and 57SB8B to be collected from 6 to 8 ft below ground surface.
- Terminal depth sample ("C" sample) 54SB4C, 57SB5C, 57SB6C, 57SB7C, and 57SB8C to be collected from a depth immediately above encountered groundwater. Based on existing data, the estimated depth of this sample will be 29 to 31 ft below ground surface.

The work plan addendum text and tables will be revised to incorporate the above information.

**Comment 7:** Section 1.6.1.1, Inside Pond Area, Page 1-9: It is proposed that a soil sample be collected at an "intermediate" depth from several borings. Table 2-4 further specifies that this intermediate depth will be 6-15 ft bgs. It is not clear that a 9-foot sampling interval is appropriate to delineate the vertical extent of contamination. Additionally, the rationale for selection of this sampling interval is not described. Please revise the Work Plan Addendum to describe the rationale for selection of the intermediate depth sampling interval. A more targeted 2-foot sampling interval should be considered. This comment also applies to the intermediate samples proposed in other areas of the site.

**RFAAP Response:** Planned discrete sample intervals for the RFI are two feet or less. The text and Table 2-4 will be revised to indicate that intermediate depth samples from within the pond area will be collected at a depth of 6 to 8 ft bgs and terminal depth samples will be collected from a depth immediately above encountered groundwater, which is expected to be a sample depth interval of 29 to 31 ft bgs. Intermediate depth samples outside of the pond area will be collected from a depth of 10 to 12 ft bgs, which when taking the depth of the pond area into account is approximately the same depth interval as the samples collected from within the pond area. Terminal depth samples collected outside of the pond area will be collected from a depth immediately above encountered groundwater, which is expected to be a sample depth interval of 33 to 35 ft bgs.

The sampling program within the pond area is designed to characterize material above the asphalt liner, assess for potential releases immediately below the asphalt liner, and characterize the nature and extent of any releases below the liner by collecting an intermediate depth sample from 6 to 8 ft bgs and a terminal sample immediately above encountered groundwater. Outside the pond area, the sampling program is designed to evaluate for releases to surface soil and characterize the lateral and vertical extent of releases to the depth of groundwater by collecting intermediate depth samples and terminal depth samples.

**Comment 8:** Section 1.6.1.2, Terracotta Drainpipe, Page 1-9: The Work Plan Addendum does not indicate whether the terracotta drainpipe is completely above grade or partially below grade. Photograph 2 of Appendix B appears to show that the pipe is at least partially above grade, but the Work Plan Addendum should clarify whether the entire length of the pipeline is also partially above grade. Additionally, it is not clear that the proposed sampling near the drainpipe target areas of the pipe that are known to be compromised. Photograph 2 shows the broken terracotta pipe located near SWMU 57, but it is not clear that the proposed samples will assess areas where leaks may have occurred since the broken areas of the pipe are not shown on a figure. Please revise the Work Plan Addendum to clarify the depth of the entire length of the terracotta pipe, and describe the proposed sampling investigation in relation to the compromised portions of the pipe.

**RFAAP Response:** The approximately 65 ft long terracotta drainage pipe is below grade except for the northern end of the pipe where it enters into the pond. An approximate four foot section of the pipe is above grade and the pipe is broken at a single point where two pipe sections are attached (Photograph 2 in Appendix B of work plan addendum). SSP boring 57SB2 was completed at the location where the pipe is broken. Three soil samples were collected at this location to evaluate potential releases from the pipe including a surface soil sample from 0 to 1 ft bgs (0.5 to 1 ft for volatiles), and intermediate depth sample from 8 to 10 ft bgs, and a terminal depth sample collected from 33 to 35 ft bgs. As discussed in work plan addendum, an additional sample will be collected at location 57SB2 from 1 to 2 ft below the bottom of the drainpipe section where it is broken to further assess for potential releases in this area. The work plan addendum text and figures will be revised to incorporate the above information.

The buried sections of the drain pipe range in depth from less than one foot near the above grade portion closest to the pond to approximately 3.5 ft south of the steam line located between Building 4934 and the pond. Depths of drainpipe vary along its length due to an approximate six foot elevation difference between the pond and building 4934, with most of the elevation change occurring within a 20 ft area between the above ground portion of the pipe and the steam line to the south as shown on Figure 2-10 in the work plan addendum. The presence, depth, and integrity of the pipe will be verified at proposed piping sample locations 57SB1 and 57SB9 to ensure that samples are collected at appropriate locations and depths to further evaluate releases from the pipe. The work plan addendum will be revised to incorporate the above information.

**Comment 9:** Section 2.3, Quality Assurance Objectives, Page 2-6: Table 2-3 provides a summary of the project data quality objectives, but it does not mention the collection and analysis of groundwater samples. Please revise Table 2-3 to include the data quality objectives associated with the proposed groundwater investigation at SWMU 57.

**RFAAP Response:** The summary information presented in Table 2-3 will be revised to incorporate the information for groundwater presented in the text of Section 2.3 including the following:

- Project objectives
  - Evaluate potential leaching of constituents of potential concern from soil to groundwater.
  - Characterize background concentrations in site groundwater for use in the nature and extent evaluation and risk assessment
  - Conduct human health and ecological risk assessments to characterize soil and groundwater related risks.
- Principal Study Questions
  - Have hazardous constituents leached from soil to groundwater at levels above site-background (metals) and human health risk screening criteria?
  - Do hazardous constituents in soil and groundwater pose an unacceptable risk to human health or the environment considering current and planned future land uses?
- Inputs to the Decision
  - Groundwater related risk-screening criteria including: risk-based concentrations (RBCs) for tap water in the most recent USEPA Region III RBC table, Federal Maximum Contaminant Levels (MCLs), and Commonwealth of Virginia Groundwater Standards.
- Decision Rules
  - Depth to groundwater.
  - Groundwater characteristics and quality.

**Comment 10:** Table 2-4, Summary of Proposed Sample Identifiers, Depths, and Analytical Methods: The proposed groundwater samples include three samples from wells, a duplicate, a matrix spike/matrix spike duplicate (MS/MSD), and what is presumed to be an equipment blank (EQB6). Since VOCs will be analyzed, a trip blank sample should also be proposed. Please revise Table 2-4 to include a trip blank sample under the proposed groundwater samples.

**RFAAP Response:** Table 2-4 will be revised to include a trip blank sample.

James O Spencer/Richmond/URSCorp
07/26/2007 06:05 PM

To Tina Devine/Richmond/URSCorp@URSCorp, Lee Mareck/Richmond/URSCorp@URSCorp
cc
bcc
Subject Fw: Workplan Addendum 21 Comments

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----- Forwarded by James O Spencer/Richmond/URSCorp on 07/26/2007 06:33 PM -----

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07/26/2007 02:48 PM

To "McKenna, Jim Mr. RFAAP ACO Staff" <jim.mckenna@us.army.mil>
cc James_O_Spencer@URSCorp.com, jerome.redder@ATK.com, jlcutler@deq.va.gov
Subject Workplan Addendum 21 Comments

Below are USEPA and VADEQ draft comments on RAAP's Draft Work Plan Addendum 21 prepared by URS and submitted in May 2007. Please call or email me with any questions. Thanks

GENERAL COMMENTS

1. Several important site features do not appear to have been identified on the site figures. For example, Figure 1-2 (Topographic Map) does not label Building 4931 even though a terra cotta pipe connects this building to Solid Waste Management Unit (SWMU) 57. Additionally, the drainage swale that surrounds SWMU 57 and then connects to a drainage way to the northwest has not been labeled. Please revise the Work Plan Addendum to include a site figure which includes these important site features.

2. Groundwater monitoring wells are proposed for SWMU 57, but the specific method for installation of these wells has not been specified. Although Standard Operating Procedures (SOPs) 20.1 and 20.11, included in Appendix A, are referenced, these SOPs address several types of drilling methods (hollow stem auger, air rotary, etc.). The drilling method for installation of each monitoring well should be indicated in the Work Plan Addendum.

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shows the broken terracotta pipe located near SWMU 57, but it is not clear that the proposed samples will assess areas where leaks may have occurred since the broken areas of the pipe are not shown on a figure. Please revise the Work Plan Addendum to clarify the depth of the entire length of the terracotta pipe, and describe the proposed sampling investigation in relation to the compromised portions of the pipe.

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William A. Geiger
USEPA Region III
1650 Arch Street
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Radford Army Ammunition Plant
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May 14, 2007

Mr. William Geiger
RCRA General Operations Branch, Mail Code: 3WC23
Waste and Chemicals Management Division
U. S. Environmental Protection Agency, Region III
1650 Arch Street
Philadelphia, PA 19103-2029

Subject: Work Plan Addendum 021 RCRA Facility Investigation for Solid Waste Management Unit 57, May 2007
Radford Army Ammunition Plant Installation Action Plan
EPA ID# VA1 210020730

Dear Mr. Geiger:

Enclosed is one copy of the subject document. Your additional two copies and the certification will be sent under separate cover. Also under separate cover one copy each will be sent to the distribution below.

Please coordinate with and provide any questions or comments to myself at (540) 639-8658, Jerry Redder of my staff (540) 639-7536 or Jim McKenna, ACO Staff (540) 639-8641.

Sincerely,

P.W. Holt, Environmental Manager
Alliant Techsystems Inc.

c: Russell Fish, P.E., EPA Region III, 3WC23

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07-815-101
JMcKenna

# RADFORD ARMY AMMUNITION PLANT
# RADFORD, VIRGINIA

## WORK PLAN ADDENDUM 021
## RCRA Facility Investigation at
## Solid Waste Management Unit 57

**FINAL**
**OCTOBER 2007**


**PREPARED BY:**

URS

5540 Falmouth Street, Suite 201
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CONTRACT NO. W9128F-04-D-001
DELIVERY ORDER NO. DA03

# PREFACE

A two-stage approach has been developed to facilitate and streamline Resource Conservation and 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 chemicals of concern, sampling strategy, etc. Each addendum, through reference to the Master Work Plan, is developed as a concise document, focused on site-specific investigations.

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**MASTER WORK PLAN ADDENDUM 021**
**RCRA FACILITY INVESTIGATION FOR SWMU 57**

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## LIST OF TABLES

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**RCRA FACILITY INVESTIGATION FOR SWMU 57**

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## LIST OF APPENDICES

## LIST OF ABBREVIATIONS AND ACRONYMS

ºC.....................Degrees Celsius
% .....................Percent
AES.................Atomic Emission Spectroscopy
ASTM .............ASTM International
bgs...................Below Ground Surface
BTAG.............Biological Technical Assistance Group
CFR.................Code of Federal Regulations
CH...................Silty Clay
CL ...................Sandy Clay
CLP .................Contract Laboratory Program
CMS ................Corrective Measures Study
COD ................Chemical Oxygen Demand
COPC ..............Chemical of Potential Concern
COPEC............Chemical of Potential Ecological Concern
COR ................Contracting Officer's Representative
CSM ................Conceptual Site Model
DAF ................Dilution Attenuation Factor
dBA.................Decibels on the A-Weighted Scale
DOD................Department of Defense
DQO................Data Quality Objective
EPIC................Environmental Photographic Interpretation Center
ERIS................Environmental Restoration Information System
ft......................Feet
g ......................Gram
GC...................Gas Chromatography
GPS .................Global Positioning System
GW..................Groundwater
HAZCOM .......Hazard Communication
HHRA .............Human Health Risk Assessment
HSA ................Horseshoe Area
HSP .................Health and Safety Plan
HSPA ..............Health and Safety Plan Addendum
HTRW.............Hazardous, Toxic, and Radioactive Waste
I-RBC..............Industrial Risk-Based Concentration
ICP ..................Inductively Coupled Plasma
ICP-MS ...........Inductively Coupled Plasma-Mass Spectrometry
IDM................Investigation-Derived Material
MCL................Maximum Contaminant Level
MDC ...............Maximum Detected Concentration
MDL................Method Detection Limit
µm ...................Micrometer
MHSP..............Master Health and Safety Plan
mm ..................Millimeter
MMA ..............Main Manufacturing Area
MQAP.............Master Quality Assurance Plan
MS...................Mass Spectrometer

## LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

MS/MSD.........Matrix Spike/Matrix Spike Duplicate
MSDS.............Material Safety Data Sheet
msl..................Mean Sea Level
MWP...............Master Work Plan
NELAP............National Environmental Laboratory Accreditation Program
NFA ................No Further Action
nm ...................Nanometer
PAH ................Polynuclear Aromatic Hydrocarbon
PCB.................Polychlorinated Biphenyl
PETN .............Pentaerythritol Tetranitrate
PID .................Photoionization Detector
PM...................Project Manager
PPE..................Personal Protective Equipment
ppm .................Parts Per Million
QA...................Quality Assurance
QC...................Quality Control
QA/QC............Quality Assurance/Quality Control
QAP ................Quality Assurance Plan
QAPA.............Quality Assurance Plan Addendum
QSM................Quality Systems Manual
R......................Rinse Blank
R-RBC ............Residential Risk-Based Concentration
RBC ................Risk-Based Concentration
RCRA.............Resource Conservation and Recovery Act
RFAAP............Radford Army Ammunition Plant
RFI ..................RCRA Facility Investigation
RL ...................Reporting Limit
SB....................Soil Boring
SC....................Clayey sand
SHSO ..............Site Health and Safety Officer
SLERA............Screening Level Ecological Risk Assessment
SM...................Silty Sand
SOP .................Standard Operating Procedure
SOW................Statement of Work
SSL..................Soil Screening Level
SSP..................Site Screening Process
SVOC..............Semi-volatile Organic Compound
SWMU............Solid Waste Management Unit
T ......................Trip Blank
T-RBC.............Tap Water Risk-Based Concentration
TAL.................Target Analyte List
TCL .................Target Compound List
TCLP...............Toxicity Characteristic Leaching Procedure
TOC ................Total Organic Carbon
TWA ...............Time Weighted Average

## LIST OF ABBREVIATIONS AND ACRONYMS (CONTINUED)

UCL ................Upper Confidence Limit
UPL.................Upper Prediction Limit
URS.................URS Group, Inc.
USACE ...........United States Army Corps of Engineers
USEPA............United States Environmental Protection Agency
UV...................Ultraviolet
VI ....................Verification Investigation
VOC................Volatile Organic Compound
WPA................Work Plan Addendum

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# 1.0 WORK PLAN ADDENDUM

In accordance with Contract Number W9128F-04-D-001, Delivery Order No. DA03, URS Group, Inc. (URS) has been tasked by the United States Army Corps of Engineers (USACE), Baltimore District to perform a Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) at Solid Waste Management Unit (SWMU) 57, the Pond by Buildings 4931 and 4928 (the site), located in the Main Manufacturing Area (MMA) at the Radford Army Ammunition Plant (RFAAP), Radford, Virginia (Figure 1-1). The RFI Work Plan for SWMU 57 is presented as Work Plan Addendum (WPA) 021, and incorporates, by reference, the elements of the RFAAP Master Work Plan (MWP) (URS 2003).

## 1.1 INTRODUCTION

The objectives of the RFI are to fill data gaps identified during the site screening process (SSP) investigation conducted at SWMU 57 in 2003 (URS 2007) by:

- Further assessing potential contaminant sources and the nature and extent of chemicals in soil;
- Evaluate potential releases to groundwater;
- Assessing the fate of detected chemicals;
- Evaluating potential risks to human health and the environment;
- Provide data to support the completion of a Corrective Measures Study (CMS); and
- If possible, reaching a final decision regarding what potential future action is warranted at this site.

The proposed RFI field program is designed to meet the above project objectives and to provide sufficient data for completion of an RFI/CMS Report including a human health risk assessment (HHRA) and screening level ecological risk assessment (SLERA). Proposed field activities include: site surveying, completion of soil borings, physical soil testing, installation of monitoring wells, collection of chemical samples of soil, groundwater, potentiometric measurements, and completion of slug tests.

This site-specific WPA provides the rationale and methods for planned field activities at SWMU 57 in support of the RFI. Consistent with the MWP, this addendum is composed of the following sections:

- Section 1, WPA 021 – SWMU 57;
- Section 2, Quality Assurance Plan (QAP) Addendum (QAPA);
- Section 3, Health and Safety Plan (HSP) Addendum (HSPA); and
- Section 4, References.

This WPA references sections and Standard Operating Procedures (SOPs) contained in the MWP for the investigation at SWMU 57. Relevant SOPs are included in Appendix A of this WPA. The WPA will be kept on the site and referenced during field activities.

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

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

## 1.2 SITE BACKGROUND – ENVIRONMENTAL SETTING

Section 3.0 of the MWP presents information regarding the environmental setting of the RFAAP. This section of the WPA presents project-specific environmental setting information derived from a review of background data including previous investigation, soil boring logs, and physical testing results.

**SWMU 57 – August 2002 – Looking Northwest**

### 1.2.1 Physiography

SWMU 57 is a 0.027-acre area (1,172 $ft^2$) consisting of an inactive, fabricated, asphalt-lined pond and associated piping. This site is located in the western section of the Horseshoe Area (HSA) on a small plateau above a hillside, which slopes downward to the northwest toward the New River (Figure 1-2). Land surface mean elevation at the site is approximately 1,805 feet above main sea level (ft msl).

### 1.2.2 Tanks/Structures

An asphalt-paved road is located to the east and several unrelated overhead pipes with associated appurtenances are present nearby. A four-foot high perimeter chain-link fence with a locked gate sits atop an asphalt-covered (one-inch thick) soil berm surrounding the pond (Figure 1-2). The pond is located in the vicinity of Buildings 4931 and 4928 with a terra-cotta pipe discharge pipe running from Building 4931 to the unit.

SWMU 68 (chromic acid treatment tanks) is 0.023-acre area located west of SWMU 57 as shown on Figure 1-3. Drainage from this area was engineered to flow into a former settling pond (SWMU 69). In 1958, RFAAP started reconditioning "Nike" and "Honest John" rocket motors utilizing a rinse of chromic acid with rust inhibitors (Hercules 1958). RFAAP operated a Virginia State Water Control Board-approved waste treatment plant (SWMU 68) in the Cast Propellant Area to treat chromic-acid wastewater prior to discharge to the New River (Hercules 1958, SWCB 1958). SWMU 68 consisted of two 4,000-gallon aboveground, open top tanks (ASTs) with associated pumps, piping, and appurtenances. Tanks in the nearby building were used prior to 1974 to treat spent chromic acid generated from the cleaning of rocket encasements (USEPA 1987). Treated wastewater was then discharged to a 12,000-gallon settling pond (SWMU 69) where chromium-hydroxide sludge precipitated (Hercules 1958). In July 1997, the site underwent closure including removal of the two treatment ASTs, appurtenances, and impacted soil (ICF Kaiser 1998). SWMU 68 was also investigated as part of the site screening process investigation conducted in 2003 by URS. SWMU 68 passed the SSP resulting in a recommendation of no further action (URS 2007).

SWMU 69 (pond by chromic acid tanks) is 0.012-acre depressed, grassed area located west of the site as shown on Figure 1-3. This area was once a shallow settling pond that collected treated wastewater containing chromium-hydroxide sludge from SWMU 68, the Chromic Acid Treatment Tanks (Hercules 1958). The pond was bermed and approximately 1 to 2 feet deep. The supernatant from SWMU 69 discharged to a perennial stream that flows to the New River (Hercules 1958). In accordance with the recommendations included in the 1992 VI Report for SWMU 69, interim measures were implemented and SWMU 69 underwent closure including removal of impacted soil (Dames & Moore 1992). The SWMU 69 Closure Report was prepared by Dames & Moore and submitted by RFAAP to the USEPA Region III and the VDEQ. Approximately 700 cubic yards of material were excavated during the closure and investigation activities and disposed of at RFAAP Fly Ash Landfill #2. After confirmatory sampling, the excavation(s) were backfilled with clean fill supplied and graded to reestablish the pre-existing drainage way. SWMU 69 was also investigated as part of the site screening process investigation conducted in 2003 by URS. SWMU 69 passed the SSP resulting in a recommendation of no further action (URS 2007).

### 1.2.3 Surface Water

The surrounding berm produces interior drainage within the pond and prevents run-on and runoff of storm water. At the time of the SSP site visit the pond appeared to be dry and heavily vegetated but during the SSP field investigation, the pond contained several inches of standing water and heavy vegetation. Additionally, the pond was observed to contain several inches of standing water and aquatic vegetation during the RFI site reconnaissance in July of 2005.

A shallow, well-defined, drainage ditch has been excavated that surrounds the pond and diverts storm water around the pond and connects with a drainage way to the northwest (Figure 1-2). This drainage way leads to an intermittent stream located approximately 500 ft northwest of the site, which periodically flows northwestward approximately 1,500 ft to the New River, the nearest naturally-occurring perennial water body. Other manholes, catch basins, storm drains, or drainage ways have not been associated with the site.

### 1.2.4 Soil and Geology

SWMU 57 is underlain by Braddock loam soil. This soil has moderate permeability and is acidic-to-strongly acidic (IT 2001). Soil boring 57SB4 completed inside the pond refused at 1.5 ft below ground surface (bgs) after penetrating clayey soil. Borings 57SB1, 57SB2, 57SB3 completed outside of the fenced area to the depth of groundwater (up to 36 ft) indicate that the site is underlain by 36 ft + of unconsolidated soil (alluvial terrace deposits) overlying carbonate bedrock of the Elbrook Formation. This soil consists of interbedded clay (CL or CH) and silty/clayey sand (SM/SC), with silty gravel present in the bottom six feet of the deepest boring (57SB2). Physical testing of two representative soil samples at the site above the silty gravel indicated acidic CL and CH soil, with organic content in the range of 2.6 to 3.6%, and a vertical hydraulic conductivity of 1.8E-07 cm/sec for the CH sample (Appendix C).

### 1.2.5 Groundwater

An unconfined aquifer occurs within the lower portion of unconsolidated alluvial terrace deposits underlying the site; groundwater is also present within the underlying bedrock. Groundwater was encountered at depths of 21.5 ft bgs (57SB1) to 35.5 ft bgs (57SB2). Based on local topography, groundwater flow in the site area is likely toward the north or northwest toward the base of the terrace and the New River. A detailed discussion of regional and RFAAP hydrogeology is presented in Section 3.8 of the MWP (URS 2003).

### 1.2.6 Site Background – History

SWMU 57 is an inactive fabricated unit historically used as an acid-settling pond. RFAAP as-built drawings from 1954 and 1967 identify the unit as the "Acid Settling Pool" with a diameter of approximately 50 ft and a capacity of 30,000 gallons. On the 1954 drawings, a six-inch diameter terra-cotta drainpipe is shown connecting the pond with a four-inch floor drain in the building south of the site (confirmed present during an August 2005 site reconnaissance). The floor drain is located near the chromic acid and Oakite-33 wash stations, and, reportedly, discharged chromic acid, hydraulic oil, Oakite-33, and zinc phosphate to the pond. Oakite-33 is a mixture of phosphoric acid and butyl Cellosolve®, which replaced chromic acid after 1974 as a rust stripper to clean rocket encasements (Dames & Moore 1992). At the time of the RFI site visit (August 2005), the terra-cotta pipe was observed to be partially broken at one location near the pond. No liquids were visible in the pipe. A photographic log is provided in Appendix B.

## 1.3 PREVIOUS INVESTIGATIONS

### 1.3.1 Verification Investigation – 1992

In 1992, Dames & Moore collected one sediment/water sample pair (57SE1/57SW1) from material present within the inactive pond for analysis of target analyte list (TAL) metals, volatile organic compounds (VOCs), and semi-volatile organic compounds (SVOCs; Figure 1-3). The sediment sample was also analyzed for Total Organic Carbon (TOC), total organic halogens, and pH.

VOCs and SVOCs were not detected in the water sample or sediment sample (Tables 1-2 and 1-3). TAL metals concentrations in the sediment including aluminum, arsenic, chromium, iron, and vanadium were above their adjusted residential risk-based concentrations (R-RBCs; Table 1-2). The arsenic concentration in sediment was above its adjusted industrial risk-based concentration (I-RBC). The iron concentration in sediment was above its Biological Technical Assistance Group (BTAG) sediment screening level (EPA 2004a). Arsenic, chromium, iron, and manganese concentrations in the water sample were above their adjusted tap water risk-based concentrations (T-RBCs; Table 1-3). Aluminum, arsenic, barium, copper, iron, lead, manganese and zinc concentrations in the water sample were above their respective BTAG freshwater screening levels (EPA 2004b).

### 1.3.2 Installation Assessment (Aerial Photograph Interpretation) – 1992

The Environmental Photographic Interpretation Center (EPIC), under the direction of USEPA, performed an assessment of multiple SWMUs at RFAAP using selected aerial photographs from 1937 to 1986 (USEPA 1992). The photogeologic analysis was performed to locate waste management areas, identify the location of sinkholes that existed prior to the construction of the RFAAP, and map fracture traces.

Activity at SWMU 57 was first noted on a 1962 aerial photograph (Figure 1-4). The interpretation of the 1971 photograph indicated the presence of a "pond" containing liquid. This area remained unchanged through the 1986 photograph (Figure 1-5), although a drainage way extending from the "pond" to the New River was noted (USEPA 1992).

### 1.3.3 Site Screening Process Investigation - 2007

The SSP was designed using specific human health and ecological screening processes to assess: 1) whether releases of hazardous substances, pollutants, contaminants, hazardous wastes, or hazardous constituents have occurred to the environment at the sites evaluated, and 2) whether further investigation or action (i.e., risk assessment, RFI, interim action), or no further action (NFA) is appropriate at a site.

For the SSP investigation conducted September-October 2003, four borings were advanced in and around SWMU 57 to evaluate for the presence or absence of chemicals in soil potentially associated with previous use as a settling pond (Figure 1-6). Three soil samples were collected from borings 57SB1, 57SB2, and 57SB3, while two samples were collected from boring 57SB4 due to refusal at 1.5 ft bgs. The samples were analyzed for target compound list (TCL) VOCs, TCL SVOCs, polynuclear aromatic hydrocarbons (PAHs), explosives (including nitroglycerin and pentaerythritol tetranitrate [PETN], and TAL metals. Sample 57SB4A was also analyzed for TCL pesticides, TCL polychlorinated biphenyls (PCBs), and TCL herbicides.

Two samples were collected for physical testing including: percent moisture, grain size, pH, TOC, specific gravity, and bulk density. Additional testing on selected samples was conducted for Atterberg limits and/or hydraulic conductivity. Analytical results for these samples are summarized in Appendix C.2.

The human health risk screening portion of the SSP consisted of the following components:

1. Identification of chemicals of potential concern (COPCs) via comparison of maximum detected concentrations (MDCs) to adjusted R-RBCs and I-RBCs;
2. Cumulative human health risk screening;
3. Chemical specific screening for lead and iron;
4. MDC comparison to soil to groundwater site screening levels (SSLs) (dilution attenuation factor [DAF] 20); and
5. Metals MDC comparison to background point estimates.

The human health risk screening resulted in the identification of the following COPCs for the site requiring additional investigation: VOCs (SSL only) and metals.

The ecological risk screening portion of the SSP consisted of the following components:

Problem formulation including identification of chemicals of potential ecological concern (COPECs);

1. Exposure assessment;
2. Ecological effects assessment; and
3. Risk characterization.

The ecological risk screening portion of the SSP resulted in the identification of the following COPECs for the site requiring additional investigation: metals.

Summaries of the SSP human health and ecological risk screening results for SWMU 57 are provided in Tables 1-4 and 1-5, respectively. In addition, a summary of conclusions and recommendations from SSP investigation is presented below and in Table 1-6. Refer to Appendix D for SWMU 57's SSP text section and screening tables and the SSP Report (URS 2007) for additional detailed information.

The SSP resulted in the recommendation of a focused RFI for soil and groundwater media at the sites based on the site-specific SSL exceedance for chloroform, the lack of groundwater data for the sites, and the results of the human health and ecological risk screenings. The RFI was to focus on metals and VOCs in soil and groundwater.

## 1.4 CONCEPTUAL SITE MODEL

A refined conceptual site model (CSM) for SWMU 57 is presented on Figure 1-7. The site is a small, fabricated, inactive pond area enclosed by a chain link fence atop an asphalt-covered berm, which is located on a terrace in the HSA of RFAAP. Subsurface geology consists of alluvial deposits overlying carbonate bedrock of the Elbrook Formation. Groundwater is present within the lower portion of the alluvial deposits (21.5 to 35.5 ft bgs) and in underlying bedrock. Based on local topography, groundwater flow is likely toward the north and northwest toward the New River.

Potentially affected media include surface soil, subsurface soil, and groundwater. Observations during the site reconnaissance and subsequent field investigation indicate the ephemeral presence of water within the pond varies from a few inches of water to dry, depending upon the amount of recent precipitation. The site is surrounded by a berm, which prevents storm water flow into or out of the pond.

### 1.4.1 Contaminant Sources

SWMU 57 is an inactive fabricated unit historically used as an acid-settling pond. Soil/sediment was noted in pond at the time of the July 2005 site visit.

### 1.4.2 Mechanisms of Contaminant Release

The site is located in a relatively flat area approximately 1,500 ft from the New River. Subsurface geology consists of alluvial deposits overlying limestone/dolomite bedrock of the Elbrook Formation. Groundwater is present within the lower portion of the alluvium (21.5 to 35.5 ft bgs) and in the underlying bedrock. Groundwater flow in the site is assumed to be north to northwest toward the New River. While site groundwater discharge may be hydraulically connected to the New River, the completeness of this pathway is unknown. If site-related groundwater impacts are identified for the sites that pose a risk to human health, the surface water pathway will be qualitatively assessed.

The sites consists of asphalt lined depressed area surrounded by an asphalt berm where precipitation and overland flow potentially infiltrate into subsurface soil. Surface water and sediment are not present within sites and therefore, potentially affected media include:

- Surface soil via historical waste discharge to the unit;
- Subsurface soil via leaching of chemicals from the unit or the associated piping;
- Groundwater via leaching of chemicals: and
- Off-site surface water via groundwater interaction.

A CSM for SWMU 57 is presented on Figure 1-7.

### 1.4.3 Exposure Pathways

#### 1.4.3.1 Human Receptors/Pathways

Although current and likely future land-use scenarios are limited to industrial operations, both residential and industrial scenarios will be evaluated. The sites are enclosed by the Installation perimeter fence; therefore, potential receptors and pathways are the following: current maintenance workers (more conservative than trespasser scenario), current/future construction workers, future commercial workers, future adult residents, and future child residents. Potentially complete pathways for each receptor are provided in Table 1-7 and pathways to be quantitatively assessed are summarized in Figure 1-8, Conceptual Site Diagram.

#### 1.4.3.2 Ecological Receptors/Pathways

Due the small size of the site (0.027 acre) and the proximity to the New River (approximately 1,500 feet), SWMU 57 would likely not be an attractive habitat to aquatic receptors with the exception of amphibians. Since amphibians were observed within the unit at the time of the July 2005 site visit, if the soil/sediment within the SWMU is to remain in place (i.e., no removal is proposed as part of the corrective measures) a qualitative assessment of potential impacts to amphibians will be conducted. SWMU 57 and the associated surrounding area will be assessed with respect to terrestrial receptors (Figure 1-9); therefore, soil represents the primary potential exposure medium for ecological receptors. Receptor categories and the species selected to represent the wildlife categories include: plant communities, soil invertebrate/microbial communities, omnivorous birds: American Robin (*Turdus migratorius*), carnivorous birds: Red-Tailed Hawk (*Buteo jamaicensis*), herbivorous animals: Meadow Vole (*Microtus pennsylvanicus*), omnivorous mammals: Red Fox (*Vulpes vulpes*); and carnivorous mammals: Short-Tailed Shrew (*Blarina brevicauda*). Refer to Table 1-8 for wildlife receptor profiles. Also on Table 1-8, note the area use factor used in the refinement of the SLERA was calculated using a site area of 0.38 acres as shown on Figure 1-9. A photographic log for the site is provided in Appendix B.

## 1.5 DATA GAP ANALYSIS

Based on the results of the SSP investigation, a focused RFI was recommended at SWMU 57 to characterize the nature and extent of COPCs and COPECs identified in soil, to evaluate potential releases to groundwater, and to further assess the risk to human health and the environment.

### 1.5.1.1 Soil

<u>Pond Area</u>

For the SSP, two soil samples have been collected from the approximate 1.5 ft thick layer of soil present above the asphalt liner within the pond area. Soil samples have not been collected below the asphalt liner. VOCs, SVOCs, Aroclor 1254, metals, and cyanide were detected in the samples collected for the SSP. Metals were identified as COPCs and COPECs requiring additional investigation based on human health and ecological risk screenings.

Additional soil sampling is required in the pond area to further assess the nature and extent of contamination within the source area, to provide sufficient data for risk assessment, and to evaluate whether COPCs have migrated vertically to soil below the asphalt liner.

<u>Drain Pipe Area</u>

For the SSP, six soil samples were collected at two locations (57SB1 and 57SB2) along the terracotta drainpipe leading from Building 4931 to the pond, with one sample location adjacent to the building and one sample location near the terminus of the drainpipe where it enters the pond. VOCs, SVOCs, Aroclor 1254, metals, and cyanide were detected in the samples collected for the SSP. Metals were identified as COPCs and COPECs requiring additional investigation based on human health and ecological risk screenings. Chloroform and bromodichloromethane were also identified as COPCs based on detected concentrations in subsurface soil above default SSLs.

Additional soil sampling is required along the drainpipe to assess for the presence of COPCs at depths proximate to the bottom of the drainpipe and to further characterize COPC concentrations along the pipe between the building and the pond.

<u>Area Surrounding Pond and Drainage Swale</u>

For the SSP, three soil samples were collected at one location (57SB3) from the low area outside of the berm of the pond at the location where a drainage swale extends northwest from the pond. Soil samples were collected from surface, intermediate, and terminal depths. VOCs, SVOCs, PAHs, metals, and cyanide were detected in the samples. Metals were identified as COPCs and COPECs requiring additional investigation based on human health and ecological risk screenings. Chloroform was also identified as a COPC based on detected concentrations in subsurface soil above default SSLs.

Additional soil sampling around the pond area and in the drainage swale is required to further assess the nature and extent of COPCs in soil and to evaluate potential migration of COPCs from the site via the drainage ditch.

#### 1.5.1.2 Sediment and Surface Water

Perennial surface water bodies are not present in the site area, although during prolonged wet periods, a trace amount to several inches of water may accumulate in the pond area due to the presence of low permeability soil and the asphalt liner. Given the operational history of the site and its current status, the residual material present above the asphalt liner is considered soil source material associated with former operations. For purposes of the RFI, this material will be evaluated as soil in the contamination assessment and risk assessments.

#### 1.5.1.3 Groundwater

Based on the results of the SSP, there is potential for releases of COPCs from soil to groundwater, and therefore, the lack of groundwater samples at the site represents a data gap. Based on the results of the SSP and site history, VOCs and metals are of COPCs for the soil-to-groundwater migration pathway.

#### 1.5.1.4 Other

Two subsurface soil samples for the SSP were submitted for physical soil testing. The lack of physical test data for surficial soil represents a data gap for the RFI.

#### 1.5.1.5 Summary of Data Gaps

Chemical classes identified as COPCs in soil due to exceedances of adjusted R-RBCs and/or ecological screening benchmarks included VOCs and metals. VOCs and metals are also the COPCs of potential concern for the soil-to-groundwater migration pathway. Due to the limited sampling conducted within the pond area and the lack of samples below the asphalt liner, a full suite of analyses is proposed for the samples collected in the area. The following table summarizes the data gap analysis and the data gap completion plan.

**SWMU 57 RFI - Data Gap Analysis and Completion Plan**

| DATA GAPS | | | COMPLETION PLAN |
|---|---|---|---|
| **Item** | **Physical** | **Chemical** | |
| Soil within pond area | Surface Soil Samples | Chemical Data – TAL Metals, TCL VOCs, TCL SVOCs, TCL PCBs, TCL Pesticides, and Explosives | Advance soil borings, collect soil samples for chemical analysis |
| | Subsurface Soil Samples | Chemical Data – TAL Metals, TCL VOCs, TCL SVOCs, TCL PCBs, TCL Pesticides, and Explosives | Advance soil borings, collect soil samples for chemical analysis |
| Soil outside bermed area | Surface Soil Samples | Chemical Data – VOCs and metals | Advance soil borings, collect soil samples for chemical analysis |
| | Subsurface Soil Samples | Chemical Data – VOCs and metals | |
| Groundwater | Groundwater Samples | Chemical Data – VOCs and metals | Install monitoring wells and sample groundwater |
| | Aquifer Characteristics | N/A | Collect potentiometric measurements and conduct slug tests |
| Pond Material | Residual Pond Material | Chemical Data – TAL Metals, TCL VOCs, TCL SVOCs, TCL PCBs, TCL Pesticides, Explosives, full Toxicity Characteristic Leaching Procedure (TCLP), and pH | Stratigraphic boring, collect samples for chemical analysis and waste characterization |
| | Pond Material Location | N/A | Complete soil borings to verify nature and thickness of material |
| Site-Wide Soil Characteristics | Physical / Geotechnical Properties | pH, oxidation/reduction, TOC, grain size, Atterberg Limits, moisture content, cation exchange capacity | Collect samples for geotechnical and physical property analysis. |

*N/A = Not Applicable*

## 1.6 PLANNED FIELD ACTIVITIES

The SWMU 57 RFI field program is designed to address the data gaps identified and discussed in Section 1.5 and meet the RFI objectives identified in Section 1.0. The selection of the investigation areas and soil sample locations followed SOP 30.7 (Sampling Strategies, included in Appendix A) using a combination of systematic grid sampling and biased sampling.

The MWP is referenced where routine activities will be performed in accordance with the MWP specifications, SOPs, and the Master Health and Safety Plan (URS 2003). Variances to the specifications are documented in this WPA. Table 1-1 identifies the MWP SOPs that will be followed as part of the RFI for field documentation, subsurface investigation, sampling, field evaluations, sample management, data management, and management of investigative derived material, decontamination, and field monitoring. Copies of the SOPs identified in Table 1-1 are included in Appendix A.

### 1.6.1 Soil Investigations and Sampling

Nineteen direct push soil borings (57SB1 through 57SB19) will be advanced at SWMU 57 to:

- Further assess the nature and extent of COPCs and COPECs in soil inside the pond area, outside the pond area, along the terracotta drainpipe, and within the drainage swale that extends northwest from the pond area;
- Provide additional information on the physical characteristics of soil and the nature of the asphalt liner within the pond;
- Assess potential for migration of chemicals detected in soil via leaching to groundwater; and
- Provide sufficient data for completion of human health and ecological risk assessments.

Figure 1-10 shows the location of the proposed borings and Table 2-4 summarizes information related to each boring including location, purpose, and proposed chemical and physical samples and depths. Surface samples of soil or sludge will be collected from 0 to 1 ft bgs with the exception of samples collected for VOC analysis which will be collected from 0.5 to 1 ft bgs. One composite sample of surface soil within the pond area will be analyzed for full TCLP and pH.

Direct push drilling will be conducted consistent with procedures outlined in SOP 20.11 (Appendix A) using a four-foot core sampler for soil sampling. Stratigraphic logs will be prepared for each boring location in accordance with SOP 10.3 (Appendix A) and soil samples obtained from the cores will be screened for the presence of VOCs using a PID consistent with SOP 90.1 (Appendix A).

#### 1.6.1.1 Inside Pond Area

One soil boring will be advanced to the depth of groundwater at the location of SSP boring 57SB4 below the SSP boring termination depth of 1.5 ft bgs (Figure 1-10). Three soil samples will be collected for chemical analysis from the following intervals: (1) immediately below the pond asphalt liner, (2) intermediate depth, and (3) terminal depth immediately above encountered groundwater (Table 2-4). Soil samples will be analyzed for TAL Metals, TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, and explosives.

Four additional soil borings (57SB5, 57SB6, 57SB7, and 57SB8) will be completed within the pond area to the depth of encountered groundwater (assumed to be 35 ft) (Figure 1-10 and Table 2-4). Four soil samples will be collected from each boring from the following intervals: (1) surface, (2) immediately below the pond asphalt liner, (3) intermediate depth, and (4) terminal depth immediately above encountered groundwater (Figure 1-7 and Table 2-4). Soil samples will be analyzed for TAL Metals, TCL VOCs, TCL SVOCs, TCL PCBs, TCL pesticides, and explosives.

Samples for the borings will be collected at the following depths:

- Surface samples (“A” samples) 57SB5A, 57SB6A, 57SB7A, and 57SB8A from 0 to 1 ft below ground surface (except for VOCs which will be collected from 0.5 to 1 ft);
- Subsurface samples (“AB” samples) 57SB4AB, 57SB5AB, 57SB6AB, 57SB7AB, and 57SB8AB to be collected immediately below the pond asphalt liner:
- Intermediate depth samples (“B” samples) 54SB4B, 57SB5B, 57SB6B, 57SB7B, and 57SB8B to be collected from 6 to 8 ft below ground surface.

- Terminal depth sample ("C" sample) 54SB4C, 57SB5C, 57SB6C, 57SB7C, and 57SB8C to be collected from a depth immediately above encountered groundwater. Based on existing data, the estimated depth of this sample will be 29 to 31 ft below ground surface.

One surface soil sample will be analyzed for TOC (Walkley-Black Method), grain size analysis (ASTM Method D 422), Atterberg Limits (ASTM Method D 4318), moisture content (ASTM Method D 2216), pH (ASTM Method 4972), and cation exchange capacity. One subsurface sample collected from below the asphalt liner will be analyzed for TOC (Walkley-Black Method) and cation exchange capacity.

#### 1.6.1.2 Terracotta Drainpipe

The approximately 65 ft long terracotta drainage pipe is below grade except for the northern end of the pipe where it enters into the pond. An approximate four foot section of the pipe is above grade and the pipe is broken at a single point where two pipe sections are attached (Photograph 2 in Appendix B of work plan addendum). SSP boring 57SB2 was completed at the location where the pipe is broken. Three soil samples were collected at this location to evaluate potential releases from the pipe including a surface soil sample from 0 to 1 ft bgs (0.5 to 1 ft for volatiles), and intermediate depth sample from 8 to 10 ft bgs, and a terminal depth sample collected from 33 to 35 ft bgs. An additional sample will be collected at location 57SB2 from 1 to 2 ft below the bottom of the drainpipe section where it is broken to further assess for potential releases in this area. One additional soil sample will also be collected from previsous SSP boring 57SB1 at a depth of approximately 1 to 2 ft below the bottom of the drainpipe (Figure 1-10 and Table 2-4).

A third soil boring (57SB9) will be completed along the drainpipe at the midpoint between SSP borings 57SB1 and 57SB2 (Figure 1-10). Three soil samples will be collected from this boring for chemical analysis including: (1) a surface sample, (2) a sample from 1 to 2 ft below the drainpipe, and (3) a terminal depth sample immediately above encountered groundwater (Table 2-4). Soil samples will be analyzed for TCL VOCs and TAL metals.

The buried sections of the drain pipe range in depth from less than one foot near the above grade portion closest to the pond to approximately 3.5 ft south of the steam line located between Building 4931 and the pond. Depths of drainpipe vary along its length due to an approximate six foot elevation difference between the pond and building 4931, with most of the elevation change occurring within a 20 ft area between the above ground portion of the pipe and the steam line to the south as shown on Figure 1-2. The presence, depth, and integrity of the pipe will be verified at proposed piping sample locations 57SB1 and 57SB9 to ensure that samples are collected at appropriate locations and depths to further evaluate releases from the pipe.

#### 1.6.1.3 Outside Pond Area

Three soil borings (57SB10, 57SB11, and 57SB12) will be completed north, east, and south of the fenced perimeter/berm within the low area surrounding the pond to supplement existing data from borings 57SB2 and 57SB3 (Figure 1-10). Each of these borings will be completed to the depth of encountered groundwater. Three soil samples will be collected from each boring for chemical analysis from the following intervals: (1) surface, (2) intermediate depth, and (3) terminal depth immediately above encountered groundwater (Table 2-4). Soil samples will be analyzed for TCL VOCs and TAL metals.

Five soil borings (57SB13, 57SB14, 57SB15, 57SB16, and 57SB17) will be completed farther outside the pond perimeter fence north, east, south, and west of the pond area at a distance of 20 to 25 ft from the perimeter fence when possible (Figure 1-10). Each of these borings will be completed to the depth of encountered groundwater. Three soil samples will be collected from each boring for chemical analysis including the following intervals: (1) surface, (2) intermediate, and (3) terminal depth immediately above encountered groundwater (Table 2-4). Soil samples will be analyzed for TCL VOCs and TAL metals.

In addition to the chemical samples, one surface soil sample will be analyzed for TOC (Walkley-Black Method), grain size analysis (ASTM Method D 422), Atterberg Limits (ASTM Method D 4318), moisture content (ASTM Method D 2216), pH (ASTM Method 4972), and cation exchange capacity.

#### 1.6.1.4 Drainage Swale

Two additional soil borings (57SB18 and 57SB19) will be completed in the 80 ft segment of swale located between boring 57SB3 and the area immediately upgradient of SWMU 68 (Figure 1-10). Three soil samples will be collected from each boring for chemical analysis including: (1) a surface sample, (2) an intermediate sample, and (3) a termination depth sample (Table 2-4). Soil samples will be analyzed for TCL VOCs and TAL metals.

### 1.6.2 Groundwater Investigation and Sampling

Potential releases to groundwater at the site will be evaluated by the installation of three groundwater-monitoring wells and collection of groundwater samples for chemical analysis for TCL VOCs and TAL metals (Table 2-4), as well as, water quality parameters including, pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity.

#### 1.6.2.1 Monitoring Well Installation

Three groundwater monitoring wells (57MW1, 57MW2, and 57MW3) will be installed at the site. Monitoring well 57MW1 will be installed in a topographically upgradient position approximately 100 ft east of the site and across the road bordering the site (Figure 1-10). Monitoring wells 57MW2 and 57MW3 will be installed adjacent to the pond area and positioned to detect possible releases from this unit (Figure 1-10).

The uppermost zone of groundwater at the site is expected to occur near the overburden and bedrock interface. Monitoring wells be installed with a 15 ft long screen so that the top of the screen is above the seasonally high water table. It is anticipated that the monitoring wells will be screened across the overburden and bedrock interface. Monitoring wells will be constructed using 2-inch diameter (nominal) Schedule 40 polyvinyl chloride (PVC) threaded screen and riser pipe. A 0.010-inch screen slot size and No. 2 sand filter pack will be used to construct the wells. Monitoring well completion depths are expected range from 45 to 60 ft bgs. A monitoring well construction diagram showing the proposed construction and materials is shown in Appendix A on Figure 20-1b.

The air rotary drilling method will be used for installation of monitoring wells given that well installation into bedrock is anticipated. A 6-inch diameter, roller bit will be used to drill within soil overburden and a 6-inch diameter, air hammer bit will be used to drill in bedrock. If unstable conditions are encountered in the borehole, then a 6-inch temporary casing will be set in the borehole to allow for boring completion and monitoring well installation. A minimum 8-inch diameter roller bit will be used in the overburden if temporary casing is required. The casing sections are fitted with auger couples to allow for incremental removal during well construction. Monitoring wells will be installed consistent with the procedures outlined in Section 5.2 of the MWP and MWP SOPs 20.1 and 20.11 (Appendix A). Split-spoon samples will be collected at 5-foot intervals for the uppermost 10 ft of each well boring and at 10-ft intervals thereafter. Slug tests will be conducted at each of the installed monitoring wells to obtain estimates of the hydraulic conductivity of the screened intervals consistent with the procedures outlined in SOP 40.3 (Appendix A).

#### 1.6.2.2 Groundwater Sampling

After installation and prior to sampling, monitoring wells will be developed consistent with SOP 20.2 (Appendix A) using a combination of surging, pumping (including low flow) to remove any accumulated solids, mobile particulates, and sediment accumulated within or in the vicinity of the newly installed monitoring well from drilling. Well development will continue until stabilization criteria in Section 3.3.1 of SOP 20.2 are achieved.

Groundwater sampling will occur no sooner than 14 days after completion of monitoring well development to allow sufficient time for well stabilization. Groundwater sampling will be conducted following the procedures outlined in SOP 30.2 (Appendix A). A single continuous set of static water levels will be collected from the three monitoring wells prior to purging and sampling. Low flow sampling will be performed according to SOP 30.2 and the latest USEPA guidance. Water quality parameters pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity will be measured using an in-line flow cell (SOP 40.1 in Appendix A) during purging and immediately before sample collection to document parameter stabilization and water quality parameters.

Groundwater samples will be collected from the three monitoring wells and analyzed for the soil COPCs identified during the SSP including: TCL VOCs and TAL metals (total and dissolved). Sample analysis will be performed consistent with the methods and requirements of the Master Quality Assurance Plan (MQAP) and Section 2.0 of the WPA. Groundwater QA/QC samples will include one duplicate, one rinsate blank, one trip blank (VOCs), and one matrix spike/matrix spike duplicate.

Site-specific background concentrations will be established for those metals exceeding their adjusted T-RBCs (i.e., COPCs) by constructing a 95% Upper Prediction Limit (UPL) as described in the 1992 USEPA Guidance Document *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities: Addendum to Interim Final Guidance*. As recommended in this guidance document and in the VDEQ Data Analysis Guidance for Solid Waste Facilities dated March 2003 (Table 1 on page 11), eight independent samples will be collected to construct the 95% UPL to provide for a reasonable estimate of the standard deviation and adequate statistical power. USEPA and the VDEQ define adequate statistical power as the ability to detect a three standard deviation increase above the mean with 50% power and a four standard deviation increase with 80% power).

The eight independent groundwater samples will be collected from upgradient monitoring well (57MW1) over an eight-month period (including the initial sampling event and seven additional sampling events). Sampling events will be timed so that at least one sampling event will be conducted during seasonally low flow conditions, during normal flow conditions, and during seasonally high flow conditions.

#### 1.6.2.3 Slug Tests

Rising head and falling head slug tests will be conducted in the newly installed monitoring wells 57MW1, 57MW2, and 57MW3 consistent with SOP 40.3 (Appendix A) to provide estimates of the hydraulic conductivity of the screened intervals of each well. Hydraulic conductivity data, physical test data, and groundwater elevation data will be used to estimate the rate of horizontal groundwater flow in the uppermost zone of groundwater at the site.

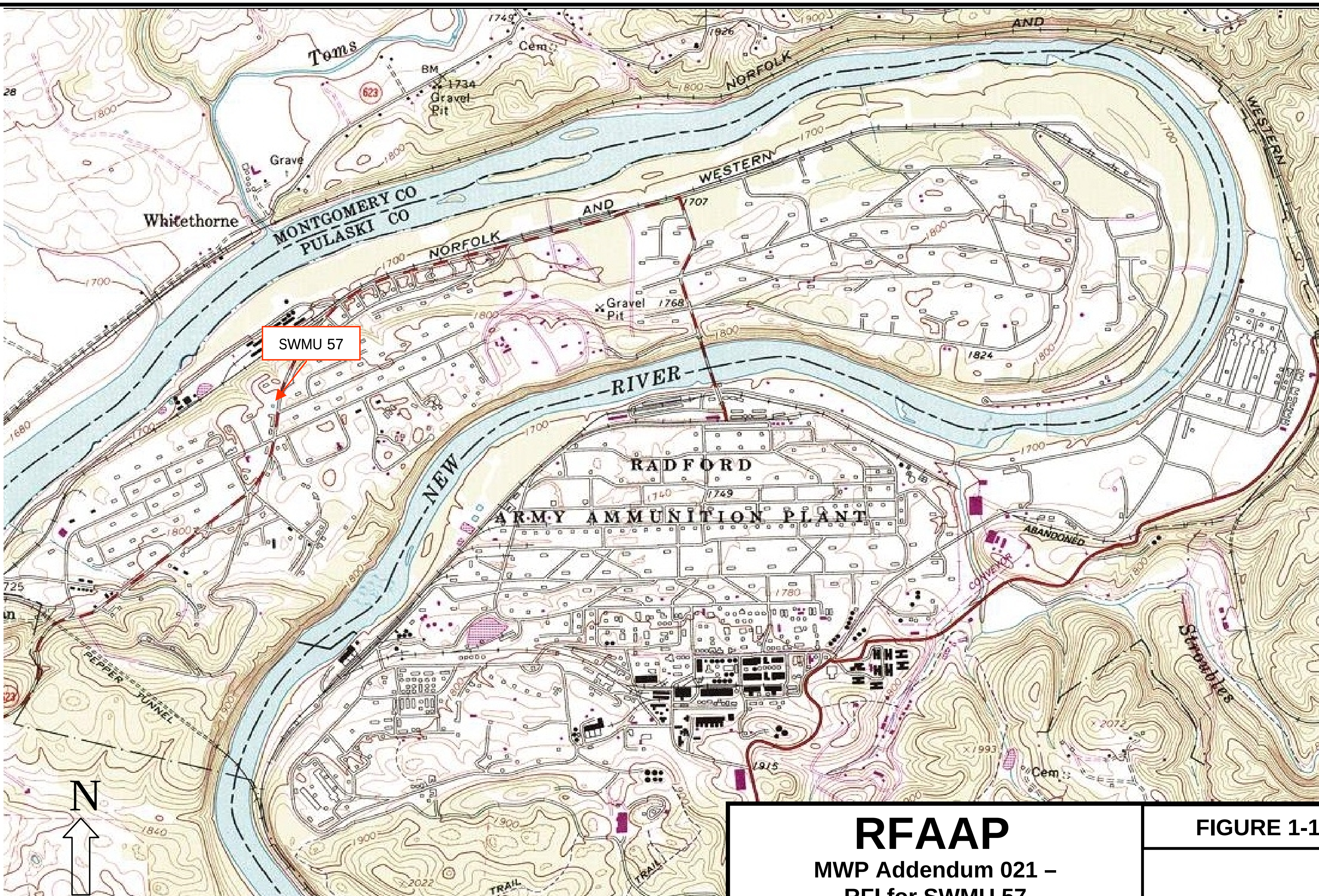
### 1.6.3 Surveying

Horizontal coordinates and ground surface elevations for soil borings/soil samples will be obtained using a GPS unit with submeter accuracy for horizontal measurements (+1 part per and million) and vertical measurements (+ 2 parts per million for vertical measurements).

Horizontal coordinates and vertical elevations of each monitoring well will be surveyed by Virginia licensed surveyor experienced working at RFAAP. Horizontal coordinates (northing and easting) will be surveyed using the North American Datum of 1983, Universal Transverse Mercator Zone 18, and vertical elevations will be surveyed using the National Geodetic Vertical Datum of 1988. At each monitoring well location, the ground surface elevation and elevation of the top of the inner well casing used for measuring water levels will be surveyed to the nearest 0.01 ft.

### 1.6.4 Investigation-Derived Material Handling and Disposal

Activities conducted during this investigation will comply with the relevant Occupational Safety and Health Administration and USEPA regulations regarding the identification, handling, and disposal of non-hazardous and hazardous investigation-derived material (IDM). Activities will be performed in accordance with the Installation safety rules, protocols, and SOP 70.1. Table 1-9 summarizes the suspected nature (hazardous versus non-hazardous) of the materials to be generated during field investigative activities.



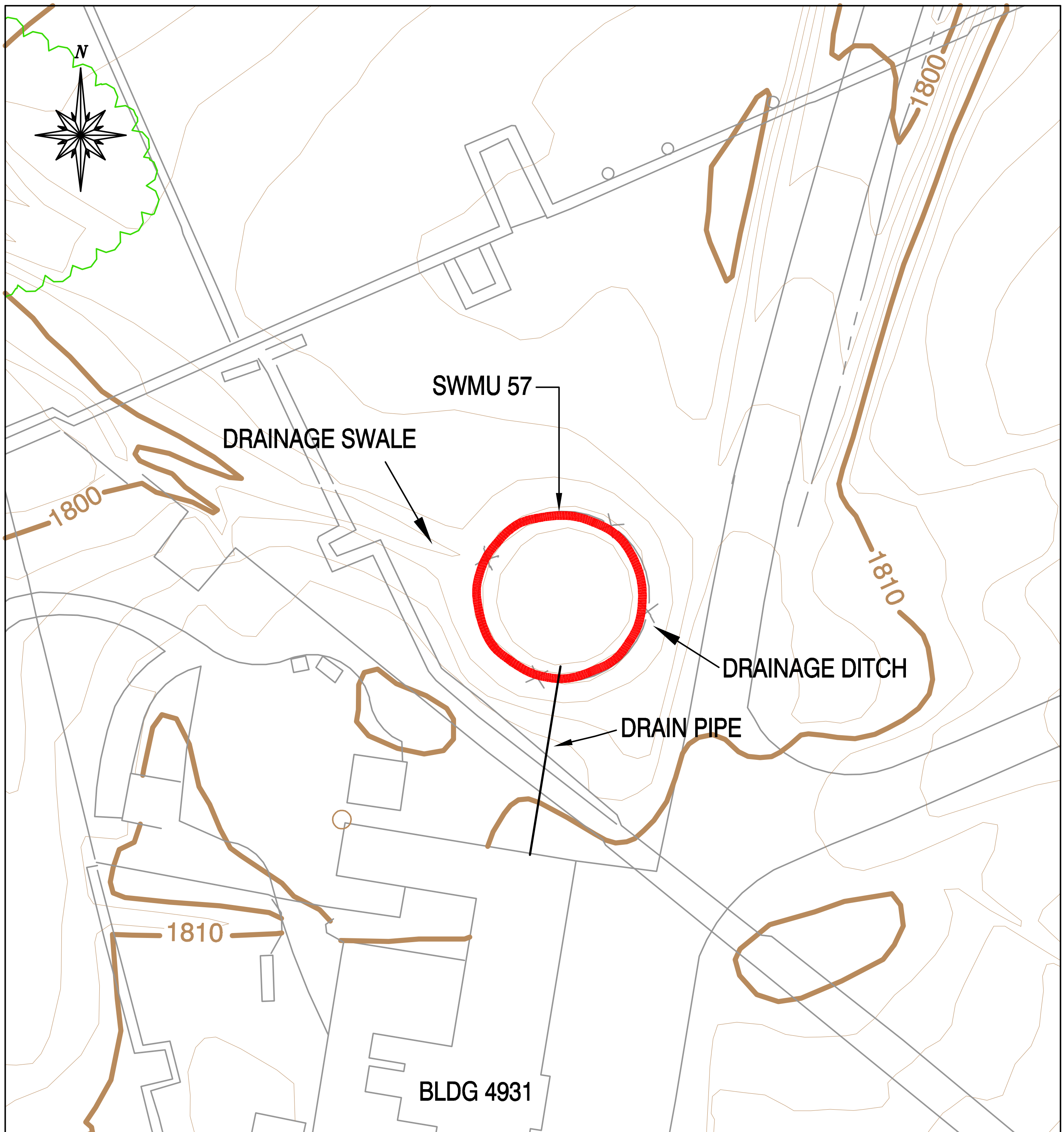

# RFAAP

## MWP Addendum 021 – RFI for SWMU 57

| | |
|---|---|
| **Date:** *April 2007* | **Prepared by:** *KDC/TDH* |
| **Scale:** *1" = 2000'* | **File Name:** *Figure 1-1.ppt* |

**FIGURE 1-1**

**SITE LOCATION MAP**




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

0 50'

1 inch = 50 feet

**Legend**

SWMU 57 Approximate Boundary

Aboveground Piping

Vegetation

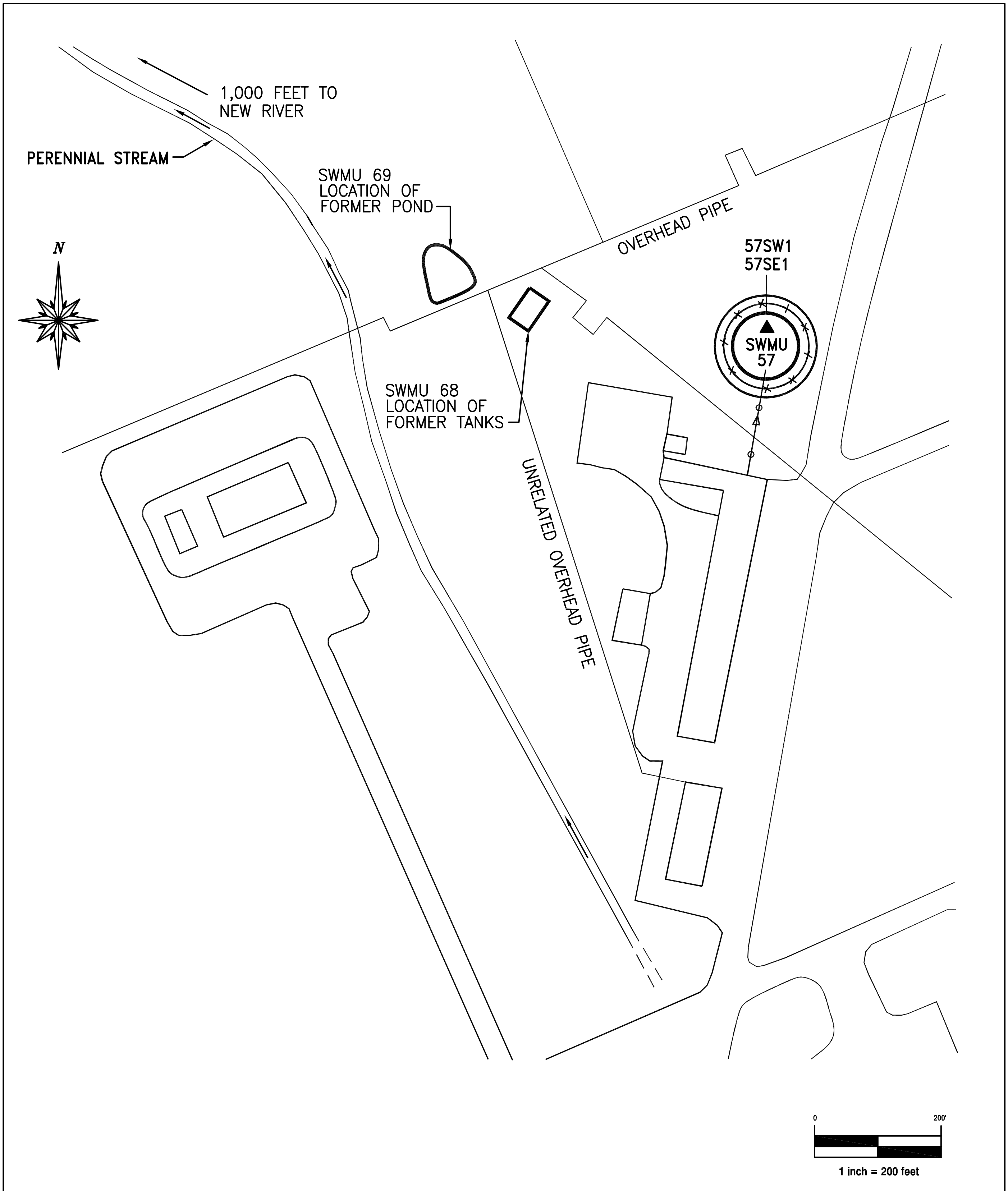
# RFAAP

**MWP Addendum 021 - RFI for SWMU 57**

| Date: | Prepared By: |
|---|---|
| May 2007 | DBC/CLD |
| Scale: 1"=50' | File Name: 11656421 |

**FIGURE 1-2**

**TOPOGRAPHIC MAP SWMU 57**

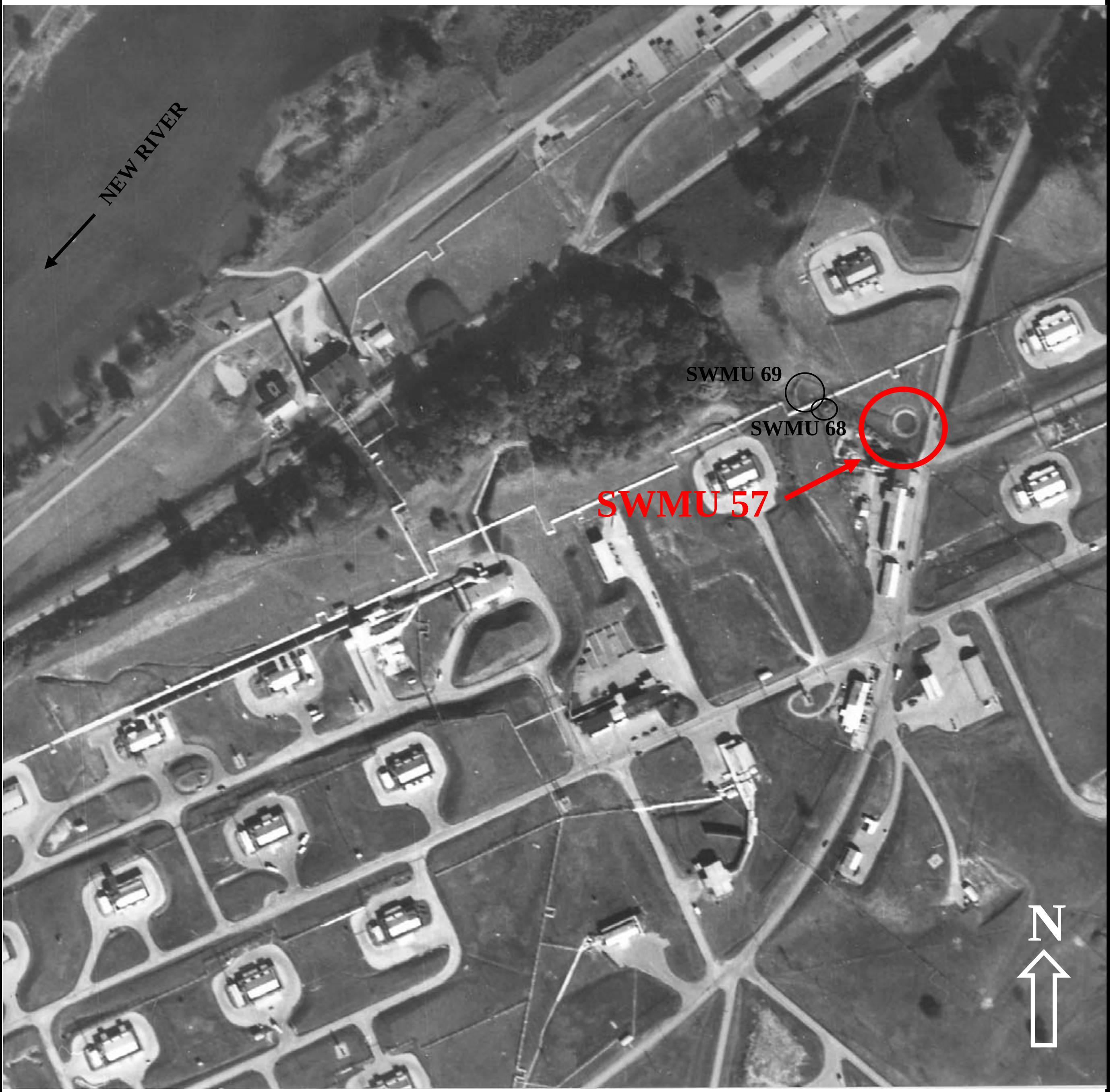



**Legend**

▲ Surface Water/Sediment Sample

(SOURCE: MODIFIED FROM DAMES & MOORE, 1992a)

| RFAAP<br>MWP Addendum 021 - RFI for SWMU 57 | | FIGURE 1-3 |
|---|---|---|
| Date: June 2004 | Prepared By: KDC/TDH | VERIFICATION INVESTIGATION SAMPLING LOCATIONS SWMU 57 |
| Scale: 1"=200' | File Name: 11656421 | |



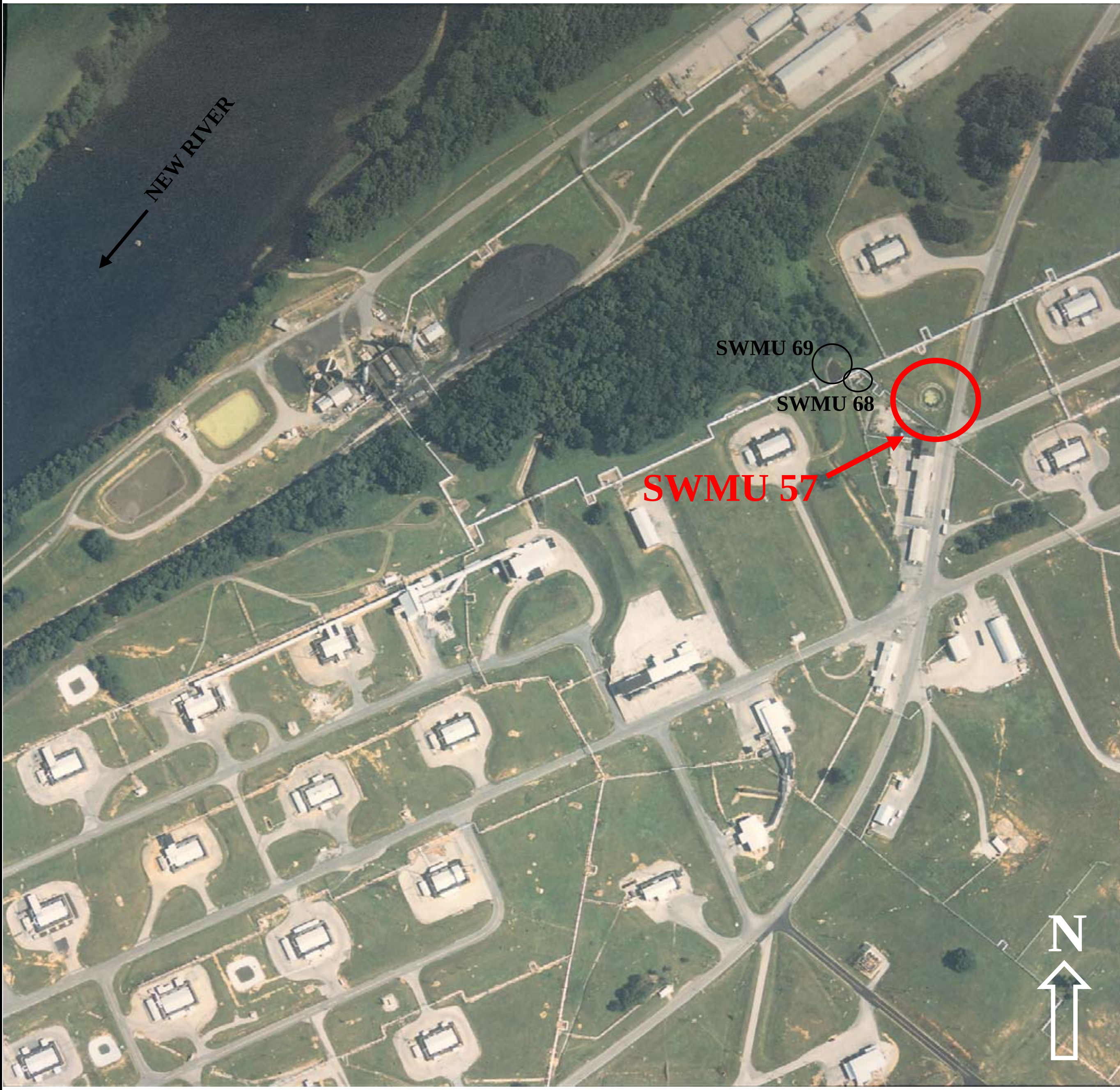

# RFAAP

**MWP Addendum 021 – RFI for SWMU 57**

| | |
|---|---|
| **Date:** *April 2007* | **Prepared by:** *LAM/CLD* |
| **Scale:** *No Scale Implied* | **File Name:** *11656421* |

**FIGURE 1-4**

**SWMU 57**
**AERIAL PHOTOGRAPH – 1962**




# RFAAP

**MWP Addendum 021 – RFI for SWMU 57**

**FIGURE 1-5**

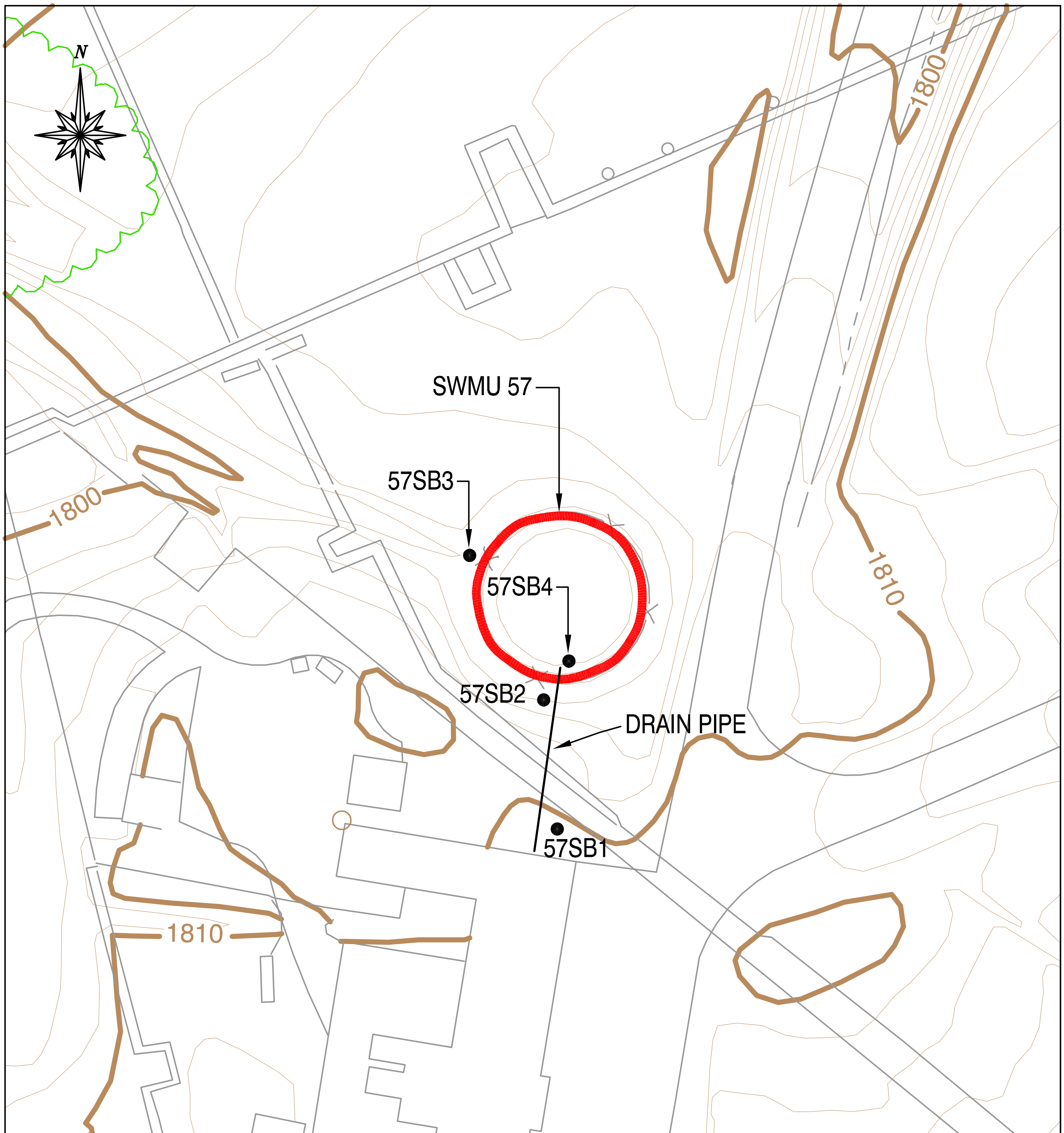
**Date:** *April 2007*

**Prepared by:** *LAM/CLD*

**Scale:** *No Scale Implied*

**File Name:** *11656421*

**SWMU 57**
**AERIAL PHOTOGRAPH – 1986**




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

0 50'
1 inch = 50 feet

**Legend**

- Soil Sampling Location
- SWMU 57 Approximate Boundary
- Aboveground Piping
- Vegetation

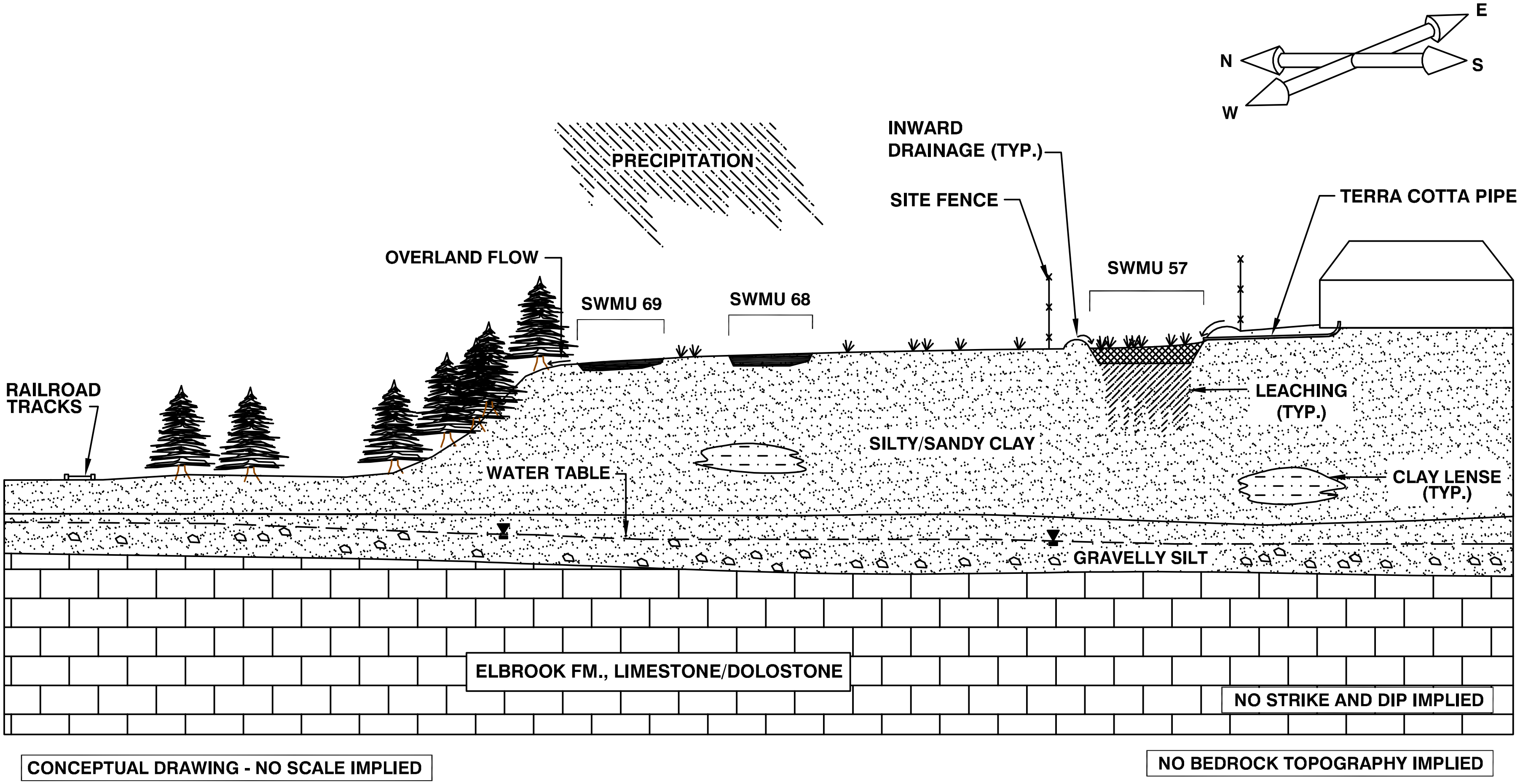
# RFAAP

**MWP Addendum 021 - RFI for SWMU 57**

| Date: | Prepared By: |
|---|---|
| June 2004 | KDC/TDH |
| **Scale:** | **File Name:** |
| 1"=50' | 11656421 |

**FIGURE 1-6**

**SSP SAMPLING LOCATION MAP SWMU 57**




# RFAAP

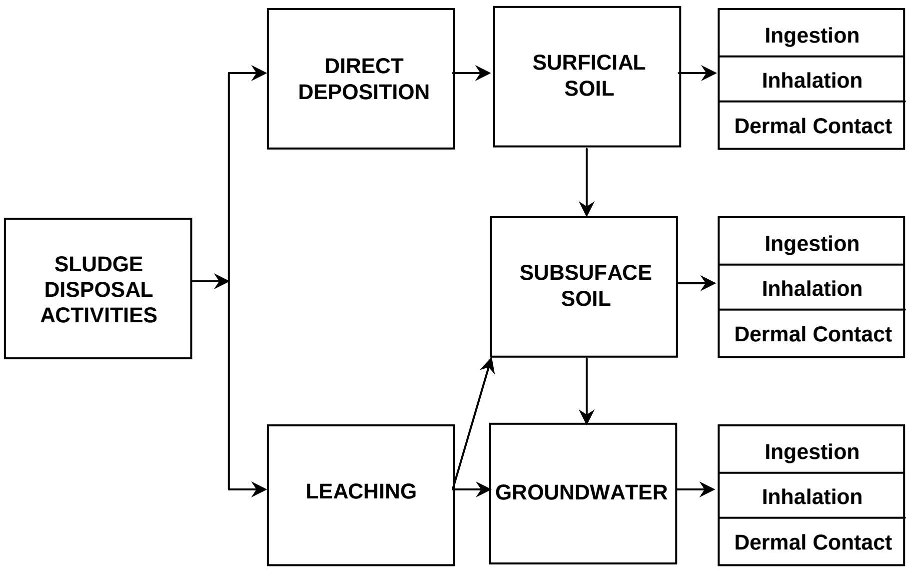
**MWP Addendum 021 - RFI for SWMU 57**

| Date: | Prepared By: |
|---|---|
| *May 2007* | *DBC/CLD* |
| **Scale:** | **File Name:** |
| *Not to Scale* | *11656421* |

**FIGURE 1-7**

**CONCEPTUAL SITE MODEL SWMU 57**

| PRIMARY SOURCE | RELEASE MECHANISMS | PATHWAY | EXPOSURE ROUTE | RECEPTORS |
|---|---|---|---|---|
| | | | | CURRENT/FUTURE · FUTURE |




| Pathway | Exposure Route | MAINTENANCE WORKER (Current/Future) | CONSTRUCTION WORKER (Current/Future) | TERRESTRIAL BIOTA (Current/Future) | COMMERCIAL/ INDUSTRIAL WORKER (Future) | ADULT RESIDENT (Future) | CHILD RESIDENT (Future) |
|---|---|---|---|---|---|---|---|
| SURFICIAL SOIL | Ingestion | ● | ● | ● | ● | ● | ● |
| | Inhalation | ● | ● | ● | ● | ● | ● |
| | Dermal Contact | ● | ● | ● | ● | ● | ● |
| SUBSUFACE SOIL | Ingestion | | ● | | ● | ● | ● |
| | Inhalation | | ● | | ● | ● | ● |
| | Dermal Contact | | ● | | ● | ● | ● |
| GROUNDWATER | Ingestion | | | | ● | ● | ● |
| | Inhalation | | ● | | ● | ● | ● |
| | Dermal Contact | | | | ● | ● | ● |

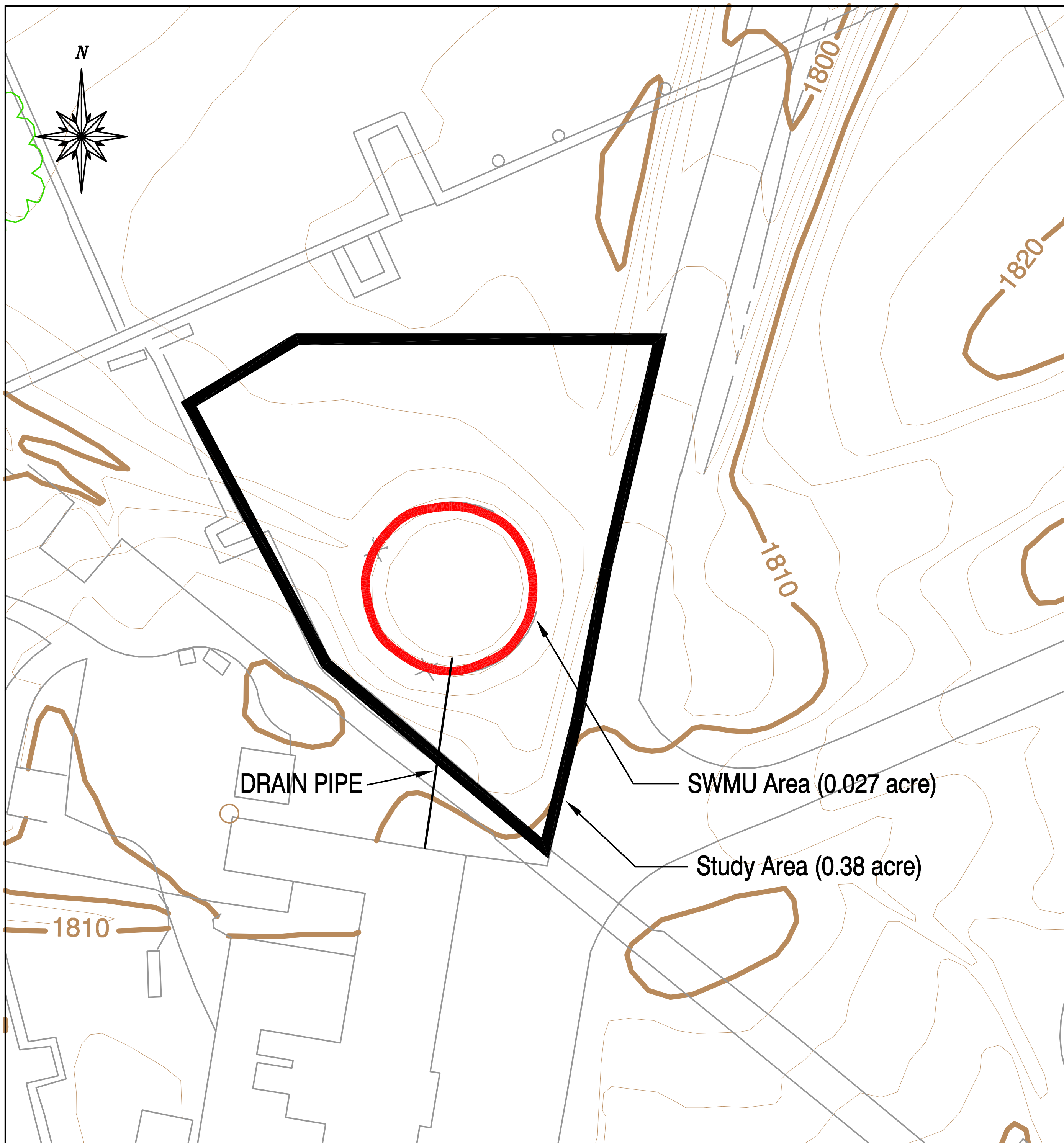
**FIGURE 1-8**

**Conceptual Site Diagram**

**Date:** *May 2007*
**Prepared by:** *CLD*
**Scale:** *Not to Scale*
**Job Number:** *11656421*

**MWP Addendum 021 -**
**RFI for SWMU 57**
**Radford Army Ammunition Plant**
**Radford, Virginia**

URS
URS Group, Inc.
5540 Falmouth Street,
Suite 201
Richmond, VA 23230




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

0 50'

1 inch = 50 feet

**Legend**

- SWMU 57 Approximate Boundary
- Study Area Approximate Boundary
- Aboveground Piping

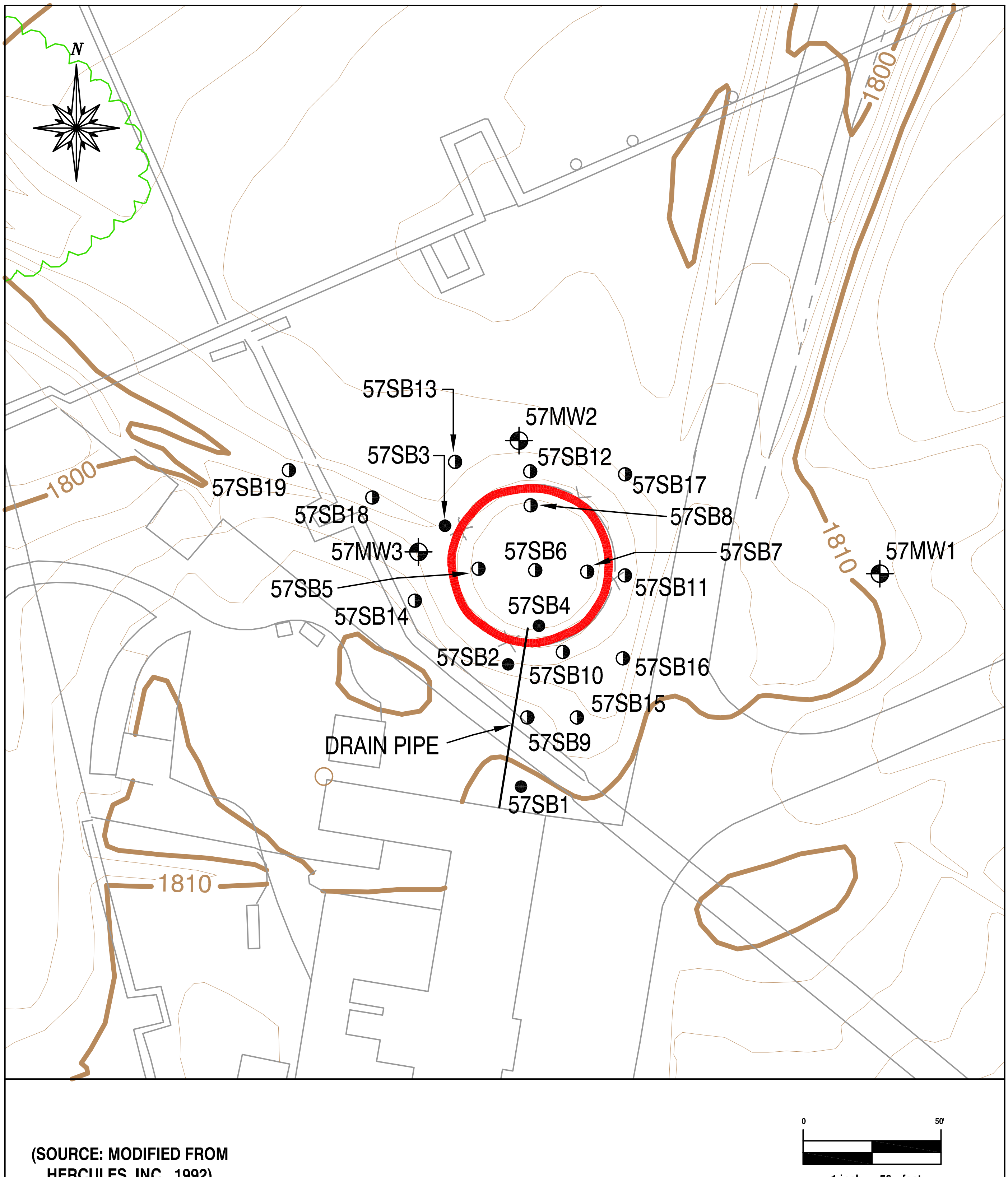
# RFAAP

**MWP Addendum 021 - RFI for SWMU 57**

| Date: | Prepared By: |
|---|---|
| *May 2007* | *DBC/CLD* |
| **Scale:** | **File Name:** |
| *1"=50'* | *11656421* |

**FIGURE 1-9**

**STUDY AREA FOR CALCULATION OF AREA USE FACTOR - SLERA SWMU 57**




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

**Legend**

- SSP Soil Sampling Location
- RFI Proposed Sampling Location
- Monitoring Well
- SWMU 57 Approximate Boundary
- Aboveground Piping

# RFAAP

**MWP Addendum 021 - RFI for SWMU 57**

| Date: | Prepared By: |
|---|---|
| *May 2007* | *DBC/CLD* |
| **Scale:** | **File Name:** |
| *1"=50'* | *11656421* |

**FIGURE 1-10**

**RFI SAMPLING LOCATION MAP SWMU 57**

**Table 1-1**
**Applicable MWP Activities and Related SOPs**
**MWP Addendum 021 – RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| Subject | MWP Section | SOPs MWP Appendix A and Appendix A to WPA 021 |
|---|---|---|
| Installation Description | 2.0 | Not Applicable |
| Environmental Setting | 3.0 | Not Applicable |
| Documentation | 4.3 | 10.1 Field Logbook<br>10.2 Surface Water, Groundwater, and Soil/Sediment Field Logbooks<br>10.3 Boring Logs<br>10.4 Chain-of-Custody Form |
| Sample Management | 5.1 | 50.1 Sample Labels<br>50.2 Sample Packaging |
| Decontamination Requirements | 5.12 | 80.1 Decontamination |
| Investigation-Derived Material | 5.13 | 70.1 Investigation-Derived Material |
| Subsurface Investigation | 5.2<br>5.8<br>9.2 | 20.1 Monitoring Well Installation<br>20.2 Monitoring Well Development<br>20.3 Well and Boring Abandonment<br>20.11 Drilling Methods and Procedures<br>30.1 Soil Sampling<br>30.2 Groundwater Sampling<br>30.7 Sampling Strategies<br>30.9 Collection of Soil Samples by USEPA SW-846 Test Method 5035 for Volatile Organic Compounds Using Disposable Samplers<br>40.1 Multi-parameter Water Quality Monitoring Instrument<br>40.2 Water Level and Well Depth Measurements<br>40.3 Slug Tests<br>90.1 Photoionization Detector (HNu Model PI-101 and HW-101) |

**Table 1-2**
**Summary of Analytical Data for Sediment Sample Collected at SWMU 57**
**Modified from Dames & Moore Verification Investigation Report**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| SITE ID<br>FIELD ID<br>SAMPLE DATE<br>DEPTH (ft bgs)<br>MATRIX<br>UNITS | CAS # | PQLs<br>mg/kg | Facility-Wide Background Point Estimate [A]<br>mg/kg | Adjusted Soil Residential RBC<br>mg/kg | Adjusted Soil Industrial RBC<br>mg/kg | BTAG Sediment Screening Value<br>mg/kg | 57SE1<br>RVFS*92<br>10-Feb-92<br>0.5<br>CSE<br>mg/kg |
|---|---|---|---|---|---|---|---|
| **TAL Metals** | | | | | | | |
| Aluminum | 7429-90-5 | 14.1 | 40,041 | 7,821 | 102,200 | -- | 30,000 |
| Arsenic | 7440-38-2 | 30 | 15.8 | 0.426 | 1.91 | 9.8 | **4.66** |
| Barium | 7440-39-3 | 1 | 209 | 1,564 | 20,440 | -- | 65.5 |
| Calcium | 7440-70-2 | 100 | -- | -- | -- | -- | 30,800 |
| Chromium(1) | 7440-47-3 | 4 | 65.3 | 23.46 | 306.6 | 43.4 | 42.5 |
| Cobalt | 7440-48-4 | 3 | 72.3 | -- | -- | 50 | 4.71 |
| Copper | 7440-50-8 | 7 | 53.5 | 313 | 4,088 | 31.6 | 12.9 |
| Iron | 7439-89-6 | 1,000 | 50,962 | 5,475 | 71,540 | 20,000 | 24,400 |
| Magnesium | 7439-95-4 | 50 | -- | -- | -- | -- | 18,500 |
| Manganese(2) | 7439-96-5 | 0.275 | 2,543 | 156 | 2,044 | 460 | 126 |
| Mercury(3) | 7439-97-6 | 0.1 | 0.13 | 2.3 | 30.66 | 0.18 | 0.142 |
| Nickel | 7440-02-0 | 3 | 62.8 | 156 | 2,044 | 22.7 | 10.3 |
| Potassium | 7440-09-7 | 37.5 | -- | -- | -- | -- | 785 |
| Sodium | 7440-23-5 | 150 | -- | -- | -- | -- | 532B |
| Vanadium | 7440-62-2 | 0.775 | 108 | 7.8 | 102 | -- | 85 |
| Zinc | 7440-66-6 | 30.2 | 202 | 2,346 | 30,660 | 121 | 61.6 |

**Notes:**
BTAG = Biological Technical Assistance Group
Sediment - BTAG Sediment Screening Values, 2004
CAS = Chemical Abstract Service
CSE = Chemical Sediment
ft bgs = Feet below ground surface
mg/kg = Milligrams per kilogram
TAL = Target Analyte List
USEPA = United States Environmental Protection Agency
PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method
RBC = Risk-Based Concentration
USEPA Region III Risk-Based Concentration values from the April 6, 2007, RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
[A] = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
(1) = Chromium VI RBC value was used
(2) = Manganese-nonfood RBC value was used
(3) = Mercuric chloride RBC value was used

| | |
|---|---|
| (double box) | = Concentration exceeds Adjusted Residential RBC |
| **bold** | = Concentration exceeds Adjusted Industrial RBC |
| (shaded) | = Concentration exceeds BTAG Sediment Screening Level |
| underline | = Concentration exceeds Facility-Wide Background Point Estimate |

**Table 1-3**
**Summary of Analytical Data for Surface Water Sample Collected at SWMU 57**
**Modified from Dames & Moore Verification Investigation Report**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| SITE ID<br>FIELD ID<br>SAMPLE DATE<br>DEPTH (ft bgs)<br>MATRIX<br>UNITS | CAS # | PQLs<br>µg/L | Adjusted Tap Water RBC<br>µg/L | MCL<br>µg/L | BTAG Freshwater Screening Value<br>µg/L | 57SW1<br>RVFS*92<br>10-Feb-92<br>0.0<br>CSW<br>µg/L |
|---|---|---|---|---|---|---|
| **TAL Metals** | | | | | | |
| Aluminum | 7429-90-5 | 141 | 3,650 | -- | 87 | 871 |
| Arsenic | 7440-38-2 | 10 | 0.045 | 10 | 5 | 6.29 |
| Barium | 7440-39-3 | 20 | 730 | 2,000 | 4 | 23.1 |
| Calcium | 7440-70-2 | 500 | -- | -- | 116,000 | 16,700 |
| Chromium(1) | 7440-47-3 | 10 | 10.95 | 100 | 85 | 15.9 |
| Copper | 7440-50-8 | 60 | 146 | 1,300 (AL) | 9 | 11.8 |
| Iron | 7439-89-6 | 38.1 | 2,555 | -- | 300 | 2,750 |
| Lead | 7439-92-1 | 10 | -- | 15 (AL) | 2.5 | 14.4 |
| Magnesium | 7439-95-4 | 500 | -- | -- | 82,000 | 6,670 |
| Manganese(2) | 7439-96-5 | 2.75 | 73 | -- | 120 | 380 |
| Potassium | 7440-09-7 | 375 | -- | -- | 53,000 | 8,850 |
| Sodium | 7440-23-5 | 500 | -- | -- | 680,000 | 14,000 |
| Zinc | 7440-66-6 | 50 | 1,095 | -- | 120 | 155 |

**Notes:**
BTAG = Biological Technical Assistance Group
Water - BTAG Freshwater Screening Values, 2004
CAS = Chemical Abstract Service
CSW = Chemical Surface Water
ft bgs = Feet below ground surface
µg/L = Microgram Per Liter
TAL = Target Analyte List
USEPA = United States Environmental Protection Agency
MCL = Maximum Contaminant Level
PQL = Practical quanitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method
RBC = Risk-Based Concentration
USEPA Region III Risk-Based Concentration values from the April 6, 2007, RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
(AL) = Action Level
(1) = Chromium VI RBC value used
(2) = Manganese-nonfood RBC value used

[Bold box] = Concentration exceeds MCL

[Double-line box] = Concentration exceeds Adjusted Tap Water RBC

[Grey shading] = Concentration exceeds BTAG Freshwater Screening Level

**Table 1-4**
**Summary of Human Health Site Screening**
**Modified from SSP Report (URS 2007)**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| Site | COPCs Identified* | Cumulative Risk Screening Surface Soil [A] | | Cumulative Risk Screening Total Soil [A] | | Lead and Iron Screening | SSL (DAF20) Comparison/Flags | SSL Exceedances of Refined SSLs or Background | COPC Metals Above Background ** | Number of COPCs/TICs with No Available Risk Screening Values |
|---|---|---|---|---|---|---|---|---|---|---|
| | | C | N | C | N | | | | | |
| SWMU 57 | Sb, As, Cd, Cr, Fe, Mn, V, BaP | Failed-R 1E-05 (As, BaP) | Failed-R HI = 12 | Failed-R 1E-05 (As, BaP) | Failed-R HI = 6 | Passed Lead Failed Iron | As, Cr, Mn, Bromodichloromethane, Chloroform | Cr, Mn, Chloroform | Cd, Cr, Fe, Mn | VOCs (1) SVOCs (20) |

**Notes:**
COPC = Chemical of Potential Concern
* for which RBCs are available
** no background estimates available for Sb and Cyanide
C = Carcinogenic
N = Noncarcinogenic
[A] = Site passed carcinogenic and noncarcinogenic industrial scenarios
Failed-R (chemical) = Failed Residential Cumulative Risk Screening due to (chemical)
HI = Hazard Index
Failed-R HI = (#) = Failed Residential Cumulative Risk Screening Due to HI of (#)
BaP = Benzo(a)pyrene
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20
EPA (SSL) values from the October 2006, RBC Table

RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the October 2006,
RBC Table and October 2006, Alternate RBC Table
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound

(shaded) = HI/Risk Attributable Concentrations Above Background

**Table 1-5**
**Summary of Ecological Site Screening**
**Modified from SSP Report (URS 2007)**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| | | | | Exposure Assessment | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | **Preliminary Risk Characterization COPECs** | **Refined Risk Characterization** | | **Preliminary Direct Contact and Refined Wildlife COPEC Metals Above Background**** | |
| **Site** | **Size (acres)** | **Cover Type** | **Direct Contact COPECS*** | **NOAEL HQ >1** | **NOAEL HQ > 1** | **NOAEL and LOAEL HQs >1** | | **Path Forward** |
| SWMU 57 | 0.027 | Grassed area | Al, Sb, Cr, Fe, Mn, Hg, V, Zn, Cyanide | Metals, Aroclor 1254 | American Robin: Cd, Pb<br>Short-tailed Shrew: As, Cd | American Robin: Cr, Zn | Cr, Fe, Mn, Hg, Zn | Inv./SLERA Soil |

**Notes:**
COPEC = Chemical of Potential Ecological Concern
LOAEL = Lowest observable adverse effects level
NOAEL = No observable adverse effects level
HQ = Hazard Quotient
Inv. = Investigation
SLERA = Screening level ecological risk assessment
* for which toxicity data is available
** no background estimates available for Sb and Cyanide

Table 1-6
Summary of Recommendations
Modified from SSP Report (URS 2007)
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Site | Further Action | | | NFA | Chemicals of Potential Concern Potentially Subject to Further Action |
|---|---|---|---|---|---|
| | **Inv.** | **HHRA** | **SLERA** | | |
| SWMU 57 | ✓ | ✓ | ✓ | | *HHRA:* metals, VOCs<br>*SLERA:* metals |

**Notes:**
Inv. = Investigation
HHRA = Human health risk assessment
SLERA = Screening level ecological risk assessment
NFA = No further action

TABLE 1-7
Selection of Exposure Pathways
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Scenario Timeframe | Medium | Exposure Medium | Exposure Point | Receptor Population | Receptor Age | Exposure Route | Type of Analysis | Rationale for Selection or Exclusion of Exposure Pathway |
|---|---|---|---|---|---|---|---|---|
| Current/Future | Surface Soil | Surface Soil | Surface Soil | Maintenance Worker | Adult | Ingestion | Quant | Receptor could ingest surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns). |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with surface soil from the site while conducting routine maintenance activities (i.e., mowing lawns). |
| | | | | Construction Worker | Adult | Ingestion | Quant | Receptor could ingest surface soil from the site during construction activities. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with surface soil from the site during construction activities. |
| | | Air | Ambient Air Above Surface Soil (Vapors and Particulates) | Maintenance Worker | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the surface soil. |
| | | | | Construction Worker | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the surface soil. |
| | Subsurface Soil | Subsurface Soil | Subsurface Soil | Maintenance Worker | Adult | Ingestion | None | Receptor is not likely to ingest subsurface soil from the site since maintenance does not include excavation. |
| | | | | | | Dermal Absorption | None | Receptor is not likely to come in contact with subsurface soil from the site since maintenance does not include excavation. |
| | | | | Construction Worker | Adult | Ingestion | Quant | Receptor could ingest subsurface soil from the site while during construction activities. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with subsurface soil from the site during construction activities. |
| | | Air | Ambient Air Above Subsurface Soil (Vapors and Particulates) | Maintenance Worker | Adult | Inhalation | None | Receptor is not likely to inhale vapors/particulates from ambient air above the subsurface soil since maintenance activities do not include excavation. |
| | | | | Construction Worker | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the subsurface soil during construction activities. |
| | Groundwater [(1)] | Groundwater | Groundwater | Maintenance Worker | Adult | Ingestion | None | Receptor is not likely to ingest groundwater from the site during maintenance activities. |
| | | | | | | Dermal Absorption | None | Receptor is not likely to contact groundwater from the site during maintenance activities. |
| | | | | Construction Worker | Adult | Ingestion | Quant | Due to the depth to groundwater (approximately 21.5-35.5 ft bgs), the receptor is not likely to ingest groundwater during excavation activities. |
| | | | | | | Dermal Absorption | Quant | Due to the depth to groundwater (approximately 21.5-35.5 ft bgs), the receptor is not likely to contact groundwater during excavation activities. |
| | | Air | Upward Migration of Vapors from Groundwater (Outdoors) | Maintenance Worker | Adult | Inhalation | None | Receptor is not like to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities. |
| | | | | Construction Worker | Adult | Inhalation | Quant | Receptor could inhale VOCs that migrated upward from groundwater to ambient air during excavation activities. |
| | | | Upward Migration of Vapors from Groundwater (Indoors) | Maintenance Worker | Adult | Inhalation | None | Receptor is assumed to be outdoors. |
| | | | | Construction Worker | Adult | Inhalation | None | Receptor is assumed to be outdoors. |
| | | | Vapors while Showering | Maintenance Worker | Adult | Inhalation | None | Receptor is assumed not to shower on-site. |
| | | | | Construction Worker | Adult | Inhalation | None | Receptor is assumed not to shower on-site. |
| Future | Surface Soil | Surface Soil | Surface Soil | Commerical/Industrial Worker | Adult | Ingestion | Quant | Receptor could ingest surface soil while working on site. |
| | | | | | | Dermal Absorption | Quant | Receptor could contact surface soil while working on site. |
| | | | | Resident | Child | Ingestion | Quant | Receptor could ingest surface soil while living on site. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with surface soil while living on site. |
| | | | | | Adult | Ingestion | Quant | Receptor could ingest surface soil while living on site. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with surface soil while living on site. |
| | | | | | Child/Adult | Ingestion | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident. |
| | | | | | | Dermal Absorption | Quant | |

TABLE 1-7
Selection of Exposure Pathways
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Scenario Timeframe | Medium | Exposure Medium | Exposure Point | Receptor Population | Receptor Age | Exposure Route | Type of Analysis | Rationale for Selection or Exclusion of Exposure Pathway |
|---|---|---|---|---|---|---|---|---|
| Future Cont. | Surface Soil Cont. | Air | Ambient Air Above Surface Soil (Vapors and Particulates) | Commerical/Industrial Worker | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the surface soil while working on site. |
| | | | | Resident | Child | Inhalation | Quant | Receptor could inhale vapros/particulates from ambient air above the surface soil while living on site. |
| | | | | | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the surface soil while living on site. |
| | | | | | Child/Adult | Inhalation | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident. No VOCs were identified as COPCs for surface soil. |
| | | | Upward Migration of Vapors from Soil (Indoors) | Commercial/Industrial Worker | Adult | Inhalation | Quant | Receptor could inhale VOCs from soil via vapor intrusion into building. |
| | | | | Resident | Adult | Inhalation | Quant | Receptor could inhale VOCs from soil via vapor intrusion into residence. |
| | | | | | Child | Inhalation | Quant | Receptor could inhale VOCs from soil via vapor intrusion into residence. |
| | | | | | Child/Adult | Inhalation | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to surface soil. The non-cancer hazard evaluations are treated separately for child and adult resident. |
| | Subsurface Soil | Subsurface Soil | Subsurface Soil | Commerical/Industrial Worker | Adult | Ingestion | Quant | Receptor could ingest subsurface soil when mixed with surface soil from construction of a commercial/industrial facility. |
| | | | | | | Dermal Absorption | Quant | Receptor could contact subsurface soil when mixed with surface soil from construction of a commercial/industrial facility. |
| | | | | Resident | Child | Ingestion | Quant | Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence. |
| | | | | | | Dermal Absorption | Quant | Receptor could come in contact with subsurface soil when mixed with surface soil from construction of a residence. |
| | | | | | Adult | Ingestion | Quant | Receptor could ingest subsurface soil when mixed with surface soil from construction of a residence. |
| | | | | | | Dermal Absorption | Quant | Receptor could come in contact with subsurface soil when mixed with surface soil from construction of a residence. |
| | | | | | Child/Adult | Ingestion<br>Dermal Absorption | Quant<br>Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non cancer hazard evaluations are treated separately for child and adult resident. |
| | | Air | Ambient Air Above Subsurface Soil (Vapors and Particulates) | Commerical/Industrial Worker | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the subsurface soil when mixed with surface soil from construction of a commercial/industrial facility. |
| | | | | Resident | Child | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the subsurface soil when mixed with surface soil from construction of a residence. |
| | | | | | Adult | Inhalation | Quant | Receptor could inhale vapors/particulates from ambient air above the subsurface soil when mixed with surface soil from constuction of a residence. |
| | | | | | Child/Adult | Inhalation | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non cancer hazard evaluations are treated separately for child and adult resident. |
| | | | Upward Migration of Vapors from Soil (Indoors) | Commercial/Industrial Worker | Adult | Inhalation | Quant | Receptor could inhale VOCs from soil via vapor intrusion into building. |
| | | | | Resident | Adult | Inhalation | Quant | Receptor could inhale VOCs from soil via vapor intrusion into residence. |
| | | | | | Child | Inhalation | Quant | Receptor could inhale VOCs from soil via vapor intrusion into residence. |
| | | | | | Child/Adult | Inhalation | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to subsurface soil. The non cancer hazard evaluations are treated separately for child and adult resident. |

TABLE 1-7
Selection of Exposure Pathways
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Scenario Timeframe | Medium | Exposure Medium | Exposure Point | Receptor Population | Receptor Age | Exposure Route | Type of Analysis | Rationale for Selection or Exclusion of Exposure Pathway |
|---|---|---|---|---|---|---|---|---|
| Future Cont. | Groundwater[1] | Groundwater | Groundwater used for Tap Water | Commercial/Industrial Worker | Adult | Ingestion | Quant | Receptor could ingest groundwater used as a water supply. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with groundwater used as a water supply for industrial process. |
| | | | | Resident | Adult | Ingestion | Quant | Receptor could ingest groundwater used as a water supply. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with groundwater used as a water supply. |
| | | | | | Child | Ingestion | Quant | Receptor could ingest groundwater used as a water supply. |
| | | | | | | Dermal Absorption | Quant | Receptor could come into contact with groundwater used as a water supply. |
| | | | | | Child/Adult | Ingestion | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. |
| | | | | | | Dermal Absorption | Quant | |
| | | Air | Upward Migration of Vapors from Groundwater (Outdoors) | Commercial/Industrial Worker | Adult | Inhalation | None | Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities. |
| | | | | Resident | Adult | Inhalation | None | Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities. |
| | | | | | Child | Inhalation | None | Receptor is not likely to inhale vapors that migrated upward from groundwater to ambient air in any significant quantities. |
| | | | | | Child/Adult | Inhalation | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. |
| | | | Upward Migration of Vapors from Groundwater (Indoors) | Commercial/Industrial Worker | Adult | Inhalation | Quant | Receptor could inhale VOCs from groundwater via vapor intrusion into building. |
| | | | | Resident | Adult | Inhalation | Quant | Receptor could inhale VOCs from groundwater via vapor intrusion into residence. |
| | | | | | Child | Inhalation | Quant | Receptor could inhale VOCs from groundwater via vapor intrusion into residence. |
| | | | | | Child/Adult | Inhalation | Quant | The cancer risk estimates for the adult resident (24 years) and child resident (6 years) are added together (30 years) to address lifetime exposure to groundwater. The non-cancer hazard evaluations are treated separately for child and adult resident. |
| | | | Vapors while Showering | Commercial/Industrial Worker | Adult | Inhalation | None | Receptor is assumed not to shower on-site. |
| | | | | Resident | Adult | Inhalation | Quant | Receptor could inhale vapors from groundwater while showering. |
| | | | | | Child | Inhalation | None | Receptor is assumed not to shower. |

Notes:
[1] Groundwater from the surface aquifer is not currently used at the sites for potable or non-potable water supply.

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Table 1-8
Wildlife Receptor Profiles
Screening Level Ecological Risk Assessment
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Representative Species | | | Composition of Diet [1] (%) | | | | Preliminary Assessment | | | | | | Refined Assessment | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Minimum Body Weight [1] | Maximum Body Weight [1] | Maximum Food Ingestion Rate [2] | Maximum Substrate Ingestion Rate [1] | | Maximum Water Ingestion Rate [3] | Average Body Weight [1] | Average Food Ingestion Rate [2] | Average Substrate Ingestion Rate [1] | Average Water Ingestion Rate [3] | Home Range (ha) | Proportion of Year Species Active | AUFs |
| Food-web Classification | Common Name | Scientific Name | Plants (incl. fungi) | Inverte-brates | Small mammals | Fish | kg | kg | kg dw/day | % of dry intake | kg dry wt./day | L/day | kg | kg dw/day | kg dry wt./day | L/day | | | Site Area (0.15) hectares |
| **Birds** | | | | | | | | | | | | | | | | | | | |
| soil-probing invertivore | American robin | *Turdus migratorius* | 62% | 38% | | | 0.0635 | 0.103 | 0.020 | 5% | 0.001 | 0.013 | 0.077 | 0.016 | 0.0008 | 0.011 | 0.48 | 1 | 0.31 |
| large carnivore | Red-tailed hawk | *Buteo jamaicensis* | | | 100% | | 0.957 | 1.235 | 0.063 | 0% | 0 | 0.068 | 1.134 | 0.059 | 0 | 0.064 | 250 | 1 | 0.0006 |
| **Mammals** | | | | | | | | | | | | | | | | | | | |
| small herbivore | Meadow vole | *Microtus pennsylvanicus* | 100% | | | | 0.017 | 0.0524 | 0.010 | 2.4% | 0.00024 | 0.0070 | 0.037 | 0.008 | 0.00019 | 0.0051 | 0.037 | 1 | 1 |
| medium carnivore | Red fox | *Vulpes vulpes* | 17% | 4% | 79% | | 2.95 | 7.04 | 0.342 | 2.8% | 0.0096 | 0.573 | 4.53 | 0.238 | 0.0067 | 0.39 | 96 | 1 | 0.0016 |
| small invertivore | Short-tailed shrew | *Blarina brevicauda* | 14% | 86% | | | 0.0125 | 0.0225 | 0.003 | 10% | 0.00031 | 0.0033 | 0.015 | 0.002 | 0.00021 | 0.0023 | 0.39 | 1 | 0.38 |

<u>**Notes:**</u>
kg = Kilogram
kg dw/day = Kilogram Dry-weight per Day
L/day = Liter per Day

[1] Wildlife Exposure Factors Handbook. U.S. Environmental Protection Agency (EPA). 1993. Office of Research and Development. 2 Volumes. EPA/600/R93/187a&b. December.
[2] Estimated food intake rate (kg [dw]/day) calculated as follows:
FI ((kg/day) = 0.0687 $Wt.^{0.882}$ for mammals (red fox and short-tailed shrew)
FI ((g/day) = 0.577 $Wt.^{0.727}$ for herbivores (meadow vole)
FI ((g/day) = 0.301 $Wt.^{0.751}$ for non-passerine birds (red-tailed hawk)
FI ((g/day) = 0.398 $Wt.^{0.850}$ for passerine birds (american robin)
[3] Estimated water intake rate (L/day) calculated as follows:
Birds: $WI=0.059Wt^{0.67}$(kg)
Mammals: $WI=0.099Wt^{0.90}$(kg)
The soil ingestion rate for the american robin set equal to 38% of the american woodcock value (0.34*10.4%=4%), based on a robin diet of 38% invertbrates.

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**Table 1-9**
**Handling and Disposal of Investigation-Derived Materials**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| Area | Material | Description | Quantity | Concern | Action | Expected Nature of Material |
|---|---|---|---|---|---|---|
| SWMU 57 | Soil cuttings | From 19 borings and 3 wells | Approx. 13 55-gal drums | COCs | TCLP, Explosives, Paint Filter Liquids, and pH | Non-hazardous. Concentrations are not expected to exceed TCLP limits. |
| SWMU 57 | Well Development Water | Aqueous IDM | Approx. 3 55-gal drums | IDM | TCLP, COD, pH, explosives | Non-hazardous. Concentrations are not expected to exceed treatment plant limits. |
| SWMU 57 | Well Purge Water | Aqueous IDM | Approx. 1 55-gal drum | IDM | COD and pH | Non-hazardous. Concentrations are not expected to exceed treatment plant limits. |
| SWMU 57 | Decontamination water | Aqueous IDM | Approx. 2 55-gal drums | IDM | TCLP, COD, pH, explosives | Non-hazardous. Concentrations are not expected to exceed TCLP, or pH limits. |
| SWMU 57 | PPE | Miscellaneous IDM | Approx. three 55-gal drums | IDM | Evaluate Soil and Water Results | Non-hazardous material. Will be disposed of as IDM. |

**Notes:**
SWMU = Solid Waste Management Unit
Approx. = Approximately
COC = Chemical of Concern
IDM = Investigation-Derived Material
TCLP = Toxicity Characteristics Leaching Procedure
COD = Chemical Oxygen Demand
PPE = Personal Protective Equipment and Clothing
gal = Gallon

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# 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 quality control (QC) requirements include development of Data Quality Objectives (DQOs), performance of internal QC checks, and execution of appropriate analytical procedures during investigative activities. This QAPA is designed to be used in conjunction with the MQAP. Table 2-1 provides a list of general quality assurance (QA) measures that will be implemented as specified in the MQAP.

**Table 2-1**

**Quality Assurance Measures Discussed in the MQAP**

| Quality Assurance Measure | Section in MQAP | SOP No. (MWP Appendix A and Appendix A of WPA 021) |
|---|---|---|
| Project Organization and Responsibilities | 2.0 | -- |
| Lines of Authority | 2.2 | -- |
| Chemical Data Measurements | 3.2 | -- |
| Levels of Concern | 3.3 | -- |
| Site Investigation | 4.0/5.0 | 20.1, 20.2, 20.3, 20.11, 30.1, 30.2, 30.7, 30.9, 40.1, 40.2, 40.3, 50.1, 50.2 70.1, 80.1 |
| Documentation Requirements | 5.6 | 10.1, 10.2, 10.3, 50.1 |
| Chain-of-custody Requirements | 5.7 | 10.4, 50.2 |
| Calibration Procedures | 7.0 | 90.1 |
| Data Reduction, Validation, Reporting, and Management | 9.0 | -- |
| Corrective Action | 10.0 | -- |
| Quality Assessments | 11.0 | -- |

The distribution list for submittals associated with this RFI is defined in the Facility Permit (USEPA, 2000a). At least six copies of draft documents and three copies of the final plans, reports, notifications, or other documents submitted as part of the RFI for SWMU 57 are to be submitted to the USEPA Regional Administrator, and shall be sent Certified Mail, Return Receipt Requested, overnight mail, or hand-carried to:

USEPA Region III
Federal Facilities Branch (3WC23)
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029

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

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

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

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

Tom Meyer
USACE, Baltimore District
ATTN: CENAB-EN-HM (10000-G)
10 South Howard Street
Baltimore, Maryland 21203

Rich Mendoza
U.S. Army Environmental Command
1 Rock Island Arsenal
Bldg 60, 3rd Fl, NW Wing, Room 320
(IMAE-CDN)
Rock Island, Illinois 61299

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

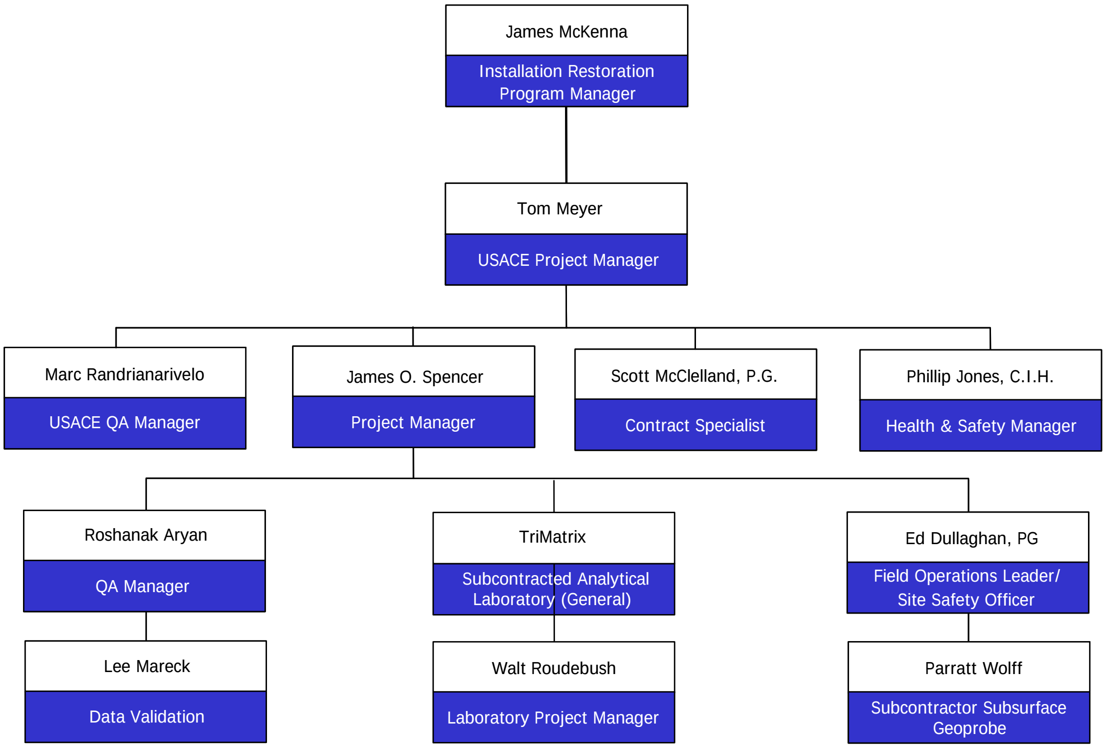
Dennis Druck
USACHPPM
5158 Blackhawk Road
ATTN: MCHB-TS-HER
Aberdeen Proving Ground, MD 21010-5403

## 2.2 PROJECT ORGANIZATION AND RESPONSIBILITIES

### 2.2.1 Contractor and Subcontractor Responsibilities

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

**Figure 2-1**
**Project Organizational Chart**




### 2.2.2 Key Points of Contact

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

The Project Manager (PM) is responsible for ensuring that activities are conducted in accordance with contractual specifications, the Statement of Work (SOW), and approved work plans. The PM will also provide technical coordination with the Installation's designated counterpart. The PM is responsible for management of operations conducted for this project. In addition, the PM will ensure that personnel assigned the project, including subcontractors, will review the technical plans prior to initiation of each task associated with the project. The PM will monitor the project budget and schedule and will ensure availability of necessary personnel, equipment, subcontractors, and services. The PM will participate in the development of the field program, evaluation of data, reporting, and the development of conclusions and recommendations.

**Table 2-2**

**Contractor and Subcontractor Key Points of Contact**

| Contractor | Key Point of Contact |
|---|---|
| Project Manager, James O Spencer<br>Email: James O Spencer@URSCorp.com | URS Group, Inc.<br>5540 Falmouth Street, Suite 201<br>Richmond, Virginia 23230<br>Tel: 804.474.5420; Fax: 804.965.9764 |

| Contractor | Key Point of Contact |
|---|---|
| Health and Safety Manager, Phillip Jones<br>Email: Phillip_L_Jones@URSCorp.com | URS Group, Inc.<br>335 Commerce Drive, Suite 300<br>Fort Washington, Pennsylvania 19034<br>Tel: 215.367.2500; Fax: 215.367.1000 |
| Quality Assurance Manager, Roshanak Aryan<br>Email: Roshanak_Aryan@URSCorp.com | URS Group, Inc.<br>5540 Falmouth Street, Suite 201<br>Richmond, Virginia 23230<br>Tel: 804.474.5431; Fax: 804.965.9764 |
| Data Validator, Lee Mareck<br>Email: Lee_Mareck@URSCorp.com | URS Group, Inc.<br>5540 Falmouth Street, Suite 201<br>Richmond, Virginia 23230<br>Tel: 804.474.5444; Fax: 804.965.9764 |
| Field Operations Leader and Site Health and Safety Officer, Ed Dullaghan<br>Email: Ed_Dullaghan@URSCorp.com | URS Group, Inc.<br>5540 Falmouth Street, Suite 201<br>Richmond, Virginia 23230<br>Tel: 804.965.9000; Fax: 804.965.9764 |
| **Subcontractor** | **Key Point of Contact** |
| Analytical Laboratory Services, General<br>TriMatrix Laboratories, Inc.<br>Email: RoudebushW@TriMatrixLabs.com | Walt Roudebush<br>5560 Corporate Exchange Court<br>Grand Rapids, MI 49512<br>Tel: 616.975.4500; Fax: 616.940.4470 |
| Subsurface Drilling<br>Parratt Wolff, Inc.<br>Email: bstevens@pwinc.com | Robert Stevens<br>PO Box 1029, 501 Millstone Drive<br>Hillsborough, NC 27278<br>Tel: 919.644.2814; Fax 919.644.2817 |

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

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

The QA Manager is responsible for ensuring that the QA procedures and objectives in the project-specific work plans are met, reviewing field and analytical data to ensure adherence to QA/QC procedures, and approving the quality of data prior to inclusion in associated reports. This may include the performance of field and laboratory audits during the investigation. In addition, the QA Manager will be responsible for the review, evaluation, and validation of analytical data for the project and will participate in interpreting and presenting analytical data. QC coordination is under the technical guidance of the QA Manager to direct the task leaders on a day-to-day or as-needed basis to ensure the application of QA/QC procedures.

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

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

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

## 2.3 QUALITY ASSURANCE OBJECTIVES

QA is defined as the overall system of activities for assuring the reliability of data produced. Section 2.1, of this WPA, references investigative, chemical, and regulatory measures associated with the QA Objectives of this project. Conformance with appended SOPs will ensure attainment of QA objectives. The system integrates the quality planning, assessment, and corrective actions of various groups in the organization to provide the independent QA program necessary to establish and maintain an effective system for collection and analysis of environmental samples and related activities. The program encompasses the generation of complete data with its subsequent review, validation, and documentation.

The DQO process is a strategic planning approach to ensure environmental data is of the appropriate type, quantity, and quality for decision-making. Project-specific DQOs are included in Table 2-3 for investigative activities. The overall QA objective is to develop and implement procedures for sample and data collection, shipment, evaluation, and reporting that will allow reviewers to assess whether the field and laboratory procedures meet the criteria and endpoints established in the DQOs. DQOs are qualitative and quantitative statements that outline the decision-making process and specify the data required to support corrective actions. DQOs specify the level of uncertainty that will be accepted in results derived from environmental data. Guidance for the Data Quality Objectives Process (USEPA 2000b), and Guidance for Data Quality Objectives for Hazardous Waste Sites (USEPA 2000c) formed the basis for the DQO process and development of RFAAP data quality criteria and performance specifications.

The DQO process consists of the seven steps specified below.

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

   a) The planning team consists of the RFAAP, USACE, USEPA, VDEQ, the RFAAP operating contractor, and URS; Relative to the implementation of this WPA, the primary decision-maker is RFAAP, in consultation with USACE, USEPA, VDEQ, the RFAAP operating contractor, and URS.

**Table 2-3**

**Summary of Project Data Quality Objectives**

| DQO Element | Project DQO Summary |
|---|---|
| Problem Statement | • Further refinement of potential contamination at SWMU 57.<br>• Possible risks to human health and the environment are currently unknown. |
| Identify Decision/Study Question | • Collect samples representative of site conditions<br>• Conduct surface/subsurface soil boring and sampling outside the pond area to characterize potential impacts to surrounding soil<br>• Collect soil samples for analysis of physical properties to aid in assessing the nature of possible constituent migration<br>• Collect groundwater samples for analysis to characterize potential impacts to groundwater due to potential leaching of chemicals from soil at the site |
| Decision Inputs | • Field investigation data: soil boring logs and physical testing results.<br>• Chemical analyses: submit soil and groundwater samples to USACE-validated off-site analytical laboratory for analyses. |
| Study Boundaries | • Physical horizontal boundary of SWMU 57 will be defined within the scope of the RFI.<br>• Sample points are designed to collect samples representative of nearby and potentially affected soil<br>• Monitoring well locations are designed to assess potential groundwater impacts from leaching of chemicals from soil and characterize background concentrations in groundwater. |
| Decision Rule | • Comparison to most recent USEPA Region III ecological screening values.<br>• Comparison to most recent USEPA Region III RBCs<br>• Comparison to most recent Federal MCLs and Commonwealth of Virginia Groundwater standards. |

| DQO Element | Project DQO Summary |
|---|---|
| Tolerable Limits on Decision Errors | • SW-846 Test Methods reporting limits. USEPA Contract Laboratory Program (CLP)-like raw data package suitable for validation (level M3 for organic, level IM2 for inorganic). |
| Optimize the Design for Obtaining Data | • Soil borings and monitoring well locations have been selected to provide information meeting the DQOs. |

b) The following project objectives have been identified:

i) Characterize the nature and extent of COPCs identified in soil during the SSP and evaluation of potential migration from the former pond area via leaching.

ii) Evaluate potential leaching of COPCs from soil to groundwater.

iii) Characterize background concentrations of metals in site groundwater for use in the nature and extent evaluation and risk assessment.

iv) Conduct human health and ecological risk assessments to characterize soil and groundwater related risks.

v) Reach a decision regarding future action at the site.

c) The RFI project budget has been established, the project team has been identified, and a project schedule has been developed.

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

a) Principal study questions include:

i) What is the nature and extent of hazardous constituents in soil within the pond area, outside of the pond area, and in the area of the terracotta drainpipe?

ii) Are hazardous constituent concentrations in soil at levels above RFAAP background (metals) and human health/ecological risk screening criteria?

iii) Have hazardous constituents migrated below the asphalt liner in the former pond area?

iv) Have hazardous constituents migrated downgradient of the former pond area via overland runoff in the drainage swale?

v) Have hazardous constituents leached from soil to groundwater at levels above site-background (metals) and human health risk screening criteria?

vi) Are concentrations of hazardous constituents present at the site in excess of relevant screening criteria identified in the USEPA SSP and do the site conditions pose an unacceptable risk to human health or the environment?

vii) Do hazardous constituent concentrations in soil and groundwater pose an unacceptable risk to human health or the environment considering current and planned future land uses?

b) The resultant alternative actions include:

i) If the nature and extent of hazardous constituents and associated potential human health/environmental risks have been sufficiently characterized to reach a future decision at the site, then the RFI Report will present this information.

ii) If it is concluded that the nature and extent of hazardous constituents and/or associated potential human health/environmental risks have not been sufficiently characterized to reach a future decision on action at a site, then the RFI Report will present recommendations for additional investigations, further risk assessment, or other actions.

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

a) RBCs in the most recent version of the USEPA Region III RBC Table for soil using the residential and industrial scenarios;

b) RBCs in the most recent version of the USEPA Region III T-RBC Table, Federal Maximum Contaminant Levels (MCLs), and Virginia State Water Control Board Water Quality Criteria for groundwater;

c) Most recent USEPA Region III ecological screening values;

d) USEPA Region III soil migration to groundwater SSLs (DAF 20);

e) USEPA RCRA Hazardous Waste Characteristics threshold levels;

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

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

h) Results of physical testing of soil for geotechnical properties;

i) Details of a visual inspection of the SWMU; and

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

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

   a) Physical horizontal boundary of SWMU 57 will be defined within the scope of the RFI by combining site historical data, previous site investigation findings, and soil boring information;

   b) The media that will be investigated include surface soil, subsurface soil, and groundwater within and outside of the SWMU boundary; and

   c) Practical constraints that could interfere with sampling include steep grade, access to the fenced pond area, boring refusal, unknown subsurface conditions, and weather.

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

   a) Parameters of interest include:

      i. TCL VOCs, TCL SVOCs, TCL Pesticides, PCBs, explosives (including nitroglycerin and PETN), TAL metals, and chemical oxygen demand (COD);

      ii. Toxicity Characteristic Leaching Procedure (TCLP) for pond soil above asphalt liner;

      iii. Grain-size analysis, Atterberg Limits, moisture content, TOC, hydraulic conductivity, soil porosity, soil bulk density, and pH;

      iv. Pond liner composition and characteristics;

      v. Depth to groundwater and bedrock; and

      vi. Groundwater characteristics and quality.

   b) Action levels include:

      i. Action levels for risk screening include USEPA Region III RBCs, most recent USEPA Region III ecological screening levels, USEPA MCLs, Virginia Groundwater Standards (State Water Control Board) in 9 VAC 25-280, as well as, statistical comparisons of metals data to facility background data, and site-specific metal background for groundwater to be established during the RFI; and

      ii. In accordance with USEPA Region III guidance, RBCs for non-carcinogenic constituents will be adjusted downward to an HQ of 0.1 to ensure that chemicals with additive effects are not prematurely eliminated during screening; and

      iii. MDLs and RLs, as specified herein, will ensure that data quality is sufficient for its intended use. The selected laboratories are within the CLP network, the proposed laboratories have been validated by USACE for the selected SW-846 Test Methods and it is assumed that sources of analytical errors will be small and known.

c) Decision rules include:

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

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

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

iv. Results of site activities will be used to refine the site conceptual model and will be used in the evaluation of remedial alternatives.

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

a) MDLs and RLs are established for each analyte within the suite of parameters sought. MDLs and RLs below the action levels will ensure the data meet the DQOs. The contract laboratory will provide a CLP-like raw data package (Level IV). Data validation will be conducted based on this QAPA, the MQAP, the Department of Defense (DOD) Quality Systems Manual (QSM), and relevant USEPA Region III guidance.

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

c) Information from previous studies and physical features of the area was used to develop a field sampling plan design that allows for a low probability of decision error.

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

a) 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;

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

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

## 2.4 SAMPLE MANAGEMENT

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

### 2.4.1 Number and Type

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

### 2.4.2 Sample Container, Preservation Method, and Holding Time Requirements

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

### 2.4.3 Sample Identification

The sample identification number will conform to past nomenclature at SWMU 57. The identification will consist of an alphanumeric designation related to the sampling location, media type, and sequential order according to the sampling event. The identification number will not exceed thirty-two characters for entry into Environmental Restoration Information System (ERIS). Samples will be coded in the following order to ensure a unique identification.

- Site Location Code: The first two characters will be the SWMU number (i.e., 57 for SWMU 57).
- Sample/Media Type: The next two characters will be the sample/media types. In this case, the characters will be SB for soil borings and GW for groundwater.
- Sampling Location Number: The next one or two characters will be the number of the sampling location (e.g., 3, 4, 5).
- The sample from the zero to six inches bgs interval will be designated with an "A" after the boring number. The sample collected from intermediate depths of the boring, or from below fill materials, will be designated with a "B" following the boring number. For samples collected within the pond where four samples per boring are specified, the samples collected from immediately below the pond liner and will be designated "AB" and the intermediate samples will be designated with "B" following the boring number to identify the samples for the intermediate samples. Samples collected from above bedrock, at the base of the boring will be designated with a "C."
- Duplicate: Duplicate samples will be identified with a "Dup" designation followed by a numeric designation corresponding to the sequence of duplicates collected (e.g., Dup-1). A record of the sample that corresponds to the duplicate will be kept in the field logbook. In this manner, duplicates will be submitted as blind duplicates, eliminating the potential for laboratory bias in analysis.

**Sample Identification Examples:**

1) A subsurface soil sample collected above the termination depth of boring location four at SWMU 57 would be identified as sample 57SB4C (for SWMU 57, soil boring four, and “C” which stands for the soil above bedrock at that location).

2) QC Samples: QC samples will be identified by date (month, day, year), followed by QC sample type, and sequential order number at one digit. The QC sample types include Matrix Spike, Matrix Spike Duplicate (MS/MSD), Rinse Blank (R), and Trip Blank (T).

### 2.4.4 Documentation

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

**Table 2-4**
**Summary of Proposed Sample Identifiers, Depths, and Analytical Methods**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| | | Chemical Analysis | | | | | | | | | | | | Physical Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample ID** | **Depth (ft bgs)** | **TAL Metals/Hg/CN (Unfiltered) SW-846 6010B/7470A/7471A/9012A** | **TAL Metals/Hg (Filtered) SW-846 6010B/7470A**** | **Pesticides/PCBs SW-846 8081A/8082** | **VOCs SW-846 8260B** | **SVOCs SW-846 8270C** | **Explosives/Nitroglycerin/PETN SW-846 8330/8332/8332M** | **PCB Congeners EPA 1668** | **Perchlorate EPA 6850** | **TCLP Full List** | **Chemical Oxygen Demand EPA 410.4** | **pH (corrosivity) SW-846 9040B** | **Paint Filter Test SW-846 9095** | **Total Organic Carbon Walkley-Black Method** | **Grain Size ASTM D422** | **Atterburg Limits ASTM D4318** | **Moisture Content ASTM D2216** | **pH ASTM D4972** | **Cation Exchange Capacity** |
| **Soil Borings** | | | | | | | | | | | | | | | | | | | |
| **TerraCotta Pipe** | | | | | | | | | | | | | | | | | | | |
| 57SB1AB | 1-2 BDP | X | | | X | | | | | | | | | | | | | | |
| 57SB2AB | 1-2 BDP | X | | | X | | | | | | | | | | | | | | |
| 57SB9 | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB9 | 1-2 BDP | X | | | X | | | | | | | | | | | | | | |
| 57SB9 | 33-35 | X | | | X | | | | | | | | | | | | | | |
| **Inside Lagoon** | | | | | | | | | | | | | | | | | | | |
| 57SB4AB | BAL | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB4B | 6-8 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB4C | 29-31 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB5A | 0-1* | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB5AB | BAL | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB5B | 6-8 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB5C | 29-31 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB6A | 0-1* | X | | X | X | X | X | | | | | | | X | X | X | X | X | X |
| 57SB6AB | BAL | X | | X | X | X | X | | | | | | | X | | | | | X |
| 57SB6B | 6-8 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB6C | 29-31 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB7A | 0-1* | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB7AB | BAL | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB7B | 6-8 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB7C | 29-31 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB8A | 0-1* | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB8AB | BAL | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB8B | 6-8 | X | | X | X | X | X | | | | | | | | | | | | |
| 57SB8C | 29-31 | X | | X | X | X | X | | | | | | | | | | | | |
| 57COMP1 | 0-1* | | | | | | | | | X | | X | | | | | | | |
| **Outside Lagoon - Inner Perimeter** | | | | | | | | | | | | | | | | | | | |
| 57SB10A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB10B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB10C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| 57SB11A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB11B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB11C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| 57SB12A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB12B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB12C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| **Outside Lagoon - Outer Perimeter** | | | | | | | | | | | | | | | | | | | |
| 57SB13A | 0-1* | X | | | X | | | | | | | | | X | X | X | X | X | X |
| 57SB13B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB13C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| 57SB14A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB14B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB14C | 33-35 | X | | | X | | | | | | | | | | | | | | |

**Table 2-4**
**Summary of Proposed Sample Identifiers, Depths, and Analytical Methods**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| | | Chemical Analysis | | | | | | | | | | | | Physical Analysis | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sample ID** | **Depth (ft bgs)** | **TAL Metals/Hg/CN (Unfiltered) SW-846 6010B/7470A/7471A/9012A** | **TAL Metals/Hg (Filtered) SW-846 6010B/7470A**** | **Pesticides/PCBs SW-846 8081A/8082** | **VOCs SW-846 8260B** | **SVOCs SW-846 8270C** | **Explosives/Nitroglycerin/PETN SW-846 8330/8332/8332M** | **PCB Congeners EPA 1668** | **Perchlorate EPA 6850** | **TCLP Full List** | **Chemical Oxygen Demand EPA 410.4** | **pH (corrosivity) SW-846 9040B** | **Paint Filter Test SW-846 9095** | **Total Organic Carbon Walkley-Black Method** | **Grain Size ASTM D422** | **Atterburg Limits ASTM D4318** | **Moisture Content ASTM D2216** | **pH ASTM D4972** | **Cation Exchange Capacity** |
| 57SB15A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB15B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB15C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| 57SB16A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB16B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB16C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| 57SB17A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB17B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB17C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| **Drainage Swale** | | | | | | | | | | | | | | | | | | | |
| 57SB18A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB18B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB18C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| 57SB19A | 0-1* | X | | | X | | | | | | | | | | | | | | |
| 57SB19B | 10-12 | X | | | X | | | | | | | | | | | | | | |
| 57SB19C | 33-35 | X | | | X | | | | | | | | | | | | | | |
| **Quality Control Samples** | | | | | | | | | | | | | | | | | | | |
| D-1 | TBD | X | | X | X | X | X | | | | | | | | | | | | |
| D-2 | TBD | X | | X | X | X | X | | | | | | | | | | | | |
| D-3 | TBD | X | | | X | | | | | | | | | | | | | | |
| D-4 | TBD | X | | | X | | | | | | | | | | | | | | |
| D-5 | TBD | X | | | X | | | | | | | | | | | | | | |
| D-6 | TBD | X | | | X | | | | | | | | | | | | | | |
| MS/MSD | TBD | X | | X | X | X | X | | | | | | | | | | | | |
| MS/MSD | TBD | X | | | X | | | | | | | | | | | | | | |
| MS/MSD | TBD | X | | | X | | | | | | | | | | | | | | |
| EQB1 | N/A | X | | X | X | X | X | | | | | | | | | | | | |
| EQB2 | N/A | X | | X | X | X | X | | | | | | | | | | | | |
| EQB3 | N/A | X | | | X | | | | | | | | | | | | | | |
| EQB4 | N/A | X | | | X | | | | | | | | | | | | | | |
| EQB5 | N/A | X | | | X | | | | | | | | | | | | | | |
| Trip Blank-1 | N/A | | | | X | | | | | | | | | | | | | | |
| Trip Blank-2 | N/A | | | | X | | | | | | | | | | | | | | |
| Trip Blank-3 | N/A | | | | X | | | | | | | | | | | | | | |
| **Groundwater** | | | | | | | | | | | | | | | | | | | |
| 57MW1 | N/A | X | X | | X | | | | | | | | | | | | | | |
| 57MW2 | N/A | X | X | | X | | | | | | | | | | | | | | |
| 57MW3 | N/A | X | X | | X | | | | | | | | | | | | | | |
| D-7 | N/A | X | X | | X | | | | | | | | | | | | | | |
| MS/MSD | N/A | X | X | | X | | | | | | | | | | | | | | |
| EQB6 | N/A | X | X | | X | | | | | | | | | | | | | | |
| Trip Blank-4 | N/A | | | | X | | | | | | | | | | | | | | |

**Notes:**

GW = Groundwater
ft bgs = Feet Below Ground Surface
GT = Geotechnical Sample
BDP = Below Depth of Pipe

BAL = Immediately Below Asphalt Liner
MS/MSD = Matrix Spike/Matrix Spike Duplicate
N/A = Not Applicable
IDM = Investigation-Derived Material

TAL = Target Analyte List
SVOC = Semivolatile Organic Compound
VOC = Volatile Organic Compound
PCB = Polychlorinated Biphenyls

TBD = To be Determined
TCLP = Toxicity Characteristic Leaching Procedure
* = Sample collection depth for VOCs 6-12 inches bgs.
** = Cyanide is not required.

**Table 2-5**
**Summary of Sample Container, Preservation Method, and Holding Time Requirements**
**MWP Addendum 021 - RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

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

**Notes:**
TAL = Target Analyte List
TCL = Target Compound List
mL = milliliter
g = gram

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

## 2.5 ANALYTICAL PROCEDURES

TriMatrix Laboratories Inc. will perform off-site analytical analyses. Analytical methods to be used and associated MDLs and RLs are identified in Tables 2-6 through 2-10. Laboratory analyses will be in accordance with USEPA SW-846 Test Methods for the analysis of the following:

- TCL VOCs;
- TCL SVOCs;
- TCL Pesticides/PCBs;
- Explosives;
- TOC; and
- TAL metals.

Samples of IDM will be characterized for disposal purposes by analyzing for the following:

- TCLP – Complete List for solid and TCLP metals for aqueous;
- pH;
- COD (aqueous, by USEPA Method 410.4);
- Explosives for solid (SW-846 Methods 8330 and 8332);
- Reactivity (ATK internal visual method and percent explosive content); and
- Paint Filter Test (solid).

Table 2-6
Summary of Analyte Detection Limits and Reporting Limits
TCL VOCs (by EPA Method 8260)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| | | Laboratory-Specific Method Detection and Reporting Limits | | | | USEPA MCLs | USEPA Region III Risk-Based Concentrations | | | | | | | | | USEPA Region III BTAG Screening Levels | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | | Water | | | Tap Water | | | Soil Industrial | | | Soil Residential | | | | | |
| | CAS | MDL | Reporting Limit | MDL | Reporting Limit | MCL | | RBC | Adjusted RBC | | RBC | Adjusted RBC | | RBC | Adjusted RBC | Aqueous Fresh Water | Soil | Sediment |
| Compound | Number | mg/kg | mg/kg | µg/L | µg/L | µg/L | C/N | µg/L | µg/L | C/N | mg/kg | mg/kg | C/N | mg/kg | mg/kg | µg/L | mg/kg | mg/kg |
| 1,1,1-Trichloroethane | 71-55-6 | 0.00041 | 0.005 | 0.150 | 1.0 | -- | N | 1.7E+03 | 1.7E+02 | N | 2.9E+05 | 2.9E+04 | N | 2.2E+04 | 2.2E+03 | 1.1E+01 | 3.0E-01 | 3.0E-02 |
| 1,1,2,2-Tetrachloroethane | 79-34-5 | 0.00030 | 0.005 | 0.120 | 1.0 | -- | C | 5.3E-02 | 5.3E-02 | C | 1.4E+01 | 1.4E+01 | C | 3.2E+00 | 3.2E+00 | 6.1E+02 | 3.0E-01 | 1.4E+00 |
| 1,1,2-Trichloro-1,2,2-trifluoroethane | 76-13-1 | 0.00033 | 0.005 | 0.150 | 1.0 | -- | N | 5.9E+04 | 5.9E+03 | N | 3.1E+07 | 3.1E+06 | N | 2.3E+06 | 2.3E+05 | -- | -- | -- |
| 1,1,2-Trichloroethane | 79-00-5 | 0.00038 | 0.005 | 0.110 | 1.0 | -- | C | 1.9E-01 | 1.9E-01 | C | 5.0E+01 | 5.0E+01 | C | 1.1E+01 | 1.1E+01 | 1.2E+03 | 3.0E-01 | 1.2E+00 |
| 1,1-Dichloroethane | 75-34-3 | 0.00050 | 0.005 | 0.160 | 1.0 | -- | N | 9.0E+02 | 9.0E+01 | N | 2.0E+05 | 2.0E+04 | N | 1.6E+04 | 1.6E+03 | 4.7E+01 | 3.0E-01 | -- |
| 1,1-Dichloroethene | 75-35-4 | 0.00049 | 0.005 | 0.130 | 1.0 | -- | N | 3.5E+02 | 3.5E+01 | N | 5.1E+04 | 5.1E+03 | N | 3.9E+03 | 3.9E+02 | 2.5E+01 | -- | 3.1E-02 |
| 1,2,3-Trichlorobenzene | 87-61-6 | 0.00635 | 0.020 | 0.320 | 1.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.0E+00 | 1.0E-01 | 8.6E-01 |
| 1,2,4-Trichlorobenzene | 120-82-1 | 0.00039 | 0.005 | 0.360 | 2.0 | 7.0E+01 | N | 6.1E+01 | 6.1E+00 | N | 1.0E+04 | 1.0E+03 | N | 7.8E+02 | 7.8E+01 | 2.4E+01 | 1.0E-01 | 2.1E+00 |
| 1,2-Dibromo-3-chloropropane | 96-12-8 | 0.00066 | 0.010 | 0.590 | 5.0 | -- | C | 2.0E-04 | 2.0E-04 | C | 3.6E+00 | 3.6E+00 | C | 2.0E-01 | 2.0E-01 | -- | -- | -- |
| 1,2-Dibromoethane | 106-93-4 | 0.00018 | 0.005 | 0.086 | 1.0 | -- | C | 5.3E-03 | 5.3E-03 | C | 1.4E+00 | 1.4E+00 | C | 3.2E-01 | 3.2E-01 | -- | 5.0E+00 | -- |
| 1,2-Dichlorobenzene | 95-50-1 | 0.00017 | 0.005 | 0.290 | 1.0 | -- | N | 2.7E+02 | 2.7E+01 | N | 9.2E+04 | 9.2E+03 | N | 7.0E+03 | 7.0E+02 | 7.0E-01 | 1.0E-01 | 1.7E-02 |
| 1,2-Dichloroethane | 107-06-2 | 0.00014 | 0.005 | 0.086 | 1.0 | -- | C | 1.2E-01 | 1.2E-01 | C | 3.1E+01 | 3.1E+01 | C | 7.0E+00 | 7.0E+00 | 1.0E+02 | 8.7E+02 | -- |
| 1,2-Dichloropropane | 78-87-5 | 0.00029 | 0.005 | 0.170 | 1.0 | 5.0E+00 | C | 1.6E-01 | 1.6E-01 | C | 4.2E+01 | 4.2E+01 | C | 9.4E+00 | 9.4E+00 | -- | 3.0E-01 | -- |
| 1,3-Dichlorobenzene | 541-73-1 | 0.00009 | 0.005 | 0.150 | 1.0 | -- | N | 1.8E+01 | 1.8E+00 | N | 3.1E+03 | 3.1E+02 | N | 2.3E+02 | 2.3E+01 | 1.5E+02 | -- | 4.4E+00 |
| 1,4-Dichlorobenzene | 106-46-7 | 0.00017 | 0.005 | 0.260 | 1.0 | -- | C | 4.7E-01 | 4.7E-01 | C | 1.2E+02 | 1.2E+02 | C | 2.7E+01 | 2.7E+01 | 2.6E+01 | 1.0E-01 | 6.0E-01 |
| 1,4-Dioxane | 123-91-1 | 0.01000 | 0.050 | 13.100 | 50 | -- | C | 6.1E+00 | 6.1E+00 | C | 2.6E+02 | 2.6E+02 | C | 5.8E+01 | 5.8E+01 | -- | -- | -- |
| 2-Butanone | 78-93-3 | 0.00290 | 0.020 | 0.570 | 10 | -- | N | 7.0E+03 | 7.0E+02 | N | 6.1E+05 | 6.1E+04 | N | 4.7E+04 | 4.7E+03 | 1.4E+04 | -- | -- |
| 2-Hexanone | 591-78-6 | 0.00070 | 0.010 | 0.400 | 10 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 9.9E+01 | -- | -- |
| 4-Methyl-2-pentanone | 108-10-1 | 0.00064 | 0.010 | 0.190 | 10 | -- | N | 6.3E+03 | 6.3E+02 | -- | -- | -- | -- | -- | -- | 1.7E+02 | 1.0E+02 | -- |
| Acetone | 67-64-1 | 0.00500 | 0.020 | 1.100 | 20 | -- | N | 5.5E+03 | 5.5E+02 | N | 9.2E+05 | 9.2E+04 | N | 7.0E+04 | 7.0E+03 | 1.5E+03 | -- | -- |
| Benzene | 71-43-2 | 0.00020 | 0.005 | 0.065 | 1.0 | 5.0E+00 | C | 3.4E-01 | 3.4E-01 | C | 5.2E+01 | 5.2E+01 | C | 1.2E+01 | 1.2E+01 | 3.7E+02 | 1.0E-01 | -- |
| Bromochloromethane | 74-97-5 | 0.00425 | 0.020 | 0.134 | 1.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.0E+02 | -- |
| Bromodichloromethane | 75-27-4 | 0.00028 | 0.005 | 0.110 | 1.0 | 8.0E+01 | C | 1.7E-01 | 1.7E-01 | C | 4.6E+01 | 4.6E+01 | C | 1.0E+01 | 1.0E+01 | -- | 4.5E+02 | -- |
| Bromoform | 75-25-2 | 0.00011 | 0.005 | 0.150 | 1.0 | 8.0E+01 | C | 8.5E+00 | 8.5E+00 | C | 3.6E+02 | 3.6E+02 | C | 8.1E+01 | 8.1E+01 | 3.2E+02 | -- | 6.5E-01 |
| Bromomethane | 74-83-9 | 0.00031 | 0.005 | 0.250 | 1.0 | -- | N | 8.5E+00 | 8.5E-01 | N | 1.4E+03 | 1.4E+02 | N | 1.1E+02 | 1.1E+01 | -- | -- | -- |
| Carbon disulfide | 75-15-0 | 0.00029 | 0.005 | 0.210 | 5.0 | -- | N | 1.0E+03 | 1.0E+02 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | 9.2E-01 | -- | 8.5E-04 |
| Carbon tetrachloride | 56-23-5 | 0.00036 | 0.005 | 0.081 | 1.0 | 5.0E+00 | C | 1.6E-01 | 1.6E-01 | C | 2.2E+01 | 2.2E+01 | C | 4.9E+00 | 4.9E+00 | 1.3E+01 | 3.0E-01 | 6.4E-02 |
| Chlorobenzene | 108-90-7 | 0.00006 | 0.005 | 0.110 | 1.0 | 1.0E+02 | N | 9.0E+01 | 9.0E+00 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | 1.3E+00 | 1.0E-01 | 8.4E-03 |
| Chloroethane | 75-00-3 | 0.00530 | 0.020 | 0.160 | 1.0 | -- | C | 3.6E+00 | 3.6E+00 | C | 9.9E+02 | 9.9E+02 | C | 2.2E+02 | 2.2E+02 | -- | -- | -- |
| Chloroform | 67-66-3 | 0.00026 | 0.005 | 0.170 | 1.0 | 8.0E+01 | C | 1.5E-01 | 1.5E-01 | N | 1.0E+04 | 1.0E+03 | N | 7.8E+02 | 7.8E+01 | 1.8E+00 | 3.0E-01 | -- |
| Chloromethane | 74-87-3 | 0.00018 | 0.005 | 0.180 | 1.0 | -- | N | 1.9E+02 | 1.9E+01 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| cis-1,2-Dichloroethene | 156-59-2 | 0.00022 | 0.005 | 0.160 | 1.0 | 7.0E+01 | N | 6.1E+01 | 6.1E+00 | N | 1.0E+04 | 1.0E+03 | N | 7.8E+02 | 7.8E+01 | -- | 3.0E-01 | -- |
| cis-1,3-Dichloropropene[1] | 10061-01-5 | 0.00026 | 0.005 | 0.072 | 1.0 | 5.0E+00 | C | 4.4E-01 | 4.4E-01 | C | 2.9E+01 | 2.9E+01 | C | 6.4E+00 | 6.4E+00 | -- | 3.0E-01 | -- |
| Cyclohexane | 110-82-7 | 0.00022 | 0.010 | 0.160 | 5.0 | -- | N | 1.2E+04 | 1.2E+03 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Dibromochloromethane | 124-48-1 | 0.00008 | 0.005 | 0.130 | 1.0 | 6.0E+01 | C | 1.3E-01 | 1.3E-01 | C | 3.4E+01 | 3.4E+01 | C | 7.6E+00 | 7.6E+00 | -- | -- | -- |
| Dichlorodifluoromethane | 75-71-8 | 0.00036 | 0.005 | 0.190 | 1.0 | -- | N | 3.5E+02 | 3.5E+01 | N | 2.0E+05 | 2.0E+04 | N | 1.6E+04 | 1.6E+03 | -- | -- | -- |
| Ethylbenzene | 100-41-4 | 0.00013 | 0.005 | 0.110 | 1.0 | 7.0E+02 | N | 1.3E+03 | 1.3E+02 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | 9.0E+01 | 1.0E-01 | 1.1E+00 |
| Isopropylbenzene | 98-82-8 | 0.00024 | 0.005 | 0.078 | 1.0 | -- | N | 6.6E+02 | 6.6E+01 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | 2.6E+00 | -- | 8.6E-02 |
| Methyl acetate | 79-20-9 | 0.00037 | 0.020 | 0.390 | 10 | -- | N | 6.1E+03 | 6.1E+02 | N | 1.0E+06 | 1.0E+05 | N | 7.8E+04 | 7.8E+03 | -- | -- | -- |
| methyl tert-Butyl ether | 1634-04-4 | 0.00025 | 0.005 | 0.074 | 1.0 | -- | C | 2.6E+00 | 2.6E+00 | C | 7.2E+02 | 7.2E+02 | C | 1.6E+02 | 1.6E+02 | 1.1E+04 | -- | -- |
| Methylcyclohexane | 108-87-2 | 0.00032 | 0.010 | 0.180 | 5.0 | -- | N | 6.3E+03 | 6.3E+02 | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Methylene chloride | 75-09-2 | 0.00320 | 0.020 | 0.210 | 5.0 | -- | C | 4.1E+00 | 4.1E+00 | C | 3.8E+02 | 3.8E+02 | C | 8.5E+01 | 8.5E+01 | 9.8E+01 | 3.0E-01 | -- |
| Styrene | 100-42-5 | 0.00005 | 0.005 | 0.043 | 1.0 | 1.0E+02 | N | 1.6E+03 | 1.6E+02 | N | 2.0E+05 | 2.0E+04 | N | 1.6E+04 | 1.6E+03 | 7.2E+01 | 1.0E-01 | 5.6E-01 |
| Tetrachloroethene | 127-18-4 | 0.00016 | 0.005 | 0.130 | 1.0 | 5.0E+00 | C | 1.0E-01 | 1.0E-01 | C | 5.3E+00 | 5.3E+00 | C | 1.2E+00 | 1.2E+00 | 1.1E+02 | 3.0E-01 | 4.7E-01 |
| Toluene | 108-88-3 | 0.00040 | 0.005 | 0.260 | 1.0 | 1.0E+03 | N | 2.3E+03 | 2.3E+02 | N | 8.2E+04 | 8.2E+03 | N | 6.3E+03 | 6.3E+02 | 2.0E+00 | 1.0E-01 | -- |
| trans-1,2-Dichloroethene | 156-60-5 | 0.00016 | 0.005 | 0.150 | 1.0 | 1.0E+02 | N | 1.1E+02 | 1.1E+01 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | 9.7E+02 | 3.0E-01 | 1.1E+00 |
| trans-1,3-Dichloropropene[1] | 10061-02-6 | 0.00028 | 0.005 | 0.087 | 1.0 | -- | C | 4.4E-01 | 4.4E-01 | C | 2.9E+01 | 2.9E+01 | C | 6.4E+00 | 6.4E+00 | -- | 3.0E-01 | -- |
| Trichloroethene | 79-01-6 | 0.00013 | 0.005 | 0.140 | 1.0 | 5.0E+00 | C | 2.6E-02 | 2.6E-02 | C | 7.2E+00 | 7.2E+00 | C | 1.6E+00 | 1.6E+00 | 2.1E+01 | 3.0E-01 | 9.7E-02 |

Table 2-6
Summary of Analyte Detection Limits and Reporting Limits
TCL VOCs (by EPA Method 8260)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Compound | CAS Number | Laboratory-Specific Method Detection and Reporting Limits: Soil MDL mg/kg | Soil Reporting Limit mg/kg | Water MDL µg/L | Water Reporting Limit µg/L | USEPA MCLs: MCL µg/L | USEPA Region III Risk-Based Concentrations: Tap Water C/N | Tap Water RBC µg/L | Tap Water Adjusted RBC µg/L | Soil Industrial C/N | Soil Industrial RBC mg/kg | Soil Industrial Adjusted RBC mg/kg | Soil Residential C/N | Soil Residential RBC mg/kg | Soil Residential Adjusted RBC mg/kg | USEPA Region III BTAG Screening Levels: Aqueous Fresh Water µg/L | Soil mg/kg | Sediment mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Trichlorofluoromethane | 75-69-4 | 0.00038 | 0.005 | 0.160 | 1.0 | -- | N | 1.3E+03 | 1.3E+02 | N | 3.1E+05 | 3.1E+04 | N | 2.3E+04 | 2.3E+03 | -- | -- | -- |
| Vinyl Chloride[2] | 75-01-4 | 0.00013 | 0.005 | 0.150 | 1.0 | 2.0E+00 | C | 1.5E-02 | 1.5E-02 | -- | -- | -- | C | 9.0E-02 | 9.0E-02 | 9.3E+02 | 3.0E-01 | -- |
| Xylenes | 1330-20-7 | 0.00025 | 0.005 | 0.250 | 3.0 | 1.0E+04 | N | 2.1E+02 | 2.1E+01 | N | 2.0E+05 | 2.0E+04 | N | 1.6E+04 | 1.6E+03 | 1.3E+01 | 1.0E-01 | -- |

**Notes:**

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
VOC = Volatile Organic Compound
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Soil - BTAG Screening Draft Values, 1995
Water - BTAG Freshwater Screening Values, 2004
Sediment - BTAG Sediment Screening Values, 2004

RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the April 6, 2007,
RBC Table and April 10, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic status per EPA RBC Table (April 2007)
C = Carcinogenic
C!/N= Carcinogenic RBC/Non-carcinogenic Adjusted RBC taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
[1] = RBC value is for 1,3-Dichloropropene
[2] = RBCs presented are for early-life, except industrial soil RBC, which is for adult

(shaded box) = Reporting limit was not low enough to meet screening criteria - but MDL does

Table 2-7
Summary of Analyte Detection Limits and Reporting Limits
TCL SVOCs (by EPA Method 8270C)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| | | Laboratory-Specific Method Detection and Reporting Limits | | | | USEPA MCLs | USEPA Region III Risk-Based Concentrations | | | | | | | | | USEPA Region III BTAG Screening Levels | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | | Water | | | Tap Water | | | Soil Industrial | | | Soil Residential | | | | | |
| | CAS | MDL | Reporting Limit | MDL | Reporting Limit | MCL | | RBC | Adjusted RBC | | RBC | Adjusted RBC | | RBC | Adjusted RBC | Aqueous Fresh Water | Soil | Sediment |
| Compound | Number | mg/kg | mg/kg | µg/L | µg/L | µg/L | C/N | µg/L | µg/L | C/N | mg/kg | mg/kg | C/N | mg/kg | mg/kg | µg/L | mg/kg | mg/kg |
| 1,1'-Biphenyl | 92-52-4 | 0.0042 | 0.17 | 0.024 | 5.0 | -- | N | 3.0E+02 | 3.0E+01 | N | 5.1E+04 | 5.1E+03 | N | 3.9E+03 | 3.9E+02 | 1.4E+01 | -- | 1.2E+00 |
| 1,2,4,5-Tetrachlorobenzene | 95-94-3 | 0.0008 | 0.17 | 0.025 | 5.0 | -- | N | 1.1E+01 | 1.1E+00 | N | 3.1E+02 | 3.1E+01 | N | 2.3E+01 | 2.3E+00 | 3.0E+00 | 1.0E-01 | 1.1E+00 |
| 2,2'-oxybis(1-Chloropropane) | 108-60-1 | 0.0043 | 0.17 | 0.047 | 5.0 | -- | C | 2.6E-01 | 2.6E-01 | C | 4.1E+01 | 4.1E+01 | C | 9.1E+00 | 9.1E+00 | -- | -- | -- |
| 2,4,5-Trichlorophenol | 95-95-4 | 0.0033 | 0.17 | 0.030 | 5.0 | -- | N | 3.7E+03 | 3.7E+02 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | -- | 1.0E-01 | -- |
| 2,4,6-Trichlorophenol | 88-06-2 | 0.0032 | 0.17 | 0.025 | 5.0 | -- | C | 6.1E+00 | 6.1E+00 | C | 2.6E+02 | 2.6E+02 | C | 5.8E+01 | 5.8E+01 | 4.9E+00 | 1.0E-01 | 2.1E-01 |
| 2,4-Dichlorophenol | 120-83-2 | 0.0035 | 0.17 | 0.022 | 5.0 | -- | N | 1.1E+02 | 1.1E+01 | N | 3.1E+03 | 3.1E+02 | N | 2.3E+02 | 2.3E+01 | 1.1E+01 | 1.0E-01 | 1.2E-01 |
| 2,4-Dimethylphenol | 105-67-9 | 0.0099 | 0.17 | 0.540 | 5.0 | -- | N | 7.3E+02 | 7.3E+01 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | -- | 1.0E-01 | 2.9E-02 |
| 2,4-Dinitrophenol | 51-28-5 | 0.0052 | 0.33 | 0.210 | 5.0 | -- | N | 7.3E+01 | 7.3E+00 | N | 2.0E+03 | 2.0E+02 | N | 1.6E+02 | 1.6E+01 | -- | 1.0E-01 | -- |
| 2,4-Dinitrotoluene | 121-14-2 | 0.0037 | 0.17 | 0.036 | 5.0 | -- | N | 7.3E+01 | 7.3E+00 | N | 2.0E+03 | 2.0E+02 | N | 1.6E+02 | 1.6E+01 | 4.4E+01 | -- | 4.2E-02 |
| 2,6-Dinitrotoluene | 606-20-2 | 0.0013 | 0.17 | 0.075 | 5.0 | -- | N | 3.7E+01 | 3.7E+00 | N | 1.0E+03 | 1.0E+02 | N | 7.8E+01 | 7.8E+00 | 8.1E+01 | -- | -- |
| 2-Chloronaphthalene | 91-58-7 | 0.0025 | 0.17 | 0.012 | 5.0 | -- | N | 4.9E+02 | 4.9E+01 | N | 8.2E+04 | 8.2E+03 | N | 6.3E+03 | 6.3E+02 | -- | -- | -- |
| 2-Chlorophenol | 95-57-8 | 0.0038 | 0.17 | 0.028 | 5.0 | -- | N | 3.0E+01 | 3.0E+00 | N | 5.1E+03 | 5.1E+02 | N | 3.9E+02 | 3.9E+01 | 2.4E+01 | 1.0E-01 | 3.1E-02 |
| 2-Methylnaphthalene | 91-57-6 | 0.0031 | 0.17 | 0.022 | 5.0 | -- | N | 2.4E+01 | 2.4E+00 | N | 4.1E+03 | 4.1E+02 | N | 3.1E+02 | 3.1E+01 | 4.7E+00 | -- | 2.0E-02 |
| 2-Methylphenol | 95-48-7 | 0.0048 | 0.17 | 0.450 | 5.0 | -- | N | 1.8E+03 | 1.8E+02 | N | 5.1E+04 | 5.1E+03 | N | 3.9E+03 | 3.9E+02 | 1.3E+01 | 1.0E-01 | -- |
| 2-Nitroaniline | 88-74-4 | 0.0046 | 0.17 | 0.280 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 2-Nitrophenol | 88-75-5 | 0.0056 | 0.17 | 0.038 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.9E+03 | -- | -- |
| 3,3'-Dichlorobenzidine | 91-94-1 | 0.0550 | 0.17 | 0.048 | 5.0 | -- | C | 1.5E-01 | 1.5E-01 | C | 6.4E+00 | 6.4E+00 | C | 1.4E+00 | 1.4E+00 | 4.5E+00 | -- | 1.3E-01 |
| 3-Nitroaniline | 99-09-2 | 0.0120 | 0.17 | 0.710 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 4,6-Dinitro-2-methylphenol | 534-52-1 | 0.0045 | 0.17 | 0.240 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 4-Bromophenyl-phenylether | 101-55-3 | 0.0034 | 0.17 | 0.039 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.5E+00 | -- | 1.2E+00 |
| 4-Chloro-3-Methylphenol | 59-50-7 | 0.0052 | 0.17 | 0.024 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 4-Chloroaniline | 106-47-8 | 0.0014 | 0.17 | 0.930 | 5.0 | -- | N | 1.5E+02 | 1.5E+01 | N | 4.1E+03 | 4.1E+02 | N | 3.1E+02 | 3.1E+01 | 2.3E+02 | -- | -- |
| 4-Chlorophenyl-phenylether | 7005-72-3 | 0.0049 | 0.17 | 0.029 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 0.0E+00 |
| 4-Methylphenol | 106-44-5 | 0.0064 | 0.17 | 0.380 | 5.0 | -- | N | 1.8E+02 | 1.8E+01 | N | 5.1E+03 | 5.1E+02 | N | 3.9E+02 | 3.9E+01 | 5.4E+02 | 1.0E-01 | 6.7E-01 |
| 4-Nitroaniline | 100-01-6 | 0.0072 | 0.17 | 0.450 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| 4-Nitrophenol | 100-02-7 | 0.0055 | 0.33 | 0.440 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.0E+01 | 1.0E-01 | -- |
| Acenaphthene | 83-32-9 | 0.0041 | 0.17 | 0.021 | 5.0 | -- | N | 3.7E+02 | 3.7E+01 | N | 6.1E+04 | 6.1E+03 | N | 4.7E+03 | 4.7E+02 | 5.8E+00 | 1.0E-01 | 6.7E-03 |
| Acenaphthylene [1] | 208-96-8 | 0.0036 | 0.17 | 0.038 | 5.0 | -- | N | 1.8E+02 | 1.8E+01 | N | 3.1E+04 | 3.1E+03 | N | 2.3E+03 | 2.3E+02 | -- | 1.0E-01 | 5.9E-03 |
| Acetophenone | 98-86-2 | 0.0052 | 0.17 | 0.033 | 5.0 | -- | N | 6.1E+02 | 6.1E+01 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | -- | -- | -- |
| Anthracene | 120-12-7 | 0.0046 | 0.17 | 0.030 | 5.0 | -- | N | 1.8E+03 | 1.8E+02 | N | 3.1E+05 | 3.1E+04 | N | 2.3E+04 | 2.3E+03 | 1.2E-02 | 1.0E-01 | 5.7E-02 |
| Atrazine | 1912-24-9 | 0.0069 | 0.17 | 0.087 | 5.0 | 3.0E+00 | C | 3.0E-01 | 3.0E-01 | C | 1.3E+01 | 1.3E+01 | C | 2.9E+00 | 2.9E+00 | 1.8E+00 | -- | 6.6E-03 |
| Benzaldehyde | 100-52-7 | 0.0084 | 0.17 | 0.056 | 5.0 | -- | N | 3.7E+03 | 3.7E+02 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | -- | -- | -- |
| Benzo(a)anthracene | 56-55-3 | 0.0030 | 0.17 | 0.058 | 5.0 | -- | C | 3.0E-02 | 3.0E-02 | C | 3.9E+00 | 3.9E+00 | C | 2.2E-01 | 2.2E-01 | 1.8E-02 | 1.0E-01 | 1.1E-01 |
| Benzo(a)pyrene | 50-32-8 | 0.0057 | 0.17 | 0.031 | 5.0 | 2.0E-01 | C | 3.0E-03 | 3.0E-03 | C | 3.9E-01 | 3.9E-01 | C | 2.2E-02 | 2.2E-02 | 1.5E-02 | 1.0E-01 | 1.5E-01 |
| Benzo(b)fluoranthene | 205-99-2 | 0.0098 | 0.17 | 0.038 | 5.0 | -- | C | 3.0E-02 | 3.0E-02 | C | 3.9E+00 | 3.9E+00 | C | 2.2E-01 | 2.2E-01 | -- | 1.0E-01 | -- |
| Benzo(g,h,i)perylene [1] | 191-24-2 | 0.0087 | 0.17 | 0.030 | 5.0 | -- | N | 1.8E+02 | 1.8E+01 | N | 3.1E+04 | 3.1E+03 | N | 2.3E+03 | 2.3E+02 | -- | 1.0E-01 | 1.7E-01 |
| Benzo(k)fluoranthene | 207-08-9 | 0.0022 | 0.17 | 0.048 | 5.0 | -- | C | 3.0E-01 | 3.0E-01 | C | 3.9E+01 | 3.9E+01 | C | 2.2E+00 | 2.2E+00 | -- | 1.0E-01 | 2.4E-01 |
| Bis(2-chloroethoxy)methane | 111-91-1 | 0.0031 | 0.17 | 0.022 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Bis(2-chloroethyl)ether | 111-44-4 | 0.0048 | 0.17 | 0.039 | 5.0 | -- | C | 9.6E-03 | 9.6E-03 | C | 2.6E+00 | 2.6E+00 | C | 5.8E-01 | 5.8E-01 | -- | -- | -- |
| Bis(2-ethylhexyl)phthalate | 117-81-7 | 0.0041 | 0.17 | 0.500 | 5.0 | 6.0E+00 | C | 4.8E+00 | 4.8E+00 | C | 2.0E+02 | 2.0E+02 | C | 4.6E+01 | 4.6E+01 | 1.6E+01 | -- | 1.8E-01 |
| Butylbenzylphthalate | 85-68-7 | 0.0047 | 0.17 | 0.760 | 5.0 | -- | N | 7.3E+03 | 7.3E+02 | N | 2.0E+05 | 2.0E+04 | N | 1.6E+04 | 1.6E+03 | 1.9E+01 | -- | 1.1E+01 |
| Caprolactam | 105-60-2 | 0.0130 | 0.33 | 0.770 | 5.0 | -- | N | 1.8E+04 | 1.8E+03 | N | 5.1E+05 | 5.1E+04 | N | 3.9E+04 | 3.9E+03 | -- | -- | -- |
| Carbazole | 86-74-8 | 0.0061 | 0.17 | 0.032 | 5.0 | -- | C | 3.3E+00 | 3.3E+00 | C | 1.4E+02 | 1.4E+02 | C | 3.2E+01 | 3.2E+01 | -- | -- | -- |
| Chrysene | 218-01-9 | 0.0028 | 0.17 | 0.030 | 5.0 | -- | C | 3.0E+00 | 3.0E+00 | C | 3.9E+02 | 3.9E+02 | C | 2.2E+01 | 2.2E+01 | -- | 1.0E-01 | 1.7E-01 |
| Dibenz(a,h)anthracene | 53-70-3 | 0.0059 | 0.17 | 0.019 | 5.0 | -- | C | 3.0E-03 | 3.0E-03 | C | 3.9E-01 | 3.9E-01 | C | 2.2E-02 | 2.2E-02 | -- | 1.0E-01 | 3.3E-02 |
| Dibenzofuran | 132-64-9 | 0.0032 | 0.17 | 0.014 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 3.7E+00 | -- | 4.2E-01 |
| Diethylphthalate | 84-66-2 | 0.0034 | 0.17 | 0.052 | 5.0 | -- | N | 2.9E+04 | 2.9E+03 | N | 8.2E+05 | 8.2E+04 | N | 6.3E+04 | 6.3E+03 | 2.1E+02 | -- | 6.0E-01 |
| Dimethylphthalate | 131-11-3 | 0.0036 | 0.17 | 0.020 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Di-n-butylphthalate | 84-74-2 | 0.0088 | 0.17 | 0.810 | 5.0 | -- | N | 3.7E+03 | 3.7E+02 | N | 1.0E+05 | 1.0E+04 | N | 7.8E+03 | 7.8E+02 | 1.9E+01 | -- | 6.5E+00 |
| Di-n-octylphthalate | 117-84-0 | 0.0038 | 0.17 | 0.041 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.2E+01 | -- | -- |
| Fluoranthene | 206-44-0 | 0.0028 | 0.17 | 0.033 | 5.0 | -- | N | 1.5E+03 | 1.5E+02 | N | 4.1E+04 | 4.1E+03 | N | 3.1E+03 | 3.1E+02 | 4.0E-02 | 1.0E-01 | 4.2E-01 |

Table 2-7
Summary of Analyte Detection Limits and Reporting Limits
TCL SVOCs (by EPA Method 8270C)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| | | Laboratory-Specific Method Detection and Reporting Limits | | | | USEPA MCLs | USEPA Region III Risk-Based Concentrations | | | | | | | | | USEPA Region III BTAG Screening Levels | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | | Water | | | Tap Water | | | Soil Industrial | | | Soil Residential | | | | | |
| | CAS | MDL | Reporting Limit | MDL | Reporting Limit | MCL | | RBC | Adjusted RBC | | RBC | Adjusted RBC | | RBC | Adjusted RBC | Aqueous Fresh Water | Soil | Sediment |
| **Compound** | **Number** | **mg/kg** | **mg/kg** | **µg/L** | **µg/L** | **µg/L** | **C/N** | **µg/L** | **µg/L** | **C/N** | **mg/kg** | **mg/kg** | **C/N** | **mg/kg** | **mg/kg** | **µg/L** | **mg/kg** | **mg/kg** |
| Fluorene | 86-73-7 | 0.0051 | 0.17 | 0.027 | 5.0 | -- | N | 2.4E+02 | 2.4E+01 | N | 4.1E+04 | 4.1E+03 | N | 3.1E+03 | 3.1E+02 | 3.0E+00 | 1.0E-01 | 7.7E-02 |
| Hexachlorobenzene | 118-74-1 | 0.0047 | 0.17 | 0.033 | 5.0 | 1.0E+00 | C | 4.2E-02 | 4.2E-02 | C | 1.8E+00 | 1.8E+00 | C | 4.0E-01 | 4.0E-01 | 3.0E-04 | -- | 2.0E-02 |
| Hexachlorobutadiene | 87-68-3 | 0.0039 | 0.17 | 0.015 | 5.0 | -- | C!/N | 8.6E-01 | 7.3E-01 | C!/N | 3.7E+01 | 2.0E+01 | C!/N | 8.2E+00 | 1.6E+00 | 1.3E+00 | -- | -- |
| Hexachlorocyclopentadiene | 77-47-4 | 0.0038 | 0.17 | 0.240 | 5.0 | 5.0E+01 | N | 2.2E+02 | 2.2E+01 | N | 6.1E+03 | 6.1E+02 | N | 4.7E+02 | 4.7E+01 | -- | -- | -- |
| Hexachloroethane | 67-72-1 | 0.0051 | 0.17 | 0.029 | 5.0 | -- | C!/N | 4.8E+00 | 3.7E+00 | C!/N | 2.0E+02 | 1.0E+02 | C!/N | 4.6E+01 | 7.8E+00 | 1.2E+01 | -- | 1.0E+00 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | 0.0039 | 0.17 | 0.021 | 5.0 | -- | C | 3.0E-02 | 3.0E-02 | C | 3.9E+00 | 3.9E+00 | C | 2.2E-01 | 2.2E-01 | -- | 1.0E-01 | 1.7E-02 |
| Isophorone | 78-59-1 | 0.0024 | 0.17 | 0.025 | 5.0 | -- | C | 7.0E+01 | 7.0E+01 | C | 3.0E+03 | 3.0E+03 | C | 6.7E+02 | 6.7E+02 | -- | -- | -- |
| Naphthalene | 91-20-3 | 0.0032 | 0.17 | 0.022 | 5.0 | -- | N | 6.5E+00 | 6.5E-01 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | 1.1E+00 | 1.0E-01 | 1.8E-01 |
| Nitrobenzene | 98-95-3 | 0.0048 | 0.17 | 0.053 | 5.0 | -- | N | 3.5E+00 | 3.5E-01 | N | 5.1E+02 | 5.1E+01 | N | 3.9E+01 | 3.9E+00 | -- | -- | -- |
| N-Nitrosodi-n-propylamine | 621-64-7 | 0.0042 | 0.17 | 0.037 | 5.0 | -- | C | 9.6E-03 | 9.6E-03 | C | 4.1E-01 | 4.1E-01 | C | 9.1E-02 | 9.1E-02 | -- | -- | -- |
| N-Nitrosodiphenylamine | 86-30-6 | 0.0048 | 0.17 | 0.037 | 5.0 | -- | C | 1.4E+01 | 1.4E+01 | C | 5.8E+02 | 5.8E+02 | C | 1.3E+02 | 1.3E+02 | 2.1E+02 | -- | 2.7E+00 |
| Pentachlorophenol | 87-86-5 | 0.0044 | 0.33 | 0.061 | 5.0 | 1.0E+00 | C | 5.6E-01 | 5.6E-01 | C | 2.4E+01 | 2.4E+01 | C | 5.3E+00 | 5.3E+00 | 5.0E-01 | 1.0E-01 | 5.0E-01 |
| Phenanthrene [1] | 85-01-8 | 0.0028 | 0.17 | 0.033 | 5.0 | -- | N | 1.8E+02 | 1.8E+01 | N | 3.1E+04 | 3.1E+03 | N | 2.3E+03 | 2.3E+02 | 4.0E-01 | 1.0E-01 | 2.0E-01 |
| Phenol | 108-95-2 | 0.0060 | 0.17 | 0.055 | 5.0 | -- | N | 1.1E+04 | 1.1E+03 | N | 3.1E+05 | 3.1E+04 | N | 2.3E+04 | 2.3E+03 | 4.0E+00 | 1.0E-01 | 4.2E-01 |
| Pyrene | 129-00-0 | 0.0032 | 0.17 | 0.044 | 5.0 | -- | N | 1.8E+02 | 1.8E+01 | N | 3.1E+04 | 3.1E+03 | N | 2.3E+03 | 2.3E+02 | 2.5E-02 | 1.0E-01 | 2.0E-01 |

**Notes:**

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
VOC = Volatile Organic Compound
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Soil - BTAG Screening Draft Values, 1995
Water - BTAG Freshwater Screening Values, 2004
Sediment - BTAG Sediment Screening Values, 2004

RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the April 6, 2007,
RBC Table and April 10, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic status per EPA RBC Table (April 2007)
C = Carcinogenic
C!/N= Carcinogenic RBC/Non-carcinogenic Adjusted RBC taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
[1] = RBC value for pyrene was used for these compounds

[shaded box] = Reporting limit was not low enough to meet screening criteria - but MDL does

Table 2-8
Summary of Analyte Detection Limits and Reporting Limits
TCL Pesticides (EPA Method 8081A) and PCBs (EPA Method 8082)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| | | Laboratory-Specific Method Detection and Reporting Limits | | | | USEPA MCLs | USEPA Region III Risk-Based Concentrations | | | | | | | | | USEPA Region III BTAG Screening Levels | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | | Water | | | Tap Water | | | Soil Industrial | | | Soil Residential | | | | | |
| | CAS | MDL | Reporting Limit | MDL | Reporting Limit | MCL | | RBC | Adjusted RBC | | RBC | Adjusted RBC | | RBC | Adjusted RBC | Aqueous Fresh Water | Soil | Sediment |
| **Compounds by Method 8081A** | Number | mg/kg | mg/kg | µg/L | µg/L | µg/L | C/N | µg/L | µg/L | C/N | mg/kg | mg/kg | C/N | mg/kg | mg/kg | µg/L | mg/kg | mg/kg |
| 4,4'-DDD | 72-54-8 | 0.00110 | 0.0033 | 0.0036 | 0.10 | -- | C | 2.8E-01 | 2.8E-01 | C | 1.2E+01 | 1.2E+01 | C | 2.7E+00 | 2.7E+00 | 1.1E-02 | 1.0E-01 | 4.9E-03 |
| 4,4'-DDE | 72-55-9 | 0.00090 | 0.0033 | 0.0036 | 0.10 | -- | C | 2.0E-01 | 2.0E-01 | C | 8.4E+00 | 8.4E+00 | C | 1.9E+00 | 1.9E+00 | -- | 1.0E-01 | 3.2E-03 |
| 4,4'-DDT | 50-29-3 | 0.00100 | 0.0033 | 0.0036 | 0.10 | -- | C | 2.0E-01 | 2.0E-01 | C | 8.4E+00 | 8.4E+00 | C | 1.9E+00 | 1.9E+00 | 1.0E-03 | 1.0E-01 | -- |
| Aldrin | 309-00-2 | 0.00054 | 0.0017 | 0.0027 | 0.05 | -- | C | 3.9E-03 | 3.9E-03 | C | 1.7E-01 | 1.7E-01 | C | 3.8E-02 | 3.8E-02 | 3.0E+00 | 1.0E-01 | 2.0E-03 |
| alpha-BHC | 319-84-6 | 0.00035 | 0.0017 | 0.0034 | 0.05 | -- | C | 1.1E-02 | 1.1E-02 | C | 4.5E-01 | 4.5E-01 | C | 1.0E-01 | 1.0E-01 | -- | 1.0E+02 | 6.0E-03 |
| alpha-Chlordane[1] | 5103-71-9 | 0.00068 | 0.0033 | 0.0033 | 0.05 | -- | C | 1.9E-01 | 1.9E-01 | C | 8.2E+00 | 8.2E+00 | C | 1.8E+00 | 1.8E+00 | -- | 1.0E-01 | -- |
| gamma-Chlordane[1] | 5103-74-2 | 0.00067 | 0.0033 | 0.0030 | 0.05 | -- | C | 1.9E-01 | 1.9E-01 | C | 8.2E+00 | 8.2E+00 | C | 1.8E+00 | 1.8E+00 | -- | 1.0E-01 | -- |
| beta-BHC | 319-85-7 | 0.00094 | 0.0033 | 0.0031 | 0.05 | -- | C | 3.7E-02 | 3.7E-02 | C | 1.6E+00 | 1.6E+00 | C | 3.5E-01 | 3.5E-01 | -- | 1.0E+02 | 5.0E-03 |
| delta-BHC[2] | 319-86-8 | 0.00046 | 0.0033 | 0.0032 | 0.10 | -- | C | 1.1E-02 | 1.1E-02 | C | 4.5E-01 | 4.5E-01 | C | 1.0E-01 | 1.0E-01 | 1.4E+02 | 1.0E+02 | 6.4E+00 |
| Dieldrin | 60-57-1 | 0.00090 | 0.0033 | 0.0028 | 0.05 | -- | C | 4.2E-03 | 4.2E-03 | C | 1.8E-01 | 1.8E-01 | C | 4.0E-02 | 4.0E-02 | 5.6E-02 | 1.0E-01 | 1.9E-03 |
| Endosulfan I[3] | 959-98-8 | 0.00085 | 0.0033 | 0.0031 | 0.10 | -- | N | 2.2E+02 | 2.2E+01 | N | 6.1E+03 | 6.1E+02 | N | 4.7E+02 | 4.7E+01 | 5.1E-02 | -- | 2.9E-03 |
| Endosulfan II[3] | 33213-65-9 | 0.00100 | 0.0033 | 0.0041 | 0.10 | -- | N | 2.2E+02 | 2.2E+01 | N | 6.1E+03 | 6.1E+02 | N | 4.7E+02 | 4.7E+01 | 5.1E-02 | -- | 1.4E-02 |
| Endosulfan sulfate | 1031-07-8 | 0.00054 | 0.0033 | 0.0029 | 0.10 | -- | N | 2.2E+02 | 2.2E+01 | N | 6.1E+03 | 6.1E+02 | N | 4.7E+02 | 4.7E+01 | -- | -- | 5.4E-03 |
| Endrin | 72-20-8 | 0.00100 | 0.0033 | 0.0037 | 0.10 | 2.0E+00 | N | 1.1E+01 | 1.1E+00 | N | 3.1E+02 | 3.1E+01 | N | 2.3E+01 | 2.3E+00 | 3.6E-02 | 1.0E-01 | 2.2E-03 |
| Endrin aldehyde[4] | 7421-93-4 | 0.00100 | 0.0033 | 0.0045 | 0.10 | -- | N | 1.1E+01 | 1.1E+00 | N | 3.1E+02 | 3.1E+01 | N | 2.3E+01 | 2.3E+00 | -- | 1.0E-01 | -- |
| Endrin ketone[4] | 53494-70-5 | 0.00064 | 0.0033 | 0.0026 | 0.05 | -- | N | 1.1E+01 | 1.1E+00 | N | 3.1E+02 | 3.1E+01 | N | 2.3E+01 | 2.3E+00 | -- | 1.0E-01 | -- |
| gamma-BHC (Lindane) | 58-89-9 | 0.00047 | 0.0017 | 0.0034 | 0.05 | 2.0E-01 | C | 5.2E-02 | 5.2E-02 | C | 2.2E+00 | 2.2E+00 | C | 4.9E-01 | 4.9E-01 | -- | 1.0E-01 | -- |
| Heptachlor | 76-44-8 | 0.00120 | 0.0067 | 0.0030 | 0.05 | 4.0E-01 | C | 1.5E-02 | 1.5E-02 | C | 6.4E-01 | 6.4E-01 | C | 1.4E-01 | 1.4E-01 | 3.8E-03 | 1.0E-01 | 6.8E-02 |
| Heptachlor epoxide | 1024-57-3 | 0.00041 | 0.0017 | 0.0031 | 0.05 | 2.0E-01 | C | 7.4E-03 | 7.4E-03 | C | 3.1E-01 | 3.1E-01 | C | 7.0E-02 | 7.0E-02 | 3.8E-03 | 1.0E-01 | 2.5E-03 |
| Methoxychlor | 72-43-5 | 0.00130 | 0.0170 | 0.0036 | 0.50 | 4.0E+01 | N | 1.8E+02 | 1.8E+01 | N | 5.1E+03 | 5.1E+02 | N | 3.9E+02 | 3.9E+01 | 1.9E-02 | 1.0E-01 | 1.9E-02 |
| Toxaphene | 8001-35-2 | 0.02200 | 0.1700 | 0.1000 | 5.0 | 3.0E+00 | C | 6.1E-02 | 6.1E-02 | C | 2.6E+00 | 2.6E+00 | C | 5.8E-01 | 5.8E-01 | 2.0E-04 | -- | 1.0E-03 |
| **Compounds by Method 8082** | | | | | | | | | | | | | | | | | | |
| Aroclor 1016 | 12674-11-2 | 0.0043 | 0.033 | 0.046 | 0.2 | 0.5 | C!/N | 9.6E-01 | 2.6E-01 | C!/N | 4.1E+01 | 7.2E+00 | N | 5.5E+00 | 5.5E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1221 | 11104-28-2 | 0.0120 | 0.067 | 0.0530 | 0.2 | 0.5 | C | 3.3E-02 | 3.3E-02 | C | 1.4E+00 | 1.4E+00 | C | 3.2E-01 | 3.2E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1232 | 11141-16-5 | 0.0045 | 0.033 | 0.05 | 0.2 | 0.5 | C | 3.3E-02 | 3.3E-02 | C | 1.4E+00 | 1.4E+00 | C | 3.2E-01 | 3.2E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1242 | 53469-21-9 | 0.0062 | 0.033 | 0.053 | 0.2 | 0.5 | C | 3.3E-02 | 3.3E-02 | C | 1.4E+00 | 1.4E+00 | C | 3.2E-01 | 3.2E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1248 | 12672-29-6 | 0.0037 | 0.033 | 0.024 | 0.2 | 0.5 | C | 3.3E-02 | 3.3E-02 | C | 1.4E+00 | 1.4E+00 | C | 3.2E-01 | 3.2E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1254 | 11097-69-1 | 0.0060 | 0.033 | 0.038 | 0.2 | 0.5 | C | 3.3E-02 | 3.3E-02 | C | 1.4E+00 | 1.4E+00 | C!/N | 3.2E-01 | 1.6E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1260 | 11096-82-5 | 0.0044 | 0.033 | 0.045 | 0.2 | 0.5 | C | 3.3E-02 | 3.3E-02 | C | 1.4E+00 | 1.4E+00 | C | 3.2E-01 | 3.2E-01 | 7.4E-05 | 1.0E-01 | -- |
| Aroclor 1262 | 37324-23-5 | 0.0100 | 0.066 | 0.055 | 0.2 | 0.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Aroclor 1268 | 11100-14-4 | 0.0060 | 0.066 | 0.0368 | 0.2 | 0.5 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |

**Notes:**

CAS = Chemical Abstract Service
mg/kg = Milligram Per kilogram
µg/L = Microgram Per liter
TCL = Target Compound List
MDL = Method Detection Limit
RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
MCL = Maximum Contaminant Level
BTAG = Biological Technical Assistance Group
Soil - BTAG Screening Draft Values, 1995
Water - BTAG Freshwater Screening Values, 2004
Sediment - BTAG Sediment Screening Values, 2004

RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the April 6, 2007,
RBC Table and April 10, 20076, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic status per EPA RBC Table (April 2007)
C = Carcinogenic
C!/N= Carcinogenic RBC/Non-carcinogenic Adjusted RBC taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
[1] = Chlordane RBC value was used
[2] = alpha-BHC RBC value was used
[3] = Endosulfan RBC value was used
[4] = Endrin RBC value was used

[shaded box] = Reporting limit was not low enough to meet screening criteria - but MDL does

Table 2-9
Summary of Analyte Detection Limits and Reporting Limits
Explosives (EPA Methods 8330, 8330M, 8332)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| Compound by Method 8330 | CAS Number | Laboratory-Specific Method Detection and Reporting Limits: Soil MDL mg/kg | Soil Reporting Limit mg/kg | Water MDL µg/L | Water Reporting Limit µg/L | USEPA MCLs: MCL µg/L | USEPA Region III Risk-Based Concentrations: Tap Water C/N | Tap Water RBC µg/L | Tap Water Adjusted RBC µg/L | Soil Industrial C/N | Soil Industrial RBC mg/kg | Soil Industrial Adjusted RBC mg/kg | Soil Residential C/N | Soil Residential RBC mg/kg | Soil Residential Adjusted RBC mg/kg | USEPA Region III BTAG Screening Levels: Aqueous Fresh Water µg/L | Soil mg/kg | Sediment mg/kg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1,3,5-Trinitrobenzene | 99-35-4 | 0.200 | 2.5 | 0.16 | 5.0 | -- | N | 1.1E+03 | 1.1E+02 | N | 3.1E+04 | 3.1E+03 | N | 2.3E+03 | 2.3E+02 | -- | -- | -- |
| 1,3-Dinitrobenzene | 99-65-0 | 0.052 | 2.5 | 0.23 | 5.0 | -- | N | 3.7E+00 | 3.7E-01 | N | 1.0E+02 | 1.0E+01 | N | 7.8E+00 | 7.8E-01 | -- | -- | -- |
| 2,4,6-Trinitrotoluene | 118-96-7 | 0.051 | 2.5 | 0.08 | 5.0 | -- | C!/N | 2.2E+00 | 1.8E+00 | C!/N | 9.5E+01 | 5.1E+01 | C!/N | 2.1E+01 | 3.9E+00 | 1.0E+02 | -- | 9.2E-02 |
| 2,4-Dinitrotoluene | 121-14-2 | 0.073 | 2.5 | 0.12 | 5.0 | -- | N | 7.3E+01 | 7.3E+00 | N | 2.0E+03 | 2.0E+02 | N | 1.6E+02 | 1.6E+01 | 4.4E+01 | -- | 4.2E-02 |
| 2,6-Dinitrotoluene | 606-20-2 | 0.099 | 2.5 | 0.27 | 5.0 | -- | N | 3.7E+01 | 3.7E+00 | N | 1.0E+03 | 1.0E+02 | N | 7.8E+01 | 7.8E+00 | 8.1E+01 | -- | -- |
| 2-Amino-4,6-dinitrotoluene[1] | 35572-78-2 | 0.088 | 2.5 | 0.20 | 5.0 | -- | N | 7.3E+01 | 7.3E+00 | N | 2.0E+03 | 2.0E+02 | N | 1.6E+02 | 1.6E+01 | 1.5E+03 | -- | -- |
| 2-Nitrotoluene | 88-72-2 | 0.071 | 2.5 | 0.26 | 5.0 | -- | N | 6.1E+01 | 6.1E+00 | N | 1.0E+04 | 1.0E+03 | N | 7.8E+02 | 7.8E+01 | -- | -- | -- |
| 3-Nitrotoluene | 99-08-1 | 0.120 | 2.5 | 0.22 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 7.5E+02 | -- | -- |
| 4-Amino-2,6-dinitrotoluene[1] | 1946-51-0 | 0.053 | 2.5 | 0.31 | 5.0 | -- | N | 7.3E+01 | 7.3E+00 | N | 2.0E+03 | 2.0E+02 | N | 1.6E+02 | 1.6E+01 | -- | -- | -- |
| 4-Nitrotoluene | 99-99-0 | 0.120 | 2.5 | 0.15 | 5.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.9E+03 | -- | 4.1E+00 |
| HMX (Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) | 2691-41-0 | 0.089 | 2.5 | 0.16 | 5.0 | -- | N | 1.8E+03 | 1.8E+02 | N | 5.1E+04 | 5.1E+03 | N | 3.9E+03 | 3.9E+02 | 1.5E+02 | -- | -- |
| Nitrobenzene | 98-95-3 | 0.059 | 2.5 | 0.18 | 5.0 | -- | N | 3.5E+00 | 3.5E-01 | N | 5.1E+02 | 5.1E+01 | N | 3.9E+01 | 3.9E+00 | -- | -- | -- |
| RDX (Hexahydro-1,3,5-trinitro-1,3,5-triazine) | 121-82-4 | 0.089 | 2.5 | 0.06 | 5.0 | -- | C | 6.1E-01 | 6.1E-01 | C | 2.6E+01 | 2.6E+01 | C | 5.8E+00 | 5.8E+00 | 3.6E+02 | -- | 1.3E-02 |
| Tetryl (Methyl-2,4,6-trinitrophenylnitramine) | 479-45-8 | 0.170 | 2.5 | 0.25 | 5.0 | -- | N | 1.5E+02 | 1.5E+01 | N | 4.1E+03 | 4.1E+02 | N | 3.1E+02 | 3.1E+01 | -- | -- | -- |
| **Compound by Method 8330M** | | | | | | | | | | | | | | | | | | |
| PETN | 78-11-5 | 0.228 | 5.0 | 0.61 | 10.0 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.5E+04 | -- | -- |
| **Compound by Method 8332** | | | | | | | | | | | | | | | | | | |
| Nitroglycerin | 55-63-0 | 0.387 | 5.0 | 0.58 | 5.0 | -- | N | 3.7E+00 | 3.7E-01 | N | 1.0E+02 | 1.0E+01 | N | 7.8E+00 | 7.8E-01 | 1.4E+02 | -- | -- |

**Notes:**

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µg/L = Microgram Per liter
TCL = Target Compound List
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RL = Reporting Limit
Method Detection and Reporting Limits Provided by TriMatrix
-- = No Risk Criteria Available
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BTAG = Biological Technical Assistance Group
Soil - BTAG Screening Draft Values, 1995
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Sediment - BTAG Sediment Screening Values, 2004

RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the April 6, 2007,
RBC Table and April 10, 2007, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C/N = Carcinogenic/Noncarcinogenic status per EPA RBC Table (April 2007)
C = Carcinogenic
C!/N= Carcinogenic RBC/Non-carcinogenic Adjusted RBC taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
[1] = RBC value is for the sum of the isomers called aminodinitrotoluenes

[shaded box] = Reporting limit was not low enough to meet screening criteria - but MDL does

Table 2-10
Summary of Analyte Detection Limits and Reporting Limits
TAL Metals (by EPA Methods 6010, 6020, and 7470)
Soil and Water Samples
MWP Addendum 021 - RFI for SWMU 57
Radford Army Ammunition Plant, Radford, Virginia

| | | Laboratory-Specific Method Detection and Reporting Limits | | | | USEPA MCLs | USEPA Region III Risk-Based Concentrations | | | | | | | | | USEPA Region III BTAG Screening Levels | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Soil | | Water | | | Tap Water | | | Soil Industrial | | | Soil Residential | | | | | |
| Compound | CAS Number | MDL mg/kg | Reporting Limit mg/kg | MDL µg/L | Reporting Limit µg/L | MCL µg/L | C/N | RBC µg/L | Adjusted RBC µg/L | C/N | RBC mg/kg | Adjusted RBC mg/kg | C/N | RBC mg/kg | Adjusted RBC mg/kg | Aqueous Fresh Water µg/L | Soil mg/kg | Sediment mg/kg |
| Aluminum | 7429-90-5 | 1.6 | 10 | 16 | 50 | -- | N | 3.7E+04 | 3.7E+03 | N | 1.0E+06 | 1.0E+05 | N | 7.8E+04 | 7.8E+03 | 8.7E+01 | 1.0E+00 | -- |
| Antimony | 7440-36-0 | 0.036 | 0.2 | 0.73 | 3 | 6.0E+00 | N | 1.5E+01 | 1.5E+00 | N | 4.1E+02 | 4.1E+01 | N | 3.1E+01 | 3.1E+00 | 3.0E+01 | 4.8E-01 | 2.0E+00 |
| Arsenic | 7440-38-2 | 0.023 | 0.1 | 0.47 | 2 | 1.0E+01 | C | 4.5E-02 | 4.5E-02 | C | 1.9E+00 | 1.9E+00 | C | 4.3E-01 | 4.3E-01 | 5.0E+00 | 3.3E+02 | 9.8E+00 |
| Barium | 7440-39-3 | 0.10 | 1 | 0.34 | 2 | 2.0E+03 | N | 7.3E+03 | 7.3E+02 | N | 2.0E+05 | 2.0E+04 | N | 1.6E+04 | 1.6E+03 | 4.0E+00 | 4.4E+02 | -- |
| Beryllium | 7440-41-7 | 0.016 | 1 | 0.50 | 2 | 4.0E+00 | N | 7.3E+01 | 7.3E+00 | N | 2.0E+03 | 2.0E+02 | N | 1.6E+02 | 1.6E+01 | 6.6E-01 | 2.0E-02 | -- |
| Cadmium | 7440-43-9 | 0.50 | 2 | 0.062 | 0.2 | 5.0E+00 | N | 1.8E+01 | 1.8E+00 | N | 5.1E+02 | 5.1E+01 | N | 3.9E+01 | 3.9E+00 | 2.5E-01 | 2.5E+00 | 9.9E-01 |
| Calcium | 7440-70-2 | 10 | 50 | 52 | 500 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 1.2E+05 | -- | -- |
| Chromium (VI)[1] | 7440-47-3 | 0.57 | 5 | 0.66 | 2 | 1.0E+02 | N | 1.1E+02 | 1.1E+01 | N | 3.1E+03 | 3.1E+02 | N | 2.3E+02 | 2.3E+01 | 8.5E+01 | 7.5E-03 | 4.3E+01 |
| Cobalt | 7440-48-4 | 0.35 | 2 | 0.22 | 1 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 2.3E+01 | 1.0E+02 | 5.0E+01 |
| Copper | 7440-50-8 | 0.022 | 0.1 | 0.32 | 1 | 1.3E+03 | N | 1.5E+03 | 1.5E+02 | N | 4.1E+04 | 4.1E+03 | N | 3.1E+03 | 3.1E+02 | 9.0E+00 | 1.5E+01 | 3.2E+01 |
| Cyanide | 57-12-5 | 0.0356 | 0.21 | 0.0022 | 0.01 | 2.0E+02 | N | 7.3E+02 | 7.3E+01 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | 5.0E+00 | 5.0E-03 | 1.0E-01 |
| Iron | 7439-89-6 | 0.46 | 10 | 3.2 | 10 | -- | N | 2.6E+04 | 2.6E+03 | N | 7.2E+05 | 7.2E+04 | N | 5.5E+04 | 5.5E+03 | 3.0E+02 | 1.2E+01 | 2.0E+04 |
| Lead[2] | 7439-92-1 | 0.041 | 0.2 | 0.24 | 1 | 1.5E+01 | -- | -- | -- | -- | 7.5E+02 | 7.5E+02 | -- | 4.0E+02 | 4.0E+02 | 2.5E+00 | 1.0E-02 | 3.6E+01 |
| Magnesium | 7439-95-4 | 3.4 | 50 | 32 | 100 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 8.2E+04 | 4.4E+03 | -- |
| Manganese (non-food) | 7439-96-5 | 0.14 | 1 | 0.74 | 3 | -- | N | 7.3E+02 | 7.3E+01 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | 1.2E+02 | 3.3E+02 | 4.6E+02 |
| Mercury[3] | 7439-97-6 | 0.0077 | 0.05 | 0.0367 | 0.2 | 2.0E+00 | -- | -- | -- | N | 3.1E+02 | 3.1E+01 | N | 2.3E+01 | 2.3E+00 | 1.0E-01 | 5.8E-02 | 1.8E-01 |
| Nickel | 7440-02-0 | 0.027 | 0.1 | 0.45 | 2 | -- | N | 7.3E+02 | 7.3E+01 | N | 2.0E+04 | 2.0E+03 | N | 1.6E+03 | 1.6E+02 | 5.2E+01 | 2.0E+00 | 2.3E+01 |
| Potassium | 7440-09-7 | 7.5 | 50 | 36 | 200 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| Selenium | 7782-49-2 | 0.063 | 0.2 | 0.73 | 3 | 5.0E+01 | N | 1.8E+02 | 1.8E+01 | N | 5.1E+03 | 5.1E+02 | N | 3.9E+02 | 3.9E+01 | 1.0E+00 | 1.8E+00 | 2.0E+00 |
| Silver | 7440-22-4 | 0.017 | 0.1 | 0.073 | 0.3 | -- | N | 1.8E+02 | 1.8E+01 | N | 5.1E+03 | 5.1E+02 | N | 3.9E+02 | 3.9E+01 | 3.2E+00 | 9.8E-06 | 1.0E+00 |
| Sodium | 7440-23-5 | 19 | 100 | 59 | 500 | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- | 6.8E+05 | -- | -- |
| Thallium | 7440-28-0 | 0.0085 | 0.1 | 0.14 | 1 | 2.0E+00 | N | 2.6E+00 | 2.6E-01 | N | 7.2E+01 | 7.2E+00 | N | 5.5E+00 | 5.5E-01 | 8.0E-01 | 1.0E-03 | -- |
| Vanadium | 7440-62-2 | 0.024 | 0.1 | 0.26 | 1 | -- | N | 3.7E+01 | 3.7E+00 | N | 1.0E+03 | 1.0E+02 | N | 7.8E+01 | 7.8E+00 | 2.0E+01 | 5.0E-01 | -- |
| Zinc | 7440-66-6 | 0.85 | 5 | 0.82 | 3 | -- | N | 1.1E+04 | 1.1E+03 | N | 3.1E+05 | 3.1E+04 | N | 2.3E+04 | 2.3E+03 | 1.2E+02 | 1.0E+01 | 1.2E+02 |

**Notes:**

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C/N = Carcinogenic/Noncarcinogenic status per EPA RBC Table (April 2007)
C = Carcinogenic
C!/N= Carcinogenic RBC/Non-carcinogenic Adjusted RBC taken from Alternate RBC table; see USEPA Region III guidance
N = Non-Carcinogenic
[1] = Chromium MCL is for total
[2] = Lead criteria are Action Levels; see USEPA Region III guidance
[3] = Mercuric chloride soil RBC value used

(shaded) = Reporting limit was not low enough to meet screening criteria - but MDL does

### 2.5.1 Organics

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

#### 2.5.1.1 VOCs by SW-846 Test Method 8260B

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

#### 2.5.1.2 SVOCs by SW-846 Test Method 8270C

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

#### 2.5.1.3 Pesticides by SW-846 Test Method 8081A

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

#### 2.5.1.4 PCBs by SW-846 Test Method 8082

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

#### 2.5.1.5 Explosives by SW-846 Test Methods 8330 and 8332

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

1) Low-Level Salting-out Method without Evaporation: Aqueous samples of low concentration are extracted by a salting-out extraction procedure with acetonitrile and sodium chloride. The small volume of acetonitrile that remains un-dissolved above the salt water is drawn off and transferred to a smaller volumetric flask. It is back-extracted by vigorous stirring with a specific volume of salt water. After equilibration, the phases are allowed to separate and the small volume of acetonitrile residing in the narrow neck of the volumetric flask is removed using a Pasteur pipette. The concentrated extract is diluted 1:1 with reagent grade water. An aliquot is separated on a C-18 reverse phase column, analyzed at 254 nanometers (nm), and confirmed on a cyanide (CN) reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.
2) Soil and sediment samples are air dried at room temperature to a constant weight. Approximately 2g are extracted using acetonitrile in an ultrasonic bath for 18 hours. Five mL of supernatant is combined with five mL of calcium chloride solution and is shaken and left to stand for 15 minutes. The supernatant is prepared for analysis by filtering through a 0.45 micrometer (µm) Teflon filter. This extract is then separated on a C-18 reverse phase column, determined at 254 nm, and confirmed on a CN reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

### 2.5.2 Metals

The following techniques will be used for analysis of inorganics.

#### 2.5.2.1 Target Analyte List Metals by ICP SW-846 Test Method 6010B Series

Prior to analysis, samples are prepared by Method 3010A for aqueous media and Method 3050B for solid media, or other appropriate methods. When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved before analysis. This method describes multi-elemental determinations by Inductively Coupled Plasma (ICP) - Atomic Emission Spectroscopy (AES) using sequential or simultaneous optical systems and axial or radial viewing of the plasma. The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by radio frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and photosensitive devices monitor the emission line intensities.

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

#### 2.5.2.2 Mercury by SW-846 Test Methods 7470A (aqueous) and 7471A (solid)

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

#### 2.5.2.3 Target Analyte List Metals by ICP SW-846 Test Method 6020 Series

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

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

#### 2.5.2.4 TOC by Walkley-Black Method

Soil samples will be analyzed for TOC by this method. This is a preferred method for TOC analyses of soil samples since the EPA 9060 or 415.1 techniques designed for aqueous samples may leave unextracted organic carbon in the soil. Organic carbon is determined by an oxidation-reduction reaction in which potassium dichromate is added to a sample, followed by addition of concentrated sulfuric acid. Dichromate ($Cr_2O_7^{2-}$) oxidizes organic carbon to $CO_2$ in an acidic medium. The reduced dichromate is quantitatively related to oxidized organic carbon. Any remaining $Cr_2O_7^{2-}$ is reduced by $Fe^{2+}$ from the ferrous sulfate titrant. The endpoint at which all $Cr_2O_7^{2-}$ has been reduced is indicated by the maroon color of an o-phenanthroline indicator.

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

#### 2.5.3.2 SVOCs by SW8270C (TCLP)

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

#### 2.5.3.3 VOCs by SW-846 Test Method 8260B (TCLP)

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

#### 2.5.3.4 Pesticides by SW8081A (TCLP)

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

#### 2.5.3.5 PCBs by SW-846 Test Method 8082 (TCLP)

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

#### 2.5.3.6 Herbicides by SW8151A (TCLP)

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

#### 2.5.3.7 Explosives by SW-846 Test Methods 8330 and 8332 (TCLP)

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

Low-Level Salting-out Method without Evaporation: Aqueous samples of low concentration are extracted by a salting-out extraction procedure with acetonitrile and sodium chloride. The small volume of acetonitrile that remains un-dissolved above the salt water is drawn off and transferred to a smaller volumetric flask. It is back-extracted by vigorous stirring with a specific volume of salt water. After equilibration, the phases are allowed to separate and the small volume of acetonitrile residing in the narrow neck of the volumetric flask is removed using a Pasteur pipette. The concentrated extract is diluted 1:1 with reagent grade water. An aliquot is separated on a C-18 reverse phase column, analyzed at 254 nanometers (nm), and confirmed on a cyanide (CN) reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

1) Soil and sediment samples are air dried at room temperature to a constant weight. Approximately 2g are extracted using acetonitrile in an ultrasonic bath for 18 hours. Five mL of supernatant is combined with five mL of calcium chloride solution and is shaken and left to stand for 15 minutes. The supernatant is prepared for analysis by filtering through a 0.45 micrometer (µm) Teflon filter. This extract is then separated on a C-18 reverse phase column, determined at 254 nm, and confirmed on a CN reverse phase column. Quantitation is accomplished by comparing the response of a peak within a retention time window to a five-point calibration curve.

#### 2.5.3.8 Target Analyte List Metals by ICP SW-846 Test Method 6010B Series (TCLP)

Prior to analysis, samples are prepared by Method 3010A for aqueous media and Method 3050B for solid media, or other appropriate methods. When analyzing groundwater samples for dissolved constituents, acid digestion is not necessary if the samples are filtered and acid preserved before analysis. This method describes multi-elemental determinations by Inductively Coupled Plasma (ICP) - Atomic Emission Spectroscopy (AES) using sequential or simultaneous optical systems and axial or radial viewing of the plasma. The instrument measures characteristic emission spectra by optical spectrometry. Samples are nebulized and the resulting aerosol is transported to the plasma torch. Element-specific emission spectra are produced by radio frequency inductively coupled plasma. The spectra are dispersed by a grating spectrometer, and photosensitive devices monitor the emission line intensities.

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

#### 2.5.3.9 Mercury by SW-846 Test Methods 7470A (aqueous) and 7471A (solid) (TCLP)

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

#### 2.5.3.10 Target Analyte List Metals by ICP SW-846 Test Method 6020 Series (TCLP)

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

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

#### 2.5.3.11 Corrosivity by SW-846 Test Methods 9040B (aqueous) and 9045C (solid)

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

#### 2.5.3.12 Chemical Oxygen Demand by EPA Method 410.4

Sample, blanks, and standards in sealed tubes are heated in an oven or block digestor in the presence of dichromate at 150 degrees Celsius ($^{o}$C). After two hours, the tubes are removed from the oven or digestor, cooled, and measured spectrophotometrically at 600 nm.

#### 2.5.3.13 Reactivity

Reactivity of waste samples is assessed by analysis of the sample for explosives by SW-846 Methods 8330 and 8332. Waste material is considered potentially reactive when 10 percent or more explosives by weight are present. A qualitative assessment of samples may also be performed by visual and microscopic methods to identify typical crystalline structures characteristic of the propellants and explosives manufactured at the facility.

### 2.5.4 Physical/Geotechnical Analysis

As discussed in Sections 1.6.1.1 and 1.6.1.3, two soil samples will be collected for analysis of physical/geotechnical parameters. A USACE-approved laboratory will conduct analyses. Analyses will be conducted for the following:

- Grain-size analysis (ASTM D 422);
- Atterberg limits (ASTM D 4318);
- Soil moisture content (ASTM D 2216);

- Total organic carbon (Walkley-Black Method);
- pH (ASTM D 4972): and
- Cation Exchange Capacity.

## 2.6 INTERNAL QUALITY CONTROL CHECK

Internal QC components that will be used by URS during operations at RFAAP are presented below and in Section 8.0 of the MQAP. The internal quality components include the field QC samples and the laboratory QC elements to be followed. Rinse blanks, trip blanks, and field duplicates will be collected during the acquisition of environmental samples at RFAAP. Table 2-11 presents guidelines for the collection of QC samples that will be taken in conjunction with environmental sampling. Field QC acceptance criteria are summarized in Table 2-12.

**Table 2-11**
**Field Quality Control Samples**

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

**Table 2-12**
**Field Quality Control Elements Acceptance Criteria**

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

Legend: A = Accuracy C = Comparability R = Representativeness P = Precision
*The difference will be evaluated when either of the field duplicate results is less than the reporting limit.

### 2.6.1 Laboratory Quality Control Elements

The laboratory QC elements are summarized in Table 2-13. Specific laboratory analytical QC criteria and corrective actions are summarized in Tables 2-14 through 2-20 for the parameters specified in Section 2.5.

**Table 2-13**
**Analytical Quality Control Elements of a Quality Assurance Program**

| Item | DQO | Parameter | Frequency of Association | Criteria Requirement |
|---|---|---|---|---|
| Analytical Method | C | Entire | Each analysis | Method analyses based on USEPA methods as defined in Section 2.5 |
| Chemical Data Packages | C | Entire | Each lot/batch | Pass peer review and formal QA/QC check. |
| Laboratory Chain of Custody | R | Entire | Each lot/batch | Custody of sample within laboratory fully accounted for and documented |
| Laboratory System Controls | A,C,P, R | Entire | During laboratory operations | No deficiencies |
| Holding Time | A,C,P, R | Entire | Each analysis | No deficiencies (USEPA Region III Modifications) |
| Method Blanks | A,R | Entire | Each lot/batch | No target analyte detected in the method blanks greater than RL |
| Laboratory Control Spike | A | Entire | Each lot/batch | Must meet criteria as defined in Tables 2-14 through 2-20 |
| Matrix Spikes and Duplicates | A,P | Entire | Each lot/batch | Must meet criteria as defined in Tables 2-14 through 2-20 |
| Surrogates | A | Entire | Organic fractions, including QC samples | Must meet criteria as defined in Tables 2-14 through 2-17 |
| Serial dilution | A | Metals | Inorganic Fractions, Each lot/batch | Must meet criteria as defined in Table 2-17 |

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

## Table 2-14
## Quality Control Method Criteria for Volatile Organic Compounds by USEPA SW-846 8260B

| Procedure | Frequency | Acceptance Criteria | | Corrective Action |
|---|---|---|---|---|
| Initial Calibration<br>5-pt curve (linear)<br>6-pt curve ($2^o$ order) | Set-up, major maintenance, or for drift correction | RRF > 0.10/0.30 for SPCCs<br>RSD ≤ 30% for CCCs response factors<br>RSD for analytes ≤ 15% or r>0.995 (linear) or $r^2$>0.99 ($2^o$ order) | | Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria. |
| Initial Calibration Verification | Immediately following initial calibration | A second source full compliment target list with a percent recovery = 75-125% | | Sample analysis cannot begin until this criterion is met. |
| Continuing Calibration Check | Every 12 hours | RRF > 0.10/0.30 for SPCCs<br>%Difference for RF of CCCs ±30% from initial calibration.<br>Mean for analytes ≤ 20% as no individual target exceeds 40%D | | Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria. |
| Method Blank | Every day/batch. | No target analytes greater than one half of the RL | | Document source of contamination. Re-analysis is required for positive results associated with blank contamination. |
| Tuning BFB | Prior to calibration and every 12 hours | Must meet tuning criteria | | Re-tune, re-calibrate, and re-analyze affected sample analyses. |
| Laboratory Control Spike | Every batch | Standards<br>Full compliment target list | Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM | Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate. |
| Internal Standards | Every sample | Recommended Standards<br>fluorobenzene<br>chlorobenzene-$d_5$<br>1,4-dichlorobenzene-$d_4$ | Retention time ±30 seconds of mid point of initial calibration<br>Area changes within a factor of two (-50% to +100%) | Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples associated with standards outside criteria. A third analytical run may be required at a dilution. |
| Surrogate | Every sample | Recommended Standards<br>Toluene-$d_8$<br>4-Bromofluorobenzene<br>1,2-Dichloroethane-$d_4$<br>Dibromofluoromethane | Laboratory generated control limits not to exceed those listed in the current version of the DOD QSM | If surrogate compounds do not meet criteria, there should be a re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies. |
| Matrix Spike and Duplicate | 1 per 20 per matrix | Standards<br>Full compliment target list | Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM | If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. |

## Table 2-15
## Quality Control Method Criteria for Semi-volatile Organic Compounds by USEPA SW-846 8270C

| Procedure | Frequency | Acceptance Criteria | | Corrective Action |
|---|---|---|---|---|
| Initial calibration<br>5-pt curve (linear)<br>6-pt curve (2° order) | Set-up, major maintenance, or for drift correction | RRF > 0.05 for SPCCs<br>RSD ≤30% for CCC compounds<br>RSD for target analytes ≤ 15% or r>0.995 (linear) or $r^2$>0.99 (2° order) | | Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria. |
| Initial Calibration Verification | Immediately following every initial calibration | A second source full compliment target list with a percent recovery = 80-120% | | Sample analysis cannot begin until this criterion is met. |
| Continuing Calibration Check | 12 hours | RRF > 0.05 for SPCCs<br>%Difference for RF of CCCs ±30% from initial calibration<br>Mean for analytes ≤ 20% as no individual target exceeds 40%D | | Sample analysis cannot begin until this criterion is met. Data reviewer should review and judge each target compound against the acceptance criteria. |
| Internal standards | Every sample | Retention time ±30 seconds from mid point of initial calibration<br>Area changes by a factor of two (-50% to +100%) | | Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples with internal standards outside criteria. |
| Tuning DFTPP | 12 hours | Must meet tuning criteria. | | Re-tune, re-calibrate, and re-analyze affected sample analyses. |
| Method Blank | Per extraction batch | No target analytes greater than one half of the RL | | Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination. |
| Laboratory Control Spike | Every batch | Standards<br>Full compliment target list | Laboratory generated control limits not to exceed recovery limits listed in the current version of the DoD QSM | Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate. |
| Internal Standards | Every sample | Recommended Standards<br>phenanthrene-d10<br>chrysene-d12<br>perylene-d12<br>1,4-dichlorobenzene-d4<br>naphthalene-d8<br>acenaphthalene-d10 | Retention time ±30 seconds of mid point of initial calibration<br>Area changes within a factor of two (-50% to +100%) | Inspect for malfunction. Demonstrate that system is functioning properly. Reanalyze samples associated with standards outside criteria. A third analytical run may be required at a dilution. |
| Surrogate Spikes | Every sample | Recommended Standards<br>nitrobenzene-$d_5$<br>2-fluorobiphenyl<br>p-terphenyl-d14<br>phenol-d5<br>2,4,6-tribromophenol<br>2-fluorophenol | Laboratory generated control limits not to exceed limits listed in the current version of the DoD QSM | If two base/neutral or acid surrogates are out of specification, or if one base/neutral or acid extractable surrogate has a recovery of less than 10%, then there should be a re-extraction and re-analysis to confirm that the non-compliance is due to sample matrix effects rather than laboratory deficiencies. |
| Matrix Spike and Duplicate | 1 per 20 samples per matrix | Standards<br>Full compliment target list | Laboratory generated control limits not to exceed recovery limits listed in the current version of the DoD QSM | If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. |

## Table 2-16
## Quality Control Method Criteria for Explosives by USEPA SW-846 8330 and 8332

| Procedure | Frequency of QC Procedure | Acceptance Criteria | | Corrective Action |
|---|---|---|---|---|
| Initial Calibration Curve<br>5-pt curve (linear)<br>6-pt curve (2o order) | Set-up, major maintenance, or for drift correction for each column used for analysis | %RSD <20% or r>0.995 (linear) or r2>0.99 (2o order) | | Sample analysis cannot begin until this criterion is met. |
| Initial Calibration Verification | Immediately following every initial calibration | A second source full compliment of target list with a percent recovery = 80-120% | | Sample analysis cannot begin until this criterion is met. |
| Continuing Calibration Check | Every ten samples or twelve hours | %D ± 15% of the response factor from the initial curve. The mean may be used as long as no individual target exceeds 30%D | | Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria. |
| Method Blank | 1 per batch | No target analytes detected greater than one half of the RL | | Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination. |
| Laboratory Control Spike | 1 per batch | Standards<br>Full compliment target list | Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM | Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate. |
| Surrogate Spikes | Every sample | Standards<br>A similar compound that is not expected to be found at the site | Laboratory generated control limits not to exceed limits listed in the current version of the DOD QSM | If surrogate compounds do not meet criteria, there should be a re-extraction and re-analysis to confirm that the non-compliance is due to the sample matrix effects rather than laboratory deficiencies. |
| Matrix Spike and Duplicate | 1 per 20 samples per matrix | Standards<br>Full compliment target list | Laboratory generated control limits not to exceed recovery limits listed in the current version of the DOD QSM | If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. |
| Target Analyte Confirmation | Every positive detection | RPD $\leq$ 40% | | Report the higher of the two concentrations unless a positive bias is apparent and qualify. |

## Table 2-17
## Quality Control Method Criteria for Target Analyte List Metals by USEPA SW-846 6020/ 6010B/7471A/ 7470A/ 9010C/ 9012A

| Procedure | Frequency of QC Procedure | Acceptance Criteria | | Corrective Action |
|---|---|---|---|---|
| Tune (MS) | Daily | Analyzed a minimum of four times with RSD < 5% for analytes in the solution. | | Sample analysis cannot begin until this criterion is met. |
| Mass Calibration (MS) | Daily | Difference < 0.1 amu from true value. | | Adjust to the correct value. |
| Resolution Check (MS) | Daily | Peak width <0.9 amu at 10% peak height | | Sample analysis cannot begin until this criterion is met. |
| Initial Calibration Curve<br>(MS, ICP, Hg, & CN) | Daily, major maintenance, or to correct drift. | MS & ICP Option 1: 1-standard and a blank with a low level standard at RL. | Low level check standard ± 20%. | The standards for that element must be re-prepared and re-analyzed again. |
| | | MS & ICP Option 2: 3-standards and a blank | r > 0.995 for each element | |
| | | Hg – 5-standards and a blank | r > 0.995 | |
| | | CN – 6 standards and a blank | r > 0.995 | |
| Distilled Standards (CN) | Once per calibration | One high and one low distilled standard within ± 10% of the true value | | Sample analysis cannot begin until this criterion is met. |
| Initial Calibration Verification (MS, ICP, Hg, & CN) | Immediately following initial calibration. | MS & ICP - A second source full compliment of target list with a percent recovery = 90-110% | | Sample analysis cannot begin until this criterion is met. |
| | | Hg – A second source full compliment of target list with a percent recovery = 80-120% | | |
| | | CN - A second source full compliment of target list with a percent recovery = 85-115% | | |
| Initial Calibration Blank (MS, ICP, Hg, & CN) | Immediately following initial calibration verification. | No target analytes detected at concentration above 2 X MDL. | | Sample analysis cannot proceed until this criterion is met. |
| Interference Check (MS & ICP) | Beginning of each sample analytical run. | Recovery ±20% of true value. | | Terminate the analysis, correct the problem, re-calibrate, re-verify the calibration, and reanalyze associated samples. |
| Continuing Calibration Check (MS, ICP, Hg, & CN) | Every 10 samples and end of analytical run. | MS & ICP - Recovery ±10%. | | Reanalyze; if the CCV fails again, stop analysis, the problem corrected, the instrument recalibrated, and the calibration re-verified prior to continuing sample analyses. |
| | | Hg - Recovery ±20%. | | |
| | | CN - Recovery ±15%. | | |
| Continuing Calibration Blank (MS, ICP, Hg, & CN) | Every 10 samples and end of analytical run. | No target analytes detected at concentration above 2 X MDL. | | Sample sequence should not continue until this criterion is met. Demonstrate "clean". Affected samples will be reanalyzed. |
| Preparation Blank (MS, ICP, Hg, & CN) | 1 per batch per matrix | No target analytes detected at concentration above one half of the RL. | | Document source of contamination. Re-digestion/re-analysis is required for positive results associated with blank contamination, unless DQOs are still met. |

## Table 2-17 (Continued)
## Quality Control Method Criteria for Target Analyte List Metals by USEPA SW-846 6020/ 6010B/7471A/ 7470A/ 9010C/ 9012A

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

## Table 2-18
## Quality Control Method Criteria for Pesticides, Herbicides, and PCBs by USEPA SW-846 8081A, 8082, and 8151A

| Procedure | Frequency of QC Procedure | Acceptance Criteria | | Corrective Action |
|---|---|---|---|---|
| Initial calibration curve<br>5-pt curve (linear)<br>6-pt curve (2o order) | Set-up, major maintenance | %RSD<20% or r>0.995 (linear) or r2>0.99 (2o order) | | Sample analysis cannot begin until this criterion is met. |
| Initial Calibration Verification | Immediately following every initial calibration | A second source full compliment of target list with a percent recovery = 85-115% | | Sample analysis cannot begin until this criterion is met. |
| Continuing Calibration Check | Bracketing samples | %D recovery ± 15% of the response factor from the initial curve or mean with no individual peak >30% | | Sample analysis cannot begin until this criterion is met. If criteria are not met, reanalyze the daily standard. If the daily standard fails a second time, initial calibration must be repeated. Data reviewer should review and judge each target compound against the acceptance criteria. |
| Endrin/4,4-DDT Breakdown | Bracketing samples | endrin degradation ≤15%.<br>4,4-DDT degradation ≤15%. | | If criterion is not met, system must be deactivated and the affected samples reanalyzed. |
| Instrument Blank | After continuing calibration and highly contaminated samples. | No target analytes detected greater than one half the RL. | | Demonstrate "clean". Affected samples will be reanalyzed. |
| Method Blank | Per extraction batch | No target analytes detected greater than one half the RL. | | Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination. |
| Laboratory Control Spike | Per extraction batch | <u>Standards</u><br>Full target list for 8081A and a mix of 1016 & 1260 for 8082 | Laboratory generated control limits not to exceed limits listed in the current version of DOD QSM | Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate. |
| Surrogate Spikes | Every sample | <u>Standards</u><br>TCMX and DCB | Laboratory generated control limits not to exceed limits listed in the current version of DOD QSM | Investigate to assess cause, correct the problem, and document actions taken; re-extract and re-analyze sample. Specific method cleanups may be used to eliminate or minimize sample matrix effects. If still out, qualify. |

## Table 2-18 (Continued)
## Quality Control Method Criteria for Pesticides, Herbicides, and PCBs by USEPA SW-846 8081A, 8082, and 8151A

| Procedure | Frequency of QC Procedure | Acceptance Criteria | | Corrective Action |
|---|---|---|---|---|
| Matrix Spike and Duplicate | 1 per 20 samples per matrix | Standards<br>Full target list for 8081A and a mix of 1016 & 1260 for 8082 | Laboratory generated control limits not to exceed limits listed in the current version of DOD QSM | If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. Specific method cleanups may be used to eliminate or minimize sample matrix effects. |
| Target Analyte Confirmation | Every positive detection | RPD $\leq$ 40% | | Report the higher of the two concentrations unless a positive bias is apparent and qualify. |

## Table 2-19
## Quality Control Method Criteria for Total Organic Carbon by Walkley-Black Method (Argonomy, Methods of Soil Analysis 29-3.5.2)

| Procedure | Frequency of QC Procedure | Acceptance Criteria | Corrective Action |
|---|---|---|---|
| Calibration (Titration Method) | Before Processing Samples a titration blank must be analyzed | 0.5+/- 0.05N | If the titrant normality is not within the QC limit, clean the burette and remake the titrant solution and/or the 1N K2Cr2O7. |
| Laboratory Duplicate | 1 per 20 samples or batch per matrix | RPD = 20% | If the RPD is out side the QC limit, it should be noted in the lab narrative. |
| Method Blank | 1 per 20 samples or batch per matrix | No target analytes detected greater than the RL. | Document source of contamination. Re-extraction/re-analysis is required for positive results associated with blank contamination. |
| Laboratory Control Sample | 1 per 20 samples per matrix | Laboratory generated control limits not to exceed recovery limits of 64-128% | Recoveries indicating a low bias require a re-extraction/reanalysis. Recoveries indicating a high bias require a re-extraction/re-analysis for associated positive field samples. Qualify associated data biased high or biased low as appropriate. |
| Matrix Spike and Duplicate | 1 per 20 samples per batch, per matrix | Laboratory generated control limits not to exceed recovery limits of 68-142% | If MS/MSD results do not meet criteria, the reviewer should review the data in conjunction with other QC results to identify whether the problem is specific to the QC samples or systematic. |

## Table 2-20
## Quality Control Method Criteria for Chemical Oxygen Demand by USEPA Method of Chemical Analysis for Water and Wastes 410.4

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

## 2.7 DATA COLLECTION AND VALIDATION

Non-CLP SW-846 Test Methods are proposed for analytical work for this WPA and analyses will be conducted by a National Environmental Laboratory Accreditation Program (NELAP) accredited analytical laboratory. Level IV CLP-like raw data will be provided along with the Form 1. Additional discussion as to the laboratory deliverables may be found in Section 9.8.3 of the MQAP. Data will be made available to the USEPA upon request and presented in the RFI Report.

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

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

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

# 3.0 HEALTH AND SAFETY PLAN ADDENDUM

## 3.1 INTRODUCTION

This site-specific HSPA was developed to provide the requirements for protection of site personnel, including government employees, URS personnel, regulators, subcontractors, and visitors, that are expected to be involved with soil boring advancement/sampling at SWMU 57.

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

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

**Table 3-1**
**Health and Safety Issues Discussed in the MHSP**

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

URS, subcontractor personnel, and site visitors will read this HSPA and will be required to follow its protocols as minimum standards. This HSPA is written for the site-specific conditions at SWMU 57 and must be amended if conditions change. A copy of this HSPA will be available at the work site.

The contractor will provide a safe work environment for personnel involved in RFAAP investigative activities. The contractor will emphasize the importance of personnel injury and illness prevention at the work site.

## 3.2 TRAINING PLAN

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

Site personnel will be informed of the specific PPE that will be worn during field activities. This includes, at a minimum, steel-toed boots, safety glasses (with side shields), gloves, and hardhat. Each field person will also have a respirator on the site, in the event that an emergency occurs and a respirator is necessary for site evacuation, or if the use of a respirator is necessary based on air monitoring results. Prior to initiation of fieldwork, the staff will be required to review the manual *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2005). Additional training, which will be conducted during daily safety "tailgate" meetings, will include emergency and evacuation procedures, general safety rules, and use of automobiles. Written documentation of safety briefings will be kept on the site.

### 3.2.1 Hazard Information Training

Hazard information training will be presented to URS and subcontractor personnel to provide a description of the Hazardous, Toxic, and Radioactive Waste (HTRW) with the potential to be found at SWMU 57. Training will also be provided on the potential biological, chemical, and physical hazards to be found at the Installation. The URS SHSO will conduct this training based on information provided by the operating contractor.

### 3.2.2 Project-Specific Hazard Analysis

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

(1) Physical Hazards

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

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

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

(3) Chemical Hazards

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

### 3.2.3 Hearing Conservation Training

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

### 3.2.4 Hazard Communication Training

In order to comply with the requirements of the OSHA Hazard Communication (HAZCOM) Standard, 29 CFR 1910.1200, URS will have a written HAZCOM Program in place. The written hazard communication program addresses training (including potential safety and health effects from exposure), labeling, current inventory of hazardous chemicals on the site, and the location and use of Material Safety Data Sheets (MSDSs). The SHSO will arrange HAZCOM training for site personnel at the time of initial site assignment. Whenever a new hazardous substance is introduced into the work area or an employee changes job locations where new chemicals are encountered, supplemental HAZCOM training shall be scheduled and presented. HAZCOM training shall be documented by the SHSO using a HAZCOM Employee Training Record. This documentation and the URS HAZCOM Program will be maintained on the site for the duration of the project, and later incorporated in the employees' personal training file.

### 3.2.5 Confined Space Entry Training

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

## 3.3 PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

The minimum and initial level of PPE for these activities will be Level D. The initial selection of PPE is based on a hazard assessment, including the review of existing analytical data and related toxicological information with respect to the proposed field activities. PPE assignments are subject to change based upon site conditions and task variation. The SHSO will review the required level of protection and safety equipment for each task with the sampling crew. The decisions on which protective level is most appropriate will be made by the SHSO.

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

## 3.4 MONITORING PLAN

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

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

### 3.5 EMERGENCY RESPONSE PLAN

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

**Table 3-2**
**Emergency Telephone Numbers**

| Contact | Telephone Number |
|---|---|
| | |
| **Emergency Response Services** | |
| Installation Fire Department** | 16 (on post) |
| Installation Security Police** | 7325 (on post)<br>(540) 639-7325 (off post) |
| Installation Safety Department** | 7294 (on post)<br>(540) 639-7294 (off post) |
| Installation Spill Response** | 7323, 7324 or 7325 (on post)<br>(540) 639-7323, 7324, or 7325 (off post) |
| Installation Medical Facility**<br>(RFAAP Hospital) | 7323 or 7325 (on post)<br>(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:**<br><br>New River Valley Medical Center<br>2900 Lamb Circle<br>Christiansburg, VA 24073<br><br>Take Route 114 toward Radford to first traffic light. Take U.S. Route 11 South and go across the bridge over the New River. Turn left after crossing the bridge, continue 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.<br><br>** These telephone numbers are referenced from *Safety, Security and Environmental Rules for Contractors and Subcontractors* (ATK 2005). | |

## 4.0 REFERENCES


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**WORK PLAN ADDENDUM 021**

**RCRA FACILITY INVESTIGATION AT SOLID WASTE MANAGEMENT UNIT 57**

**RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA**

**FINAL OCTOBER 2007**

URS

**CONTRACT NO. W9128F-04-D-001 DELIVERY ORDER NO. DA03**

**WORK PLAN ADDENDUM 021**

**RCRA FACILITY INVESTIGATION AT SOLID WASTE MANAGEMENT UNIT 57**

**RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA**

**FINAL OCTOBER 2007**

URS

**CONTRACT NO. W9128F-04-D-001 DELIVERY ORDER NO. DA03**

**WORK PLAN ADDENDUM 021**

**RCRA FACILITY INVESTIGATION AT SOLID WASTE MANAGEMENT UNIT 57**

**RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA**

**FINAL OCTOBER 2007**

URS

**CONTRACT NO. W9128F-04-D-001 DELIVERY ORDER NO. DA03**

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**RCRA FACILITY INVESTIGATION AT SOLID WASTE MANAGEMENT UNIT 57**

**RADFORD ARMY AMMUNITION PLANT RADFORD, VIRGINIA**

**FINAL OCTOBER 2007**

URS

**CONTRACT NO. W9128F-04-D-001 DELIVERY ORDER NO. DA03**

# APPENDIX A

# STANDARD OPERATING PROCEDURES

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# Standard Operating Procedures

| SOP SERIES | TITLE |
|---|---|
| **10.0** | **DOCUMENTATION** |
| 10.1 | Field Logbook |
| 10.2 | Surface Water, Groundwater, and Soil/Sediment Field Logbooks |
| 10.3 | Boring Logs |
| 10.4 | Chain-of-Custody Forms |
| **20.0** | **SUBSURFACE INVESTIGATION** |
| 20.1 | Monitoring Well Installation |
| 20.2 | Monitoring Well Development |
| 20.3 | Well and Boring Abandonment |
| 20.11 | Drilling Methods and Procedures |
| **30.0** | **SAMPLING** |
| 30.1 | Soil Sampling |
| 30.2 | Groundwater Sampling |
| 30.7 | Sampling Strategies |
| 30.9 | Collection of Soil Samples By USEPA SW-846 Method 5035 Using Disposable Samplers |
| **40.0** | **FIELD EVALUATION** |
| 40.1 | Multiparameter Water Quality Monitoring Instrument |
| 40.2 | Water Level and Well-Depth Measurements |
| 40.3 | Slug Tests |
| **50.0** | **SAMPLE MANAGEMENT** |
| 50.1 | Sample Labels |
| 50.2 | Sample Packaging |
| **70.0** | **INVESTIGATION-DERIVED MATERIAL** |
| 70.1 | Investigation-Derived Material |
| **80.0** | **DECONTAMINATION** |
| 80.1 | Decontamination |
| **90.0** | **AIR MONITORING EQUIPMENT** |
| 90.1 | Photoionization Detector (HNu Model PI-101 and HW-101) |

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# STANDARD OPERATING PROCEDURE 10.1
# FIELD LOGBOOK

## 1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording daily site investigation activities.

Records should contain sufficient information so that anyone can reconstruct the sampling activity without relying on the collector's memory.

## 2.0 MATERIALS

- Field Logbook;
- Indelible ink pen; and
- Clear tape.

## 3.0 PROCEDURE

Information pertinent to site investigations will be recorded in a bound logbook. Each page/form will be consecutively numbered, dated, and signed. All entries will be made in indelible ink, and all corrections will consist of line out deletions that are initialed and dated. If only part of a page is used, the remainder of the page should have an "X" drawn across it. At a minimum, entries in the logbook will include but not be limited to the following:

- Project name (cover);
- Name and affiliation of personnel on site;
- Weather conditions;
- General description of the field activity;
- Sample location;
- Sample identification number;
- Time and date of sample collection;
- Specific sample attributes (e.g., sample collection depth flow conditions or matrix);
- Sampling methodology (grab or composite sample);
- Sample preservation, as applicable;
- Analytical request/methods;
- Associated quality assurance/quality control (QA/QC) samples;
- Field measurements/observations, as applicable; and
- Signature and date of personnel responsible for documentation.

## 4.0 MAINTENANCE

Not applicable.

## 5.0 PRECAUTIONS

None.

## 6.0 REFERENCES

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# STANDARD OPERATING PROCEDURE 10.2
# SURFACE WATER, GROUNDWATER, AND SOIL/SEDIMENT FIELD LOGBOOKS

## 1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for recording surface water, groundwater, and soil/sediment sampling information, as well as instrument calibration data in field logbooks.

## 2.0 MATERIAL

- Applicable field logbook (see attached forms); and
- Indelible ink pen.

## 3.0 PROCEDURE

All information pertinent to surface water, groundwater, or soil/sediment sampling will be recorded in the appropriate logbook. Each page/form of the logbook will be consecutively numbered. All entries will be made with an indelible ink pen. All corrections will consist of line out deletions that are initialed and dated.

### 3.1 SOIL/SEDIMENT

#### 3.1.1 Field Parameters/Logbook (Form 10.2-a)

1. HIGH CONCENTRATION EXPECTED?: Answer “Yes” or “No.”;
2. HIGH HAZARD?: Answer “Yes” or “No.”;
3. INSTALLATION/SITE: Record the complete name of the installation or site;
4. AREA: Record the area designation of the sample site;
5. INST. NAME: Record the two-letter installation name for Radford Army Ammunition Plant – “RD”;
6. SAMPLE MATRIX CODE: Record the appropriate sample matrix code. Common codes are “SD” for solid - sediment, “SI” for soil - gas, “SL for solid sludge, “SO” for surface other, “SS” for solid – soil, “SW” for surface wipe, “WD” for water – potable, “WG” for water – ground, “WS” water – surface, “WT” – water treated and “WW” water -waste;
7. SITE ID: Record a code up to 20 characters or numbers that is unique to the site;
8. ENV. FIELD SAMPLE IDENTIFIER: Record a code up to 20 characters specific for the sample;
9. DATE: Enter the date the sample was taken;
10. TIME: Enter the time (12-hour or 24-hour clock acceptable as long as internally consistent) the sample was taken;
11. AM PM: Circle “AM” or “PM” to designate morning or afternoon (12-hour clock);
12. SAMPLE PROG: Record “RFI” (RCRA Facility Investigation) or other appropriate sample program;
13. DEPTH (TOP): Record the total depth sampled;
14. DEPTH INTERVAL: Record the intervals at which the plug will be sampled;

15. UNITS: Record the units of depth (feet, meters);
16. SAMPLE MEASUREMENTS: Check the appropriate sampling method;
17. CHK: Check off each container released to a laboratory;
18. ANALYSIS: Record the type of analysis to be performed on each sample container;
19. SAMPLE CONTAINER: Record the sample container type and size;
20. NO.: Record the number of containers;
21. REMARKS: Record any remarks about the sample;
22. TOTAL NUMBER OF CONTAINERS FOR SAMPLE: Record the total number of containers;
23. SITE DESCRIPTION: Describe the location where the sample was collected;
24. SAMPLE FORM: Record the form of the sample (i.e., clay, loam, etc.) using The Unified Soil Classification System (USCS);
25. COLOR: Record the color of the sample as determined from standard Munsell Color Charts;
26. ODOR: Record the odor of the sample or "none";
27. PID: Record the measured PID values or other similar measurement instrument value;
28. UNUSUAL FEATURES: Record anything unusual about the site or sample;
29. WEATHER/TEMPERATURE: Record the weather and temperature; and
30. SAMPLER: Record your name.

#### 3.1.2 Map File Form (refer to form 10.2-c)

1. SITE ID: Record the Site ID from the field parameter form;
2. POINTER: Record the field sample number for the sample being pointed to;
3. DESCRIPTION/MEASUREMENTS: Describe the location where the sample was taken, along with distances to landmarks;
4. SKETCH/DIMENSIONS: Diagram the surroundings and record the distances to landmarks;
5. MAP REFERENCE: Record which U.S.G.S. Quad Map references the site;
6. COORDINATE DEFINITION: Write the compass directions and the X- and Y-coordinates of the map run;
7. COORDINATE SYSTEM: Write "UTM" (Universal Transverse Mercator);
8. SOURCE: Record the 1-digit code representing the Map Reference;
9. ACCURACY: Give units (e.g., write "1-M" for 1 meter);
10. X-COORDINATE: Record the X-coordinate of the sample site location;
11. Y-COORDINATE: Record the Y-coordinate of the sample site location;
12. UNITS: Record the units used to measure the map sections;
13. ELEVATION REFERENCE: Record whether topography was determined from a map or a topographical survey;
14. ELEVATION SOURCE: Record the 1-digit code representing the elevation reference;

15. ACCURACY: Record the accuracy of the map or survey providing the topographical information;
16. ELEVATION: Record the elevation of the sampling site;
17. UNITS: Write the units in which the elevation is recorded; and
18. SAMPLER: Write your name.

## 3.2 SURFACE WATER

### 3.2.1 Field Parameter Logbook (Forms 10.2-b and 10.2-c)

1. CAL REF: Record the calibration reference for the pH meter;
2. pH: Record the pH of the sample;
3. TEMP: Record the temperature of the sample in degrees Celsius;
4. COND: Record the conductivity of the water;
5. Description of site and sample conditions (refer to 10.2-b);
6. Map File Form (refer to Section 3.1.2).

## 3.3 GROUNDWATER (FORMS 10.2- D)

### 3.3.1 Field Parameter Logbook (Form 10.2.b)

Refer to Section 3.2.1.

### 3.3.2 Map File and Purging Forms

1. WELL NO. OR ID: Record the abbreviation appropriate for where the sample was taken. Correct abbreviations can be found on pages 18-21 of the IRDMIS User's Guide for chemical data entry;
2. SAMPLE NO.: Record the reference number of the sample;
3. WELL/SITE DESCRIPTION: Describe the location where the sample was taken, along with distances to landmarks;
4. X-COORD AND Y-COORD: Record the survey coordinates for the sampling site;
5. ELEV: Record the elevation where the sample was taken;
6. UNITS: Record the units the elevation was recorded in;
7. DATE: Record the date in the form MM/DD/YY;
8. TIME: Record the time, including a designation of AM or PM;
9. AIR TEMP.: Record the air temperature, including a designation of C or F (Celsius or Fahrenheit);
10. WELL DEPTH: Record the depth of the well in feet and inches;
11. CASING HEIGHT: Record the height of the casing in feet and inches;
12. WATER DEPTH: Record the depth (underground) of the water in feet and inches;
13. WELL DIAMETER: Record the diameter of the well in inches;
14. WATER COLUMN HEIGHT: Record the height of the water column in feet and inches;
15. SANDPACK DIAM.: Record the diameter of the sandpack. Generally, this will be the same as the bore diameter;

16. EQUIVALENT VOLUME OF STANDING WATER: Use one of the following equations to determine one equivalent volume (EV);

    1 EV = volume in casing + volume in saturated sandpack. Or:

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

Where:

$R_s$ = radius of sandpack in inches
$R_w$ = radius of well casing in inches
$h_s$ = height of sandpack in inches
$h_w$ = water depth in inches

$0.0043 = gal/in^3$
and filter pack porosity is assumed as 30%, or

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

Where:

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

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Wh)(0.30)

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

Vol. in sandpack =
(0.0043 gal/in3)(p)(12 in/ft)(Rb2 - Rc2)(Sh)(0.30)

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

where:

Rb = radius of the borehole, and
Sh = length of the sandpack.

Show this calculation in the comments section.

1. PUMP RATE: Record pump rate;
2. TOTAL PUMP TIME: Record total purge time and volume;
3. WELL WENT DRY? Write “YES” or “NO”;
4. PUMP TIME: Record pump time that made the well go dry;
5. VOLUME REMOVED: Record the volume of water (gal) removed before the well went dry;
6. RECOVERY TIME: Record the time required for the well to refill;

7. PURGE AGAIN?: Answer “YES” or “NO”;
8. TOTAL VOL. REMOVED: Record the total volume of water (in gallons) removed from the well;
9. CAL REF.: Record the calibration reference for the pH meter;
10. TIME: Record time started (INITIAL T(0)), 2 times DURING the sampling and the time sampling ended (FINAL);
11. pH: Record the pH at start of sampling (INITIAL), twice DURING the sampling, and at the end of sampling (FINAL);
12. TEMP: Record the water temperature (Celsius) at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
13. COND: Record the conductivity of the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
14. D.O.: Record the dissolved oxygen level in the water at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
15. TURBIDITY: Record the readings from the turbidity meter (nephelometer) and units at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
16. ORD: Record the oxidation/reduction (RedOx) potential of the water sample at the start of sampling, twice DURING the sampling, and at the end of sampling (FINAL);
17. HEAD SPACE: Record any positive readings from organic vapor meter reading taken in well headspace before sampling;
18. NAPL: Record the presence and thickness of any non-aqueous phase liquids (LNAPL and DNAPL)
19. COMMENTS: Record any pertinent information not already covered in the form; and
20. SIGNATURE: Sign the form.

### 3.4 FIELD CALIBRATION FORMS (REFER TO FORM 10.2-E)

1. Record time and date of calibration;
2. Record calibration standard reference number;
3. Record meter ID number;
4. Record initial instrument reading, recalibration reading (if necessary), and final calibration reading on appropriate line;
5. Record value of reference standard (as required);
6. COMMENTS: Record any pertinent information not already covered on form; and
7. SIGNATURE: Sign form.

## 4.0 MAINTENANCE

Not applicable.

## 5.0 PRECAUTIONS

None.

## 6.0 REFERENCE

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

**FIELD PARAMETER/LOGBOOK FORM 10.2-a**
**SOIL AND SEDIMENT SAMPLES**

---

HIGH CONCENTRATION EXPECTED? ____________________ HIGH HAZARD?

---

INSTALLATION/SITE ___________________________________________ AREA ____________________

INST NAME ___________ FILE NAME ____________________________________________

SAMPLE MATRIX CODE _____________ SITE ID ______________________
ENV. FIELD SAMPLE IDENTIFIER ____________________

DATE (MM/DD/YY) __/__/__ TIME ___________ AM PM SAMPLE PROGRAM

DEPTH (TOP) _______ DEPTH INTERVAL _______________ UNIT ______________

SAMPLING METHOD:

SPLIT SPOON ___ AUGER ___ SHELBY TUBE ___ SCOOP ___ OTHER

---

| CHK | ANALYSIS | SAMPLE CONTAINER | NO. | REMARKS |
|---|---|---|---|---|

TOTAL NUMBER OF CONTAINERS FOR SAMPLE______

---

**DESCRIPTION OF SITE AND SAMPLE CONDITIONS**

SITE DESCRIPTION:____________________________________________________________________

SAMPLE FORM _______________________ COLOR ________________ ODOR ______________

PID (HNu)______________________ UNUSUAL FEATURES________________________

WEATHER/TEMPERATURE

SAMPLER ____________________

**FIELD PARAMETER/LOGBOOK FORM 10.2-b**
**GROUNDWATER AND SURFACE WATER SAMPLES**

---

HIGH CONCENTRATION EXPECTED? _________________ HIGH HAZARD?

---

INSTALLATION/SITE _______________________ AREA

INST CODE ___________ FILE NAME ______________________ SITE TYPE

SITE ID ____________________ FIELD SAMPLE NUMBER

DATE (MM/DD/YY) __/__/__ TIME ___________ AM PM SAMPLE PROG.

DEPTH (TOP) __________ DEPTH INTERVAL ____________ UNITS

---

**SAMPLING MEASUREMENTS**

CAL REF. _____ pH _____ TEMPERATURE °C _____ CONDUCTIVITY _____ REDOX _____

DISSOLVED OXYGEN ____ TURBIDITY _____ OTHER

---

| CHK | ANALYSIS | SAMPLE CONTAINER | NO. | REMARKS |
|---|---|---|---|---|

TOTAL NUMBER OF CONTAINERS FOR SAMPLE______

---

**DESCRIPTION OF SITE AND SAMPLE CONDITIONS**

SITE DESCRIPTION______________________________________________________________

SAMPLING METHOD________________________________________

SAMPLE FORM ___________________ COLOR _________ ODOR ________

PID (HNu)___________________________________________

UNUSUAL FEATURES_______________________________

WEATHER/TEMPERATURE____________________________________________ SAMPLER _________________

**EXAMPLE MAP FILE LOGBOOK FORM 10.2-c**
**SURFACE WATER, SOIL, AND SEDIMENT SAMPLES**

---

SITE ID___________________________ POINTER____________________

DESCRIPTION/MEASUREMENTS_________________________________________________________________

SKETCH/DIMENSIONS :

MAP REFERENCE__________________________________________

COORDINATE DEFINITION (X is _________________ Y is ____________)

COORDINATE SYSTEM ________________ SOURCE ________________ ACCURACY____________________

X-COORDINATE ____________ Y-COORDINATE ____________ UNITS__________

ELEVATION REFERENCE____________________________________

ELEVATION SOURCE _________________ ACCURACY _______________ELEVATION___________________

UNITS________________

SAMPLER__________

**EXAMPLE MAP FILE AND PURGING LOGBOOK FORM 10.2-d**
**GROUNDWATER SAMPLES**

---

WELL COORD. OR ID ________________________ SAMPLE NO.______________

WELL/SITE DESCRIPTION__________________________________________________________________

______________________________________________________________________________________

X-COORD. ________ Y-COORD. _______________ ELEV. __________ UNITS

DATE ____/____/____ TIME __________________ AIR TEMP.

---

WELL DEPTH ______________ FT. ______ IN. CASING HT. _____ FT. _____ IN.

WATER DEPTH _______ FT. ______ IN. WELL DIAMETER _________ IN.

WATER COLUMN HEIGHT ________ FT. ______ IN. SANDPACK DIAM. _____ IN.

EQUIVALENT VOLUME OF STANDING WATER ________________ (GAL) (L)

VOLUME OF BAILER ________ (GAL) (L) or PUMP RATE __________ (GPM) (LPM)

TOTAL NO. OF BAILERS (5 EV) __________ or PUMP TIME _________ MIN.

WELL WENT DRY? [Yes] [No] NUM. OF BAILERS ________ or PUMP TIME

VOL. REMOVED ______________ (GAL) (L) RECOVERY TIME

PURGE AGAIN? [Yes] [No] TOTAL VOL. REMOVED ___________ (GAL) (L)

| DATE & TIME | QUANTITY REMOVED | TIME REQ'D | pH | Cond | Temp | ORD | Turb | DO | Character of water (color / clarity / odor / partic.) |
|---|---|---|---|---|---|---|---|---|---|
| (before) | | | | | | | | | |
| (during) | | | | | | | | | |
| (during) | | | | | | | | | |
| (during | | | | | | | | | |
| (after) | | | | | | | | | |

COMMENTS_______________________________________________________________________

SIGNATURE___________________________________________

**EXAMPLE FIELD CALIBRATION FORM 10.2-e**
**FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY,**
**ORD, AND DISSOLVED OXYGEN METERS**

| INITIAL CALIBRATION | FINAL CALIBRATION |
|---|---|
| DATE: | DATE: |
| TIME: | TIME: |

**pH METER CALIBRATION**

CALIBRATION STANDARD REFERENCE NO:_________________

METER ID____________________

| pH STANDARD | INITIAL READING | RECALIB. READING | FINAL READING |
|---|---|---|---|
| 7.0 | | | |
| 10.0 | | | |
| 4.0 | | | |

**CONDUCTIVITY METER CALIBRATION**

CALIBRATION STANDARD REFERENCE NO:_________________

METER ID____________________

| COND. STANDARD | INITIAL READING | RECALIB. READING | FINAL READING |
|---|---|---|---|
| | | | |
| | | | |

**TEMPERATURE METER CALIBRATION**

METER ID____________________

| TEMP. STANDARD | INITIAL READING | RECALIB. READING | FINAL READING |
|---|---|---|---|
| ICE WATER | | | |
| BOILING WATER | | | |
| OTHER _________ | | | |

**EXAMPLE FIELD CALIBRATION FORM 10.2-e**
**FOR pH, CONDUCTIVITY, TEMPERATURE, TURBIDITY,**
**ORD, AND DISSOLVED OXYGEN METERS**

## TURBIDITY METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:_________________

METER ID____________________

| STANDARD | INITIAL READING | RECALIB. READING | FINAL READING |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## ORD METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:_________________

METER ID____________________

| STANDARD | INITIAL READING | RECALIB. READING | FINAL READING |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

## DISSOLVED OXYGEN METER CALIBRATION

CALIBRATION STANDARD REFERENCE NO:_________________

METER ID____________________

| STANDARD | INITIAL READING | RECALIB. READING | FINAL READING |
|---|---|---|---|
| | | | |
| | | | |
| | | | |

COMMENTS______________________________________________________________________________

SIGNATURE______________________________________

# STANDARD OPERATING PROCEDURE 10.3
# BORING LOGS

## 1.0 INTRODUCTION

The purpose of this standard operating procedure (SOP) is to describe the methods to be followed for classifying soil and rock, as well as preparing borehole logs and other types of soil reports.

## 2.0 MATERIALS

The following equipment is required for borehole logging:

- HTRW ENG Form 5056-R and 5056A-R boring log forms;
- Daily inspection report forms;
- Chain-of-custody forms;
- Request for analysis forms;
- ASTM D 2488 classification flow chart;
- Soil and/or Rock color chart (i.e., Munsell®);
- Grain size and roundness chart;
- Graph paper;
- Engineer's scale;
- Previous reports and boring logs;
- Pocketknife or putty knife;
- Hand lens;
- Dilute hydrochloric acid (10% volume);
- Gloves;
- Personal protective clothing and equipment, as described in work plan addenda health and safety plan;
- Photoionization detector or other appropriate monitoring equipment per site-specific health and safety plan; and
- Decontamination supplies (SOP 80.1).

## 3.0 PROCEDURE

Each boring log should fully describe the subsurface environment and the procedures used to obtain this description.

Boring logs should be prepared in the field on USACE Engineer Form 5056-R and 5056-R. Logs should be recorded in the field directly on the boring log form and not transcribed from a field book.

A "site geologist" should conduct borehole logging and soil/rock identification and description or other professional trained in the identification and description of soil/rock.

### 3.1 BORING LOG INFORMATION

As appropriate, the following information should be recorded on the boring log during the course of drilling and sampling activities:

- Project information including name, location, and project number;
- Each boring and well should be uniquely numbered and located on a sketch map as part of the log;
- Type of exploration;
- Weather conditions including events that could affect subsurface conditions;
- Dates and times for the start and completion of borings, with notations by depth for crew shifts and individual days;
- Depths/heights in feet and in decimal fractions of feet;
- Descriptions of the drilling equipment including rod size, bit type, pump type, rig manufacturer and model, and drilling personnel;
- Drilling sequence and descriptions of casing and method of installation;
- Description and identification of soils in accordance with ASTM Standard D 2488;
- Descriptions of each intact soil sample for the parameters identified in Section 3.2;
- Descriptions and classification of each non-intact sample (e.g., wash samples, cuttings, auger flight samples) to the extent practicable;
- Description and identification of rock;
- Description of rock (core(s)) for the parameters identified in Section 3.7;
- Scaled graphic sketch of the rock core (included or attached to log) according to the requirements identified in Section 3.7;
- Lithologic boundaries, with notations for estimated boundaries;
- Depth of water first encountered in drilling, with the method of first determination (any distinct water level(s) below the first zone will also be noted);
- Interval by depth for each sample taken, classified, and/or retained, with length of sample recovery and sample type and size (diameter and length);
- Blow counts, hammer weight, and length of fall for driven samplers;
- Rate of rock coring and associated rock quality designation (RQD) for intervals cored;
- Drilling fluid pressures, with driller's comments;
- Total depth of drilling and sampling;
- Drilling fluid losses and gains should be recorded;
- Significant color changes in the drilling fluid returned;
- Soil gas or vapor readings with the interval sampled, with information on instrument used and calibration;

- Depth and description of any in-situ test performed; and
- Description of other field tests conducted on soil and rock samples.

### 3.2 SOIL PARAMETERS FOR LOGGING

In general, the following soil parameters should be included on the boring log when appropriate:

- Identification per ASTM D 2488 with group symbol;
- Secondary components with estimated percentages per ASTM D 2488;
- Color;
- Plasticity per ASTM D 2488;
- Density of non-cohesive soil or consistency of cohesive soil;
- Moisture condition per ASTM D 2488 (dry, moist, or wet);
- Presence of organic material;
- Cementation and HCL reaction testing per ASTM D 2488;
- Coarse-grained particle description per ASTM D 2488 including angularity, shapes, and color;
- Structure per ASTM D 2488 and orientation;
- Odor; and
- Depositional environment and formation, if known.

ASTM D 2488 categorizes soils into 13 basic groups with distinct geologic and engineering properties based on visual-manual identification procedures. The following steps are required to classify a soil sample:

1. Observe basic properties and characteristics of the soil. These include grain size grading and distribution, and influence of moisture on fine-grained soil.
2. Assign the soil an ASTM D 2488 classification and denote it by the standard group name and symbol.
3. Provide a written description to differentiate between soils in the same group if necessary.

Many soils have characteristics that are not clearly associated with a specific soil group. These soils might be near the borderline between groups, based on particle distribution or plasticity characteristics. In such a case, assigning dual group names and symbols (e.g., GW/GC or ML/CL) might be an appropriate method of describing the soil. The two general types of soils, for which classification is performed, coarse- and fine-grained soils, are discussed in the following sections.

### 3.3 COURSE-GRAINED SOIL IDENTIFICATION

For soils in the coarse-grained soils group, more than half of the material in the soil matrix will be retained by a No. 200 sieve (75-µm).

1. Coarse-grained soils are identified on the basis of the following:
   a) Grain size and distribution;
   b) Quantity of fine-grained material (i.e., silt and clay as a percentage); and

c) Character of fine-grained material.

2. The following symbols are used for classification:

| Basic Symbols | Modifying Symbols |
|---|---|
| G = gravel | W = well graded |
| S = sand | P = poorly graded |
| | M = with silty fines |
| | C = with clayey fines |

3. The following basic facts apply to coarse-grained soil classification.

- The basic symbol G is used if the estimated percentage of gravel is greater than that for sand. In contrast, the symbol S is used when the estimated percentage of sand is greater than the percentage of gravel.
- Gravel ranges in size from 3-inch to 1/4-inch (No. 4 sieve) diameter. Sand ranges in size from the No. 4 sieve to No. 200 sieve. The Grain Size Scale used by Engineers (ASTM Standard D 422-63) 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 millimeters thick |
| Laminated | Alternating layers of varying material or color with layers less than 6 millimeters thick |
| Fissured | Breaks along definite planes of fracture with little resistance |
| Slickensided | Fracture planes that appear polished or glossy, can be striated |
| Blocky | Inclusion of small pockets of different soils |
| Homogeneous | Same color and appearance throughout |

### 3.7 ROCK CORE PARAMETERS FOR LOGGING

In general, the following parameters should be included on the boring log when rock coring is conducted:

- Rock type;
- Formation;
- Modifier denoting variety;
- Bedding/banding characteristics;
- Color;
- Hardness;
- Degree of cementation;
- Texture;
- Structure and orientation;
- Degree of weathering;
- Solution or void conditions;
- Primary and secondary permeability including estimates and rationale; and
- Lost core interval and reason for loss.

A scaled graphic sketch of the core should provided on or attached to the log, denoting by depth, location, orientation, and nature (natural, coring-induced, or for fitting into core box) of all core breaks. Where fractures are too numerous to be shown individually, their location may be drawn as a zone.

The RQD values for each core interval (run) should be calculated and included on the boring log. The method of calculating the RQD is as follows per ASTM D 6032:

RQD = [Σ length of intact core pieces > 100 mm (4-inches)] x 100%/total core length.

### 3.8 PROCEDURES FOR ROCK CLASSIFICATION

For rock classification record mineralogy, texture, and structural features (e.g., biotite and quartz fine grains, foliated parallel to relict bedding oriented 15 to 20 degrees to core axis, joints coated with iron oxide). Describe the physical characteristics of the rock that are important for engineering considerations such as fracturing (including minimum, maximum, and most common and degree of spacing), hardness, and weathering.

1. The following is to be used as a guide for assessing fracturing:

| AEG Fracturing | Spacing |
|---|---|
| Crushed | up to 0.1 foot |
| Intense | 0.1–0.5 foot |
| Moderate | 0.5 foot–10 feet |
| Slight | 1.0 foot–3.0 feet |
| Massive | >3.0 feet |

2. Record hardness using the following guidelines:

| Hardness | Criteria |
|---|---|
| Soft | Reserved for plastic material |
| Friable | Easily crumbled by finger pressure |
| Low | Deeply gouged or carved with pocketknife |
| Moderate | Readily scratched with knife; scratch leaves heavy trace of dust |
| Hard | Difficult to scratch with knife; scratch produces little powder and is often faintly visible |
| Very Hard | Cannot be scratched with knife |

3. Describe weathering using the following guidelines:

| Weathering | Decomposition | Discoloration | Fracture Condition |
|---|---|---|---|
| Deep | Moderate to complete alteration of minerals feldspars altered to clay, etc. | Deep and thorough | All fractures extensively coated with oxides, carbonates, or clay |

| | | | |
|---|---|---|---|
| Moderate | Slight alteration of minerals, cleavage surface lusterless and stained | Moderate or localized and intense | Thin coatings or stains |
| Weak | No megascopic alteration of minerals | Slight and intermittent and localized | Few strains on fracture surfaces |
| Fresh | Unaltered, cleavage, surface glistening | | |

### 3.9 PROCEDURE FOR LOGGING REFUSE

The following procedure applies to the logging of subsurface samples composed of various materials in addition to soil as may be collected from a landfill or other waste disposal site.

1. Observe refuse as it is brought up by the hollow stem auger, bucket auger, or backhoe.

2. If necessary, place the refuse in a plastic bag to examine the sample.

3. Record observations according to the following criteria:

   - Composition (by relative volume), e.g., paper, wood, plastic, cloth, cement, or construction debris. Use such terms as "mostly" or "at least half." Do not use percentages;
   - Moisture condition: dry, moist, or wet;
   - State of decomposition: highly decomposed, moderately decomposed, slightly decomposed, etc.;
   - Color: obvious mottling and/or degree of mottling;
   - Texture: spongy, plastic (cohesive), friable;
   - Odor;
   - Combustible gas readings (measure down hole and at surface); and
   - Miscellaneous: dates of periodicals and newspapers, ability to read printed materials, degree of drilling effort (easy, difficult, and very difficult).

### 3.10 SUBMITTAL REQUIREMENTS

Each original boring log should be submitted to the Contracting Officer Representative (CRO) after completion of the boring. When a monitoring well will be installed in a boring, the boring log and well installation diagram should be submitted together.

## 4.0 MAINTENANCE

Not applicable.

## 5.0 PRECAUTIONS

Not applicable.

## 6.0 REFERENCES

ASTM Standard D 422-63 (2002)e1. 2002. *Standard Test Method for Particle-Size Analysis of Soils.*

ASTM Standard D 1586–99 (1999). 1999. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 2488-06. 2006. *Standard Practice for Description and Identification of Soils Visual-Manual Procedure).*

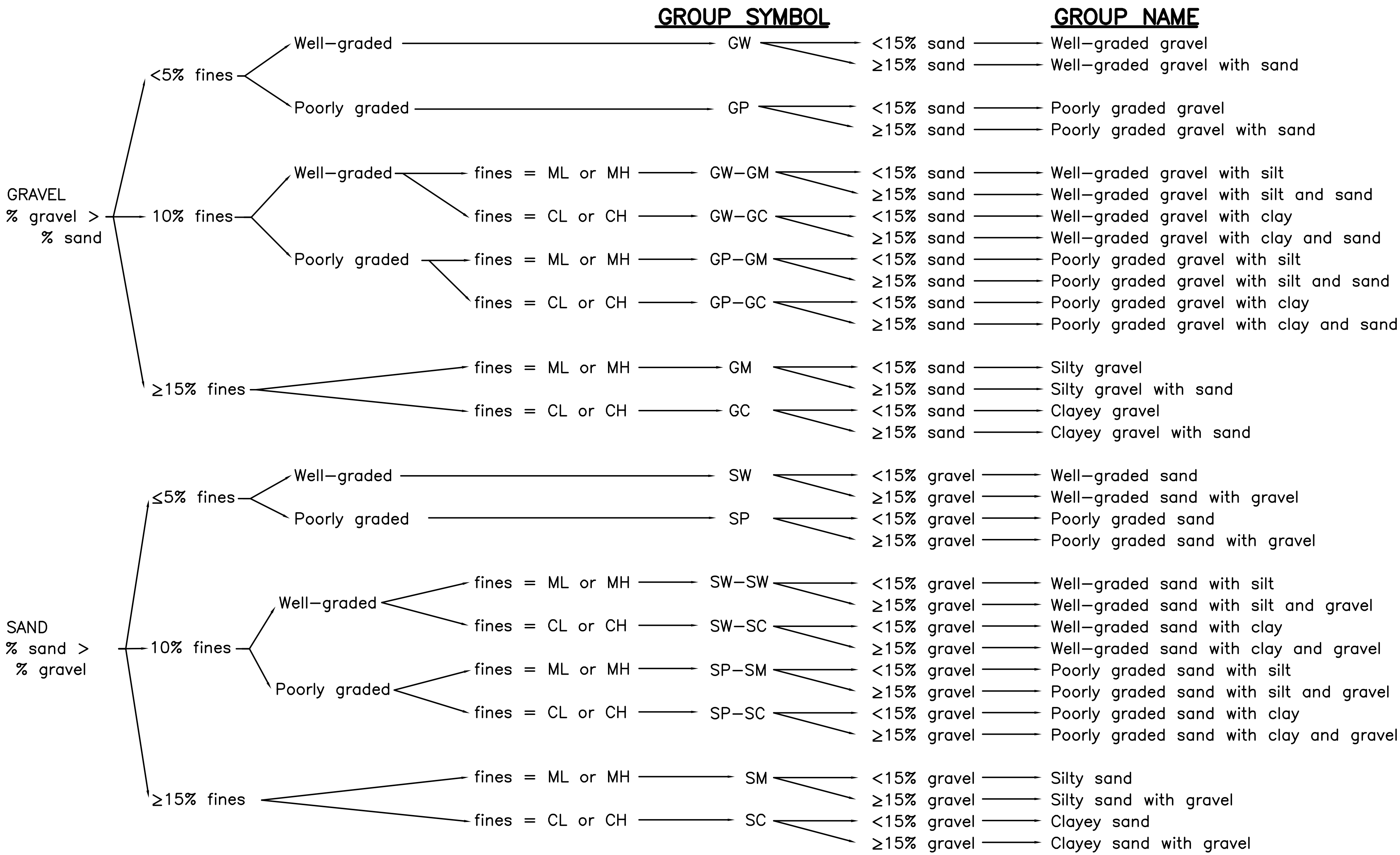
ASTM Standard D 5434-03. 2003. *Guide for Field Logging of Subsurface Explorations of Soil and Rock.*

ASTM Standard D 6032-02 (2006). 2006. *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%.

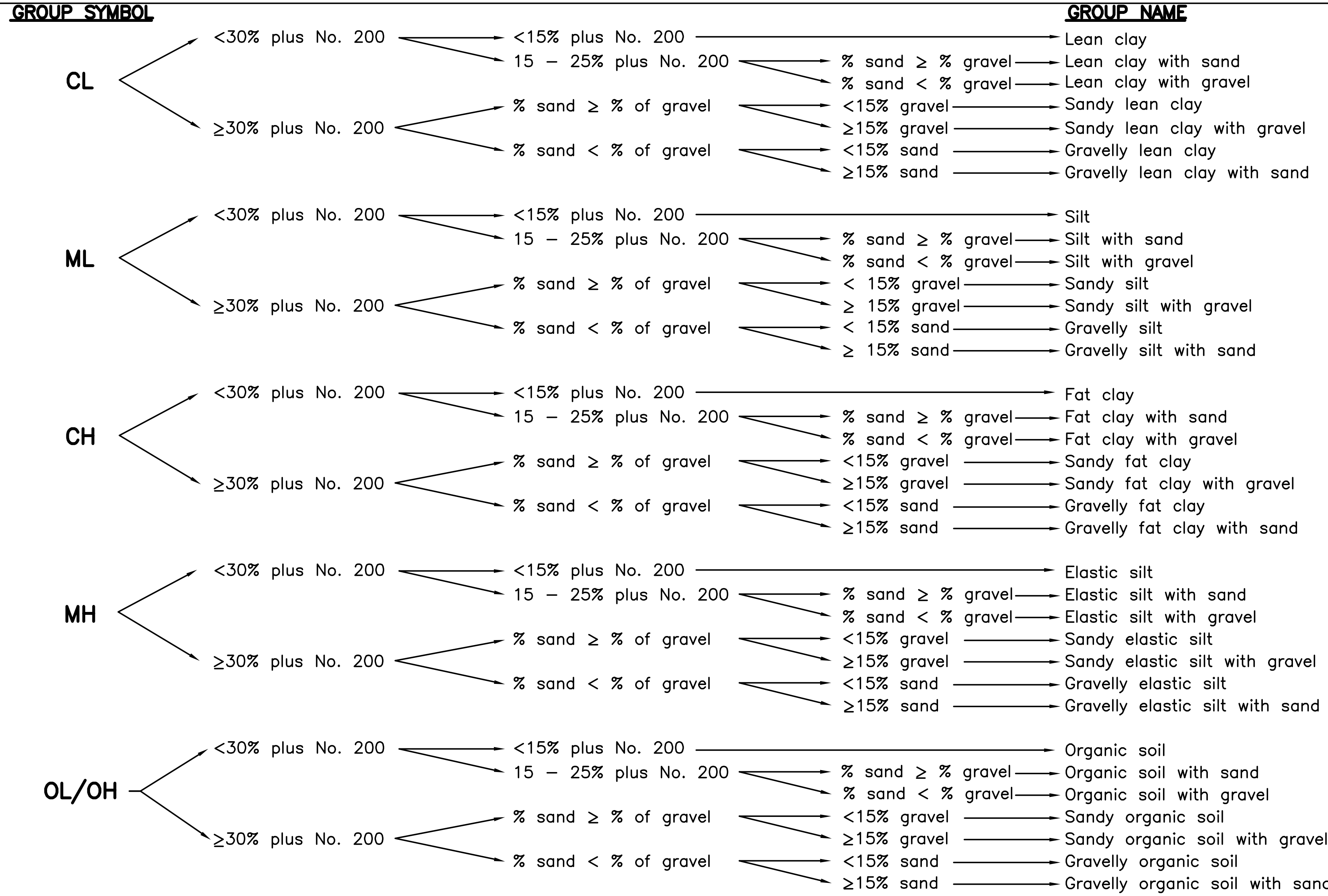
SOURCE: ASTM D 2488

**Radford Army Ammuntion Plant**

**FIGURE 10.03a**

**FLOW CHART FOR IDENTIFYING COARSE-GRAINED SOILS**

| | |
|---|---|
| **Date:** *October 2007* | **Prepared By:** *DBC/TLD* |
| **Scale:** *N.T.S.* | **File Name:** *SOP Figure 10.03a_Coarse* |




NOTE: PERCENTAGES ARE BASED ON ESTIMATING AMOUNTS OF FINES, SAND, AND GRAVEL TO THE NEAREST 5%.

SOURCE: ASTM D 2488

| Radford Army Ammuntion Plant | | FIGURE 10.03b |
|---|---|---|
| **Date:** October 2007 | **Prepared By:** DBC/TLD | **FLOW CHART FOR IDENTIFYING FINE-GRAINED SOILS** |
| **Scale:** N.T.S. | **File Name:** SOP Figure 10.03b_Fine | |

# STANDARD OPERATING PROCEDURE 20.1
# MONITORING WELL INSTALLATION

## 1.0 SCOPE AND APPLICATION

The installation of monitoring wells is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to delineate the quality control measures required to ensure the accurate installation of monitoring wells. For a particular site investigation, the associated work plan addenda should be consulted for specific installation instructions. The term "monitoring wells", as used herein is defined to denote any environmental sampling well.

## 2.0 MATERIALS

### 2.1 DRILLING EQUIPMENT

- Appropriately sized drill rig adequately equipped with augers, bits, drill stem, etc;
- Steam cleaner and approved source water for decontamination of drilling equipment, etc.;
- Source of approved water;
- Photoionization detector or other appropriate monitoring instrument per the site-specific Health and Safety plan;
- Water level indicator (electrical);
- Weighted steel tape measure;
- Steel drums and other appropriate containers for investigation-derived materials (drill cuttings, contaminated PPE, decontamination solutions, etc.);
- Absorbent pads and/or logs;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination supplies, pad with heavy plastic sheeting (SOP 80.1).

### 2.2 WELL INSTALLATION MATERIALS

Technical information on all installed materials (screens, riser pipe, filter pack, bentonite, cement, etc.) and representative samples of the proposed filter pack will be supplied to the Contracting Officer's Representative (COR) before initiating well installation.

Well screen slot size and filter pack gradation will be determined based on existing site geology before initiating site-specific investigations.

- Well screen :

  Polyvinyl Chloride (PVC): JOHNSON (or equivalent); PVC commercially slotted continuous slot, wire wrapped screen; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to National Sanitation Foundation (NSF) Standard 14 for potable water usage or ASTM Standard Specification F 480 and bear the appropriate rating logo. PVC should be free of ink markings, cleaned, and prepackaged by manufacturer;

Stainless Steel: JOHNSON (or equivalent); stainless steel Vee-Wire continuous slot, wire wrapped screen; 304 stainless steel (unless the sum concentration of $Cl^-$, $F^-$, and $Br^-$ is <1000 ppm, case type 316 should be used); ASTM F 480 flush threads; cleaned, wrapped, and heat-sealed by manufacturer;

- Riser pipe:
  - — PVC: JOHNSON (or equivalent); STD. PVC; 4-in. diameter.; SCH 40; SCH 80; flush-threaded (leak-proof) joints; PVC should conform to NSF Standard 14 or F 480; free of ink markings; cleaned and prepackaged by manufacturer;
  - — Stainless Steel: JOHNSON (or equivalent); SCH 5; 304 stainless steel; ASTM type A312 material; 4-in. diameter.; cleaned, wrapped and heat-sealed by manufacturer;
- Plugs/Caps: JOHNSON (or equivalent); standard PVC or stainless steel;
- Filter pack: MORIE, clean sorted gravel (or equivalent);
- Bentonite seal: BAROID, bentonite pellets (3/8-in. diameter.);
- Cement: Type II Portland Cement; if sulfate concentrations are higher than 1500 ppm, Type IV Portland Cement will be used;
- Bentonite powder: BAROID, Aquagel Gold Seal;
- Steel Protective Casing: BRAINARD-KILMAN (or equivalent) zinc-plated steel, lockable, painted;
- Containers for purged water, as required;
- Submersible pump or bailer of appropriate capacity, and surge block sized to fit well;
- Hach DREL 2000 portable laboratory (or equivalent);
- Multiprobe Electronic Water Quality Recorder (Hydrolab);
- Electric well sounder and measuring tape;
- Portland Type II cement (see footnote); and
- Steel Posts (pickets), painted (see footnote).

### 2.3 DOCUMENTATION

- Copy of work plans and health and safety plan;
- Copy of USACE EM 110-1-4000 Monitoring Well Requirements;
- Copies of permits (area entry, hot work, well, and utility clearance);
- Boring log forms;
- Well completion diagram form; and
- Field logbook.

### 2.4 GEOLOGIST'S PERSONAL EQUIPMENT

- Boring log materials per SOP 10.3; and
- Personal protective equipment and clothing (PPE) as required by the site-specific health and safety plan.

## 3.0 PROCEDURE

### 3.1 MATERIALS APPROVAL

#### 3.1.1 Source Water

Water sources for drilling, grouting, sealing, filter pack placement, well installation, and equipment decontamination must be approved by the COR before arrival of the drilling equipment. Information required for the water source includes:

- Water source;
- Manufacturer/owner and their address and telephone number;
- Type of treatment and filtration prior to tap;
- Time of access;
- Cost per gallon (if applicable); and
- Dates and results associated with all available chemical analyses over the past 2 years, and the name and address of the analytical laboratory (if applicable).

#### 3.1.2 Bentonite

Pure sodium bentonite with no additives (bentonite) will be the only drilling fluid additive allowed, and its use must be approved by the COR before the arrival of the drilling equipment. The information required for evaluation includes brand name, manufacturer, manufacturer's address and telephone number, product description, and intended use for the product, and potential effects on chemical analysis of water samples.

#### 3.1.3 Granular Filter Pack

Granular filter pack material must be approved by the COR before drilling. A one-pint representative sample must be supplied to the COR. Information required includes lithology, grain size distribution, brand name, source, processing method, and size of intended screen.

#### 3.1.4 Cement

Portland Type II cement will be used for grout (or Type IV, as noted in Section 2.2).

### 3.2 DRILLING

The objective of the selected drilling technique used at given site is to ensure that the drilling method provides representative data while minimizing subsurface contamination, cross contamination, and drilling costs.

Drilling methods that are appropriate for boring or monitoring well installation will depend on the subsurface geology most likely to be encountered in the boring. The geology for each site should be determined by reviewing previous investigation data (boring data, geophysics, etc.) from the site or nearby areas. Specific drilling methods that will be used to support site activities will be incorporated into work plan addenda.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of monitoring wells at the Radford Army Ammunition Plant (RFAAP) based on the different types of conditions encountered. The different drilling methods discussed in this section of the Master Work Plan including:

- Hollow Stem Auger (for soil);

- Air Rotary (soil and rock);
- Water Rotary and wire-line casing advancement (soil and rock);
- Drill-Through-Casing Driver (soil and rock); and
- Sonic (soil and rock).

### 3.2.1 Responsibilities of the Site Geologist

A Site Geologist will be present during all well drilling and installation activities and will fully characterize all tasks performed in support of these activities in the monitoring well logbook. The Site Geologist will be responsible for the logging samples, monitoring drilling operations, recording water losses/gains and groundwater data, preparing the boring logs and well diagrams, and recording the well installation procedures for one operating rig. The Site Geologist will have sufficient equipment in operable condition on-site to perform efficiently his/her duties.

### 3.2.2 Additives

No lubricants will be used on down hole drilling equipment. Additives containing either lead or copper will not be allowed. In addition, polychlorinated biphenyls will not be permitted in hydraulic fluids or other fluids used in the drilling rig, pumps, or other field equipment and vehicles.

Surface runoff or other fluids will not be allowed to enter any boring or well during or after drilling/construction.

Antifreeze used to keep equipment from freezing will not contain rust inhibitors and sealants. Antifreeze is prohibited in any areas in contact with drilling fluid. Absorbent pillows will be placed to catch any obvious leaks from the drill rig.

### 3.2.3 Boring Logs and Field Notes

Borings for monitoring wells will be logged by a geologist as described in SOP 10.3. Logs will be recorded on USACE HTRW ENG Form 5056-R and 5056A-R boring log forms.

Daily investigation activities at the site related to drilling should be recorded in field logbooks as described in SOPs 10.1 and 10.2.

## 3.3 WELL CONSTRUCTION AND INSTALLATION

Specifications for monitoring well construction and installation for a given site being investigated are to be included in work plan addenda. In case the previously defined criteria have not been met before the depth range for a given hole is reached, the geologist will stop the drilling and confer with the supervisor. The current boring conditions (depth, nature of the stratigraphic unit, and water-table depth) will be compared to those of other wells nearby to decide whether to continue drilling or to terminate and complete the well.

### 3.3.1 Overburden Wells

Overburden wells at the RFAAP are typically designed as a 4-inch diameter, single cased well (see Figure 20-1a) installed into a surficial aquifer, which is present above bedrock. For this type of well, the well boring would be terminated before penetrating any underlying confining unit and/or bedrock.

Section 5.2.2 of the Master Work Plan discusses the different drilling methods that may be appropriate for installation of overburden wells.

If dense, non-aqueous liquid (DNAPL) is encountered during drilling, the well boring will be terminated and completed at the base of the overburden aquifer being monitored.

### 3.3.2 Bedrock Wells

Multi-cased wells or wells with an outer casing installed into competent bedrock should be specified for wells that are designed to monitor groundwater within bedrock (see Figure 20-1c). The installation of a multi-cased well or outer casing will isolate the zone(s) monitored from overburden and will minimize the potential for cross-contamination during and after drilling.

The general procedure to be followed for installation of a multi-cased well is as follows. This procedure assumes the installation of a 4-inch diameter monitoring well. Specific procedures, drilling techniques and design of monitoring wells will be presented in work plan addenda for site-specific investigations.

1. If soil sampling is required within overburden, use appropriate drilling techniques to advance the boring and collect the soil samples.

2. A minimum 10-inch drill bit should be advanced from the surface into competent bedrock a distance not less than 2 feet. A drilling technique appropriate for penetrating overburden and bedrock should be used such as air rotary.

3. After the borehole has been advanced to the target depth within competent bedrock, a 6-inch diameter steel or Schedule 80 PVC outer casing should be lowered to the bottom of the boring.

4. Once the outer casing has been lowered to the bottom of the boring, the casing should be grouted in-place using a decontaminated tremie pipe equipped with a side discharge. The annulus between the outer casing and borehole wall will be injected with grout until undiluted grout reaches the surface.

5. The grouting mixture, specification, and placement should be consistent with the requirements identified in Section 3.3.8.

6. The grout should be allowed to cure a minimum of 24 hours before further drilling.

7. After adequate curing time for outer casing, drilling with a 5-5/8-inch bit until the desired total depth is reached should complete the well boring.

8. Once the well boring is completed, an appropriate bedrock well will be constructed based on site-specific conditions. The types of wells that may be installed may include a constructed well with screen, casing, filter pack, seal, and grout; an open-bedrock well; or a lined open bedrock well (see Section 3.3.3).

### 3.3.3 Well Screen Usage

Well screen usage for a given site should be specified in work plan addenda based on expected site conditions.

In general, wells installed within overburden will be installed with a screen as per Figure 20.01-a or 20.01-b. Bedrock wells may be installed with or without a screen depending on site specific conditions such as the depth of water bearing zones, stability of bedrock, occurrence of karst zones, and construction of existing wells at the site being investigated.

In general, bedrock wells installed within karst zones will be completed as open-hole construction (see Figure 20.01c). If evidence of potential or severe borehole collapse (unstable bedrock) is indicated during drilling, casing and screen will be installed in the borehole as a removable lining. If desired, multiple flow zones may be monitored in an open bedrock well by installing a multiport well, which has monitoring/sampling intervals sealed off from the rest of the boring and from each other by packers.

### 3.3.4 Beginning Well Installation

Schedule

Monitoring well installation should begin within 12 hours of boring completion for holes that are uncased or partially cased with temporary drill casing. In the case where a partially cased hole into bedrock is to be partially developed prior to well insertion, the well installation should begin within 12 hours of this initial development. For holes that are fully cased, installation should begin within 48 hours. Once begun, well installation should not be interrupted.

Placement of Materials

Temporary casing and hollow stem augers may be removed from the boring prior to well installation if the potential for cross contamination is low and if the borehole will remain stable during the time required for installation.

Where borehole conditions are unstable, some or all of the well materials may need to be installed prior to removal of the temporary casing or hollow stem augers. The casing or hollow stem augers should have an inside diameter sufficient to allow the installation of the screen and casing plus annular space for a pipe through which to place filter pack and grout.

Any materials blocking the bottom of the drill casing or hollow stem auger should be dislodged and removed from the casing prior to well insertion.

### 3.3.5 Screens, Casing, and Fittings

Borehole Specifications

The borehole for each well should be of sufficient diameter to provide for at least 2 inches of annular space between the borehole wall and all sides of the casing.

Well Screens

Material specifications for well screens, casings, and fittings are discussed in Section 2.2.
Screen bottoms should be securely fitted with a threaded cap or plug of the same composition as the screen. The cap/plug should be within 0.5 feet of the open portion of the screen. A sediment trap/sump will not be used.

Screen slot size will be appropriately sized to retain 90%–100% of the filter pack material, the size of which will be determined by sieve analysis of formation material.

Well screen lengths should be specified in work plan addenda and will be based on various site-specific factors such as environmental setting, subsurface conditions, analytes of concern, regulatory considerations, etc.

Assembly and Placement of Well Screen and Casing

Personnel should take precautions to assure that grease, oil, or other contaminants do not contact any portion of the well screen and casing assembly. Clean latex or nitrile gloves should be worn when handling the screen and casing assembly. Flush, threaded joints usually can be tightened by hand. If necessary, steam cleaned wrenches may be used to tighten joints.

In general, each section of the well assembly is lowered into the borehole, one section at a time, screwing each section securely into the section below it. No grease, lubricant, polytetrafluoroethylene (PTFE) tape, or glue may be used in joining the sections of screen and casing.

The assembly should be lowered to its predetermined level and held in position for placement of the filter pack. It is essential that the assembly be installed straight (with centralizers as appropriate) to allow for appropriate sampling. Buoyant forces associated with fluids in the borehole may require that the assembly be installed with the aid of hydraulic rams of the drill rig. When the well assembly is placed to predetermined level, a temporary cap should be place on the well to prevent foreign material from entering the well.

The bottoms of well screens should be placed no more than 3 feet above the bottom of the drilled borehole. If significant overdrilling is required, a pilot boring should be used. Sufficient filter pack should be placed at the bottom of the borehole

The well casing should be pre-cut (square) to extend 2 to 2.5 feet above the ground surface. Before placement of the last piece of well casing, a notch or other permanent reference point will be cut, filed, or scribed into the top edge of the casing.

The tops of all well casing will be capped with covers composed of materials compatible with the products used in the well installation. Caps will be loose fitting, constructed to preclude binding to the well casing caused by tightness of fit, unclean surfaces, or weather conditions. In either case, it should be secure enough to preclude the introduction of foreign material into the well, yet allow pressure equalization between the well and the atmosphere.

The top of each well casing should be level so that the maximum difference in elevation between the highest and lowest points of the casing is less than or equal to 0.02 ft.

### 3.3.6 Filter Pack

The volume of filter pack that is required to fill the annular between the well screen/casing and borehole should be computed, measured, and recorded.
Granular filter packs will be chemically and texturally clean, inert, and siliceous. The gradation of filter packs will be selected based on the screen size used and will be specified in the work plan addenda for the site being investigated.

Primary Filter Pack

Filter pack material should be placed in the borehole using a decontaminated tremie pipe. An appropriate amount of primary filter pack should be placed in the borehole prior to final positioning of the well screen to provide an appropriate barrier between the bottom of the borehole and the bottom of the screen. Once the initial filter pack has been placed and the well assembly is appropriately positioned and centered in the borehole, the remaining primary filter pack should be placed in increments (and tamped) as the tremie pipe is gradually raised.

As the primary filter pack is placed, approved source water may need to be added to help move the filter pack. A weighted tape should be used to measure the top of the filter pack as it is being placed. If bridging of the filter pack occurs, then this bridging should be broken mechanically prior to adding additional filter pack.

When temporary casing or hollow stem augers are used, the casing or augers should be removed in increments such that lifting of the well assembly is minimal. After removal of each increment, it should be confirmed by direct measurement that the primary filter pack has not been displaced during the removal.
The primary filter pack should extend from the bottom of the borehole to 3 to 5 ft above the top of the screen.

Secondary Filter Pack

The primary filter pack may be capped with 1 to 2 feet of feet of secondary filter pack to prevent the intrusion of the bentonite seal into the primary filter pack. The need for this filter pack (and specifications) should be addressed in work plan addenda for the site being investigated. Such factors as the gradation of the primary filter pack, the potential for grout extrusion, and site hydrogeology should be considered when evaluating the need for this filter pack.

### 3.3.7 Bentonite Seal

A bentonite seal, consisting of hydrated 3/8-inch diameter. bentonite pellets, will be installed immediately above the filter pack. The seal may be installed with a tremie pipe, which is lowered to the top of the filter pack and slowly raised as the pellets fill the annular space. In deep wells, the pellets may bridge and block the tremie pipe; in this case, pellets may be placed by free fall into the borehole. A weighted tape should be used to measure the top of seal as it is installed.

When cement grout is to be used above the bentonite seal, a minimum of 3 to 4 hours should be allowed for hydration of the pellets.

When installing a seal above the water table, water should be added to the bentonite for proper hydration. In this case, the seal should be placed in lifts of 0.5 to 1 foot with each lift hydrated for a period of 30 minutes.
If the bentonite seal is to be installed far below the water table, a bentonite slurry seal will be installed. Cement-bentonite grout will not be used below the water table. The slurry will be mechanically blended aboveground to ensure a lump-free mixture. The slurry will consist of bentonite powder and approved water mixed to a minimum of 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 than 1/8 inch above the grout filled annulus between the well riser and the protective casing.

Any annulus formed between the outside of the protective casing and the borehole will be filled to ground surface with cement.

Concrete Pad

After the grout has thoroughly set and the well protective casing has been installed, a protective concrete pad will be installed around the well. This pad will be at least 4 inches thick and 4 feet square and sloped away from the well to provide for adequate drainage.

Protective Posts

Additional protection will be provided at each well location by the installation of four steel posts outside of each corner of the concrete pad. The installation of protective posts should occur before the well is sampled. The posts should have a minimum diameter of 3 inches, be placed 2 to 3 feet below ground surface, and extend at least 3 feet above ground surface. Posts should be painted orange using a brush.

Posts should be set in post holes, which are backfilled with concrete. For additional protection, the posts can be filled with concrete.

### 3.3.10 Well Construction Diagram and Field Notes

The construction of each well will be depicted as built in a well construction diagram (see Figure 20.1a). The diagram will be attached to the boring log and the following will be graphically denoted:

- Bottom of boring;
- Screen location, length, and size;
- Coupling locations;
- Granular filter pack;
- Seal;
- Grout;
- Cave-in;
- Centralizers;
- Height of riser;
- Protective casing detail;
- Water level 24 hours after completion with date and time of measurement;
- Quantity and composition of materials used; and
- Material between bottom of boring and bottom of screen.

Daily activities at the site related to monitoring well installation should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

## 3.4 GENERAL SEQUENCE OF MONITORING WELL COMPLETION

The following is a general sequence of monitoring well completion with reference to the specific details included in Section 3.3.

1. Completion of borehole;
2. Assembly and placement of well assembly as described in Section 3.3.5;
3. Placement of the appropriate filter pack(s) as discussed in Section 3.3.6;
4. Installation of an appropriate bentonite seal as discussed in Section 3.3.7;
5. Grouting the remaining annular space of the borehole as discussed in Section 3.3.8;
6. Set the protective casing for the well as discussed in Section 3.3.9;

7. Complete the protective concrete pad as discussed in Section 3.3.9; and
8. Install the protective posts as discussed in Section 3.3.9.

### 3.5 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

## 4.0 MAINTENANCE

Not applicable.

## 5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

## 6.0 REFERENCES

ASTM Standard D 5092-04e1. 2004. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

ASTM Standard F 480-06b. 2006. *Standard Specification for Thermoplastic Well Casing Pipe and Couplings Made in Standard Dimension Ratios (SDR), SCH 40 and SCH 80.*

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<br>Lat. ___ ___ ___ Long ___ ___ ___ or<br>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)<br>______<br>______ |
| Maximum Depth of Frost Penetration (estimated) | Location of Well Relative to Waste/Source<br>u ☐ Upgradient s ☐Sidegradient<br>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 sell near screen:
GP ☐ GM☐ GC ☐ GW☐ SW☐ SP☐
SM ☐ SC☐ ML ☐ MH☐ CL ☐ CH ☐
Bedrock ☐

17. Sieve analysis attached? ☐ Yes ☐ No

18. Drilling method used: Rotary ☐
Hollow Stem Auger ☐
______ Other ☐

19. Drilling fluid used Water ☐ Air ☐
Drilling mud ☐ None ☐

20. Drilling additives used? ☐ Yes ☐ No
Describe ______

21. Source of water (attach analysis):
______

E. Secondary filter, top ______ m. TOC or ______ m. MSL

F. Bentonite seal, top ______ m. TOC or ______ m. MSL

G. Secondary filter, top ______ m. TOC or ______ m. MSL

H. Primary filter, top ______ m. TOC or ______ m. MSL

I. Screen joint ______ m. TOC or ______ m. MSL

J. Well bottom ______ m. TOC or ______ m. MSL

K. Filter pack, bottom ______ m. TOC ______ m. MSL

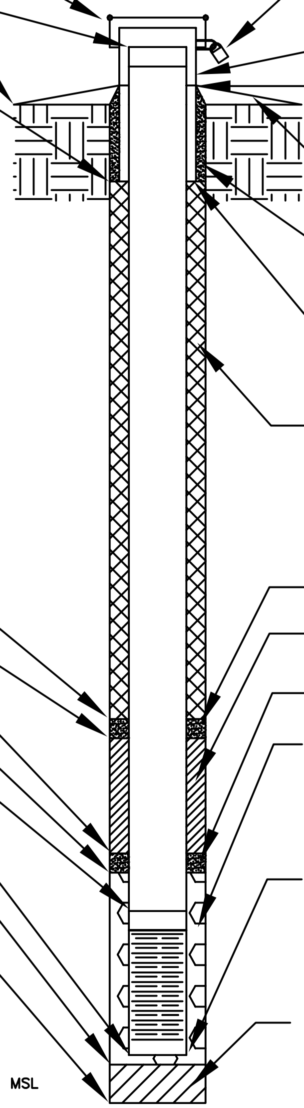
L. Borehole, bottom ______ m. TOC or ______ m. MSL

M. Borehole, diameter ______ mm.

N. O.D. well casing ______ mm.

O. I.D. well casing ______ mm.

P. 24–hr water level after completion ______ m. TOC or ______ m. MSL



1. Cap and Lock? ☐Yes ☐No

2. Protective posts? ☐ Yes ☐ No

3. Protective casing:
a. Inside diameter: ______ mm.
b. Length: ______ m.

4. Drainage port(s) ☐ Yes ☐ No

5. Surface seal: Gravel blanket ☐
a. Cap Bentonite ☐
Concrete ☐
______ Other ☐

b. Annular space seal: Bentonite ☐
Cement ☐
______ Other ☐

6. Material between well casing and protective casing: Bentonite ☐
Cement ☐
______ Other ☐

7. Annular space seal: A. Granular Bentonite ☐
b. ______ Lbs/gal mud weight........Bentonite–sand slurry ☐
c. ______ Lbs/gal mud weight..................Bentonite slurry ☐
d. ______ x Bentonite..................Bentonite–cement grout ☐
e. ______ $m^3$ volume added for any of the above
f. How installed: Tremie ☐
Tremie pumped ☐
Gravity ☐

8. Centralizers ☐ Yes ☐ No

9. Secondary Filter ☐ Yes ☐ No
a. Volume added ______ $m^3$ ______ Bags/Size

10. Bentonite seal: a. Bentonite granules ☐
b. 1/4in. 3/6in. 1/2in. Bentonite pellets ☐
c. ______ Other ☐

11 Secondary Filter ☐ Yes ☐ No
a. Volume added ______ $m^3$ ______ Bags/Size

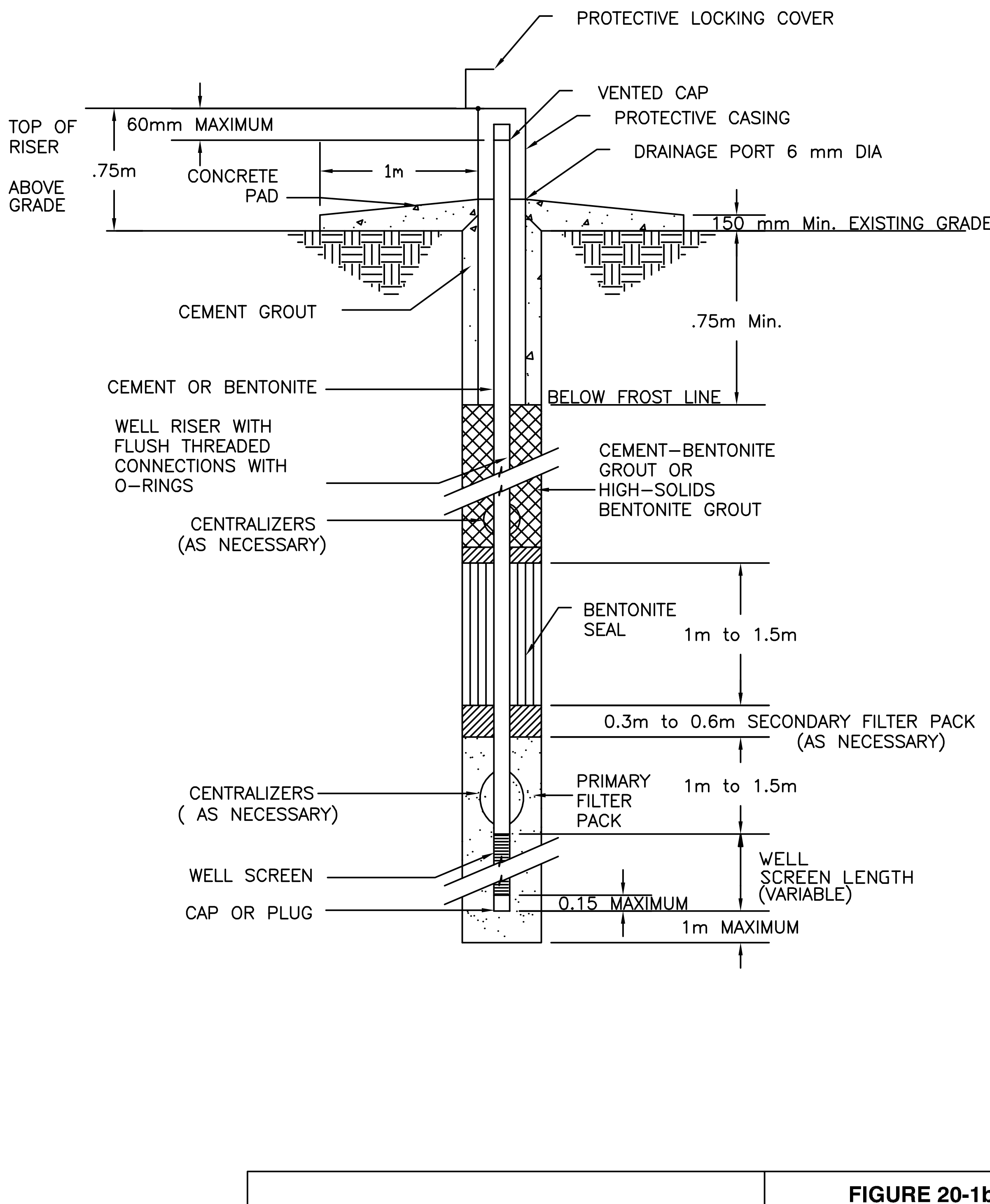
12. Filter pack material: Manufacturer, product name & mesh size
a.
b. Volume added ______ $m^3$ ______ Bags/Size

13. Well casing: Flush threated PVC schedule 40 ☐
Flush threated PVC schedule 80 ☐
______ Other ☐

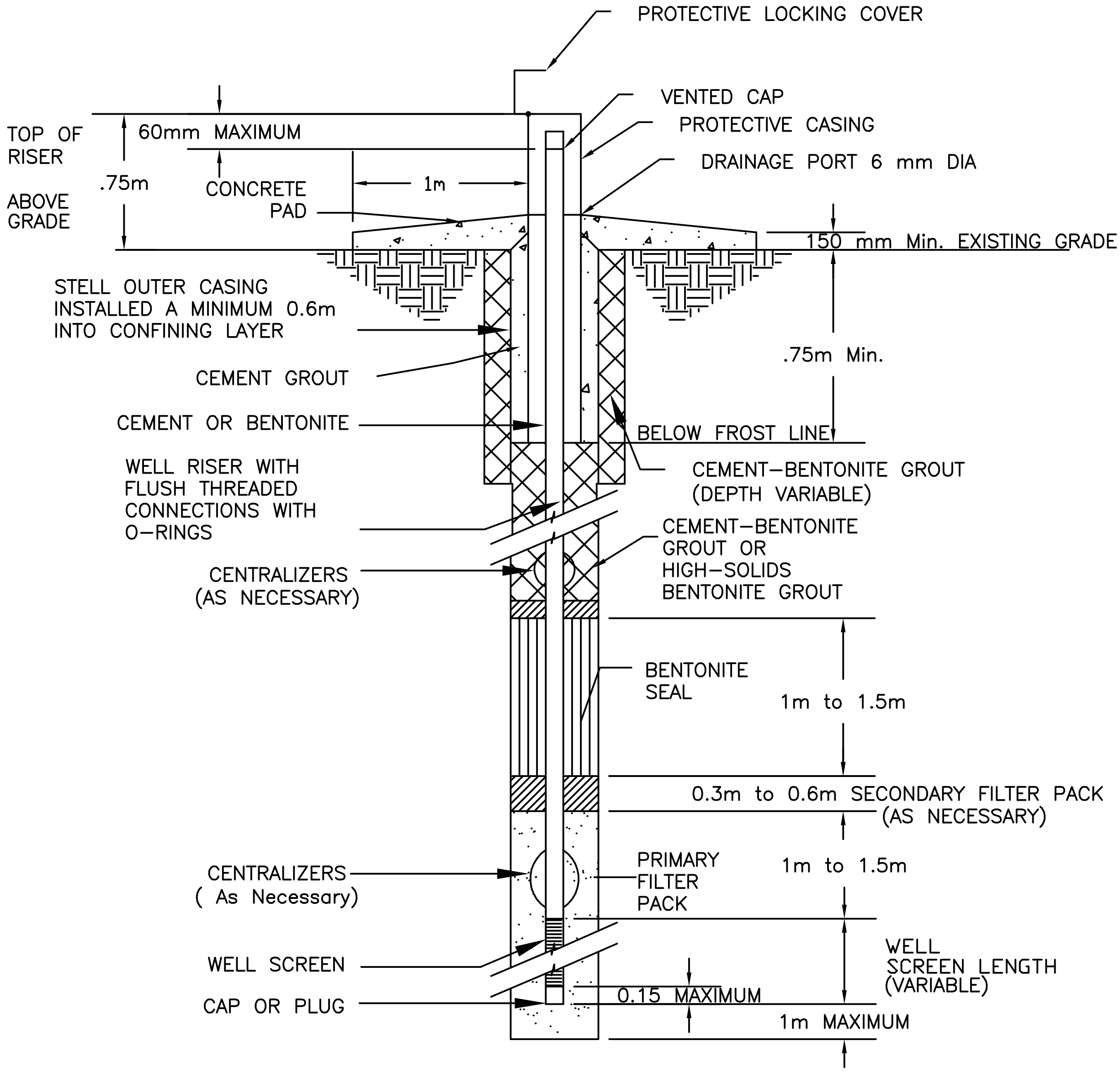
14. Screen material:
a. Screen type: Factory cut ☐
Continous slot ☐
______ Other ☐
b. Manufacturer
c. Slot size: 0.______ In.
d. Slotted length: ______ In.

15. Backfill material (below filter pack): None ☐
______ Other ☐

| Radford Army Ammuntion Plant | | FIGURE 20-1a |
|---|---|---|
| **Date:** *October 2007* | **Prepared By:** *URS Corp./DBC* | **SCHEMATIC CONSTRUCTION DIAGRAM OF MONITORING WELL** |
| **Scale:** *NO SCALE* | **File Name:** *SOP Figure 20-1a* | |




| Radford Army Ammuntion Plant | | FIGURE 20-1b |
|---|---|---|
| **Date:** *October 2007* | **Prepared By:** *URS Corp./DBC* | **SCHEMATIC CONSTRUCTION OF SINGLE-CASED WELL WITH STICKUP COMPLETION** |
| **Scale:** *NO SCALE* | **File Name:** *SOP Figure 20-1b* | |




| **Radford Army Ammuntion Plant** | | **FIGURE 20-1c** |
|---|---|---|
| **Date:** October 2007 | **Prepared By:** URS Corp./DBC | **SCHEMATIC CONSTRUCTION OF MULTI-CASED WELL WITH CONCRETE PAD** |
| **Scale:** NO SCALE | **File Name:** SOP Figure 20-1c | |

# 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.

ASTM Standard D 5092-04e1. 2004. *Standard Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers.*

*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.

**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.

<u>General Considerations</u>

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.

<u>Abandonment with Well Materials In Place</u>

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.

<u>Abandonment by Removal</u>

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 5299-99 (2005). 2005. *Standard Guide for Decommissioning of Ground Water Wells, Vadose Zone Monitoring Devices, Boreholes, and Other Devices for Environmental Activities.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000, 1 November.

# STANDARD OPERATING PROCEDURE 20.11
# DRILLING METHODS AND PROCEDURES

## 1.0 SCOPE AND APPLICATION

The use of an appropriate drilling procedure is contingent upon the existing conditions at the project site. The purpose of this standard operating procedure (SOP) is to outline procedures for the various methods of soil and rock drilling identified in the Master Work Plan. In addition it provides procedures for using sampling devices commonly used during soil and rock drilling such as split-barrel sampling, thin walled tube sampling, direct push samplers, and rock coring. For a particular site investigation, the associated work plan addendum will identify the appropriate drilling method and method of sampling, along with proposed sampling depths and intervals and any special procedures or methods.

## 2.0 MATERIALS

The following types of materials are generally appropriate for drilling:

### 2.1 SPLIT-BARREL SAMPLING

- Split barrel sampler;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

### 2.2 THIN WALLED TUBE SAMPLING

- Thin walled tubes;
- Sealing materials for sample such as sealing wax, metal disks, wood disks, tape, cheesecloth, caps, etc;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

### 2.3 DIRECT PUSH SAMPLING

- Direct push unit with hydraulic ram, hammer, etc;
- Sample collection devices, associated equipment and expendable supplies such as sample liners, sample retainers, appropriate lubricants, etc;
- Hollow extension rods;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;

- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

### 2.4 HOLLOW-STEM AUGER DRILLING

- Drill rig and associated equipment;
- Hollow stem auger assemblies for drilling to appropriate depth including auger heads, drive assembly, pilot assembly, and hollow-stem auger sections;
- Auxiliary devices such as wrenches, auger forks, hoisting hooks, swivels, and adaptors;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

### 2.5 DIRECT AIR ROTARY DRILLING

- Drill rig with rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Sampling devices and equipment, as appropriate;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

### 2.6 DRILL-THROUGH CASING DRIVER

- Drill rig equipped with a mast-mounted, percussion driver;
- Casing, drill rods, and drill bits or hammers;
- Air compressor and filters, pressure lines, discharge hose, swivel, dust collector, and air-cleaning device (cyclone separator);
- Sampling devices and equipment, as appropriate;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Welding equipment and materials for installation of casing;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and

- Decontamination supplies and equipment per SOP 80.1.

### 2.7 DIRECT WATER-BASED ROTARY DRILLING

- Drill rig with derrick, rotary table and Kelly or top-head drive unit;
- Drill rods, bits, and core barrels (as appropriate);
- Casing;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, cyclone de-sander(s), drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1.
- Decontamination supplies and equipment per SOP 80.1.

### 2.8 DIRECT ROTARY WIRELINE-CASING ADVANCEMENT DRILLING

- Drill rig with either hollow spindle or top-head drive;
- Drill rods, coring or casing bits, overshot assembly, pilot bit, and core barrel;
- Water based drilling fluid, with approved additives as appropriate;
- Mud tub, suction hose, drilling fluid circulation pump, pressure hose, and swivel;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

### 2.9 DIAMOND CORE DRILLING

- Direct rotary drill rig and associated equipment (see Sections 2.4, 2.5 or 2.6);
- Core barrels and core bits;
- Core lifters;
- Core boxes, engineers scale, permanent marking pen, and camera for photographing cores;
- Auxiliary tools for handling, assembling, and disassembling tools and samplers;
- Borehole logging materials per SOP 10.3 and sampling equipment and materials, as appropriate per SOP 30.1;
- Containers to manage investigation-derived material per SOP 70.1; and
- Decontamination supplies and equipment per SOP 80.1.

## 3.0 PROCEDURES

### 3.1 PENETRATION TEST AND SPLIT-BARREL SAMPLING OF SOILS

The following general procedure may be followed as outlined in ASTM Standard Test Method D 1586.

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.

1. Clean out the borehole to targeted sampling depth using most appropriate method, which avoids disturbing the material to be sampled. If groundwater is encountered, maintain the liquid level in the borehole at or above the groundwater level during sampling.
2. Place the sample tub so that its bottom rests on the bottom of the borehole.
3. Advance the sampler without rotation by a continuous relatively rapid motion.
4. Determine the length of the advance by the resistance and condition of the formation, the length of the advance should never exceed 5 to 10 diameters of the tube in sands and 10 to 15 diameters of the tube in clay.
5. When the formation is too hard for push type of sampling, the tube may be driven or the practice used for ring-lined barrel sampling may be used per ASTM Standard D 3550. 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.

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 (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.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).

2. Establish point for borehole measurements.

3. Attach an initial assembly of a bit, down hole hammer, or core barrel with a single section of drill rod, below the rotary table or top-head drive unit, with the bit placed below the top of the dust collector.

4. Activate the air compressor to circulate air through system.

5. Initiate rotation of bit.

6. Continue with air circulation and rotation of the drill-rod column to the depth where sampling or in-situ testing is required or until the length of the drill rod section limits further penetration.

7. Monitor air pressure during drilling operations. Maintain low air pressure at bit to prevent fracturing of surrounding material.

8. Stop rotation and lift the bit slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.

9. Open reaching a desired depth of sampling, stop the air circulation and rest bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
10. When sampling, remove the drill rod column from the borehole or leave the drill rod assembly in place if the sampling can be performed through the hollow axis of the drill rods and bit.
11. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
12. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
13. The procedure described in Steps 8 through 12 should be conducted for each sampling or testing interval.
14. Drilling to a greater depth may be accomplished by attaching an additional drill rod section to the top of the previously advanced drill-rod column and resuming drilling operations as described above.
15. When drilling through material suspected of being contaminated, the installation of single or multiple (nested) outer casings may be required to isolate zones suspected contamination (see SOP 20.1 for grouting requirements). Outer casings may be installed in a pre-drilled borehole or using a method in which casing is advanced at the same of drilling.
16. Monitoring wells or piezometers may be installed by:
    a. Drilling with or without sampling to the target depth.
    b. Removal of the drill rod assembly and insertion of the monitoring well (or piezometer) assembly.
    c. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
17. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
18. The drill rod assembly, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
19. Borehole logging should be completed per SOP 10.3.
20. Borehole abandonment, when required, should be conducted according to SOP 20.3

### 3.6 DRILL-THROUGH CASING DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5872.

1. Stabilize drill rig and raise mast at desired location. Appropriately position the cyclone separator and seal it to the ground surface considering the prevailing wind direction (exhaust).
2. Establish point for borehole measurements.
3. Attach an initial assembly of a bit or down hole hammer with a single section of drill rod and casing to the top-head drive unit.
4. Activate the air compressor to circulate air through system.
5. Drilling may be accomplished by
    a. Method 1- the casing will fall, or can be pushed downward behind the bit.
    b. To drill using Drive the casing first followed by drilling out the plug inside the casing.
    c. Method 2 - Advancing the casing and bit as a unit, with the drill bit or hammer, extending up to 12-inches below the casing.
6. Method 3 - Under reaming method where bit or hammer pens a hole slightly larger than the casing so that Method 1, drive the casing first and drill out the plug in the casing by moving the bit or hammer beyond

the casing and then withdrawing it into the casing. Air exiting the bit will remove the cuttings up the hole. Separate cuttings from the return air with a cyclone separator or similar device.

7. To drill using Method 2, advance casing and bit as unit with the bit or hammer extending up to 12-inches beyond the casing depending on the conditions. While drilling, occasionally stop the casing advancement, retract the bit or hammer inside the casing to clear and maintain air circulation to clear cuttings.
8. To drill using Method 3, use a special down hole bit or hammer to open a hole slightly larger than the outside diameter of the casing so that the casing will fall or can be pushed downward immediately behind the bit. After advancing the casing, retract the radial dimension of the drill bit to facilitate removal of the down hole bit or hammer and drill tools inside the casing. Cuttings are removed from the borehole with the air that operates the bit or hammer and can be separated from the air with a cyclone separator or similar device.
9. Monitor air pressure during drilling operations. Maintain low air pressure at bit or hammer to prevent fracturing of surrounding material.
10. Continue air circulation and rotation of the drill rod column until drilling is completed to the target depth (for sampling, in-situ sampling, etc.) or until the length of the drill-rod section limits further penetration.
11. Stop rotation and lift bit or hammer slightly off the bottom of the hole to facilitate removal of drill cuttings and continue air circulation until the drill cuttings are removed from the borehole annulus.
12. After reaching a desired depth of sampling, stop the air circulation and rest the bit on bottom of hole to determine the depth. Record the borehole depth and any resultant caving in. If borehole caving is apparent set a decontaminated casing to protect the boring.
13. When sampling, remove the drill rod column from the borehole. Compare the sampling depth to clean-out depth by first resting the sampler on the bottom of the hole and compare that measurement with the clean-out depth measurement.
14. If bottom-hole contamination is apparent (indicated by comparison of sample depth to clean-out depth), it is recommended that the minimum depth below the sampler/bit be 18 inches for testing. Record the depth of sampling or in-situ testing and the depth below the sampler/bit.
15. The procedure described in Steps 11 through 14 should be conducted for each sampling or testing interval.
16. Drilling to a greater depth may be accomplished by attaching an additional drill rod section and casing section to the top of the previously advanced drill-rod column/casing and resuming drilling operations as described above.
17. Monitoring wells or piezometers may be installed by:
    a. Casing advancement in increments, with or without sampling to the target depth.
    b. Removal of the drill rods and the attached drill bit while the casing is temporarily left in place to support the borehole wall.
    c. Insertion of the monitoring well (or piezometer) assembly.
    d. Addition of monitoring well (or piezometer) completion materials (see SOP 20.1).
18. Drill cuttings should be appropriately controlled and contained as IDM per SOP 70.1.
19. The drill rod assembly, casing, sampling devices, and other drilling equipment contacting potentially contaminated material must be decontaminated before and after each use per the methods specified in SOP 80.1.
20. Borehole logging should be completed per SOP 10.3.
21. Borehole abandonment, when required, should be conducted according to SOP 20.3.

### 3.7 DIRECT WATER-BASED ROTARY DRILLING

The following general procedure may be followed as outlined in ASTM Standard Guide D 5783.

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.

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.

1. Use core-drilling procedures, such as the water-rotary drilling method outlined in Section 3.6.
2. Seat the casing on bedrock or firm formation to prevent raveling of the borehole and to prevent loss of drilling fluid. Level the formation that the casing will be seated on as needed.
3. Begin core drilling using an N-size double-tube, swivel-type core barrel or other approved size or type. Continue core drilling until core blockage occurs or until the net length of the core has been drilled.
4. Remove the core barrel from the borehole, and dis-assemble the core barrel as necessary to remove the core.
5. Reassemble the core barrel and return it to hole.
6. Continue core drilling.
7. Place the recovered core in the core box with the upper (surface) end of the core at the upper-left corner of the core box. Wrap soft or friable cores, etc. as needed or required. Use spacer blocks or slugs properly marked to indicate any noticeable gap in recovered core that might indicate a change or void in the formation. Fit fracture, bedded, or jointed pieces of core together as they naturally occurred.
8. The core within each completed box should be photographed after core surface has been cleaned or peeled, as appropriate, and wetted. Each photo should be in sharp focus and contain a legible scale in feet and tenths of feet (or metric if appropriate). The core should be oriented so that the top of the core is at the top of the photograph. A color chart should be included in the photograph frame as a check on photographic accuracy. The inside lid of the box should also be shown.
9. The inside of the box lid should be labeled at a minimum with the facility name, project name, boring number, box number, and core interval.

10. A preliminary field log of the core must be completed before the core box has been packed for transport (see SOP 10.3). Detailed logging may be conducted at a later time providing the core is appropriately handled and transported.
11. Four levels of sample protection may be used depending on character of the rock and the intended use of the rock core including:
    a. *Routine care* – for rock cored in 5 to 10 foot runs. Consists of placing in structurally sound boxes. Lay flat tubing may be used prior to placing the core.
    b. *Special care* – for rock samples to be tested that are potentially moisture sensitive, such as shale. This care consists of sealing with a tight fitting wrapping of plastic film and application of wax at the ends of the sample.
    c. *Critical care* – for rock samples that may be sensitive to shock and vibration and/or temperature. Protect by encasing each sample in cushioning material, such as sawdust, rubber, polystyrene, foam, etc. A minimum one-inch thick layer of cushioning material should be used. Thermally insulate samples that are potentially sensitive to changes in temperature.
    *d.* *Soil-Like care* – handle per ASTM Standard D 4220.
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 2113-06 (2006). 1993. *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation.*

ASTM Standard D 1586-99. 1999. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 1587-00 (2007) e1. 2007. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.*

ASTM Standard D 3550-01 (2007). 2007. *Standard Practice for Think Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils.*

ASTM Standard D 4220-95 (2007). 2007. *Standard Practices for Preserving and Transporting Soil Samples.*

ASTM Standard D 4630-96 (2002). 2002. *Standard Test Method for Determining Transmissivity and Storage Coefficient of Low-Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test.*

ASTM Standard D 4631-95 (2000). 2000. *Standard Test Method for Determining Transmissivity and Storativity of Low-Permeability Rocks by In Situ Measurements Using Pressure Pulse Technique.*

ASTM Standard D 5079-02 (2006). 2006. *Standard Practices for Preserving and Transporting Rock Core Samples.*

ASTM Standard D 5782-95 (2006). 2006. *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 (2006). 2006. *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 (2006). 2006. *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 (2006). 2006. *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 (2005). 2005. *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 (2005). 2005. *Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations.*

USACE. 1998. *Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites.* EM 1110-1-4000. 1, November.

# STANDARD OPERATING PROCEDURE 30.1
# SOIL SAMPLING

## 1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for sampling surface and subsurface soils.

## 2.0 MATERIALS

- Stainless steel scoop, spoon, trowel, knife, spatula, (as needed);
- Split-spoon, Shelby tube, or core barrel sampler;
- Hand auger or push tube sampler;
- Drill rig and associated equipment (subsurface soil);
- Stainless steel bowls;
- Photoionization detector or other appropriate instrument as specified in site-specific health and safety plan;
- Sampling equipment for collection of volatile organic samples;
- Appropriate sample containers;
- Appropriate sample labels and packaging material.;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Decontamination equipment and supplies (SOP 80.1).

## 3.0 PROCEDURE

### 3.1 DOCUMENTATION

Soil sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

### 3.2 SURFICIAL SOIL SAMPLES

The targeted depths for surficial soil samples (surface and near surface) will be specified in the work plan addenda developed for site-specific investigations.

1. All monitoring equipment should be appropriately calibrated before beginning sampling according to the requirements of the work plan addenda and SOP 90.1 or 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Use a spade, shovel, or trowel or other equipment (manufactured from material, which is compatible with the soil to be sampled) to remove any overburden material present (including vegetative mat) to the level specified for sampling.
4. Measure and record the depth at which the sample will be collected with an engineers scale or tape.

5. Remove the thin layer that was in contact with the overburden removal equipment using a clean stainless steel scoop or equivalent and discard it.
6. Begin sampling with the acquisition of any discrete sample(s) for analysis of volatile organic compounds (VOCs), with as little disturbance as possible. VOC samples will not be composited or homogenized.
7. When a sample will not be collected with a core type of sampler (push tube, split spoon, etc.), the sample for VOC analysis will be collected from freshly exposed soil. The method of collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
8. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
9. Collect a suitable volume of sample from the targeted depth with a clean stainless steel scoop (or similar equipment), push tube sampler, or bucket auger
10. For core type of samplers, rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife. Samples collected with a bucket auger or core type of sampler should be logged per the requirements of SOP 10.3.
11. If homogenization or compositing of the sampling location is not appropriate for the remaining parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
12. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and then placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
13. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
14. Return any remaining unused soil to the original sample location. If necessary, add clean sand to bring the subsampling areas back to original grade. Replace the vegetative mat over the disturbed areas.

### 3.3 SUBSURFACE SAMPLES

All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.

1. All monitoring equipment should be appropriately calibrated before sampling according to the requirement of the work plan addendum and SOP 90.1 or SOP 90.2.
2. All sampling equipment should be appropriately decontaminated before and after use according to the requirements of the work plan addendum and SOP 80.1.
3. Collect split-spoon; core barrel, Shelby tube, sonic core or other similar samples during drilling.
4. Upon opening sampler or extruding sample, immediately screen soil for VOCs using a PID or appropriate instrument. If sampling for VOCs, determine the area of highest concentration; use a

stainless steel knife, trowel, or lab spatula to cut the sample; and screen for VOCs with monitoring instrument(s).

5. Log the sample on the boring log before extracting from the sampler per the requirements of SOP 10.3.
6. Any required VOC samples will be collected first followed by the other parameters. VOC samples will not be composited or homogenized and will be collected from the area exhibiting the highest screening level. The method of VOC sample collection will follow the procedures specified in SOP 30.8 (Methanol Preservation Method) or 30.9 (En Core® Method) based on the requirements of the work plan addenda.
7. Field screen the sample with properly calibrated photoionization detector (PID) or other appropriate instrument. Cut a cross-sectional slice from the core or center of the sample and insert the monitoring instrument(s). Based on the screening results, collect the VOC fraction, as applicable.
8. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
9. If homogenization or compositing of the sampling location is not appropriate for other parameters, the sample should be directly placed into appropriate sample containers with a stainless steel spoon or equivalent.
10. If homogenization of the sample location is appropriate or compositing of different locations is desired, transfer the sample to a stainless steel bowl for mixing. The sample should be thoroughly mixed with a clean stainless steel spoon, scoop, trowel, or spatula and placed in appropriate sample containers per the requirements for containers and preservation specified in work plan addenda. Secure the cap of each container tightly.
15. Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
16. Discard any remaining sample into the drums used for collection of cuttings.
17. Abandon borings according to procedures outlined in SOP 20.2.

### 3.4 INVESTIGATION-DERIVED MATERIAL

Investigation-derived material will be managed in accordance with procedures defined in the work plan addenda for the site being investigated and SOP 70.1.

**NOTES:** If sample recoveries are poor, it may be necessary to composite samples before placing them in jars. In this case, the procedure will be the same except that two split-spoon samples (or other types of samples) will be mixed together. The boring log should clearly state that the samples have been composited, which samples were composited, and why the compositing was done. In addition, VOC fraction should be collected from the first sampling device.

When specified, samples taken for geotechnical analysis (e.g., percent moisture, density, porosity, and grain size) will be undisturbed samples, such as those collected using a thin-walled (Shelby tube) sampler, sonic core sampler, etc.

## 4.0 MAINTENANCE

Not applicable.

## 5.0 PRECAUTIONS

Refer to the site-specific health and safety plan.

Soil samples will not include vegetative matter, rocks, or pebbles unless the latter are part of the overall soil matrix.

## 6.0 REFERENCES


ASTM Standard D 1586-99. 1999. *Standard Test Method for Penetration Test and Split-Barrel Sampling of Soils.*

ASTM Standard D 1587-00 (2007) e1. 2007. *Standard Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes.*

ASTM Standard D 5633-04. 2004. *Standard Practice for Sampling with a Scoop.*

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3. 1 February.

# STANDARD OPERATING PROCEDURE 30.2
# GROUNDWATER SAMPLING

## 1.0 SCOPE AND APPLICATION

The purpose of this standard operating procedure (SOP) is to delineate protocols for the collection of groundwater samples from monitoring wells.

## 2.0 MATERIALS

- Work Plans;
- Field logbooks and field parameter forms;
- Plastic sheeting;
- Decontamination equipment and supplies (SOP 80.1);
- Variable-speed, low-flow submersible pump with safety drop cable;
- Nylon stay-ties;
- Generator;
- Dedicated Teflon tubing or Teflon lined polyethylene tubing;
- Flow-through-cell and probes for measuring pH, temperature, specific conductance, oxidation/reduction potential, dissolved oxygen, and turbidity (SOP 40.1);
- Electronic water-level indicator;
- Appropriate sample bottles, labels, chain-of-custody forms, and sample shipping supplies etc;
- Cooler with ice;
- Silicone tubing;
- 0.45-micron disposable filters (as appropriate).
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan;
- Photoionization detector (PID) or other appropriate monitoring instrument per the site-specific health and safety plan; and
- Appropriate containers for investigation-derived material.

## 3.0 PROCEDURE

### 3.1 DOCUMENTATION

Groundwater sampling information should be recorded in the field logbooks as described in SOPs 10.1 and 10.2.

The following are general rules for the field parameter logbook for groundwater, as described in SOP 10.2:

- Only information for one site or installation per logbook. The same book maybe used for more than one sampling event.

- The first five pages will be reserved for index, general notes, etc. Sign and date each entry.
- Fill in the forms.
- Duplicate copies, index pages, and calibration sheets remain intact.

### 3.2 OVERVIEW OF SAMPLING TECHNIQUES

In general, two different techniques may be used to sample groundwater from monitoring wells at Radford Army Ammunition Plant (RFAAP):

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

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

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

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

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

- In a well with potential or documented multiple flow zones and where individual flow zones will not be evaluated;
- In moderately producing wells (> 0.5 liters per minute) where no discrete flow zones were documented during drilling; and
- In wells sampled during seasonal high groundwater conditions with enhanced yield (and potentially additional flow zones).

Groundwater samples should be collected no sooner than 14 days after well development. Information from the boring logs, well completion records, and well development records should be reviewed before sampling a well to determine the most appropriate sampling technique. Pertinent information for each well to be sampled includes:

- Well construction;
- Depth and nature of water producing zones;
- Sustainable pumping rate of the well to be sampled;
- Well recharge characteristics; and
- Baseline turbidity.

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

In general, when using the pumps specified in the following sections, situate any gasoline-powered generator on level ground approximately 15 ft downwind from the well. All generator maintenance (oil and fueling) is to be performed off site. If the hose(s) and/or power cord of the pump is not on a reel, place the pump with its hose and power cord on the plastic sheeting downhill from the well.

### 3.3 TYPE I SAMPLING PROCEDURES

Type I low flow purging and sampling procedures include the following:

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.
- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.
- Well depth at the time of purging will be obtained from well construction and existing data.
- Slowly lower a clean, stainless steel, adjustable flow rate, submersible pump and dedicated Teflon or Teflon-lined polyethylene tubing to the desired depth. As the pump is slowly lowered into the well, secure the safety drop cable, tubing, and electrical lines to each other using nylon stay-ties.
- For wells with very low sustainable pumping rates (≤ 0.5 liters per minute), the pump should be set in the middle of the saturated screen section of the well or middle of the water column for open wells. The pump should be set 12 hours prior to purging so that the depth to water equilibrates and sediments disturbed during pump placement have time to settle.
- For wells with sustainable pumping rates (> 0.5 liters per minute), the pumps will be set at a desired depth prior to purging, allowing for the depth to water to equilibrate before sampling. The desired depth will be specified in work plan addenda based on site-specific conditions and DQOs.
- Connect the pump tubing to an in-line flow-through cell(s) and connect the multi-parameter probe to the cell(s). The end of the tubing exiting the in-line flow-through cell should be placed to discharge into a appropriate container(s) to collect purge water.
- Immediately prior to purging, the depth to water will be measured and record. Start pumping the water at a rate of 100 to 400 milliliters per minute. Avoid surging. The pumping rate should cause minimal drawdown (less than 0.2 ft). Water level measurements should be collected continuously to document stabilization of the water level. Pumping rates should, if needed, be reduced to the minimal capabilities of the pump to avoid dewatering the screen interval and ensure stabilization of indicator parameters.
- During purging, water quality indicator parameters will be monitored at the in-line flow-through cell(s) every 3 to 5 minutes. The parameters to be monitored include pH, specific conductance, oxidation/reduction potential (Eh), dissolved oxygen, and turbidity.

- Continue purging until stabilization of indicator parameters is achieved. Stabilization is defined as three consecutive readings that are within the following criteria:
  - ± 0.1 for pH;
  - ±3% for specific conductance;
  - ±10 mV for oxidation/reduction potential (Eh); and
  - ±10% for turbidity and dissolved oxygen.
- If the parameters have stabilized, but the turbidity is not in the range of 5 to 10 NTU, then both filtered and unfiltered samples should be collected for any metals analysis. Filter metal samples should be collected with an in-line filter using a high capacity 0.45-micron particulate filter. This filter should be pre-rinsed according to the manufacturer's instructions.
- Once purging is completed, reduce the pumping rate to its lowest steady rate and disconnect the tubing from the in-line flow-though cell(s).
- Collect groundwater samples directly from the end of the tubing into clean containers provided by the laboratory. The container requirements and preservatives for groundwater samples are specified in work plan addenda. Allowing the pump discharge to flow gently down the inside of the container with minimal turbulence should fill all sample containers. Volatile organic compound (VOC) and gas sensitive parameter samples should be collected first followed by other parameters.
- In general, samples should be collected and containerized in the order of the volatilization sensitivity of the parameters. A preferred collection order for some common parameters is VOCs, extractable organics, metals, cyanide, sulfate and chloride, turbidity, and nitrate and ammonia. The parameters to be collected at any well location are site-specific and are specified in work plan addenda.
- Appropriately, label the samples (SOP 50.1), complete the chain-of-custody (SOP 10.4), and package the samples for shipping (SOP 50.2).
- After the sample collection is complete, remove the pump, tubing, and associated lines. Note: sample tubing will be dedicated to each well.
- Measure and record the total depth of the well.
- Secure the well be replacing and locking the lid.

### 3.4 TYPE II SAMPLING PROCEDURES

- The work area outside the well will be prepared by placing plastic sheeting on the ground around the well casing to avoid cross-contamination.
- All equipment used to purge and sample the wells will be thoroughly decontaminated before and after use according to the requirements of the work plan addenda and SOP 80.1.
- All equipment to be used for monitoring water quality parameters will be calibrated before beginning purging according to the requirements of the work plan addenda and SOP 40.1.
- Note the condition of the well and well head.
- Monitor the headspace of the well with a photoionization detector as the well cap is removed.
- Measure and record the depth to water with an electronic water level indicator. The measurement of well depth will not be taken until after sampling is completed so that potential re-suspension of any settled solids at the bottom of the well is avoided.

- Well depth at the time of purging will be obtained from well construction and existing data.
- Calculate the standing water column in the well by subtracting the depth to water from the total depth of the well as recorded during completion of the well.
- From the water depth, well diameter, sand pack length, etc., calculate the equivalent volume (1 EV) of water in the well.

  1 EV = volume in casing + volume in saturated sand pack. Therefore; if the water table lies below the top of the sand pack, use the following equation:

  $1\ EV = (pR_w^2 h_w) + (0.30p(R_s^2 - R_w^2)h_w) * (0.0043)$

  If the water table lies above the top of the sand pack use this equation:

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

  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

ASTM Standard D 5903-96 (2006). 2006. *Planning and Preparing for a Groundwater Sampling Events.*

USACE. 2001. R*equirements for the Preparation of Sampling and Analysis Plans.* EM 200-1-3, 1 February.

USEPA. 1995. *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures United States Environmental Protection Agency*, Office of Solid Waste and Emergency Response, EPA/540/S-95/504, December 1995.

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 determine the mean or total contaminant levels and provide these advantages:

- Increased sampling precision results due to sample point grouping and application of random sampling approach.
- Control of variances associated with contamination, location, and topography.

### 3.1.3 Systematic Grid

The most common statistical sampling strategy is termed either systematic grid or systematic random sampling. This approach is used when a large site must be sampled to characterize the nature and extent of contamination.

Samples are collected at predetermined intervals within a grid pattern according to the following approach:

- Select the first sampling point randomly; remaining sampling points are positioned systematically from the first point.
- Determine the grid design: one or two-dimensional. One-dimensional sample grids may be used for sampling along simple man-made features. Two-dimensional grid systems are ideal for most soil applications.
- Determine the grid type: square or triangular. Sampling is usually performed at each grid-line intersection. Other strategies include sampling within a grid center or obtaining composite samples within a grid.
- Each stratum is sampled based on using the simple random sampling approach but determined using a systematic approach.

### 3.1.4 Hot-Spot Sampling

Hot spots are small, localized areas of media characterized by high contaminant concentrations. Hot-spot detection is generally performed using a statistical sampling grid. The following factors should be addressed:

- Grid spacing and geometry. The efficiency of hot-spot searches is improved by using a triangular grid. An inverse relationship exists between detection and grid point spacing, e.g., the probability of hot-spot detection is increased as the spacing between grid points is decreased.
- Hot-spot shape/size. The larger the hot spot, the higher the probability of detection. Narrow or semi-circular patterns located between grid sampling locations may not be detected.
- False-negative probability. Estimate the false negative (β-error) associated with hot-spot analysis.

### 3.1.5 Geostatistical Approach

Geostatistics describe regional variability in sampling and analysis by identifying ranges of correlation or zones of influence. The general two-stage approach includes the following:

- Conducting a sampling survey to collect data defining representative sampling areas.
- Defining the shape, size, and orientation of the systematic grid used in the final sampling event.

## 3.2 NON-STATISTICAL SAMPLING

### 3.2.1 Biased Sampling

Specific, known sources of site contamination may be evaluated using biased sampling. Locations are chosen based on existing information.

### 3.2.2 Judgmental Sampling

This sampling approach entails the subjective selection of sampling locations that appear to be representative of average conditions. Because this method is highly biased, it is suggested that a measure of precision be included through the collection of multiple samples.

## 4.0 MAINTENANCE

Not applicable.

## 5.0 REFERENCES


Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring.* John Wiley & Sons, Inc. 320 p.

USACE. 2001. *Requirements for the Preparation of Sampling and Analysis Plans.* EM200-1-3. 1 February.

**TABLE 1**
**SAMPLING STRATEGIES**

| SAMPLING STRATEGY | DESCRIPTION | APPLICATION | LIMITATIONS |
|---|---|---|---|
| **Classical Statistical Sampling Strategies** | | | |
| Simple Random Sampling | Representative sampling locations are chosen using the theory of random chance probabilities. | Sites where background information is not available and no visible signs of contamination are present. | May not be cost-effective because samples may be located too close together. Does not take into account spatial variability of media. |
| Stratified Random Sampling | Site is divided into several sampling areas (strata) based on background or site survey information. | Large sites characterized by a number of soil types, topographic features, past/present uses, or manufacturing storage areas. | Often more cost-effective than random sampling. More difficult to implement in the field and analyze results. Does not take into account spatial variability of media. |
| Systematic Grid Sampling | Most common statistical strategy; involves collecting samples at predetermined, regular intervals within a grid pattern. | Best strategy for minimizing bias and providing complete site coverage. Can be used effectively at sites where no background information exists. Ensures that samples will not be taken too close together. | Does not take into account spatial variability of media. |
| Hot-Spot Sampling | Systematic grid sampling strategy tailored to search for hot spots. | Sites where background information or site survey data indicate that hot spots may exist. | Does not take into account spatial variability of media. Tradeoffs between number of samples, chance of missing a hot spot, and hot spot size/shape must be weighed carefully. |
| Geostatistical Approach | Representative sampling locations are chosen based on spatial variability of media. Resulting data are analyzed using kriging, which creates contour maps of the contaminant concentrations and the precision of concentration estimates. | More appropriate than other statistical sampling strategies because it takes into account spatial variability of media. Especially applicable to sites where presence of contamination is unknown. | Previous investigation data must be available and such data must be shown to have a spatial relationship. |
| **Non-Statistical Sampling Strategies** | | | |
| Biased Sampling | Sampling locations are chosen based on available information. | Sites with known contamination sources. | Contaminated areas can be overlooked if background information or visual signs of contamination do not indicate them. Best used if combined with a statistical approach, depending on the project objectives. |
| Judgmental Sampling | An individual subjectively selects sampling locations that appear to be representative of average conditions. | Homogenous, well-defined sites. | Not usually recommended due to bias imposed by individual, especially for final investigations. |

# STANDARD OPERATING PROCEDURE 30.9
# COLLECTION OF SOIL SAMPLES BY USEPA SW 846 METHOD 5035 USING DISPOSABLE SAMPLERS

## 1.0 SCOPE AND APPLICATION

This standard operating procedure (SOP) outlines the recommended protocol and equipment for collection of representative soil samples to monitor potential volatile organic contamination in soil samples.

This method of sampling is appropriate for surface or subsurface soils contaminated with low to high levels of volatile organic compounds (VOCs). This sampling procedure may be used in conjunction with any appropriate determinative gas chromatographic procedure, including, but not necessarily limited to, SW-846 Method 8015, 8021, and 8260.

## 2.0 MATERIALS

- Work Plans;
- Field Logbook;
- Photoionization Detector (PID) or other monitoring instrument(s) per site-specific health and safety plan;
- Personal protective equipment and clothing per site-specific health and safety plan;
- Soil sampling equipment, as applicable (SOP 30.1);
- Disposable sampler;
- T-handle and/or Extrusion Tool; and
- Decontamination equipment and supplies (SOP 80.1).

## 3.0 PROCEDURE

### 3.1 METHOD SUMMARY

Disposable samplers are sent to the field to be used to collect soil samples. Three samplers must be filled for each soil sampling location, two for the low-level method (sodium bisulfate preservation) and one for the high level method (methanol preservation). After sample collection, disposable samplers are immediately shipped back to the laboratory for preservation (adding soil sample into methanol and sodium bisulfate solution). The ratio of volume of methanol to weight of soil is 1:1 as specified in SW-846 Method 5035 (Section 2.2.2). The amount of preservative in the solution corresponds to approximately 0.2 g of preservative for each 1 g of sample. Enough sodium bisulfate should be present to ensure a sample pH of ≤ 2.

If quality assurance/quality control (QA/QC) samples are needed, seven samplers will be needed for the original, matrix spike, and matrix spike duplicate analysis. Soil samples are collected in the field using the disposable samplers, sealed and returned to the laboratory. A separate aliquot of soil is collected in a 125-mL container for dry weight determination.

## 3.2 SAMPLE CONTAINERS, PRESERVATION, HANDLING AND STORAGE

After sample collection, the disposable samplers must be cooled to and maintained at 4°C. The contents of the samplers will be analyzed using EPA methods 8015, 8021, and/or 8260. The **disposable** sampler is a single use device. It cannot be cleaned and/or reused.

***Disposable samplers have a 48 hour holding time from sample collection to sample preparation in the laboratory. Return the samplers to the laboratory immediately after sampling.***

## 3.3 SAMPLE PROCEDURES

Before sampling, the disposable sampler should be prepared as follows:

1. Unpack the cooler/sampling kit received from the laboratory. Disposable samplers are packed in sealed aluminized bags. These should be over packed in plastic zip lock bags. A T-Handle will also be needed to collect samples with the disposable sampler.
2. Hold coring body and push plunger rod down until small 0-ring rests against tabs. This will assure that plunger moves freely.
3. Depress locking lever on the sampler T-Handle (or other extraction device). Place coring body, plungers end first, into the open end of the T-Handle, aligning the two slots on the coring body with the two locking pins in the T-Handle. Twist the coring body clockwise to lock the pins in the slots. Check to ensure the sampler is locked in place. Sampler is ready for use.

The following procedure should be followed when using a disposable sampler to sample for VOCs in soil:

1. After the soil-sampling device (split spoon, corer, etc.) is opened, the sampling process should be completed in a minimum amount of time with the least amount of disruption.
2. Visual inspection and soil screening should be conducted after the sampler is opened and a fresh surface is exposed to the atmosphere. Soil screening should be conducted with an appropriate instrument (PID or FID).
3. Rough trimming of the sampling location surface should be considered if the sampling surface is not fresh or other waste, different soil strata, or vegetation may contaminate it. Surface layers can be removed using a clean stainless steel, spatula, scoop, or knife.
4. Orient the T-Handle with the T-up and the coring body down. This positions the plunger bottom flush with bottom of coring body (ensure that plunger bottom is in position). Using T-Handle, push sampler into soil until the coring body is completely full taking care not to trap air behind the sampler. When full, the small o-ring will be centered in the T-Handle viewing hole. Remove sampler from soil. Wipe excess soil from coring body exterior with a clean disposable paper towel.
5. Cap coring body while it is still on the T-Handle. ***Push*** cap over flat area of ridge ***and twist*** to lock cap in place. ***Cap must be seated to seal sampler.***
6. Remove the capped sampler by depressing locking lever on T-Handle while twisting and pulling sampler from T-Handle.
7. Lock plunger by rotating extended plunger rod fully counterclockwise until wings rest firmly against tabs.
8. Fill the 125-mL wide mouth jar for the non-preserved portion of the sample to be used for a moisture determination. These may be in a cardboard box. Retain all packaging to return the samples.
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 4ºC 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
- Do not force pins into the connectors; note the keying sequence.

## 6.0 REFERENCES

Manufacturer's Handbook.

# 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 (2001). 2001. *Standard Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well).*

M^c^Alary, T. A., and Barker, J.F. 1987. “Volatilization Losses of Organics During Ground Water Sampling from Low Permeability Materials” in *Ground Water Monitoring Review.* Fall 1987.

Thornhill, Jerry T. 1989. Accuracy of Depth to Groundwater Measurements; in “EPA Superfund Ground Water Issue” EPA/540/4-89/002.

# STANDARD OPERATING PROCEDURE 40.3
# SLUG TESTS

## 1.0 PURPOSE

The purpose of this standard operating procedure (SOP) is to provide information and technical guidance for performing falling- and rising-head *in situ* hydraulic conductivity tests and data analyses. The slug test method involves causing a sudden change in head in a control well and measuring the water level response within that control well. Head change may be induced by suddenly injecting into the well or removing from the well a known quantity of water, rapid removal of a mechanical "slug" from below the water level, increasing or decreasing the air pressure in the well casing, or emplacement of a mechanical slug into the water column.

The water level response in the well is a function of the mass of water in the well and the transmissivity and coefficient of storage of the aquifer. The results of the slug test may be used to determine an estimate of the hydraulic conductivity of the aquifer material near the well.

## 2.0 MATERIALS

- Work Plans;
- Field logbook;
- Well construction information and boring log;
- Photoionization detector (PID) or other monitoring instruments per site-specific health and safety plan;
- Decontamination equipment and supplies (SOP 80.1);
- Aquifer test data sheets;
- Personal protective equipment and clothing (PPE) per site-specific health and safety plan; and
- Slug-inducing equipment (solid slug, line, etc.) large enough to displace groundwater beyond the well filter pack.

## 3.0 PROCEDURE

Initially, an appropriate test methodology should be chosen. The selection of the appropriate test method (rising or falling head) is dependent primarily on saturated screen length, the well diameter, and the estimated hydraulic conductivity. If the screen extends above the water table, a rising-head test (water removal) should be used. The performance of a falling-head test (water added) in this circumstance would overstate the hydraulic conductivity value, as the measured response would reflect the equilibration rate of previously unsaturated material; unsaturated materials would equilibrate faster than saturated materials. When the measured water level in a monitoring well is above the screened portion of the well, a falling-head test methodology should be employed. A rising-head test may also be performed, but only if the initial water level reading (after the slug is removed) is above the screened interval.

For larger diameter and deeper wells, as a general rule and particularly for high conductivity materials, it is not feasible to remove a large enough slug or water volume to cause a sufficient change in head. In these cases the falling-head test method should be used.

It is recommended that a pressure transducer be used whenever possible to record water levels and time. A pressure transducer is required to record useful data when the hydraulic conductivity is high (greater than $10^{-3}$ cm/sec). The standard stopwatch and water-level indicator method is adequate for lower conductivity units.

The procedures outlined below assume use of a pressure transducer. Readings should be collected at intervals set on the data logger if used. If manual readings are collected, the following intervals should be applied:

- 0 to 5 minutes, every 10 seconds;
- 5 to 10 minutes, every 30 seconds;
- 10 to 30 minutes, every 1 minute; and
- 30 to 60 minutes, every 2 minutes.

### 3.1 Falling-Head Tests

1. Install pressure transducer near the total well depth and permit transducer and water levels to equilibrate to ambient conditions. Secure transducer cable to prevent movement during the test. Begin transducer readings.
2. Manually measure the static water level.
3. Insert slug completely below static water level or add a water "slug."
4. Intermittently measure water level and note the time of measurement with reference to the data logger.
5. Continue monitoring until water level is within 90% of the static level.

If a solid slug was used, stop the falling-head test recording at this point and begin a rising-head test by removing the solid slug from the well. If a solid slug was not used, simply end recording by the data logger at the completion of the falling-head test.

### 3.2 Rising-Head Tests

1. Install pressure transducer near the total well depth and permit transducer and water levels to equilibrate to ambient conditions. Secure transducer cable to prevent movement during testing.
2. Manually measure the static water level.
3. Remove sufficient volume of water to lower the water level a minimum of 1 ft below static water level, or
4. Install the solid slug fully below water level; permit static conditions to return and then remove the solid slug.
5. Begin readings with data logger.
6. Intermittently measure water level and note time of measurement with reference to data logger.
7. Continue monitoring until the water level is within 90% of the static level.

As a check on equipment operation and in the event that test data for a particular well are not usable, the data should be printed out in the field. If there is equipment failure (e.g., a non-attainment of a 1-foot minimum head change, unexplained fluctuations in water levels, etc.), the test can be rerun with minimum time lost.

The well numbers, static and subsequent water levels, programmed test numbers, and general comments should be recorded in the field notebook.

## 4.0 PRECAUTIONS

Not applicable.

## 5.0 REFERENCES


ASTM Standard D 4043-96 (2004). *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. 2001 (Reissued May 2006). *EPA Requirements for Quality Assurance Project Plans.* EPA/240/B-01/003, QA/R5, Final, Office of Research and Development, Washington, D.C. March 2001

**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. 2001 (Reissued May 2006). *EPA Requirements for Quality Assurance Project Plans.* EPA/240/B-01/003, QA/R5, Final, Office of Research and Development, Washington, D.C. March 2001

# STANDARD OPERATING PROCEDURE 70.1
# INVESTIGATION-DERIVED MATERIAL

## 1.0 SCOPE AND APPLICATION

Management of investigation-derived material (IDM) minimizes the potential for the spread of waste material onsite or offsite through investigation activities. The purpose of this standard operating procedure (SOP) is to provide general guidelines for appropriate management of potentially contaminated materials derived from the field investigations. Specific procedures related to the transportation and disposal of hazardous waste are beyond the scope of this SOP.

## 2.0 INTRODUCTION

Investigation derived material (IDM) consists of waste materials that are known or suspected to be contaminated with waste substances through the actions of sample collection or personnel and equipment decontamination. These materials include decontamination solutions, disposable equipment, drill cuttings and fluids, and water from groundwater monitoring well development and purging. To the extent possible, the site manager will attempt to minimize the generation of these materials through careful design of decontamination schemes and groundwater sampling programs. Testing conducted on soil and water investigation-derived material will show if they are also hazardous wastes as defined by RCRA. This will determine the proper handling and ultimate disposal requirements.

The criteria for designating a substance as hazardous waste according to RCRA is provided in 40 CFR 261.3. If IDM meet these criteria, RCRA requirements will be followed for packaging, labeling, transporting, storing, and record keeping as described in 40 CFR 262.34. Those materials that are judged potentially to meet the criteria for a regulated solid or hazardous waste will be placed in DOT-approved 55-gallon steel drums or another type of DOT approved container; based on waste characteristics and volume.
Investigation-derived material will be appropriately placed in containers, labeled, and tested to determine disposal options in accordance with RCRA regulations and Virginia Hazardous Waste Management Regulations.

## 3.0 INVESTIGATION-DERIVED MATERIAL MANAGEMENT

Procedures that minimize potential for the spread of waste material include minimizing the volume of material generated, material segregation, appropriate storage, and disposal according to RCRA requirements.

### 3.1 WASTE MINIMIZATION

In the development of work plan addenda, each aspect of the investigation will be reviewed to identify areas where excess waste generation can be eliminated. General procedures that will eliminate waste include avoidance of unnecessary exposure of materials to hazardous material and coordination of sampling schedules to avoid repetitious purging of wells and use of sampling equipment.

### 3.2 WASTE SEGREGATION

Waste accumulation and management procedures to be used depend upon the type of material generated. For this reason, IDM described below are segregated into separate 55-gallon storage drums or other appropriate DOT containers. Waste materials that are known to be free of potential hazardous waste contamination (such as broken sample bottles or equipment containers and wrappings) must be collected separately for disposal to municipal systems. Large plastic garbage or "lawn and leaf" bags are useful for collecting this trash. Even "clean" sample bottles or Tyvek should be disposed of with care. Although they are not legally a problem, if they are discovered by the public they may cause concern. Therefore, items that are known to be free from contamination but are also known to represent "hazardous or toxic waste" to the public must not be disposed of in any public trash receptacle, such as found at your hotel or park.

### 3.2.1 Decontamination Solutions

Solutions considered investigation-derived materials range from detergents, organic solvents, and acids used to decontaminate small hand samplers to steam-cleaning rinsate used to wash drill rigs and other large equipment. These solutions are to be placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT approved containers. Residual liquid IDM from decontamination pads will be removed and appropriately placed in container(s) at the end of each field day.

### 3.2.2 Soil Cuttings and Drilling Muds

Soil cuttings are solid to semi-solid soils generated during trenching activities or drilling for the collection of subsurface soil samples or the installation of monitoring wells. Depending on the type of drilling, drilling fluids known as "muds" may be used to remove soil cuttings. Drilling fluids flushed from the borehole must be directed into a settling section of a mud pit. This allows reuse of the decanted fluids after removal of the settled sediments. Drill cuttings, whether generated with or without drilling fluids, are to be removed with a flat-bottomed shovel and placed in 55-gallon drums with bolt-sealed lids or other appropriate DOT containers, as conditions or volume of IDM dictate.

### 3.2.3 Well Development and Purge Water

Well development and purge water is removed from monitoring wells to repair damage to the aquifer following well installation, obtain characteristic aquifer groundwater samples, or measure aquifer hydraulic properties. The volume of groundwater to be generated will determine the appropriate container to be used for accumulation of IDM.

For well development and purging, 55-gallon drums are typically an efficient container for accumulation. When larger volumes of water are removed from wells, such as when pumping tests are conducted, the use of large-volume portable tanks such as "Baker Tanks" should be considered for IDM accumulation.

Analytical data for groundwater samples associated with the well development and purge water will be used to assist in characterizing IDM and evaluating disposal options.

### 3.2.4 Personal Protective Equipment and Disposable Sampling Equipment

Personal protective equipment and clothing (PPE) may include such items as Tyvek coveralls, gloves, booties, and APR cartridges. Disposable sampling equipment may include such items as plastic sheeting, bailers, disposable filters, disposable tubing and paper towels. PPE and disposable sampling equipment that have or may have contacted contaminated media (soil, water, etc.) will be segregated and placed in 55-gallon drums separate from soil and water IDM. Disposition of this type of IDM will be determined by the results of IDM testing of the media in which the PPE and sampling equipment contacted.

## 3.3 MATERIAL ACCUMULATION

The IDM in containers must be placed in an appropriate designated RCRA container accumulation area at RFAAP, where it is permissible to accumulate such waste. IDM placed into a designated 90-day accumulation area will be properly sealed, labeled and covered. All drums will be placed on pallets.

A secure and controlled waste staging area will be designated by the installation prior the commencement of field sampling activities. Per the facility's requirements as a RCRA large quantity generator, waste accumulation cannot exceed 90 days for materials presumed or shown to be RCRA-designated hazardous wastes; waste which is known not to be RCRA-designated waste should be promptly disposed to municipal waste systems or appropriate facility.

### 3.3.1 IDM Accumulation Containers

Containers will be DOT-approved (DOT 17H 18/16GA OH unlined) open-head steel drums or other DOT approved container, as appropriate.

Container lids should lift completely off be secured by a bolt ring (for drum). Order enough containers to accumulate all streams of expected IDM including soil, PPE and disposable sampling equipment, decontamination water, purge water, etc.

Solid and liquid waste streams will not be mixed in a container. PPE and expendable sampling equipment will be segregated from other IDM and placed in different containers than soil. Containers inside containers are not permitted. PPE must be placed directly in a drum not in a plastic bag.

Pallets are often required to allow transport of filled drums to the staging area with a forklift. Normal pallets are 3×4 ft and will hold two to three 55-gallon drums depending on the filled weight. If pallets are required for drum transport or storage, field personnel are responsible for ensuring that the empty drums are placed on pallets before they are filled and that the lids are sealed on with the bolt-tighten ring after the drums are filled. Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move the drums by hand.

### 3.3.2 Container Labeling

Each container that is used to accumulate IDM will be appropriately labeled at the time of accumulation and assigned a unique identification number for tracking purposes. The following information will be written in permanent marker on a drum label affixed on the exterior side at a location at least two-thirds of the way up from the bottom of the drum.

- Facility name.
- Accumulation start date and completion date.
- Site identifier information (SWMU, boring, well, etc.).
- Description of IDM.
- Drum ID No.

## 4.0 MATERIAL CHARACTERIZATION AND DISPOSAL

IDM will be characterized and tested to determine whether it is a hazardous waste as defined by 40 CFR Part 261 and to determine what disposal options exist in accordance with RCRA regulations and the Virginia Hazardous Waste Management Regulations (VHWMR).

In general, IDM will be considered a hazardous waste if it contains a listed hazardous waste or if the IDM exhibits a characteristic of hazardous waste.

Work plan addenda will identify the appropriate characterization and testing program for IDM based on the following:

- Site-specific conditions related to chemicals of concern, etc.
- The nature and quantity of expected IDM to be generated during site-specific investigations.

- Applicable Federal, State, and local regulations, such as RCRA, VHWMR regulations and policies and procedures, and Army Regulation 200-1.
- RFAAP specific requirements and policies for IDM characterization and disposal at the time of the investigation.

In general, appropriate USEPA SW 846 Test Methods for Evaluating Solid Waste will be used for testing IDM and will be specified in work plan addenda. Other appropriate test methods may be specified by RFAAP in addition to SW 846 Methods that are specific to installation operations, the site of interest (percent explosive content, reactivity, etc.), or requirements for disposal at RFAAP water treatment facilities or publicly owned treatment works.

Responsibility for the final disposal of IDM will be determined before field activities are begun and will be described in work plan addenda. Off-site disposal of IDM will be coordinated with RFAAP (generator) to ensure appropriate disposition. The contractor will coordinate IDM transportation and disposal activities for RFAAP (generator).

At the direction of RFAAP, appropriate waste manifests will be prepared by the USACE contractor or Alliant Techsystems subcontractor for transportation and disposal. Alliant Techsystems or other appropriate RFAAP entity will be listed as the generator and an appointed representative from RFAAP will review and sign the manifest for offsite disposal.

RFAAP will make the final decision on the selection of the transporter, storage, and disposal facility (TSDFs) or recycling facility. RFAAP will provide the contractor a listing of previously used TSDFs for priority consideration. Proposed facilities that are not included on the listing are required to provide a copy of the TSDFs most recent state or federal inspection to the installation. Waste characterization and testing results will be submitted to RFAAP (generator) for review and approval before final disposition of the material.

Hazardous waste: Prior to final disposition, a hazardous waste manifest will be furnished by the TSDF to accompany transport to the disposal facility. Following final disposition, a certificate of disposal will be furnished by the disposal facility. Copies of the manifests and certificates of disposal are to be provided to RFAAP and retained on file by the contractor or subcontractor.

## 4.0 PRECAUTIONS

- Because the weight of one drum can exceed 500 lbs, under no circumstances should personnel attempt to move drums by hand.
- Refer to the site-specific health and safety plan when managing IDM.

## 5.0 REFERENCES

*Safety Rules for Contractors and Subcontractors*, (As Updated). 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

# SITE PHOTOGRAPHS

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PHOTO 1: SWMU 57 looking north.

PHOTO 2: Broken terra-cotta pipe located near SWMU 57.


PHOTO 3: Unassociated aboveground piping located north of SWMU 57.


PHOTO 4: Unassociated aboveground piping located west of SWMU 57.

# APPENDIX C

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# APPENDIX C.1

# SITE SCREENING PROCESS INVESTIGATION BORING LOGS

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**Project: Radford Army Ammunition Plant- SSP**
**Project Location: Radford, Virginia**
**Project Number: 09604-317**

# Log of Borehole 57SB1

Sheet 1 of 1

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 10-07-03 0945-1035 | Logged By | J. Spangler | Reviewed By | C. Lawrence |
| Drilling Method | Geoprobe - Direct Push Technology | Drilling Contractor | Richard Simmons Drilling | Total Depth of Borehole | 24.0 feet |
| Drill Rig Type | Tractor- Mounted Geoprobe | Drill Bit Size/Type | 4 ft x 2 in Rectractable Macrocore Sampler | Ground Surface Elevation | |
| Groundwater Level(s) | approximately 21.5 ft bgs during drilling | Sampling Method | 4 ft x 2 in Macrocore Sampler with Liner | Hammer Data | NA |
| Borehole Backfill | Bentonite Pellets | Comments | | | |

| Elevation, feet | Downhole Depth, feet | SAMPLES Type | SAMPLES Number | SAMPLES Recovery (feet) | SAMPLES PID (ppm) | Graphic Log | Lithologic Log (USCS Code) | MATERIAL DESCRIPTION | FIELD NOTES |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | CL | 7.5YR 4/3 brown, Clay with fine sand and trace silt, moist, moderately stiff, moderately plastic | Sample 57SB1A collected 0.0-1.0 ft bgs |
| | | | 1 | 3.1 | ND | | ML | 7.5YR 4/6 strong brown, Sandy Silt with clay, very fine, moist, low plasticity | |
| | 5 | | 2 | 4.0 | ND | | CH/CL | 5YR 5/6 yellowish red, Clay, moist, highly plastic, very stiff<br>6.9 ft bgs, becomes sandy, fine, moderately stiff, plastic<br>Grades to highly silty with depth | |
| | 10 | | 3 | 4.0 | ND | | ML | 5YR 5/8 yellowish red, Silt with some clay, moist, very soft | Sample 57SB1B collected 10.0-12.0 ft bgs |
| | | | 4 | 4.0 | ND | | ML | 7.5YR 5/8 strong brown, Sandy Silt, very fine, moist, soft<br>12.25-14.8 ft bgs, 7.5YR 6/6 reddish yellow, Sandy Silt, very fine, moist, very soft<br>Grades sandier with depth | |
| | 15 | | | | | | GM/GP | 10YR 6/6 brownish yellow, Gravel with silt and sand, moist | |
| | 20 | | 5<br>6 | 2.7<br>3.0 | ND<br>ND | | ML | 7.5YR 7/8 reddish yellow mottled with light gray, Silt with claystone fragments, moist, very soft<br>7.5YR 6/8 reddish yellow, increasing claystone fragments, sticky<br>Groundwater at approximately 21.5 ft bgs | Sample 57SB1C collected 18.0-20.0 ft bgs |
| | 25 | | | | | | | Boring terminated 24.0 ft bgs | |
| | 30 | | | | | | | | |

Report: ENV_12AS_CLEVELAND+/-USCS; File: RFAAP_SSP.GPJ; 12/8/2003 57SB1

URS

| Project: Radford Army Ammunition Plant- SSP | Log of Borehole 57SB2 |
|---|---|
| Project Location: Radford, Virginia | |
| Project Number: 09604-317 |  |

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 10-07-03 1400-1500 | Logged By | J. Spangler | Reviewed By | C. Lawrence |
| Drilling Method | Geoprobe - Direct Push Technology | Drilling Contractor | Richard Simmons Drilling | Total Depth of Borehole | 36.0 feet |
| Drill Rig Type | Tractor- Mounted Geoprobe | Drill Bit Size/Type | 4 ft x 2 in Rectractable Macrocore Sampler | Ground Surface Elevation | |
| Groundwater Level(s) | 35.5 ft bgs during drilling | Sampling Method | 4 ft x 2 in Macrocore Sampler with Liner | Hammer Data | NA |
| Borehole Backfill | Bentonite Pellets | Comments | Initial Boring Refusal 3.0 ft bgs; Offset boring 6 inches | | |

| Elevation, feet | Downhole Depth, feet | SAMPLES Type | Number | Recovery (feet) | PID (ppm) | Graphic Log | Lithologic Log (USCS Code) | MATERIAL DESCRIPTION | FIELD NOTES |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | 10YR 3/3 dark brown, Sand and Silt, very fine, underlain by Gravel fill | Sample 57SB2A collected 0.0-1.0 ft bgs |
| | | | 1 | 3.0 | ND | | CL | 5YR 5/6 yellowish red, Sandy Clay, fine, stiff, very plastic, alternating with sand and clay layers | |
| | | | | | | | NR | 3.0-4.0 ft bgs; No Recovery, presumed Gravel | |
| | | | | | | | GM/GP | 5YR 4/4 reddish brown, Gravel with sand and silt, hard | |
| | 5 | | 2 | 4.0 | ND | | ML/CL | 7.5YR 6/8 reddish yellow, Silt and Clay, dry, friable, dense<br>Clay grades out<br>9.0 ft bgs, Claystone inclusions, slight saprolitic texture<br>10.0-11.5 ft bgs, Claystone inclusions; weathered, saprolitic texture; black | Sample 57SB2B, MS, MSD collected 8.0-12.0 ft bgs |
| | 10 | | 3 | 4.0 | ND | | | | |
| | | | 4 | 4.0 | ND | | ML/SM | 10YR 6/6 brownish yellow, Silt, trace gravel and claystone inclusions, trace medium to coarse sand, moist<br>15.0 ft bgs, some very pale brown to gray mottling, trace medium to coarse sand | |
| | 15 | | 5 | 4.0 | ND | | | | |
| | | | | | | | Siltstone | 10YR 6/6 brownish yellow, Siltstone with claystone layers, saprolitic texture, slightly moist | |
| | 20 | | 6 | 4.0 | ND | | ML | 10YR 6/6 brownish yellow, Silt, saprolitic texture, slightly moist, very dense, hard<br>Increasing sand and gravel (mudstone/claystone) | |
| | 25 | | 8 | 4.0 | ND | | | | |
| | | | | | | | GP/GM | 10YR 5/8 yellowish brown, Silty Gravel with sand, moist, moderately dense; sand, fine to coarse; gravel, medium | |
| | 30 | | | | | | | | |

**Project: Radford Army Ammunition Plant- SSP**
**Project Location:** Radford, Virginia
**Project Number:** 09604-317

# Log of Borehole 57SB2



| Elevation, feet | Downhole Depth, feet | SAMPLES Type | Number | Recovery (feet) | PID (ppm) | Graphic Log | Lithologic Log (USCS Code) | MATERIAL DESCRIPTION | FIELD NOTES |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | | 9 | 2.6 | ND | | GP/GM | 10YR 5/8 yellowish brown, Silty Gravel with sand, moist, moderately dense; sand, fine to coarse; gravel, medium | |
| | | | 10 | 4.0 | ND | | | | Sample 57SB2C collected 33.0-35.0 ft bgs |
| | 35 | | | | | | | Groundwater at 35.5 ft bgs ▽ | |
| | | | | | | | | Offset Boring terminated 36.0 ft bgs | |
| | 40 | | | | | | | | |
| | 45 | | | | | | | | |
| | 50 | | | | | | | | |
| | 55 | | | | | | | | |
| | 60 | | | | | | | | |
| | 65 | | | | | | | | |

| Project: Radford Army Ammunition Plant- SSP | Log of Borehole 57SB3 |
|---|---|
| Project Location: Radford, Virginia | |
| Project Number: 09604-317 | Sheet 1 of 2 |

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 10-07-03 1045-1215 | Logged By | J. Spangler | Reviewed By | C. Lawrence |
| Drilling Method | Geoprobe - Direct Push Technology | Drilling Contractor | Richard Simmons Drilling | Total Depth of Borehole | 34.5 feet |
| Drill Rig Type | Tractor- Mounted Geoprobe | Drill Bit Size/Type | 4 ft x 2 in Rectractable Macrocore Sampler | Ground Surface Elevation | |
| Groundwater Level(s) | 32.0 ft bgs during drilling | Sampling Method | 4 ft x 2 in Macrocore Sampler with Liner | Hammer Data | NA |
| Borehole Backfill | Bentonite Pellets | Comments | | | |

| Elevation, feet | Downhole Depth, feet | Samples: Type | Samples: Number | Samples: Recovery (feet) | Samples: PID (ppm) | Graphic Log | Lithologic Log (USCS Code) | MATERIAL DESCRIPTION | FIELD NOTES |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | 5YR 3/3 reddish brown, Sandy Silt, fine, slightly moist | Sample 57SB3A and SBD6 collected 0.0-1.0 ft bgs |
| | | | 1 | 4.0 | ND | | ML | 2.5YR 5/8 red, Silt with clay and sand, very fine, moist, micaceous, soft<br>Increasing moisture and sand with depth<br>Black sand (weathered rock) | |
| | 5 | | 2 | 4.0 | ND | | | | |
| | | | | | | | SC/SM | 7.5YR 5/6 strong brown, Clayey Sand with silt, very fine, soft to moderately dense, micaceous<br>10.0 ft bgs, some black sand | |
| | 10 | | 3 | 4.0 | ND | | | | |
| | | | | | | | SM | 7.5YR 6/4 light brown, Silty Sand with some clay, very fine, very moist, soft to moderately stiff, moderately dense | |
| | | | | | | | CL/CH | 7.5YR 6/4 light brown, Sandy Clay/Clayey Sand, moist, dense<br>13.5-14.0 ft bgs, Clay is very plastic | |
| | | | 4 | 4.0 | ND | | CL | 7.5YR 7/8 reddish yellow, Clay with silt and trace sand, saprolitic texture<br>Increasing clay | Sample 57SB3B collected 14.0-16.0 ft bgs |
| | 15 | | | | | | CH | 7.5YR 5/8 strong brown, Clay with trace black sand, very plastic<br>17.6-17.8 ft bgs, Sandy Clay lense, stiff, slightly moist | |
| | | | 5 | 4.0 | ND | | | | |
| | 20 | | 6 | 4.0 | ND | | ML | 7.5YR 6/8 reddish yellow, Silt with claystone inclusions, dense, moist; claystone inclusions have saprolitic texture<br>21.8 ft bgs, becomes soft with trace black sand, increasing moisture | |
| | 25 | | 7 | 4.0 | ND | | | | |
| | | | | | | | ML | 10YR 5/8 yellowish brown, Silt with some clay, very soft | |
| | | | | | | | | 10YR 4/6 dark yellowish brown, Silt with some clay and claystone inclusions, soft; | Sample 57SB3C |
| | 30 | | | | | | | | |

**Project: Radford Army Ammunition Plant- SSP**
**Project Location:** Radford, Virginia
**Project Number:** 09604-317

# Log of Borehole 57SB3



| Elevation, feet | Downhole Depth, feet | SAMPLES: Type | SAMPLES: Number | SAMPLES: Recovery (feet) | SAMPLES: PID (ppm) | Graphic Log | Lithologic Log (USCS Code) | MATERIAL DESCRIPTION | FIELD NOTES |
|---|---|---|---|---|---|---|---|---|---|
| | 30 | | 8 | 2.0 | ND | | | claystone has saprolitic texture | collected 29.0-31.0 ft bgs |
| | | | | | | | | Increasing moisture | |
| | | | | | | | ML | Groundwater at 32.5 ft bgs | |
| | | | 9 | 2.5 | ND | | | | |
| | 35 | | | | | | | Boring terminated 34.5 ft bgs | |
| | 40 | | | | | | | | |
| | 45 | | | | | | | | |
| | 50 | | | | | | | | |
| | 55 | | | | | | | | |
| | 60 | | | | | | | | |
| | 65 | | | | | | | | |

| Project: Radford Army Ammunition Plant- SSP | Log of Borehole 57SB4 |
|---|---|
| Project Location: Radford, Virginia | |
| Project Number: 09604-317 | Sheet 1 of 1 |

| | | | | | |
|---|---|---|---|---|---|
| Date(s) Drilled | 10-08-03 1000-1600 | Logged By | J. Spangler | Reviewed By | C. Lawrence |
| Drilling Method | Hand Auger | Drilling Contractor | URS Group, Inc. | Total Depth of Borehole | 1.5 feet |
| Drill Rig Type | NA | Drill Bit Size/Type | 3-inch Hand Auger | Ground Surface Elevation | |
| Groundwater Level(s) | Surface Water | Sampling Method | Stainless-Steel 3-inch Hand Auger | Hammer Data | NA |
| Borehole Backfill | Bentonite Pellets | Comments | Boring located inside Settling Lagoon | | |

| Elevation, feet | Downhole Depth, feet | SAMPLES Type | SAMPLES Number | SAMPLES Recovery (feet) | SAMPLES PID (ppm) | Graphic Log | Lithologic Log (USCS Code) | MATERIAL DESCRIPTION | FIELD NOTES |
|---|---|---|---|---|---|---|---|---|---|
| | 0 | | | | | | | Highly organic swamp mud, wet | Sample 57SB4A collected 0.5 ft bgs |
| | | | 1 | 1.0 | | | CH/SC | 2.5Y 5/3 light olive brown, Sandy Clay, fine, wet, very plastic, sticky, stiff | |
| | 1 | | 2 | 0.5 | | | | | Sample 57SB4B collected 1.5 ft bgs |
| | 2 | | | | | | | Boring Refusal 1.5 ft bgs<br>Note: 2 offset borings, identical lithology, identical refusal | |
| | 3 | | | | | | | | |
| | 4 | | | | | | | | |
| | 5 | | | | | | | | |
| | 6 | | | | | | | | |
| | 7 | | | | | | | | |
| | 8 | | | | | | | | |
| | 9 | | | | | | | | |
| | 10 | | | | | | | | |

# APPENDIX C.2

# PHYSICAL SOIL SAMPLE RESULTS

# Radford Army Ammunition Plant
## LABORATORY TESTING DATA SUMMARY

| BORING NO. | DEPTH (ft) | IDENTIFICATION TESTS: WATER CONTENT (%) | LIQUID LIMIT | PLASTIC LIMIT | PLAS. IND. | USCS SYMB. (1) | SIEVE MINUS NO. 200 (%) | HYDROMETER % MINUS 2 µm (%) | ORGANIC CONTENT (burnoff) (%) | pH: Distilled Water | pH: 0.01 M CaCl Solution | TOTAL UNIT WEIGHT (pcf) | DRY UNIT WEIGHT (pcf) | SPECIFIC GRAVITY | PERMEABILITY (cm/sec) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13SB10 | 2-3 | 29.6 | | np | | SM | 28.6 | | 3.5 | 6.9 | 6.6 | 115.9 | 89.4 | 2.688 | 1.3E-5 | |
| 13SB7 | 12.7 | 16.0 | | | | GC | 13.3 | | 1.1 | 6.3 | 6.2 | 130.0 | 112.0 | 2.711 | | |
| 37SB1 | 6-6.5 | 21.8 | 22 | 18 | 4 | SC-SM | 43.0 | | 1.5 | 6.3 | 6.0 | 130.1 | 106.8 | 2.677 | 1.6E-7 | |
| 37SB2 | 15.5-16 | 17.0 | | | | SM | 33.7 | | 1.6 | 5.1 | 5.4 | 122.7 | 104.9 | 2.746 | 2.3E-4 | |
| 38SB1 | 7 | 20.9 | | | | SM | 34.8 | | 1.7 | 7.1 | 6.6 | 125.8 | 104.1 | 2.713 | | |
| 38SB2 | 15.5 | 3.7 | | | | SM | 13.8 | | 1.1 | 6.8 | 6.3 | 116.0 | 111.9 | 2.702 | 2.0E-3 | |
| 46SB1 | 14.5 | 24.5 | 32 | 18 | 14 | SC | 50.0 | 23 | 2.2 | 5.7 | 5.9 | 127.5 | 102.4 | 2.729 | 3.0E-8 | |
| 46SB2 | 9.5-10 | 20.4 | | | | SM | 26.9 | | 1.8 | 6.2 | 5.7 | 123.4 | 102.5 | 2.735 | | |
| 57SB2 | 7.5-8 | 28.4 | | | | CL-ML | 70.2 | | 2.6 | 5.6 | 3.9 | 94.1 | 73.3 | 2.701 | | |
| 57SB3 | 16.5-17 | 46.4 | 83 | 29 | 54 | CH | 89.6 | 46 | 3.6 | 5.3 | * | 106.4 | 72.7 | 2.694 | 1.8E-7 | |
| 68SB2 | 18-18.5 | 30.4 | | | | CL-ML | 54.9 | | 1.5 | 6.8 | 6.2 | 100.2 | 76.8 | 2.680 | | |
| 68SB3 | 7-7.5 | 35.8 | 49 | 29 | 20 | ML | 75.9 | 26 | 3.6 | 5.2 | 3.8 | 115.4 | 85.0 | 2.744 | 1.9E-6 | |
| 69SB1 | 11-12 | 34.1 | 34 | 19 | 15 | CL | 74.1 | | 3.3 | 9.5 | 7.8 | 128.2 | 95.6 | 2.688 | | |
| 69SB3 | 7.5-8.5 | 32.7 | | | | CL | 77.7 | | 3.5 | 7.1 | 6.0 | 117.7 | 88.7 | 2.707 | 6.6E-9 | |
| ASB1 | 22-24 | 36.6 | 63 | 30 | 33 | CH | 58.8 | | 3.6 | 4.2 | 3.8 | 115.6 | 84.7 | 2.735 | | |
| ASB2 | 14-16 | 43.4 | 56 | 35 | 21 | MH | 78.4 | | 2.5 | 4.3 | 3.9 | 110.2 | 76.8 | 2.662 | 6.7E-7 | |
| FSB1 | 18.5-19 | 30.6 | 47 | 20 | 27 | CL | 79.2 | 30 | 1.4 | 7.1 | * | 119.2 | 91.2 | 2.628 | 8.6E-8 | |
| FSB2 | 7.5-8 | 15.6 | | | | SM | 19.9 | | 1.4 | 6.8 | 6.3 | 111.0 | 96.1 | 2.807 | | |
| QSB1 | 9.5-10 | 26.4 | 31 | 21 | 10 | CL | 52.6 | | 1.8 | 6.4 | 6.5 | 123.8 | 97.9 | 2.717 | 1.2E-7 | |
| QSB2 | 24 | 6.2 | | | | GP | 3.9 | | 0.6 | 6.4 | 6.2 | 121.6 | 114.6 | 2.692 | | |
| | | | | | | | | | | | | | | | | |

Note: (1) CS symbol based on visual observation and Sieve and Atterberg limits reported.

Prepared by: RV Reviewed by: CMJ Date: 12/01/2003

**TABLE ________**
**Radford Army Ammunition Plant**
**SUMMARY OF LABORATORY PERMEABILITY TESTS PERFORMED ON RECONSTITUTED SAMPLES**

| BORING NO. | SAMPLE NO. | DEPTH (ft) | WATER CONTENTS INITIAL / PRE-TEST (%) | TOTAL UNIT WGTS INITIAL / PRE-TEST (pcf) | DRY UNIT WGTS INITIAL / PRE-TEST (pcf) | STRESSES EFFECTIVE / BACK PRESSURE (psi) | DURING CONSOL. TIME / VOLUMETRIC STRAIN (days, %) | DURING TEST PERMEANT / INITIAL GRADIENT | COEFFICIENT OF PERM. K, (@ 20 C) (cm/sec) | REMARKS |
|---|---|---|---|---|---|---|---|---|---|---|
| 13SB10 | | 2-3 | 29.6 | 115.9 | 89.4 | 5.0 | over night | tap water | 1.3E-5 | P6775 |
| | | | 33.2 | 122.9 | 92.3 | 100.0 | 3.2 | 18 | | |
| 37SB1 | | 6-6.5 | 21.8 | 130.1 | 106.8 | 5.0 | over night | tap water | 1.6E-7 | P6776 |
| | | | 20.5 | 131.7 | 109.3 | 100.0 | 2.3 | 21 | | |
| 37SB2 | | 15.5-16 | 17.0 | 122.7 | 104.9 | 5.0 | over night | tap water | 2.3E-4 | P6779 |
| | | | 23.9 | 130.3 | 105.2 | 100.0 | 0.3 | 4 | | |
| 38SB2 | | 15.5 | 3.7 | 116.0 | 111.9 | 5.0 | over night | tap water | 2.0E-3 | P6785 |
| | | | 18.2 | 133.7 | 113.1 | 100.0 | 1.1 | 1 | | |
| 46SB1 | | 14.5 | 24.5 | 127.5 | 102.4 | 5.0 | over night | tap water | 3.0E-8 | P6782 |
| | | | 24.4 | 127.8 | 102.8 | 100.0 | 0.4 | 23 | | |
| 57SB3 | | 16.5-17 | 46.4 | 106.4 | 72.7 | 5.0 | over night | tap water | 1.8E-7 | P6783 |
| | | | 48.3 | 108.4 | 73.0 | 100.0 | 0.5 | 21 | | |
| 68SB3 | | 7-7.5 | 35.8 | 115.4 | 85.0 | 5.0 | over night | tap water | 1.9E-6 | P6780 |
| | | | 36.5 | 116.8 | 85.6 | 100.0 | 0.8 | 18 | | not recon. |
| 69SB3 | | 7.5-8.5 | 32.7 | 117.7 | 88.7 | 5.0 | over night | tap water | 6.6E-9 | P6773 |
| | | | 32.2 | 121.4 | 91.8 | 100.0 | 3.4 | 39 | | |
| ASB2 | | 14-16 | 43.4 | 110.2 | 76.8 | 5.0 | over night | tap water | 6.7E-7 | P6774 |
| | | | 42.0 | 111.4 | 78.4 | 100.0 | 2.1 | 16 | | |
| FSB-1 | | 18.5-19.0 | 30.6 | 119.2 | 91.2 | 5.0 | over night | tap water | 8.6E-8 | P6784 |
| | | | 28.8 | 120.8 | 93.8 | 100.0 | 2.7 | 23 | | |
| QSB1 | | 9.5-10 | 26.4 | 123.8 | 97.9 | 5.0 | over night | tap water | 1.2E-7 | P6781 |
| | | | 24.6 | 126.7 | 101.7 | 100.0 | 3.7 | 22 | | |
| | | | | | | | | | | |

## PERMEABILITY TEST: FALLING HEAD - CONSTANT VOLUME U-TUBE
## ASTM D 5084 - 90

Project No.: 31737767 | BORING: 57SB3 | Test No.: P6783

Project Name: Radford Army Ammunition Plant | SAMPLE: | DEPTH (ft): 16.5-17

**Specimen - Apparatus set-up - Test Information** | Cell No. 5 | Apparatus No. 4 | Stage No.: 2

**Preliminary Length/Area Calculations**

| | | | | | |
|---|---|---|---|---|---|
| Lo = | 2.691 | in | Lo= | 6.836 | cm |
| dLc= | 0.058 | in | Ao = | 20.16 | $cm^2$ |
| Lc= | 2.633 | in | Vo = | 137.79 | $cm^3$ |
| | | | Lc= | 6.688 | cm |
| dVc = 3 Vo * ( dLc/Lo) | | | dVc= | 8.91 | $cm^3$ |
| | | | Vc = | 128.88 | $cm^3$ |
| Sc = | 0.347 | $cm^{-1}$ | Ac= | 19.269 | $cm^2$ |

1) Specimen Tested in : [x] Triaxial Cell or [ ] Compaction Mold or
[x] with stones or [ ] Stones with filter paper or ______ top + bottom

2) Specimen orientation for: [x] Vertical or [ ] Horizontal permeability determination

3) During saturation: Water flushed up sides of specimen to remove ai [x] No [ ] Yes

4) During consolidation: [x] Top and bottom drainage or [ ] Top [ ] Bottom only

5) Direction of permeant : [x] Up during or [ ] Down during permeation

6) Permeant: water used [x] Tap [ ] Distilled

or [ ] Demineralized [ ] 0.005 N calcium sulfate (CaSO4)

**Equations Used**

Kt = - 0.0000750 * Sc/dT(min) * ln (ho/hf)

RT = (-0.02452*(ave. temp in C) + 1.495)

K @ 20 ºC = RT * Kt TubeC= 1.3181

| Consol Stage-Trial No. | Temp. ° C | Date | Time hr | Time min | Time sec | Initial $\sigma_c$ psi | Initial Ub psi | U-tube Reading Head (cm) (cc) | U-tube Reading Tail (cm) (cc) | Flow in/out gradient | Permeability Preliminary Final at 20ºC cm/sec Dev. from Ave. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| initial | 22.0 | 11/4/03 | 09 | 20 | 00 | 105.0 | 100.0 | 57.30 | 46.30 | 0.98 | 2.04E-07 |
| final | 22.0 | 11/4/03 | 09 | 49 | 00 | | | 55.60 | 46.85 | | 1.83E-07 |
| 1 | RT = 0.956 | dT = | 29.00 min | | | $\sigma'_c$ = | 0.7 ksf | 0.127 | 0.129 | io= 20.7 | 5% |
| initial | 22.0 | 11/4/03 | 09 | 51 | 00 | 105.0 | 100.0 | 57.30 | 46.30 | 0.97 | 2.01E-07 |
| final | 22.4 | 11/4/03 | 10 | 23 | 00 | | | 55.47 | 46.90 | | 1.80E-07 |
| 2 | RT = 0.951 | dT = | 32.00 min | | | $\sigma'_c$ = | 0.7 ksf | 0.136 | 0.141 | io= 20.7 | 3% |
| initial | 22.4 | 11/4/03 | 10 | 24 | 00 | 105.0 | 100.0 | 57.50 | 46.20 | 0.95 | 1.90E-07 |
| final | 22.7 | 11/4/03 | 10 | 56 | 00 | | | 55.71 | 46.80 | | 1.69E-07 |
| 3 | RT = 0.942 | dT = | 32.00 min | | | $\sigma'_c$ = | 0.7 ksf | 0.133 | 0.141 | io= 21.2 | -4% |
| initial | 22.7 | 11/4/03 | 10 | 57 | 00 | 105.0 | 100.0 | 57.50 | 46.20 | 0.98 | 1.91E-07 |
| final | 23.0 | 11/4/03 | 11 | 32 | 00 | | | 55.56 | 46.83 | | 1.67E-07 |
| 4 | RT = 0.935 | dT = | 35.00 min | | | $\sigma'_c$ = | 0.7 ksf | 0.145 | 0.148 | io= 21.2 | -4% |

**TEST SUMMARY**

**Final Specimen and Test Conditions**

| | | | | |
|---|---|---|---|---|
| Lc = | 6.688 | cm | $\varepsilon_{axial}$ = | 2.2% |
| Ac = | 20.506 | $cm^2$ | | |
| Vc= | 137.15 | $cm^3$ | $\varepsilon_{vol}$ = | 0.5% |
| Sc = | 0.326 | $cm^{-1}$ | Sc = Lc / Ac , final | |

| | w (%) | $\gamma_\tau$ (pcf) | $\gamma_d$ (pcf) | S (%) |
|---|---|---|---|---|
| Initial | 46.36 | 106.4 | 72.7 | 95.1 |
| PreTest | 48.34 | 108.4 | 73.0 | 100.0 |

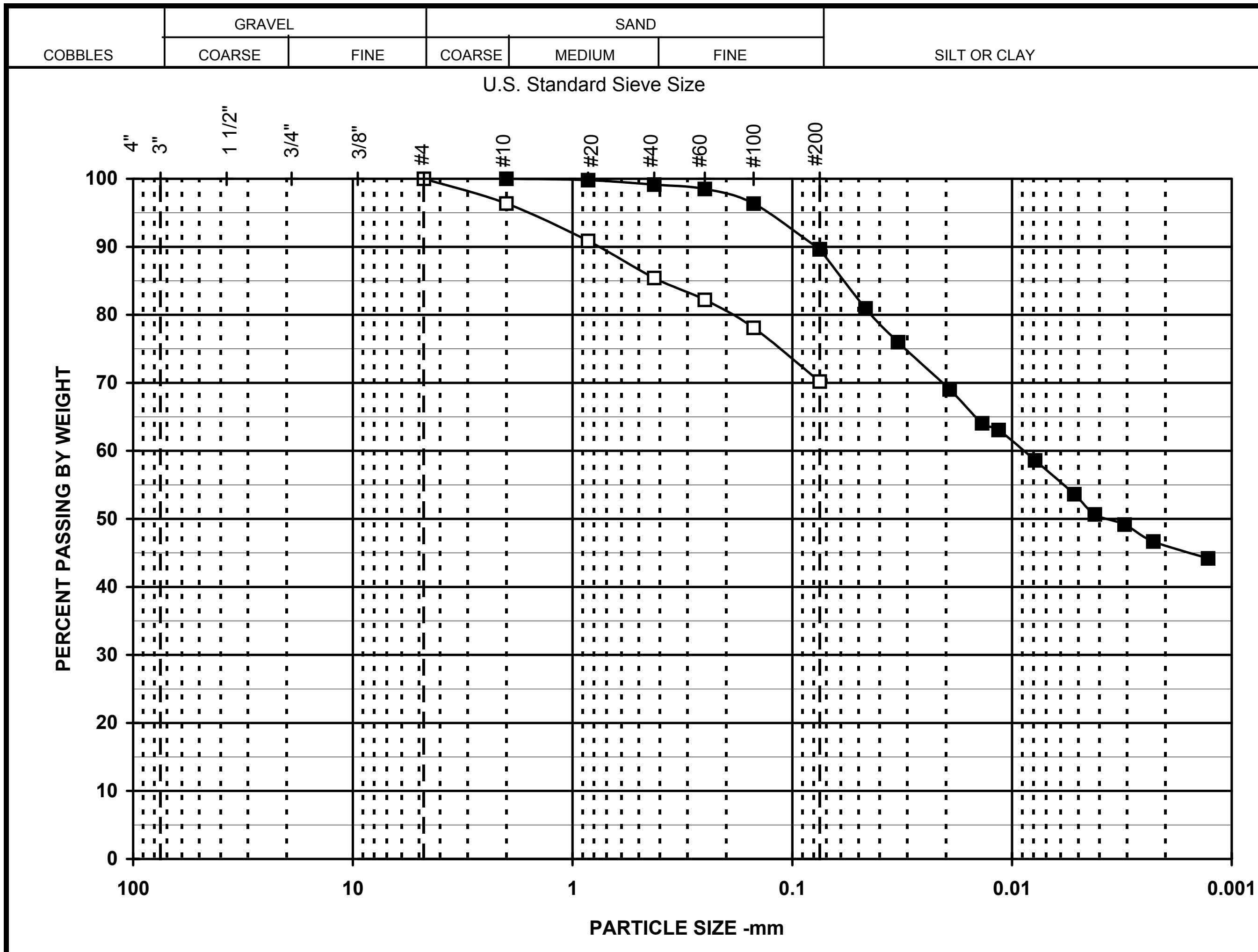
**HYDRAULIC CONDUCTIVITY SUMMARY**

Averages for trials: 1-4

ave K @ 20 ºC: **1.75E-07** cm/sec

$(i_o)$ave = 21.0

Tested By: DT Reviewed By: G. Thomas




| Symbol | □ | ■ | ○ |
|---|---|---|---|
| Boring | 57SB2 | 57SB3 | |
| Sample | | | |
| Spec | | | |
| Depth | 7.5-8 | 16.5-17 | |
| % +3" | | | |
| % Gravel | | | |
| % SAND | 29.8 | 10.4 | |
| % FINES | 70.2 | 89.6 | |
| % -2µ | | 46 | |
| Cc | | | |
| Cu | | | |
| LL | | 83 | |
| PL | | 29 | |
| PI | | 54 | |
| USCS | CL-ML | CH | |
| w (%) | 28.4 | | |

| Particle Size (Sieve #) | PERCENT FINER □ | ■ | ○ |
|---|---|---|---|
| 4" | | | |
| 3" | | | |
| 1 1/2" | | | |
| 3/4" | | | |
| 3/8" | | | |
| 4 | 100.0 | | |
| 10 | 96.4 | 100.0 | |
| 20 | 90.9 | 99.8 | |
| 40 | 85.4 | 99.1 | |
| 60 | 82.2 | 98.5 | |
| 100 | 78.1 | 96.3 | |
| 200 | 70.2 | 89.6 | |

| SYMBOL | DESCRIPTION AND REMARKS |
|---|---|
| □ | brown silty CLAY, some c-f sand. |
| | |
| ■ | yellowish brown CLAY, trace f. sand. |
| | |
| ○ | |
| | |

**PARTICLE SIZE DISTRIBUTION**

Radford Army Ammunition Plant

| Project No. 31737767 | December 2003 | Figure |
|---|---|---|

**URS Corporation**

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# APPENDIX D

## SITE SCREENING PROCESS TEXT AND SCREENING TABLES FOR SWMU 57

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# 7.0 SWMU 57 – POND BY BUILDINGS 4931 & 4928

## 7.1 SITE BACKGROUND – ENVIRONMENTAL SETTING

Physiography

SWMU 57 is a 0.027-acre area (1,172 $ft^2$), consisting of a man-made, asphalt-lined former lagoon. This site is located in the western section of the HSA on a small plateau above a hillside, which slopes downward to the northwest toward the New River (Figure 7-1). Land surface elevation at the site is approximately 1,805 ft msl.

**SWMU 57 – August 2002 – Looking Northwest**

An asphalt-paved road is located to the east and several overhead pipes with associated appurtenances are present nearby. A four-foot high perimeter chain-link fence with a locked gate encloses the site. A four-foot high, asphalt-covered (one-inch thick) soil berm surrounds the former lagoon inside of the fence (Figure 7-1). At the time of the SSP site visit and field investigation, the former lagoon was observed to be dry and heavily vegetated.

Tanks and Structures

Several overhead pipes with associated appurtenances, the site perimeter fence, and historically related buildings to the south are present in the site area. Other tanks or structures are not present near the site.

Surface Water

The surrounding berm produces interior drainage with the former lagoon area and prevents run-on and runoff of surface water. A shallow, well-defined, drainage ditch surrounds the former lagoon and connects with a drainageway to the northwest (Figure 7-1). This drainageway leads to a perennial stream located approximately 500 ft northwest of the site, which in turn flows northeastward and northwestward approximately 1,500 ft to the New River. Other manholes, catch basins, storm drains, or other drainageways have not been associated with the site.

Soil and Geology

SWMU 57 is underlain by Braddock loam soil. This soil has moderate permeability and is acidic-to-strongly acidic (IT 2001a). SSP boring 57SB4 completed inside the former lagoon refused at 1.5 ft bgs after penetrating clayey soil. Borings 57SB1, 57SB2, 57SB3 completed outside of the fenced area to the depth of groundwater (up to 36 ft) indicate that the site is underlain by 36 ft + of unconsolidated soil (alluvial terrace deposits). This soil consists of interbedded clay (CL or CH) and silty/clayey sand (SM/SC), with silty gravel present in the bottom six feet of the deepest boring (57SB2). Physical testing of two representative soil samples at the site above the silty gravel indicated acidic CL and CH soil, with organic content in the range of 2.6 to 3.6%, and a vertical hydraulic conductivity of 1.8E-07 cm/sec for the CH sample (Table 3-1).

Groundwater

An unconfined aquifer occurs within the lower portion of unconsolidated alluvial terrace deposits underlying the site; groundwater is also present within the underlying bedrock. Groundwater was encountered at depths of 21.5 ft bgs (57SB1) to 35.5 ft bgs (57SB2). The groundwater depth below the

SWMU is approximately 30 ft bgs. Based on local topography, groundwater flow in the site area is likely toward the north or northwest toward the base of the terrace and the New River.

## 7.2 SITE BACKGROUND - HISTORY

SWMU 57 is an inactive unit historically used as an acid-settling pond. RFAAP as-built drawings from 1954 and 1967 identify the site as the “Acid Settling Pool” with a diameter of approximately 50 ft and a capacity of 30,000 gallons. On the 1954 drawings, a six-inch diameter terra-cotta drainpipe is shown running to the “pond” from a four-inch Duriron® floor drain in the building south of the site. The floor drain is located near the Chromic Acid and Oakite 33 wash stations, and, reportedly, discharged chromic acid, hydraulic oil, Oakite-33, and zinc phosphate to the site (ATK, 2002). Oakite-33 is a mixture a phosphoric acid and butyl Cellosolve® used after 1974 as an acidic rust stripper to clean rocket encasements instead of the previously used chromic acid (Dames and Moore 1992b). At the time of the SSP site visit, the terra-cotta pipe was observed to be partially broken at one location near the “pond” and dry.

## 7.3 PREVIOUS INVESTIGATIONS

### 7.3.1 Verification Investigation – 1992

In 1992, Dames and Moore collected one sediment/surface water sample pair (57SE1/57SW1) from within the former lagoon for analysis of TAL metals, VOCs, and SVOCs (Figure 7-2). The sediment sample was also analyzed for TOC, total organic halogens, and pH.

VOCs and SVOCs were not detected in the surface water or sediment sample (Tables 7-1 and 7-2). TAL metals concentrations in the sediment did not exceed both their background point estimates and adjusted R-RBCs (or BTAG screening levels). Arsenic, chromium, iron, and manganese concentrations in the surface water sample were above their adjusted tap water RBCs (Table 7-2). Aluminum, chromium, copper, lead, and zinc concentrations in the surface water sample were above their Draft BTAG screening levels.

### 7.3.2 Review of EPIC Aerial Photo Assessment Report

Activity at SWMU 57 was first noted on a 1962 aerial photograph. The interpretation of the 1971 photograph indicated the presence of a “pond” containing liquid. This area remained unchanged through the 1986 photograph, although a drainageway extending from the “pond” to the New River was noted (USEPA 1992).

## 7.4 WORK PLAN DATA GAP ANALYSIS

The data gap analysis presented in Section 1.7.5 of WPA 016 indicated that limited soil sampling and analyses had occurred at SWMU 57 (URS 2003b). The following data gaps were identified:

- TCL VOCs - surface and subsurface soil;
- TCL SVOCs/PAHs - surface and subsurface soil;
- TCL PCBs and pesticides - surface soil;
- Explosives - surface and subsurface soil;
- TAL inorganics - surface and subsurface soil; and
- Site-specific physical soil testing data.

## 7.5 SSP FIELD ACTIVITIES

Three borings (57SB1, 57SB2, and 57SB3) were advanced outside of SWMU 57 and one soil boring (57SB4) was advanced within SWMU 57 to evaluate the presence or absence of chemicals in surface soil and subsurface soil (Figure 7-1). Except for 57SB4, which refused at 1.5 ft bgs, each boring was advanced to the depth of encountered groundwater using a tractor mounted, direct-push Geoprobe® unit. Discrete samples were collected from surface, intermediate, and terminal intervals for the three borings advanced outside the SWMU, and two samples were collected from the boring within the SWMU due to shallow refusal depth as summarized below.

**SWMU 57 SSP Sample and Boring Information**

| Boring ID | Total Depth of Boring (ft bgs) | Surface Sample ID | Sample Depth (ft) | Intermediate Sample ID | Sample Depth (ft) | Terminal Sample ID | Sample Depth (ft) |
|---|---|---|---|---|---|---|---|
| 57SB1 | 24.0 | 57SB1A | 0.0 - 1.0 | 57SB1B | 10.0 - 12.0 | 57SB1C | 18.0 - 20.0 |
| 57SB2 | 36.0 | 57SB2A | 0.0 - 1.0 | 57SB2B | 8.0 - 12.0 | 57SB2C | 33.0 - 35.0 |
| 57SB3 | 34.5 | 57SB3A | 0.0 - 1.0 | 57SB3B | 14.0 - 16.0 | 57SB3C | 29.0 - 31.0 |
| 57SB4 | 1.5 | 57SB4A | 0.5 | 57SB4B | 1.5 | Not Collected | -- |

Soil samples were analyzed for TCL VOCs, TCL SVOCs, PAHs, explosives (including nitroglycerin and PETN), and TAL inorganics. Surface soil sample 57SB4A was also analyzed for TCL pesticides, TCL PCBs, and TCL herbicides. SSP analytical results (detected chemicals) are summarized in Table 7-3.

Two soil samples were collected from 57SB2 (7.5-8.0 ft bgs) and 57SB3 (16.5-17.0 ft bgs) for physical testing including: percent moisture, grain size, pH, TOC, specific gravity, and bulk density. Additional physical testing was conducted on sample 57SB3 including: Atterberg limits, hydrometer analysis, and hydraulic conductivity. Analytical results for these samples are summarized in Table 3-1 and the complete results are presented in Appendix E.

Slight deviations to WPA 016 were necessary to adjust to field conditions encountered at the site. The fence located outside the berm prevented the Geoprobe® unit from gaining access for boring 57SB4 in the interior of the former lagoon; therefore, this boring was advanced using a hand auger. Hand auger refusal occurred at a shallow depth (1.5 ft bgs) at multiple locations, and therefore, two soil samples were collected from 57SB4 instead of three.

## 7.6 HUMAN HEALTH RISK SCREENING

### 7.6.1 Identification of COPCs and Cumulative Risk Screen

Tables 7-4 and 7-5 present the results of the COPC evaluations for surface soil and total soil, respectively. COPCs identified for surface soil and total soil included:

- *TAL metals:* aluminum (NSV), antimony, arsenic, cadmium, chromium, cobalt (NSV), iron, manganese, and vanadium.
- *VOC TICs:* 1 compound (NSV);
- *TCL SVOCs:* 4-chloro-3-methylphenol (NSV) and benzo(a)pyrene; and
- *SVOC TICs:* 14 compounds (NSVs) for surface soil and 20 compounds (NSVs) for total soil.

### 7.6.2 Cumulative Risk Screen

Table 7-6 presents the results of the cumulative risk screening for surface soil. Tables 7-7 and 7-8 present the results of the risk screening for total soil. A summary of the screening results is presented below:

**Cumulative Human Health Risk Screening Results for SWMU 57**

| | Surface Soil | | | Total Soil | | |
|---|---|---|---|---|---|---|
| **Residential Excess Cancer Risk** | Fail | 1.E-05 | Arsenic, benzo(a)pyrene | Fail | 1.E-05 | Arsenic, benzo(a)pyrene |
| **Industrial Excess Cancer Risk** | Pass | 3.E-06 | -- | Pass | 3.E-06 | -- |
| **Residential Noncarcinogenic** | Fail | 12 | Sb, As, Cd, Cr, Fe, Mn, V | Fail | 6 | Sb, As, Cd, Cr, Fe, Mn, V |
| **Industrial Noncarcinogenic** | Pass | 0.9 | -- | Pass | 0.4 | -- |

The cumulative human health risk screens failed for residential surface soil (carcinogenic and noncarcinogenic) and residential total soil (carcinogenic and noncarcinogenic). Cumulative risk screenings passed for industrial scenarios.

Noncarcinogenic residential cumulative risk screenings for surface soil and total soil resulted in HIs of 12 and 6, respectively, which exceeded the EPA target HI of 1. Due to multiple chemicals contributing to an HI greater than 1, the HIs have been segregated based on primary target organs for chronic exposure. The following tables present the results of the HI segregation using data obtained from Oak Ridge National Laboratory's RAIS, which includes data from various sources such as USEPA and the ATSDR:

**HI Segregation for Target Organs – SWMU 57 – Surface Soil**

| Target Organ | Sb | As | Cd | Cr | Fe | Mn | V | Total HI |
|---|---|---|---|---|---|---|---|---|
| Skin | -- | 0.2 | -- | -- | -- | -- | -- | 0.2 |
| CNS | -- | 0.2 | -- | -- | -- | 2 | -- | ***2*** |
| CV | -- | 0.2 | -- | -- | 3 | -- | -- | ***3*** |
| Blood | -- | -- | -- | -- | -- | -- | 1 | ***1*** |
| Liver | -- | -- | -- | -- | 3 | -- | -- | ***3*** |
| Kidney | -- | -- | 0.4 | -- | 3 | -- | 1 | ***4*** |
| GI | 3 | -- | -- | 2 | -- | -- | 1 | ***6*** |
| Reproductive | -- | -- | -- | -- | -- | 2 | -- | ***2*** |

HI segregation resulted in values equal to or higher than the cumulative SSP HI threshold of 0.5 for a target organ including: the CNS, CV, blood, liver, kidney, GI, and reproductive.

**HI Segregation for Target Organs – SWMU 57 – Total Soil**

| Target Organ | Sb | As | Cd | Cr | Fe | Mn | V | Total HI |
|---|---|---|---|---|---|---|---|---|
| Skin | -- | 0.3 | -- | -- | -- | -- | -- | 0.3 |
| CNS | -- | 0.3 | -- | -- | -- | 0.9 | -- | ***1*** |
| CV | -- | 0.3 | -- | -- | 2 | -- | -- | ***2*** |
| Blood | -- | -- | -- | -- | -- | -- | 0.9 | ***0.9*** |
| Liver | -- | -- | -- | -- | 2 | -- | -- | ***2*** |
| Kidney | -- | -- | 0.2 | -- | 2 | -- | 0.9 | ***3*** |
| GI | 0.2 | -- | -- | 0.7 | -- | -- | 0.9 | ***2*** |
| Reproductive | -- | -- | -- | -- | -- | 0.9 | -- | ***0.9*** |

HI segregation resulted in values equal to or higher than the cumulative SSP HI threshold of 0.5 for a target organ including: the CNS, CV, blood, liver, kidney, GI, and reproductive.

### 7.6.3 Lead and Iron Screening

The MDC for lead at the site was 222 mg/kg, which was below the action level of 400 mg/kg; therefore, further risk characterization for lead was not required.

Iron concentrations at the site for surface soil and total soil resulted in HQs greater than the iron SSP threshold HQ of 0.5 for the residential scenario, and therefore, the site required further characterization for iron through a margin of exposure evaluation. Appendix H presents the margin of exposure evaluation for surface soil and total soil. A summary of the results for SWMU 57 is presented below.

**Iron Margin of Exposure Evaluation – Future Child Resident**

| | **Surface Soil** | | | **Total Soil** | | |
|---|---|---|---|---|---|---|
| | | Estimated Site Intake | Exposure Screening Level | | Estimated Site Intake | Exposure Screening Level |
| **RDA Screen (mg/day)** | Fail | 15.1 | 10 | Fail | 10.1 | 10 |
| **Provisional Reference Dose (RfD) Screen (mg/kg-day)** | Fail | 1.01 | 0.66 | Fail | 0.67 | 0.66 |

The site failed the margin of exposure evaluation for iron in soil.

### 7.6.4 Comparison to Generic SSLs

The MDC comparisons of subsurface soil to generic SSLs (DAF 20) for detected chemicals indicated that arsenic, chromium, manganese, bromodichloromethane, and chloroform exceeded their SSLs (Table 7-9).

The SSL exceedance for arsenic is not a concern because the detected concentration is below its background point estimates. Chromium exceeds its background point estimate and SSL in one terminal depth sample (57SB1C). Manganese exceeds its background point estimate and SSL in one intermediate sample (57SB2B).

Bromodichloromethane slightly exceeded its SSL of 1.1 µg/kg in sample 57SB2C, with an estimated concentration below the RL (1.2 µg/kg). Chloroform exceeded its SSL in one "B" sample and three "C" samples (Table 7-9).

### 7.6.5 Comparison to Site-Specific SSLs

The MDC for bromochloromethane was below the site-specific SSL calculated (6 µg/kg) using the average TOC value from the physical sample collected at the site during the SSP (Appendix F). Chloroform exceeded its site-specific SSL of 4 µg/kg in one "B" sample and two "C" samples (Appendix F).

### 7.6.6 COPC Comparison to Background

The comparison of MDCs for metals identified as COPCs in surface soil and total soil with their background point estimates resulted in background exceedances for cadmium, chromium, iron, and manganese (Table 7-10).

#### 7.6.6.1 Human Health Risk Screening Summary

COPCs with screening values were limited to metals. The residential cumulative human health risk screens failed for surface soil (carcinogenic and noncarcinogenic) and total soil (carcinogenic and noncarcinogenic). Cumulative risk screenings for industrial scenarios passed.

Carcinogenic residential risk screening failed for surface soil and total soil primarily due to arsenic concentrations below the background point estimate. This screening result is not a concern given that: 1) the risk associated with background levels of arsenic contributes 90% of the cumulative risk of 1E-05, and 2) the other COPC for the site, benzo(a)pyrene, contributes negligible risk (1E-06 for surface soil and 5.E-07 for total soil).

Noncarcinogenic residential risk screening failed for surface soil primarily due to metals concentrations above background point estimates (HI of 7.4 due to cadmium, chromium, iron, and manganese) and antimony for which no background point estimate is available (HQ of 3.3).

Noncarcinogenic residential risk screening failed for total soil primarily due to metals concentrations above background point estimates (HI of 4.0 due to cadmium, chromium, iron, and manganese).

The site passed lead screening for soil. Surface soil and total soil failed the margin of exposure evaluation for iron.

Generic SSL exceedances were limited to bromodichloromethane, chloroform, arsenic, chromium, and manganese. Bromodichloromethane is not a concern because the detected concentration is below its calculated site-specific SSL. Chloroform exceeded its site-specific SSL in one intermediate sample and in three termination depth samples. The arsenic SSL exceedance is not a concern because its MDC is below the background point estimate. Chromium exceeded its SSL and its background point estimate in termination sample (57SB1C) collected immediately above encountered groundwater. Manganese exceeds its background point estimate and SSL in one intermediate sample (57SB2B).

## 7.7 ECOLOGICAL RISK SCREENING

### 7.7.1 Problem Formulation

#### 7.7.1.1 Ecological Site Characterization

An overview of the site physiography, water resources, soil, and geology for the site is presented in Section 7.1. SWMU 57 is a 0.027-acre area (1,172 $ft^2$) consisting of an asphalt-lined former lagoon that provides minimal habitat value to wildlife potentially occurring in the area (photograph on page 7-1). A four-foot high chain-link fence encircles the site and a shallow, well-defined ditch surrounds the site and connects with a drainageway to the northwest. An asphalt road borders the site to the east and a network of process pipes and utility lines border the site to the west and north. A complex of buildings related to facility operations is located within 100 ft to the south of the area.

Observations made during the site reconnaissance indicate that an invasive hydrophytic vegetation community of cattail (*Typha sp*.) occurs within the site (photograph on page 7-1). In areas surrounding the former lagoon, vegetation is typical of maintained grass habitats observed elsewhere at RFAAP. Signs of chemical stress to vegetation were not observed during the reconnaissance.

The habitat could support some ecological use (i.e., shelter and foraging) by some smaller common species in the area. Given its limited size, restricted access by a chain-link fence, and frequent disturbance by facility operations on the adjacent asphalt road, few individuals would be expected to utilize the site for a lengthy period.

Threatened, rare, or endangered species were not observed during the site reconnaissance. These species are not likely to be present within the boundaries of the site. Threatened, rare, and endangered specifies information for RFAAP is discussed in Section 3.3.3.

### 7.7.2 Ecological Conceptual Site Model

The ECSM for SWMU 57 (and other terrestrial sites for the SSP) is presented on Figure 3-1. The limited area surrounding the former lagoon is typical mowed grass that occurs throughout the RFAAP facility. While this is a small area unlikely to support important populations of terrestrial receptors, individual receptors may traverse the area from time to time. Soil represents an unlikely but sole potential exposure medium to ecological receptors. Based on the site characterization and data, the following complete exposure pathway exists: terrestrial receptor exposure to surface soil.

Detected chemical occurrence and distribution table is presented in Table 7-11. In addition, Table 7-12 summarize the nondetected chemicals for SWMU 57. Potential ecological receptors may be exposed to COPECs in soil through the following exposure routes:

- Direct contact/absorption from soil;
- Direct ingestion of soil;
- Incidental ingestion of soil; and
- Direct ingestion of biota with accumulated COPECs.

Receptors of concern selected for SWMU 57 include:

- Plants;
- Soil invertebrate/microbial community;
- Omnivorous birds (American Robin; *Turdus migratorius*);

- Carnivorous birds (Red-Tailed Hawk; *Buteo jamaicensis*);
- Herbivorous mammals (Meadow Vole; *Microtus pennsylvanicus*);
- Carnivorous mammals (Short-Tailed Shrew; *Blarina brevicauda*); and
- Omnivorous mammals (Red Fox; *Vulpes vulpes*).

Relevant assessment and measurement endpoints for the identified terrestrial receptors are presented in Section 3.3.6.1.

### 7.7.3 Preliminary Exposure Estimate and Risk Characterization

The preliminary exposure estimate and ecological effects evaluation considers the most conservative risk scenario. Highly conservative assumptions are used to estimate COPEC exposure to terrestrial receptors for pathways to be quantitatively evaluated. Conservative TRVs are used to evaluate the ecological effects of exposure using the two approaches discussed below.

#### 7.7.3.1 Preliminary Exposure Estimate and Ecological Effects Evaluation

<u>Direct Contact Approach</u>

The MDCs for detected chemicals in soil are used as the preliminary exposure estimate concentrations to develop a conservative risk scenario for the direct contact pathway to soil invertebrates. Table 7-13 presents the preliminary exposure estimates for the direct contact approach.

<u>Dose Rate Modeling Approach</u>

In the dose rate modeling approach, detected bioaccumulative chemical MDCs, along with assumptions of maximum ingestion rate, minimum body weight, 100% area use, and 100% bioavailability are used in the conservative risk scenario as the preliminary exposure estimate for soil COPECs and compared to the calculated TRVs. MDCs used in the preliminary exposure estimate for soil COPECs are presented in Table 7-11.

#### 7.7.3.2 Background Concentrations of Metals

Background point estimates for metals were incorporated in the ecological screening to assess site soil concentrations in the context of facility-wide background levels (IT 2001a). Essential nutrients, including calcium, magnesium, potassium, and sodium were not considered COPECs in the risk screening in accordance with the SSP (USEPA 2001a) and the MWP (URS 2003b). The results of the background comparison for SWMU 57 are provided in Table 7-14. The results of this comparison have been incorporated into the risk management decision and ecological summary.

#### 7.7.3.3 Preliminary Risk Characterization

<u>Terrestrial Plants</u>

Qualitative characterization of vegetative communities common to grassed areas at RFAAP is provided in Section 3.3.7.4. Stressed or dead vegetation was not observed in the small area surrounding the lagoon in SWMU 57 during the site reconnaissance. This grass area is typical of regularly mowed areas at RFAAP.

<u>Soil Invertebrates and Microbial Communities</u>

Direct contact HQs calculated for soil invertebrates and microbial communities are presented in Table 7-13. Other potentially complete exposure pathways to soil invertebrate and microbial communities include direct ingestion of soil and biota. However, there is insufficient information to quantify these pathways, and while these pathways exist, they are likely secondary to the direct contact/absorption pathway and should not substantially alter the risk characterization.

Of the detected chemicals for which ecological screening values were available, the concentrations of aluminum, antimony, chromium, iron, manganese, mercury, vanadium, zinc, and cyanide resulted in HQ values that were greater than 1 (Table 7-13). However, MDCs for aluminum and vanadium were below their background point estimates (Table 7-14).

<u>Terrestrial Wildlife</u>

Quantitative risk characterization for terrestrial wildlife is limited to direct ingestion of biota and incidental ingestion of soil. The ECSM identifies a potentially complete direct contact exposure pathway to omnivorous birds, and herbivorous and carnivorous mammals; however, there is insufficient information to quantify this pathway. This pathway is likely secondary to the ingestion of biota and incidental ingestion of soil; therefore, it should not substantially alter the risk characterization.

The risk to each potential wildlife receptor at the site is presented in Table 7-15 and summarized as follows:

| Receptor | NOAEL Only Exceedances | NOAEL and LOAEL Exceedances |
|---|---|---|
| American Robin | Aroclor 1254 | cadmium, chromium, lead, selenium, zinc |
| Red-tailed Hawk | none | chromium, zinc |
| Meadow Vole | cadmium | none |
| Red Fox | arsenic, cadmium, selenium | mercury, zinc |
| Short-tailed Shrew | lead, mercury, selenium, Aroclor 1254 | arsenic, cadmium, zinc |

### 7.7.4 Refined Exposure Estimate, Ecological Effects Evaluation, and Risk Characterization

#### 7.7.4.1 Refined Exposure Estimate and Ecological Effects Evaluation - Dose Modeling

The conservative assumptions used in the preliminary exposure estimate and ecological effects evaluation were replaced with more environmentally realistic assumptions resulting in a more realistic estimate of potential risk.

Refined exposure estimates and ecological effects were not developed for soil invertebrates and microbial communities because an appropriate 95% UCL could not be calculated using the surface soil data.

The refined exposure estimates and ecological effects were developed for wildlife receptors having complete exposure pathways to be quantitatively evaluated (i.e., omnivorous birds and carnivorous and herbivorous mammals). In the refined model, a realistic area use factor ($AF_{refined}$) was calculated as the ratio of the site area to the average home range of the receptor (Appendix I, Table I-16).

#### 7.7.4.2 Refined Risk Characterization -Terrestrial Wildlife

The refined risk characterization for SWMU 57 is presented in Table 7-15 and summarized as follows:

| Receptor | NOAEL Only Exceedances | NOAEL and LOAEL Exceedances | COPECs Below Background Point Est. |
|---|---|---|---|
| American Robin | cadmium (8.8)<br>lead (8.1) | chromium (12.3/2.5)*<br>zinc (14.2/1.6) | none |
| Red-tailed Hawk | none | none | n/a |
| Meadow Vole | none | none | n/a |
| Red Fox | none | none | n/a |
| Short-tailed Shrew | arsenic (4.9)<br>cadmium (6.6) | none | arsenic |

*Note: (12.3/2.5) = NOAEL-based HQ/LOAEL-based HQ

#### 7.7.4.3 Exposure and Risk Uncertainty Analysis

Potential risk and exposure uncertainty is discussed in Section 3.3.9. While factors such as the lack of TSVs and wildlife profile assumptions may create limited uncertainty, the very small size and negligible habitat quality of the site in combination with these limited uncertainties has produced a conservative assessment of potential ecological risks associated with SWMU 57.

### 7.7.5 Ecological Risk Screening Summary

Based in the refined ecological risk screening, the information collected and presented indicates that a more thorough assessment is warranted for metals.

## 7.8 CONCEPTUAL SITE MODEL

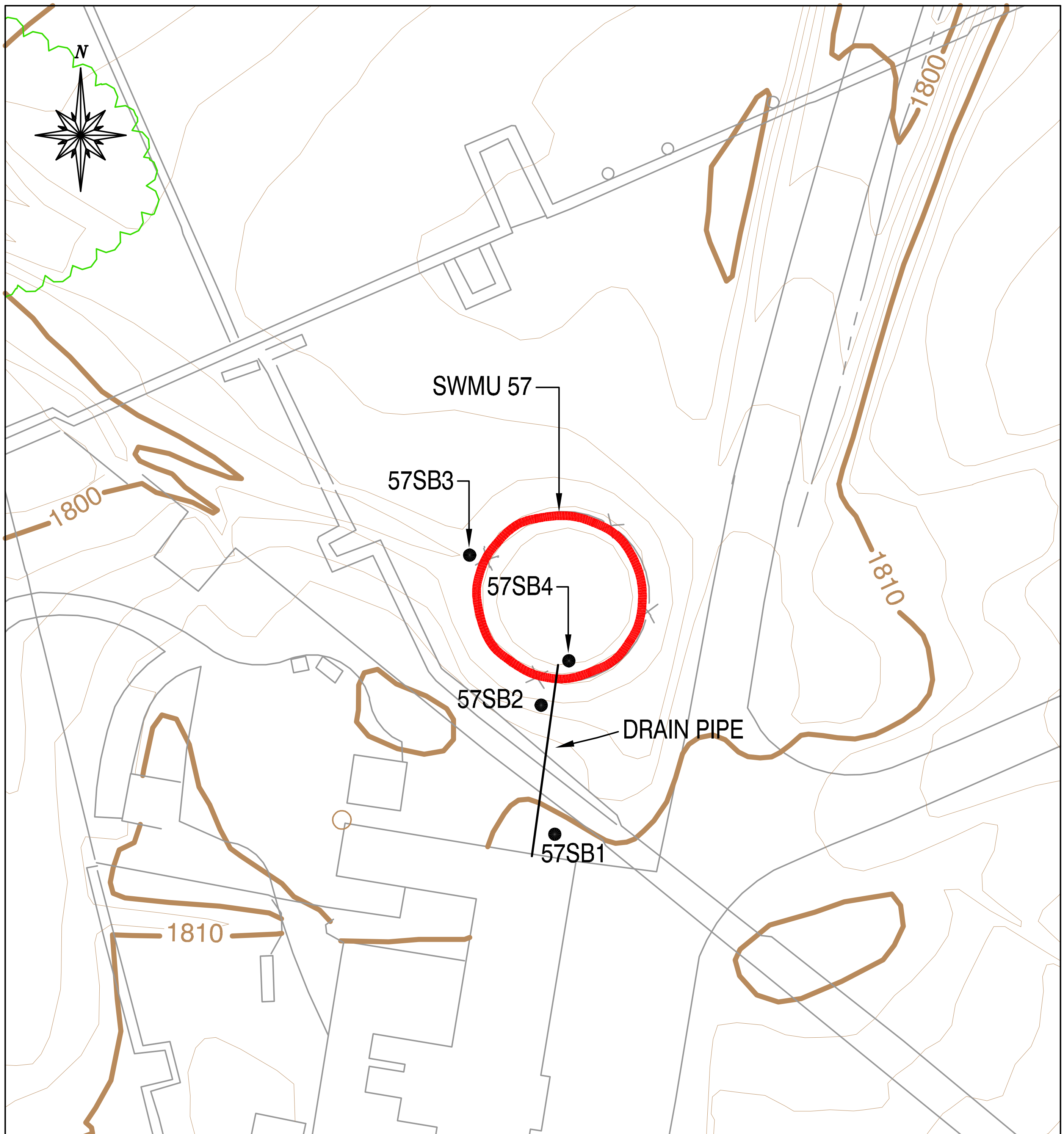
A refined CSM for SWMU 57 is presented on Figure 7-3. The site is a small former lagoon area enclosed by a fence and berm, which is located on a terrace in the HSA of RFAAP. Subsurface geology consists of alluvial deposits overlying carbonate bedrock of the Elbrook Formation. Groundwater is present within lower portion of the alluvial deposits (21 to 36 ft bgs) and in underlying bedrock. Based on local topography, groundwater flow is likely toward the north and northwest toward the New River.

Potentially affected media include surface soil, subsurface soil, and groundwater. Observations during the SSP site reconnaissance and subsequent field investigation did not indicate the presence of measurable surface water or sediment within the former lagoon area. The site is surrounded by a berm, which prevents surface water flow onto or off the site. COPCs identified in soil with screening values included metals.

Although current and likely future land-use scenarios are limited to industrial operations, both residential and industrial scenarios are evaluated for the SSP. The site is enclosed by a fence and the Installation is enclosed by a perimeter fence; therefore, potential receptors are limited to site workers (more conservative than trespasser scenario), future construction workers, and terrestrial biota (for area outside of site fence). Site workers and construction workers could contact surface soil inside and outside the site fence. Terrestrial biota could contact surface soil within the grass area outside of the fence. Leaching of chemicals is considered a potential release mechanism to subsurface soil that may be contacted by potential future construction workers. Leaching of chemicals is considered a potential release mechanism to groundwater.

## 7.9 RECOMMENDATION FOR FUTURE ACTION

The site is recommended for a focused RFI based on the falure of the residential risk screening, site-specific SSL exceedance for chloroform, the lack of groundwater data for the site, and the results of the ecological risk screening. The RFI will focus on metals and VOCs in soil and groundwater.




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

**Legend**

- Soil Sampling Location
- SWMU 57 Approximate Boundary
- Aboveground Piping
- Vegetation

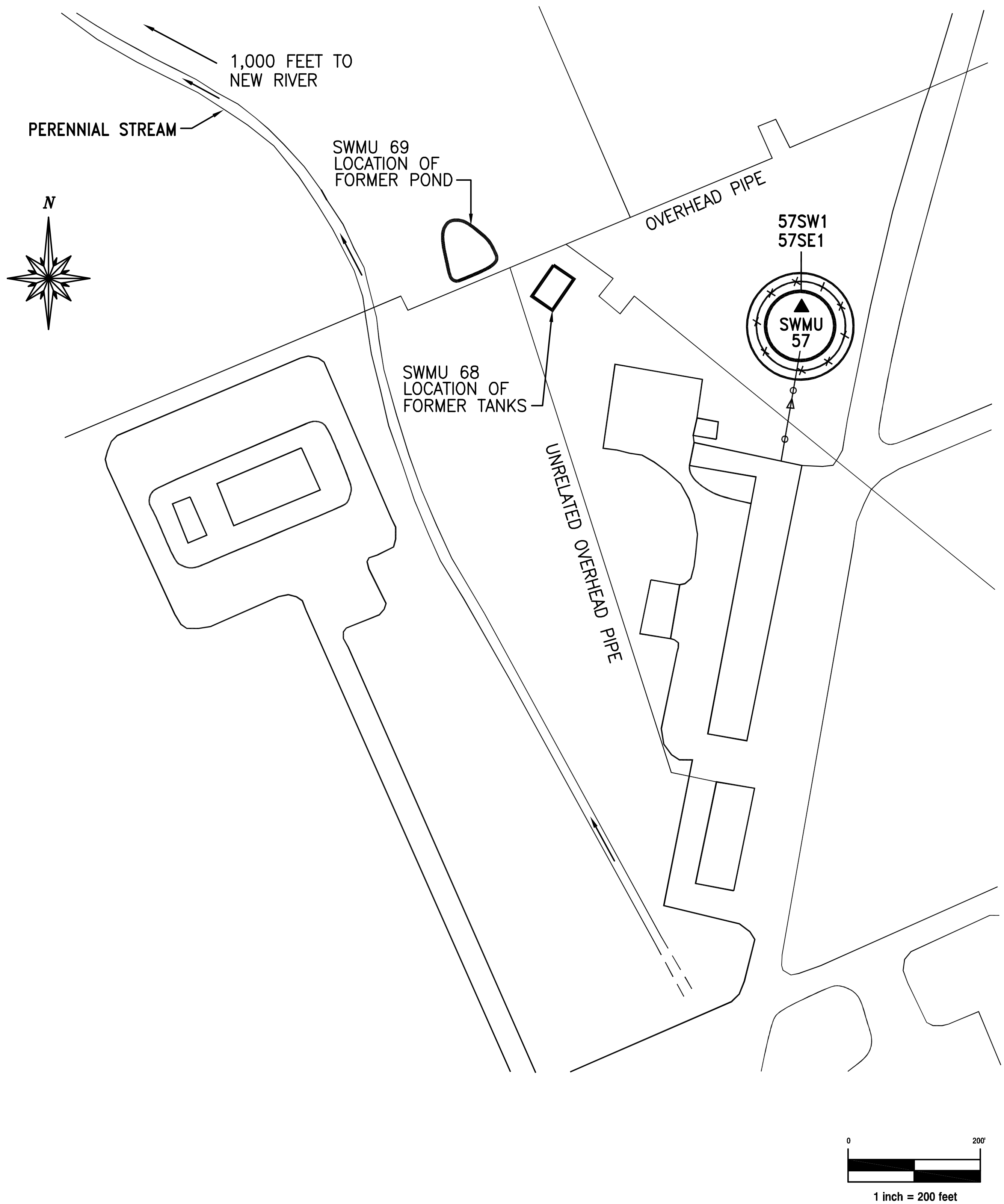
# RFAAP

**SSP REPORT**

| Date: | Prepared By: |
|---|---|
| *June 2004* | *KDC/TDH* |
| **Scale:** | **File Name:** |
| *1"=50'* | *15900619* |

**FIGURE 7-1**

**SSP SAMPLING LOCATION MAP SWMU 57**




**Legend**

▲ Surface Water/Sediment Sample

(SOURCE: MODIFIED FROM DAMES & MOORE, 1992a)

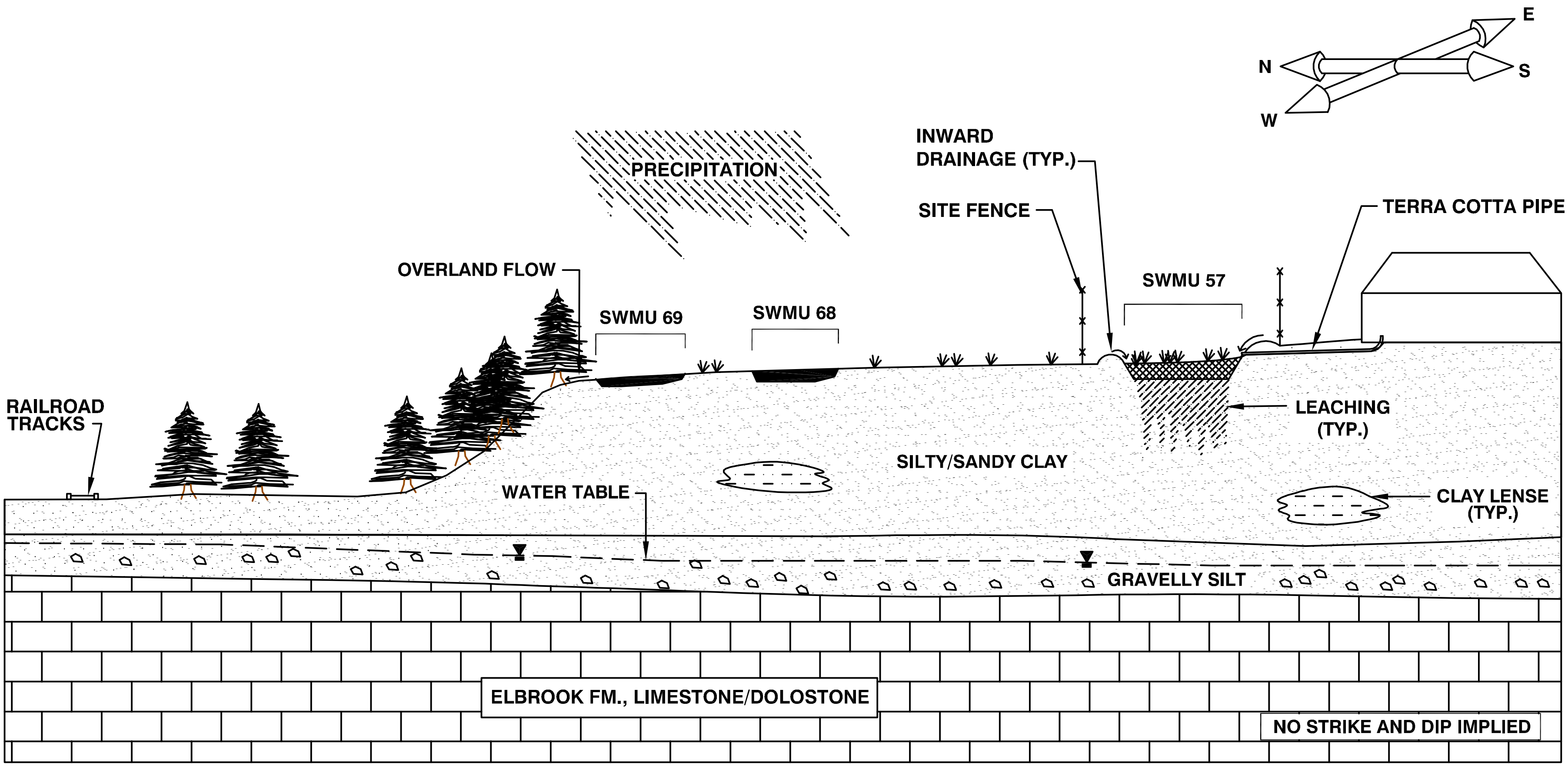
# RFAAP

## SSP REPORT

| | |
|---|---|
| **Date:** June 2004 | **Prepared By:** KDC/TDH |
| **Scale:** 1"=200' | **File Name:** 15900619 |

**FIGURE 7-2**

**PREVIOUS INVESTIGATION SAMPLING LOCATIONS SWMU 57**




CONCEPTUAL DRAWING - NO SCALE IMPLIED

NO BEDROCK TOPOGRAPHY IMPLIED

| RFAAP SSP REPORT | | FIGURE 7-3 |
|---|---|---|
| Date: June 2004 | Prepared By: KDC/TDH | CONCEPTUAL SITE MODEL SWMU 57 |
| Scale: Not to Scale | File Name: 15900619 | |

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## Table 7-1
## Summary of Analytical Data for Sediment Sample Collected at SWMU 57
## Modified from Dames and Moore Verification Investigation Report
## SSP Report
## Radford Army Ammunition Plant, Radford, Virginia

| SITE ID<br>FIELD ID<br>SAMPLE DATE<br>DEPTH (ft bgs)<br>MATRIX<br>UNITS | PQLs<br>mg/kg | 57SE1<br>RVFS*92<br>10-Feb-92<br>0.5<br>CSE<br>mg/kg | Adjusted Soil Industrial RBC<br>mg/kg | Adjusted Soil Residential RBC<br>mg/kg | Draft BTAG Screening Level<br>mg/kg | Facility-Wide Background Point Estimates [(A)]<br>mg/kg |
|---|---|---|---|---|---|---|
| **TAL Metals** | | | | | | |
| Aluminum | 14.1 | 30,000 | 102,200 | 7,821 | -- | 40,041 |
| Arsenic | 30 | **4.66** | 1.91 | 0.426 | 0.057 | 15.8 |
| Barium | 1 | 65.5 | 7,154 | 548 | -- | 209 |
| Calcium | 100 | 30,800 | -- | -- | -- | -- |
| Chromium[(1)] | 4 | 42.5 | 307 | 23.5 | 0.005 | 65.3 |
| Cobalt | 3 | 4.71 | 2,044 | 156 | -- | 72.3 |
| Copper | 7 | 12.9 | 4,088 | 313 | 34 | 53.5 |
| Iron | 1,000 | 24,400 | 30,660 | 2,346 | -- | 50,962 |
| Magnesium | 50 | 18,500 | -- | -- | -- | -- |
| Manganese[(2)] | 0.275 | 126 | 2,044 | 156 | -- | 2,543 |
| Mercury[(3)] | 0.1 | <u>0.142</u> | 30.7 | 2.35 | 0.15 | 0.13 |
| Nickel | 3 | 10.3 | 2,044 | 156 | 20.9 | 62.8 |
| Potassium | 37.5 | 785 | -- | -- | -- | -- |
| Sodium | 150 | 532B | -- | -- | -- | -- |
| Vanadium | 0.775 | 85 | 102 | 7.8 | -- | 108 |
| Zinc | 30.2 | 61.6 | 30,660 | 2,346 | 150 | 202 |

**Notes:**
BTAG = USEPA Region III Draft, Biological Technical Assistance Group Screening Level
CSE = Chemical Sediment
ft bgs = Feet below ground surface
mg/kg = Milligrams per kilogram
PQL = Practical quantitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method
RBC = Risk-Based Concentration
USEPA = United States Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 14, 2004, RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
TAL = Target Analyte List
[(A)] = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
[(1)] = Chromium VI RBC value was used
[(2)] = Manganese-nonfood RBC value was used
[(3)] = Mercuric chloride RBC value was used

**bold** = Concentration exceeds Industrial RBC

[double box] = Concentration exceeds Residential RBC

[shaded] = Concentration exceeds BTAG Screening Level

<u>underline</u> = Concentration exceeds Facility-Wide Background Point Estimate

**Table 7-2**
**Summary of Analytical Data for Surface Water Sample Collected at SWMU 57**
**Modified from Dames and Moore Verification Investigation Report**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| SITE ID<br>FIELD ID<br>SAMPLE DATE<br>DEPTH (ft bgs)<br>MATRIX<br>UNITS | PQLs<br>µg/L | 57SW1<br>RVFS*92<br>10-Feb-92<br>0.0<br>CSW<br>µg/L | Adjusted Tap Water RBC<br>µg/L | MCL<br>µg/L | Draft BTAG Screening Level<br>µg/L |
|---|---|---|---|---|---|
| **TAL Metals** | | | | | |
| Aluminum | 141 | 871 | 3,650 | -- | 25 |
| Arsenic | 10 | 6.29 | 0.045 | 10 | 48 |
| Barium | 20 | 23.1 | 256 | 2,000 | 10,000 |
| Calcium | 500 | 16,700 | -- | -- | -- |
| Chromium(1) | 10 | 15.9 | 11.0 | 100 | 2 |
| Copper | 60 | 11.8 | 146 | 1,300 (AL) | 6.5 |
| Iron | 38.1 | 2,750 | 1,100 | -- | 320 |
| Lead | 10 | 14 | -- | 15 (AL) | 3.2 |
| Magnesium | 500 | 6,670 | -- | -- | -- |
| Manganese(2) | 2.75 | 380 | 73 | -- | 14,500 |
| Potassium | 375 | 8,850 | -- | -- | -- |
| Sodium | 500 | 14,000 | -- | -- | -- |
| Zinc | 50 | 155 | 1,095 | -- | 30 |

**Notes:**

BTAG = USEPA Region III Draft, Biological Technical Assistance Group Screening Level
CSW = Chemical Surface Water
ft bgs = Feet below ground surface
MCL = Maximum Contaminant Level
PQL = Practical quanitation limit; the lowest concentration that can be reliably detected at a defined level of precision for a given analytical method
RBC = Risk-Based Concentration
USEPA = United States Environmental Protection Agency
USEPA Region III Risk-Based Concentration (RBC) values from the April 14, 2004, RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
TAL = Target Analyte List
µg/L = Microgram Per Liter
(AL) = Action Level
(1) = Chromium VI RBC value used
(2) = Manganese-nonfood RBC value used

[bold box] = Concentration exceeds Tap Water RBC

[double box] = Concentration exceeds MCL

[grey shading] = Concentration exceeds Draft BTAG Screening Level

**Table 7-3**
**Detected Analytes for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| Sample ID / Sample Date / Sample Depth (ft bgs) | CAS # | C/N | Facility-Wide Background Point Estimate[A] | Adjusted Soil RBC (Residential) | Adjusted Soil RBC (Industrial) | SSL DAF 20 | Draft BTAG Screening Level | 57SB1A 10/7/2003 0-1 Result | LQ, VQ, r | MDL | RL | 57SB1B 10/7/2003 10-12 Result | LQ, VQ, r | MDL | RL | 57SB1C 10/7/2003 18-20 Result | LQ, VQ, r | MDL | RL | 57SB2A 10/7/2003 0-1 Result | LQ, VQ, r | MDL | RL | 57SB2B 10/7/2003 8-12 Result | LQ, VQ, r | MDL | RL | 57SB2C 10/7/2003 33-35 Result | LQ, VQ, r | MDL | RL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **TAL Metals (mg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | 7429-90-5 | -- | 40,041 | -- | -- | -- | 1 | 11,900 | | 1.83 | 50 | 23,800 | | 1.83 | 50 | 38,900 | | 9.15 | 250 | 32,200 | | 9.15 | 250 | 13,900 | | 1.83 | 50 | 21,800 | | 1.83 | 50 |
| Antimony | 7440-36-0 | N | -- | 3.13 | 40.9 | 13.2 | 0.48 | 1.2 | | 0.0518 | 0.5 | 0.21 | J | 0.0518 | 0.5 | 0.15 | J | 0.0518 | 0.5 | 3.6 | | 0.0518 | 0.5 | <0.5 | U | 0.0518 | 0.5 | 0.073 | J | 0.0518 | 0.5 |
| Arsenic | 7440-38-2 | C | 15.8 | 0.43 | 1.91 | 0.026 | 328 | ***1.6*** | | 0.0232 | 0.4 | ***1.6*** | | 0.0232 | 0.4 | ***3.1*** | | 0.0232 | 0.4 | ***3.6*** | | 0.0232 | 0.4 | ***1.1*** | | 0.0232 | 0.4 | ***7.1*** | | 0.0232 | 0.4 |
| Barium | 7440-39-3 | N | 209 | 1,564 | 20,440 | 6,015.2 | 440 | 99 | | 0.106 | 5 | 56 | | 0.106 | 5 | 73 | | 0.106 | 5 | 80 | | 0.106 | 5 | 39 | | 0.106 | 5 | 42 | | 0.106 | 5 |
| Beryllium | 7440-41-7 | N | 1.02 | 15.64 | 204.4 | 1,153.7 | 0.02 | 0.44 | J,J,s | 0.0391 | 1 | 0.58 | J,J,s | 0.0391 | 1 | 0.84 | J,J,s | 0.0391 | 1 | 0.48 | J,J,s | 0.0391 | 1 | 1.1 | ,J,s | 0.0391 | 1 | 3.2 | ,J,s | 0.0391 | 1 |
| Cadmium | 7440-43-9 | N | 0.69 | 3.91 | 51.1 | 27.4 | 2.5 | 1.5 | | 0.182 | 1 | 2.8 | | 0.182 | 1 | 4 | | 0.182 | 1 | 6.7 | | 0.182 | 1 | 0.46 | J | 0.182 | 1 | 1.3 | | 0.182 | 1 |
| Calcium | 7440-70-2 | -- | -- | -- | -- | -- | -- | 4,440 | | 16.6 | 250 | 1,030 | | 16.6 | 250 | <250 | U | 16.6 | 250 | 1,530 | | 16.6 | 250 | <250 | U | 16.6 | 250 | 207 | J | 16.6 | 250 |
| Chromium[1] | 7440-47-3 | N | 65.3 | 23.46 | 306.6 | 42.05 | 0.0075 | 20 | | 0.912 | 5 | 28 | | 0.912 | 5 | ***88*** | | 0.912 | 5 | ***70*** | | 0.912 | 5 | 9.3 | | 0.912 | 5 | 33 | | 0.912 | 5 |
| Cobalt | 7440-48-4 | -- | 72.3 | -- | -- | -- | 100 | 5.8 | ,J,s | 0.208 | 1 | 8.7 | ,J,s | 0.208 | 1 | 12 | ,J,s | 0.208 | 1 | 6.1 | ,J,s | 0.208 | 1 | 26 | ,J,s | 0.208 | 1 | 19 | ,J,s | 0.208 | 1 |
| Copper | 7440-50-8 | N | 53.5 | 312.86 | 4,088 | 10,518 | 15 | 4.9 | | 0.368 | 1 | 13 | | 0.368 | 1 | 28 | | 0.368 | 1 | 18 | | 0.368 | 1 | 15 | | 0.368 | 1 | 23 | | 0.368 | 1 |
| Iron | 7439-89-6 | N | 50,962 | 2,346 | 30,660 | -- | 12 | 13,400 | | 17.9 | 250 | 41,300 | | 35.8 | 500 | 37,300 | | 35.8 | 500 | 39,700 | | 35.8 | 500 | 34,500 | | 35.8 | 500 | 39,500 | | 35.8 | 500 |
| Lead[2] | 7439-92-1 | -- | 26.8 | 400 | 750 | -- | 0.01 | 19 | | 0.0218 | 1 | 29 | | 0.0218 | 1 | 19 | | 0.0218 | 1 | 49 | | 0.0218 | 1 | 2.6 | | 0.0218 | 1 | 9.8 | | 0.0218 | 1 |
| Magnesium | 7439-95-4 | -- | -- | -- | -- | -- | 4,400 | 2,700 | | 3.21 | 250 | 1,430 | | 3.21 | 250 | 5,120 | | 3.21 | 250 | 1,560 | | 3.21 | 250 | 487 | | 3.21 | 250 | 22,300 | | 3.21 | 250 |
| Manganese | 7439-96-5 | N | 2,543 | 156.43 | 2,044 | 951.9 | 330 | 699 | | 0.264 | 5 | 264 | | 0.264 | 5 | 354 | | 0.264 | 5 | 361 | | 0.264 | 5 | ***1,090*** | | 1.32 | 25 | 632 | | 0.264 | 5 |
| Mercury[3] | 7439-97-6 | -- | 0.13 | 2.35 | 30.66 | -- | 0.058 | 0.049 | J | 0.0077 | 0.1 | 0.035 | J | 0.0077 | 0.1 | 0.053 | J | 0.0077 | 0.1 | 0.16 | | 0.0077 | 0.1 | 0.013 | J | 0.0077 | 0.1 | <0.1 | U | 0.0077 | 0.1 |
| Nickel | 7440-02-0 | N | 62.8 | 156.43 | 2,044 | -- | 2 | 6 | | 0.0356 | 0.5 | 14 | | 0.0356 | 0.5 | 18 | | 0.0356 | 0.5 | 12 | | 0.0356 | 0.5 | 11 | | 0.0356 | 0.5 | 75 | | 0.356 | 5 |
| Potassium | 7440-09-7 | -- | -- | -- | -- | -- | -- | 528 | ,J,s | 5 | 100 | 1,240 | ,J,s | 5 | 100 | 3,290 | ,J,s | 5 | 100 | 968 | ,J,s | 5 | 100 | 999 | ,J,s | 5 | 100 | 4,570 | ,J,s | 5 | 100 |
| Selenium | 7782-49-2 | N | -- | 39.11 | 511 | 18.98 | 1.8 | 0.51 | J | 0.0502 | 1 | 0.33 | J | 0.0502 | 1 | 0.71 | J | 0.0502 | 1 | 0.69 | J | 0.0502 | 1 | 0.55 | J | 0.0502 | 1 | 0.75 | J | 0.0502 | 1 |
| Silver | 7440-22-4 | N | -- | 39.11 | 511 | 31.03 | 0.0000098 | 0.054 | J | 0.0044 | 3 | 0.028 | J | 0.0044 | 3 | 0.11 | J | 0.0044 | 3 | 0.1 | J | 0.0044 | 3 | 0.034 | J | 0.0044 | 3 | 0.12 | J | 0.0044 | 3 |
| Sodium | 7440-23-5 | -- | -- | -- | -- | -- | -- | 33 | J,B,p | 8.92 | 100 | 74 | J,B,p | 8.92 | 100 | 343 | | 8.92 | 100 | 312 | | 8.92 | 100 | 161 | | 8.92 | 100 | 84 | J,B,p | 8.92 | 100 |
| Thallium | 7440-28-0 | N | 2.11 | 0.55 | 7.2 | 3.6 | 0.001 | 0.17 | J | 0.027 | 0.5 | 0.18 | J | 0.027 | 0.5 | 0.24 | J | 0.027 | 0.5 | 0.25 | J | 0.027 | 0.5 | 0.11 | J | 0.027 | 0.5 | 0.18 | J | 0.027 | 0.5 |
| Vanadium | 7440-62-2 | N | 108 | 7.82 | 102.2 | 730.1 | 0.5 | 29 | | 0.207 | 1 | 69 | | 0.207 | 1 | 58 | | 0.207 | 1 | 76 | | 0.207 | 1 | 18 | | 0.207 | 1 | 50 | | 0.207 | 1 |
| Zinc | 7440-66-6 | N | 202 | 2,346 | 30,660 | 13,622 | 10 | 52 | | 0.517 | 4 | 54 | | 0.517 | 4 | 97 | | 0.517 | 4 | 160 | | 2.59 | 20 | 9.3 | | 0.517 | 4 | 43 | | 0.517 | 4 |
| **TCL Pesticides/PCBs (μg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1254 [4] | 11097-69-1 | C | -- | 1.6E+02 | 1.4E+03 | 1.1E+03 | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| **TCL VOCs (μg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2-Butanone | 78-93-3 | N | -- | 4.7E+06 | 6.1E+07 | 2.9E+04 | -- | 29 | | 5.8 | 24 | 24 | J | 6.65 | 26 | 26 | J | 7.45 | 30 | 30 | | 6.6 | 26 | 23 | J | 6.6 | 26 | 21 | J | 6.6 | 26 |
| Acetone | 67-64-1 | N | -- | 7.0E+06 | 9.2E+07 | 2.2E+04 | -- | 100 | B,B,z | 5.8 | 24 | 50 | B,B,z | 6.65 | 26 | 54 | B,B,z | 7.45 | 30 | 100 | B,B,z | 6.6 | 26 | 51 | B,B,z | 6.6 | 26 | 37 | B,B,z | 6.6 | 26 |
| Bromodichloromethane | 75-27-4 | C | -- | 1.0E+04 | 4.6E+04 | 1.1E+00 | 450,000 | <5.8 | U | 0.581 | 5.8 | <6.7 | U | 0.666 | 6.7 | <7.5 | U | 0.746 | 7.5 | <6.6 | U | 0.661 | 6.6 | <6.6 | U | 0.661 | 6.6 | ***1.2*** | J | 0.661 | 6.6 |
| Chloroform | 67-66-3 | N | -- | 7.8E+04 | 1.0E+06 | 9.1E-01 | 300 | <5.8 | U | 0.517 | 5.8 | 17 | | 0.593 | 6.7 | 24 | | 0.665 | 7.5 | <6.6 | U | 0.589 | 6.6 | <6.6 | U | 0.589 | 6.6 | 15 | | 0.589 | 6.6 |
| Ethylbenzene | 100-41-4 | N | -- | 7.8E+05 | 1.0E+07 | 1.5E+04 | 100 | <5.8 | U | 0.491 | 5.8 | <6.7 | U | 0.563 | 6.7 | <7.5 | U | 0.63 | 7.5 | <6.6 | U | 0.558 | 6.6 | <6.6 | U | 0.558 | 6.6 | <6.6 | U | 0.558 | 6.6 |
| Methylene chloride | 75-09-2 | C | -- | 8.5E+04 | 3.8E+05 | 1.9E+01 | 300 | 3.6 | J | 3.26 | 24 | 5.3 | J | 3.74 | 26 | 6.4 | J | 4.19 | 30 | 6 | J | 3.71 | 26 | 4.9 | J | 3.71 | 26 | 4.8 | J | 3.71 | 26 |
| Toluene | 108-88-3 | N | -- | 6.3E+05 | 8.2E+06 | 2.7E+04 | 100 | <5.8 | U | 0.538 | 5.8 | <6.7 | U | 0.617 | 6.7 | <7.5 | U | 0.691 | 7.5 | <6.6 | U | 0.612 | 6.6 | <6.6 | U | 0.612 | 6.6 | <6.6 | U | 0.612 | 6.6 |
| Trichloroethene | 79-01-6 | C | -- | 1.6E+03 | 7.2E+03 | 2.6E-01 | 300 | <5.8 | U | 0.785 | 5.8 | <6.7 | U | 0.9 | 6.7 | <7.5 | U | 1.01 | 7.5 | <6.6 | U | 0.894 | 6.6 | <6.6 | U | 0.894 | 6.6 | <6.6 | U | 0.894 | 6.6 |
| **VOC TICs (μg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hexanal | -- | -- | -- | -- | -- | -- | -- | 7 | E,NJ,t | 0 | 1 | -- | | | | -- | | | | 28 | E,NJ,t | 0 | 1 | -- | | | | -- | | | |
| **TCL SVOCs (μg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2-Methylnaphthalene | 91-57-6 | N | -- | 3.1E+04 | 4.1E+05 | 4.4E+03 | -- | <200 | U | 3.29 | 200 | <220 | U | 3.56 | 220 | <260 | U | 4.11 | 260 | <220 | U | 3.56 | 220 | <220 | U | 3.56 | 220 | <220 | U | 3.56 | 220 |
| 4-Chloro-3-Methylphenol | 59-50-7 | -- | -- | -- | -- | -- | -- | 23 | J,B,x | 6.25 | 200 | 29 | J | 6.77 | 220 | 44 | J | 7.82 | 260 | 19 | J,B,x | 6.77 | 220 | 16 | J,B,x | 6.77 | 220 | <220 | U | 6.77 | 220 |
| Acenaphthylene [5] | 208-96-8 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | <200 | U | 1.8 | 200 | <220 | U | 1.95 | 220 | <260 | U | 2.25 | 260 | 2 | J,J,l | 1.95 | 220 | <220 | U | 1.95 | 220 | <220 | U | 1.95 | 220 |
| Acetophenone | 98-86-2 | N | -- | 7.8E+05 | 1.0E+07 | 3.2E+03 | -- | <200 | U | 2.28 | 200 | <220 | U | 2.47 | 220 | <260 | U | 2.85 | 260 | <220 | U | 2.47 | 220 | <220 | U | 2.47 | 220 | <220 | U | 2.47 | 220 |
| Anthracene | 120-12-7 | N | -- | 2.3E+06 | 3.1E+07 | 4.7E+05 | 100 | <200 | U | 5.54 | 200 | <220 | U | 6.01 | 220 | <260 | U | 6.93 | 260 | <220 | U | 6.01 | 220 | <220 | U | 6.01 | 220 | <220 | U | 6.01 | 220 |
| Benzo(a)pyrene | 50-32-8 | C | -- | 2.2E+01 | 3.9E+02 | 1.2E+02 | 100 | 12 | J | 6.85 | 200 | <220 | U | 7.42 | 220 | <260 | U | 8.57 | 260 | 30 | J | 7.42 | 220 | <220 | U | 7.42 | 220 | <220 | U | 7.42 | 220 |
| Benzo(b)fluoranthene | 205-99-2 | C | -- | 2.2E+02 | 3.9E+03 | 1.5E+03 | 100 | 23 | J | 11.7 | 200 | <220 | U | 12.7 | 220 | <260 | U | 14.6 | 260 | 55 | J,J,l | 12.7 | 220 | <220 | U | 12.7 | 220 | <220 | U | 12.7 | 220 |
| Benzo(g,h,i)perylene [5] | 191-24-2 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | <200 | U | 10.5 | 200 | <220 | U | 11.3 | 220 | <260 | U | 13.1 | 260 | <220 | U | 11.3 | 220 | <220 | U | 11.3 | 220 | <220 | U | 11.3 | 220 |
| Bis(2-ethylhexyl)phthalate | 117-81-7 | C | -- | 4.6E+04 | 2.0E+05 | 2.9E+06 | -- | 27 | J | 2.48 | 200 | 22 | J | 2.69 | 220 | 63 | J | 3.11 | 260 | 62 | J,B,z | 2.69 | 220 | 20 | J | 2.69 | 220 | 48 | J,B,z | 2.69 | 220 |
| Butylbenzylphthalate | 85-68-7 | N | -- | 1.6E+06 | 2.0E+07 | 1.7E+07 | -- | <200 | U | 5.38 | 200 | 10 | J | 5.82 | 220 | 30 | J | 6.72 | 260 | 44 | J | 5.82 | 220 | <220 | U | 5.82 | 220 | <220 | U | 5.82 | 220 |
| Caprolactam | 105-60-2 | N | -- | 3.9E+06 | 5.1E+07 | -- | -- | 15 | J | 7.66 | 400 | 11 | J | 8.29 | 430 | 36 | J | 9.57 | 500 | <430 | U | 8.29 | 430 | <430 | U | 8.29 | 430 | <430 | U | 8.29 | 430 |
| Chrysene | 218-01-9 | C | -- | 2.2E+04 | 3.9E+05 | 4.8E+04 | 100 | 17 | J | 12.2 | 200 | <220 | U | 13.3 | 220 | <260 | U | 15.3 | 260 | <220 | U | 13.3 | 220 | <220 | U | 13.3 | 220 | <220 | U | 13.3 | 220 |
| Diethylphthalate | 84-66-2 | N | -- | 6.3E+06 | 8.2E+07 | 4.5E+05 | -- | 8 | J,B,x | 2.28 | 200 | 10 | J,B,x | 2.47 | 220 | 12 | J,B,x | 2.85 | 260 | 7 | J,B,x | 2.47 | 220 | 12 | J,B,x | 2.47 | 220 | 5 | J,B,x | 2.47 | 220 |
| Di-n-butylphthalate | 84-74-2 | N | -- | 7.8E+05 | 1.0E+07 | 5.0E+06 | -- | 330 | | 4.58 | 200 | 430 | | 4.97 | 220 | 410 | | 5.73 | 260 | 55 | J,B,z | 4.97 | 220 | 44 | J | 4.97 | 220 | 38 | J,B,z | 4.97 | 220 |
| Fluoranthene | 206-44-0 | N | -- | 3.1E+05 | 4.1E+06 | 6.3E+06 | 100 | 30 | J | 2.82 | 200 | <220 | U | 3.06 | 220 | <260 | U | 3.53 | 260 | 26 | J | 3.06 | 220 | <220 | U | 3.06 | 220 | <220 | U | 3.06 | 220 |
| Fluorene | 86-73-7 | N | -- | 3.1E+05 | 4.1E+06 | 1.4E+05 | 100 | <200 | U | 2.02 | 200 | <220 | U | 2.18 | 220 | <260 | U | 2.52 | 260 | <220 | U | 2.18 | 220 | <220 | U | 2.18 | 220 | <220 | U | 2.18 | 220 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | C | -- | 2.2E+02 | 3.9E+03 | 4.2E+03 | 100 | 7 | J | 4.7 | 200 | <220 | U | 5.1 | 220 | <260 | U | 5.88 | 260 | 42 | J,J,l | 5.1 | 220 | <220 | U | 5.1 | 220 | <220 | U | 5.1 | 220 |
| Naphthalene | 91-20-3 | N | -- | 1.6E+05 | 2.0E+06 | 1.5E+02 | 100 | <200 | U | 3.3 | 200 | <220 | U | 3.58 | 220 | <260 | U | 4.13 | 260 | <220 | U | 3.58 | 220 | <220 | U | 3.58 | 220 | <220 | U | 3.58 | 220 |
| Phenanthrene [5] | 85-01-8 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | 13 | J | 2.76 | 200 | <220 | U | 2.99 | 220 | <260 | U | 3.45 | 260 | 18 | J | 2.99 | 220 | <220 | U | 2.99 | 220 | <220 | U | 2.99 | 220 |
| Pyrene | 129-00-0 | N | -- | 2.3E+05 | 3.1E+06 | 6.8E+05 | 100 | 29 | J | 1.78 | 200 | <220 | U | 1.92 | 220 | <260 | U | 2.22 | 260 | 38 | J | 1.92 | 220 | <220 | U | 1.92 | 220 | <220 | U | 1.92 | 220 |
| **SVOC TICs (μg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (Z)-9-Octadecenamide | 301-02-0 | -- | -- | -- | -- | -- | -- | -- | | | | 810 | E,NJ,t | 0 | 100 | 79 | E,NJ,t | 0 | 100 | -- | | | | -- | | | | 80 | E,NJ,t | 0 | 100 |
| 1-Heptadecanol | 1454-85-9 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 1-Hexadecanol | 36653-82-4 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | 31 | E,NJ,t | 0 | 100 |
| 1-Octadecanol | 112-92-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 1-Pentadecanol | 629-76-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | 52 | E,NJ,t | 0 | 10 |
| 1,1'-Biphenyl, 2,3,3',4,4'-pentachloro- | 32598-14-4 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 1,2-Benzenedicarboxylicacid, bis(2-methy | 84-69-5 | -- | -- | -- | -- | -- | -- | 440 | E,NJ,t | 0 | 100 | 540 | E,NJ,t | 0 | 100 | -- | | | | -- | | | | 38 | E,B,x | 0 | 100 | -- | | | |
| 1,2-Benzenedicarboxylic acid, butyl 2-me | 17851-53-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | 51 | E,NJ,t | 0 | 10 | -- | | | | -- | | | |
| 1,2-Benzenedicarboxylic acid, butyl 8-me | 89-18-9 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | 34 | E,NJ,t | 0 | 50 |
| 1,2-Benzenedicarboxylic acid, butyl cycl | 84-64-0 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | 470 | E,NJ,t | 0 | 1 | -- | | | | -- | | | | -- | | | |
| 2(5H)-Furanone, 5,5-dimethyl- | 20019-64-1 | -- | -- | -- | -- | -- | -- | 260 | E,NJ,t | 0 | 100 | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 2,4,6-Triallyloxy-1,3,5-triazine | 101-37-1 | -- | -- | -- | -- | -- | -- | 94 | E,NJ,t | 0 | 100 | 130 | E,NJ,t | 0 | 100 | -- | | | | -- | | | | 68 | E,NJ,t | 0 | 100 | -- | | | |
| 7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6, | 10001-439-24 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |

**Table 7-3**
**Detected Analytes for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| Sample ID / Sample Date / Sample Depth (ft bgs) | CAS # | C/N | Facility-Wide Background Point Estimate[A] | Adjusted Soil RBC (Residential) | Adjusted Soil RBC (Industrial) | SSL DAF 20 | Draft BTAG Screening Level | 57SB1A 10/7/2003 0-1 | | MDL | RL | 57SB1B 10/7/2003 10-12 | | MDL | RL | 57SB1C 10/7/2003 18-20 | | MDL | RL | 57SB2A 10/7/2003 0-1 | | MDL | RL | 57SB2B 10/7/2003 8-12 | | MDL | RL | 57SB2C 10/7/2003 33-35 | | MDL | RL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | |
| Bis(2-ethylhexyl)maleate | 142-16-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | 120 | E,NJ,t | 0 | 100 | -- | | | | -- | | | | -- | | | |
| Erucylamide | 112-84-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | 600 | E,B,x | 0 | 10 | -- | | | | 330 | E,B,x | 0 | 10 |
| Oxirane, hexadecyl- | 7390-81-0 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| Phenol, (1,1,3,3-tetramethylbutyl)- | 27193-28-8 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| Phosphoric acid, tris (3-methylphenyl) e | 78-30-8 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| Phsophoric acid, tris(3-methylphenyl) es | 563-04-2 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| Stearic Acid | 57-11-4 | -- | -- | -- | -- | -- | -- | -- | | | | 64 | E,NJ,t | 0 | 1 | 110 | E,NJ,t | 0 | 1 | -- | | | | -- | | | | -- | | | |
| **PAHs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Anthracene | 120-12-7 | N | -- | 2.3E+06 | 3.1E+07 | 4.7E+05 | 100 | 1.9 | J,L,s | 0.84 | 24 | <28 | U,UL,s | 0.91 | 28 | <31 | U | 1.05 | 31 | 1.5 | J | 0.91 | 28 | <28 | U | 0.91 | 28 | <28 | U,UL,s | 0.924 | 28 |
| Benzo(a)anthracene | 56-55-3 | C | -- | 2.2E+02 | 3.9E+03 | 4.8E+02 | 100 | <24 | U,UL,s | 0.96 | 24 | <28 | U,UL,s | 1.04 | 28 | <31 | U | 1.2 | 31 | 7.1 | J | 1.04 | 28 | <28 | U | 1.04 | 28 | <28 | U,UL,s | 1.06 | 28 |
| Benzo(a)pyrene | 50-32-8 | C | -- | 2.2E+01 | 3.9E+02 | 1.2E+02 | 100 | 18 | J,L,s | 1.2 | 24 | <28 | U,UL,s | 1.3 | 28 | <31 | U | 1.5 | 31 | 10 | J | 1.3 | 28 | <28 | U | 1.3 | 28 | <28 | U,UL,s | 1.32 | 28 |
| Benzo(b)fluoranthene | 205-99-2 | C | -- | 2.2E+02 | 3.9E+03 | 1.5E+03 | 100 | 14 | J,L,s | 1.56 | 24 | <28 | U,UL,s | 1.69 | 28 | <31 | U | 1.95 | 31 | <28 | U | 1.69 | 28 | <28 | U | 1.69 | 28 | <28 | U,UL,s | 1.72 | 28 |
| Benzo(g,h,i)perylene [5] | 191-24-2 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | 27 | ,L,s | 15 | 24 | <28 | U,UL,s | 16.3 | 28 | <31 | U | 18.8 | 31 | <28 | U | 16.3 | 28 | <28 | U | 16.3 | 28 | <28 | U,UL,s | 16.5 | 28 |
| Benzo(k)fluoranthene | 207-08-9 | C | -- | 2.2E+03 | 3.9E+04 | 1.5E+04 | 100 | 8.5 | J,L,s | 1.2 | 24 | <28 | U,UL,s | 1.3 | 28 | <31 | U | 1.5 | 31 | <28 | U | 1.3 | 28 | <28 | U | 1.3 | 28 | <28 | U,UL,s | 1.32 | 28 |
| Chrysene | 218-01-9 | C | -- | 2.2E+04 | 3.9E+05 | 4.8E+04 | 100 | 11 | J,L,s | 1.44 | 24 | <28 | U,UL,s | 1.56 | 28 | <31 | U | 1.8 | 31 | 9.2 | J | 1.56 | 28 | <28 | U | 1.56 | 28 | <28 | U,UL,s | 1.58 | 28 |
| Fluoranthene | 206-44-0 | N | -- | 3.1E+05 | 4.1E+06 | 6.3E+06 | 100 | 57 | ,L,s | 2.04 | 24 | <28 | U,UL,s | 2.21 | 28 | <31 | U | 2.55 | 31 | 29 | | 2.21 | 28 | <28 | U | 2.21 | 28 | <28 | U,UL,s | 2.24 | 28 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | C | -- | 2.2E+02 | 3.9E+03 | 4.2E+03 | 100 | 11 | J,L,s | 0.84 | 24 | <28 | U,UL,s | 0.91 | 28 | <31 | U | 1.05 | 31 | 7.2 | J | 0.91 | 28 | <28 | U | 0.91 | 28 | <28 | U,UL,s | 0.924 | 28 |
| Phenanthrene [5] | 85-01-8 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | 24 | ,L,s | 0.72 | 24 | <28 | U,UL,s | 0.78 | 28 | <31 | U | 0.9 | 31 | 11 | J | 0.78 | 28 | <28 | U | 0.78 | 28 | <28 | U,UL,s | 0.792 | 28 |
| Pyrene | 129-00-0 | N | -- | 2.3E+05 | 3.1E+06 | 6.8E+05 | 100 | 82 | ,L,s | 1.08 | 24 | <28 | U,UL,s | 1.17 | 28 | <31 | U | 1.35 | 31 | 20 | J | 1.17 | 28 | <28 | U | 1.17 | 28 | <28 | U,UL,s | 1.19 | 28 |
| **Cyanide (mg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cyanide | 57-12-5 | N | -- | 1.6E+02 | 2.0E+03 | 1.5E+02 | 0.005 | 0.1 | J | 0.0356 | 0.5 | <0.5 | U | 0.0356 | 0.5 | <0.5 | U | 0.0356 | 0.5 | 0.09 | J | 0.0356 | 0.5 | 0.08 | J | 0.0356 | 0.5 | <0.5 | U | 0.0356 | 0.5 |
| **Percent Solids (%)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percent Solids | -- | -- | -- | -- | -- | -- | -- | 86 | | 0.1 | 0.1 | 75 | | 0.1 | 0.1 | 67 | | 0.1 | 0.1 | 76 | | 0.1 | 0.1 | 76 | | 0.1 | 0.1 | 76 | | 0.1 | 0.1 |

Table 7-3
Detected Analytes for SWMU 57
SSP Report
Radford Army Ammunition Plant, Radford, Virginia

| Sample ID<br>Sample Date<br>Sample Depth (ft bgs) | CAS # | C/N | Facility-Wide Background Point Estimate[A] | Adjusted Soil RBC (Residential) | Adjusted Soil RBC (Industrial) | SSL DAF 20 | Draft BTAG Screening Level | 57SB3A 10/7/2003 0-1 | | MDL | RL | 57SB3A-DUP(SBD6) 10/7/2003 0-1 | | MDL | RL | 57SB3B 10/7/2003 14-16 | | MDL | RL | 57SB3C 10/7/2003 29-31 | | MDL | RL | 57SB4A 10/7/2003 0.5 | | MDL | RL | 57SB4B 10/7/2003 1.5 | | MDL | RL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | |
| **TAL Metals (mg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aluminum | 7429-90-5 | -- | 40,041 | -- | -- | -- | 1 | 28,900 | | 9.15 | 250 | 33,000 | | 9.15 | 250 | 37,400 | | 9.15 | 250 | 29,600 | | 9.15 | 250 | 30,100 | | 9.15 | 250 | 33,300 | | 9.15 | 250 |
| Antimony | 7440-36-0 | N | -- | 3.13 | 40.9 | 13.2 | 0.48 | 102 | | 1.3 | 0.5 | 104 | | 1.3 | 0.5 | 0.29 | J | 0.0518 | 0.5 | <0.5 | U | 0.0518 | 0.5 | 6.3 | | 0.0518 | 0.5 | 9.7 | | 0.0518 | 0.5 |
| Arsenic | 7440-38-2 | C | 15.8 | 0.43 | 1.91 | 0.026 | 328 | 5.1 | | 0.0232 | 0.4 | 5.3 | | 0.0232 | 0.4 | 12 | | 0.0232 | 0.4 | 5.9 | | 0.0232 | 0.4 | 4.7 | | 0.0232 | 0.4 | 2 | | 0.0232 | 0.4 |
| Barium | 7440-39-3 | N | 209 | 1,564 | 20,440 | 6,015.2 | 440 | 107 | ,J,f | 0.106 | 5 | 154 | ,J,f | 0.106 | 5 | 62 | | 0.106 | 5 | 52 | | 0.106 | 5 | 149 | | 0.106 | 5 | 51 | | 0.106 | 5 |
| Beryllium | 7440-41-7 | N | 1.02 | 15.64 | 204.4 | 1,153.7 | 0.02 | 0.45 | J,J,s | 0.0391 | 1 | 0.39 | J,J,s | 0.0391 | 1 | 1.4 | ,J,s | 0.0391 | 1 | 2 | ,J,s | 0.0391 | 1 | 0.6 | J,J,s | 0.0391 | 1 | 0.45 | J | 0.0333 | 1 |
| Cadmium | 7440-43-9 | N | 0.69 | 3.91 | 51.1 | 27.4 | 2.5 | 27 | ,J,f | 0.182 | 1 | 41 | ,J,f | 0.182 | 1 | 1.2 | | 0.182 | 1 | 0.87 | J | 0.182 | 1 | 1.5 | | 0.182 | 1 | 1.6 | | 0.182 | 1 |
| Calcium | 7440-70-2 | -- | -- | -- | -- | -- | -- | 1,750 | ,J,f | 16.6 | 250 | 2,760 | ,J,f | 16.6 | 250 | <250 | U | 16.6 | 250 | 294 | | 16.6 | 250 | 1,420 | | 16.6 | 250 | 372 | ,J,m | 16.6 | 250 |
| Chromium[1] | 7440-47-3 | N | 65.3 | 23.46 | 306.6 | 42.05 | 0.0075 | 268 | ,J,f | 4.56 | 25 | 454 | ,J,f | 4.56 | 25 | 43 | | 0.912 | 5 | 31 | | 0.912 | 5 | 43 | | 0.912 | 5 | 45 | ,J,m | 0.912 | 5 |
| Cobalt | 7440-48-4 | -- | 72.3 | -- | -- | -- | 100 | 75 | ,J,s | 0.208 | 1 | 8 | ,J,s | 0.208 | 1 | 23 | ,J,s | 0.208 | 1 | 18 | ,J,s | 0.208 | 1 | 9.7 | ,J,s | 0.208 | 1 | 13 | ,J,s | 0.208 | 1 |
| Copper | 7440-50-8 | N | 53.5 | 312.86 | 4,088 | 10,518 | 15 | 27 | | 0.368 | 1 | 38 | | 0.368 | 1 | 38 | | 0.368 | 1 | 17 | | 0.368 | 1 | 26 | | 0.368 | 1 | 18 | ,J,s | 0.368 | 2 |
| Iron | 7439-89-6 | N | 50,962 | 2,346 | 30,660 | -- | 12 | 47,100 | | 35.8 | 500 | 46,500 | | 71.6 | 1000 | 53,400 | | 71.6 | 1000 | 35,200 | | 35.8 | 500 | 78,700 | | 71.6 | 1000 | 59,000 | | 42.4 | 200 |
| Lead[2] | 7439-92-1 | -- | 26.8 | 400 | 750 | -- | 0.01 | 175 | | 0.545 | 25 | 268 | | 1.09 | 50 | 19 | | 0.0218 | 1 | 9.2 | | 0.0218 | 1 | 19 | | 0.0218 | 1 | 18 | | 0.0218 | 1 |
| Magnesium | 7439-95-4 | -- | -- | -- | -- | -- | 4,400 | 1,420 | | 3.21 | 250 | 1,990 | | 3.21 | 250 | 4,280 | | 3.21 | 250 | 35,000 | | 16.1 | 1250 | 923 | | 3.21 | 250 | 971 | ,J,m | 3.21 | 250 |
| Manganese | 7439-96-5 | N | 2,543 | 156.43 | 2,044 | 951.9 | 330 | 544 | | 0.264 | 5 | 514 | | 0.264 | 5 | 518 | | 0.264 | 5 | 828 | | 0.264 | 5 | 3,200 | | 1.32 | 25 | 273 | | 0.264 | 5 |
| Mercury[3] | 7439-97-6 | -- | 0.13 | 2.35 | 30.66 | -- | 0.058 | 0.11 | | 0.0077 | 0.1 | 0.13 | | 0.0077 | 0.1 | 0.023 | J | 0.0077 | 0.1 | <0.1 | U | 0.0077 | 0.1 | 0.14 | | 0.0077 | 0.1 | 0.041 | J | 0.0077 | 0.1 |
| Nickel | 7440-02-0 | N | 62.8 | 156.43 | 2,044 | -- | 2 | 13 | | 0.0356 | 0.5 | 14 | | 0.0356 | 0.5 | 28 | | 0.0356 | 0.5 | 50 | | 0.0356 | 0.5 | 8.7 | | 0.0356 | 0.5 | 12 | | 0.0356 | 0.5 |
| Potassium | 7440-09-7 | -- | -- | -- | -- | -- | -- | 967 | ,J,s | 5 | 100 | 1,060 | ,J,s | 5 | 100 | 3,020 | ,J,s | 5 | 100 | 5,900 | ,J,s | 5 | 100 | 908 | ,J,s | 5 | 100 | 1,080 | | 5 | 100 |
| Selenium | 7782-49-2 | N | -- | 39.11 | 511 | 18.98 | 1.8 | 0.57 | J | 0.0502 | 1 | 0.64 | J | 0.0502 | 1 | 0.55 | J | 0.0502 | 1 | 0.88 | J | 0.0502 | 1 | 0.57 | J | 0.0502 | 1 | 0.4 | J | 0.0502 | 1 |
| Silver | 7440-22-4 | N | -- | 39.11 | 511 | 31.03 | 0.0000098 | 0.11 | J | 0.0044 | 3 | 0.15 | J | 0.0044 | 3 | 0.11 | J | 0.0044 | 3 | 0.15 | J | 0.0044 | 3 | 0.076 | J | 0.0044 | 3 | 0.063 | J | 0.0044 | 3 |
| Sodium | 7440-23-5 | -- | -- | -- | -- | -- | -- | 76 | J,B,p | 8.92 | 100 | 97 | J,B,p | 8.92 | 100 | 339 | | 8.92 | 100 | 169 | | 8.92 | 100 | 127 | | 8.92 | 100 | 497 | | 18.1 | 100 |
| Thallium | 7440-28-0 | N | 2.11 | 0.55 | 7.2 | 3.6 | 0.001 | 0.24 | J | 0.027 | 0.5 | 0.24 | J | 0.027 | 0.5 | 0.28 | J | 0.027 | 0.5 | 0.22 | J | 0.027 | 0.5 | 0.3 | J | 0.027 | 0.5 | 0.18 | J,B,x | 0.027 | 0.5 |
| Vanadium | 7440-62-2 | N | 108 | 7.82 | 102.2 | 730.1 | 0.5 | 69 | | 0.207 | 1 | 67 | | 0.207 | 1 | 59 | | 0.207 | 1 | 59 | | 0.207 | 1 | 84 | | 0.207 | 1 | 66 | | 0.207 | 1 |
| Zinc | 7440-66-6 | N | 202 | 2,346 | 30,660 | 13,622 | 10 | 895 | ,J,f | 5.17 | 40 | 1,370 | ,J,f | 12.9 | 100 | 53 | | 0.517 | 4 | 52 | | 0.517 | 4 | 281 | | 2.59 | 20 | 88 | | 0.517 | 4 |
| **TCL Pesticides/PCBs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1254[4] | 11097-69-1 | C | -- | 1.6E+02 | 1.4E+03 | 1.1E+03 | -- | -- | | | | -- | | | | -- | | | | -- | | | | 12 | J,J,g | 4.2 | 46 | -- | | | |
| **TCL VOCs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2-Butanone | 78-93-3 | N | -- | 4.7E+06 | 6.1E+07 | 2.9E+04 | -- | 28 | | 6.5 | 26 | 32 | | 6.6 | 26 | 29 | J | 7.95 | 32 | 25 | J | 6.65 | 26 | 30 | | 7.05 | 14 | 27 | J | 6.75 | 28 |
| Acetone | 67-64-1 | N | -- | 7.0E+06 | 9.2E+07 | 2.2E+04 | -- | 99 | B,B,z | 6.5 | 26 | 160 | ,B,z | 6.6 | 26 | 77 | B,B,z | 7.95 | 32 | 55 | B,B,z | 6.65 | 26 | 55 | B,B,z | 7.05 | 14 | 66 | B,B,z | 6.75 | 28 |
| Bromodichloromethane | 75-27-4 | C | -- | 1.0E+04 | 4.6E+04 | 1.1E+00 | 450,000 | <6.5 | U | 0.651 | 6.5 | <6.6 | U | 0.661 | 6.6 | <7.9 | U | 0.797 | 7.9 | <6.7 | U | 0.666 | 6.7 | <7 | U | 0.706 | 7 | <6.8 | U | 0.676 | 6.8 |
| Chloroform | 67-66-3 | N | -- | 7.8E+04 | 1.0E+06 | 9.1E-01 | 300 | <6.5 | U | 0.58 | 6.5 | <6.6 | U | 0.589 | 6.6 | <7.9 | U | 0.709 | 7.9 | 1.1 | J | 0.593 | 6.7 | <7 | U | 0.629 | 7 | <6.8 | U | 0.602 | 6.8 |
| Ethylbenzene | 100-41-4 | N | -- | 7.8E+05 | 1.0E+07 | 1.5E+04 | 100 | 0.66 | J | 0.55 | 6.5 | <6.6 | U | 0.558 | 6.6 | <7.9 | U | 0.673 | 7.9 | <6.7 | U | 0.563 | 6.7 | <7 | U | 0.596 | 7 | <6.8 | U | 0.571 | 6.8 |
| Methylene chloride | 75-09-2 | C | -- | 8.5E+04 | 3.8E+05 | 1.9E+01 | 300 | 6.5 | J | 3.65 | 26 | 4.3 | J | 3.71 | 26 | 6.8 | J | 4.47 | 32 | 5.4 | J | 3.74 | 26 | <7 | U | 3.96 | 7 | <28 | U | 3.79 | 28 |
| Toluene | 108-88-3 | N | -- | 6.3E+05 | 8.2E+06 | 2.7E+04 | 100 | 1.3 | J | 0.603 | 6.5 | 2.6 | J | 0.612 | 6.6 | <7.9 | U | 0.738 | 7.9 | <6.7 | U | 0.617 | 6.7 | <7 | U | 0.654 | 7 | <6.8 | U | 0.626 | 6.8 |
| Trichloroethene | 79-01-6 | C | -- | 1.6E+03 | 7.2E+03 | 2.6E-01 | 300 | 1.9 | J | 0.88 | 6.5 | 1.6 | J | 0.894 | 6.6 | <7.9 | U | 1.08 | 7.9 | <6.7 | U | 0.9 | 6.7 | <7 | U | 0.955 | 7 | <6.8 | U | 0.914 | 6.8 |
| **VOC TICs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Hexanal | -- | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| **TCL SVOCs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2-Methylnaphthalene | 91-57-6 | N | -- | 3.1E+04 | 4.1E+05 | 4.4E+03 | -- | 6 | J | 3.56 | 220 | 12 | J | 3.56 | 220 | <270 | U | 4.38 | 270 | <220 | U | 3.56 | 220 | <240 | U | 3.84 | 240 | <230 | U | 3.84 | 230 |
| 4-Chloro-3-Methylphenol | 59-50-7 | -- | -- | -- | -- | -- | -- | 46 | J | 6.77 | 220 | 38 | J | 6.77 | 220 | 16 | J,B,x | 8.34 | 270 | <220 | U | 6.77 | 220 | 17 | J,B,x | 7.29 | 240 | 18 | J | 7.29 | 230 |
| Acenaphthylene[5] | 208-96-8 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | 4 | J | 1.95 | 220 | 9 | J | 1.95 | 220 | <270 | U | 2.4 | 270 | <220 | U | 1.95 | 220 | <240 | U | 2.1 | 240 | <230 | U | 2.1 | 230 |
| Acetophenone | 98-86-2 | N | -- | 7.8E+05 | 1.0E+07 | 3.2E+03 | -- | 36 | J | 2.47 | 220 | 75 | J | 2.47 | 220 | <270 | U | 3.04 | 270 | <220 | U | 2.47 | 220 | <240 | U | 2.66 | 240 | <230 | U | 2.66 | 230 |
| Anthracene | 120-12-7 | N | -- | 2.3E+06 | 3.1E+07 | 4.7E+05 | 100 | <220 | U | 6.01 | 220 | 9 | J | 6.01 | 220 | <270 | U | 7.39 | 270 | <220 | U | 6.01 | 220 | <240 | U | 6.47 | 240 | <230 | U | 6.47 | 230 |
| Benzo(a)pyrene | 50-32-8 | C | -- | 2.2E+01 | 3.9E+02 | 1.2E+02 | 100 | 12 | J | 7.42 | 220 | 20 | J | 7.42 | 220 | <270 | U | 9.14 | 270 | <220 | U | 7.42 | 220 | <240 | U | 7.99 | 240 | <230 | U | 7.99 | 230 |
| Benzo(b)fluoranthene | 205-99-2 | C | -- | 2.2E+02 | 3.9E+03 | 1.5E+03 | 100 | 20 | J | 12.7 | 220 | 35 | J | 12.7 | 220 | <270 | U | 15.6 | 270 | <220 | U | 12.7 | 220 | <240 | U | 13.7 | 240 | <230 | U | 13.7 | 230 |
| Benzo(g,h,i)perylene[5] | 191-24-2 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | <220 | U | 11.3 | 220 | 15 | J | 11.3 | 220 | <270 | U | 14 | 270 | <220 | U | 11.3 | 220 | <240 | U | 12.2 | 240 | <230 | U | 12.2 | 230 |
| Bis(2-ethylhexyl)phthalate | 117-81-7 | C | -- | 4.6E+04 | 2.0E+05 | 2.9E+06 | -- | 480 | | 2.69 | 220 | 62 | J | 2.69 | 220 | 60 | J,B,z | 3.31 | 270 | 52 | J,B,z | 2.69 | 220 | 21 | J,B,z | 2.9 | 240 | 24 | J,B,z | 2.9 | 230 |
| Butylbenzylphthalate | 85-68-7 | N | -- | 1.6E+06 | 2.0E+07 | 1.7E+07 | -- | <220 | U | 5.82 | 220 | <220 | U | 5.82 | 220 | <270 | U | 7.17 | 270 | <220 | U | 5.82 | 220 | <240 | U | 6.27 | 240 | <230 | U | 6.27 | 230 |
| Caprolactam | 105-60-2 | N | -- | 3.9E+06 | 5.1E+07 | -- | -- | 43 | J | 8.29 | 430 | 25 | J | 8.29 | 430 | <530 | U | 10.2 | 530 | <430 | U | 8.29 | 430 | <460 | U | 8.93 | 460 | <440 | U | 8.93 | 440 |
| Chrysene | 218-01-9 | C | -- | 2.2E+04 | 3.9E+05 | 4.8E+04 | 100 | 23 | J | 13.3 | 220 | 22 | J | 13.3 | 220 | <270 | U | 16.3 | 270 | <220 | U | 13.3 | 220 | <240 | U | 14.3 | 240 | <230 | U | 14.3 | 230 |
| Diethylphthalate | 84-66-2 | N | -- | 6.3E+06 | 8.2E+07 | 4.5E+05 | -- | 19 | J,B,x | 2.47 | 220 | 21 | J,B,x | 2.47 | 220 | <270 | U | 3.04 | 270 | 7 | J,B,x | 2.47 | 220 | 11 | J,B,x | 2.66 | 240 | 6 | J,J,l | 2.66 | 230 |
| Di-n-butylphthalate | 84-74-2 | N | -- | 7.8E+05 | 1.0E+07 | 5.0E+06 | -- | 360 | | 4.97 | 220 | 230 | | 4.97 | 220 | 55 | J,B,z | 6.11 | 270 | 38 | J,B,z | 4.97 | 220 | 41 | J,B,z | 5.35 | 240 | 76 | J,B,z | 5.35 | 230 |
| Fluoranthene | 206-44-0 | N | -- | 3.1E+05 | 4.1E+06 | 6.3E+06 | 100 | 40 | J | 3.06 | 220 | 45 | J | 3.06 | 220 | <270 | U | 3.76 | 270 | <220 | U | 3.06 | 220 | <240 | U | 3.29 | 240 | <230 | U | 3.29 | 230 |
| Fluorene | 86-73-7 | N | -- | 3.1E+05 | 4.1E+06 | 1.4E+05 | 100 | <220 | U | 2.18 | 220 | 3 | J | 2.18 | 220 | <270 | U | 2.69 | 270 | <220 | U | 2.18 | 220 | <240 | U | 2.35 | 240 | <230 | U | 2.35 | 230 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | C | -- | 2.2E+02 | 3.9E+03 | 4.2E+03 | 100 | 7 | J | 5.1 | 220 | 12 | J | 5.1 | 220 | <270 | U | 6.27 | 270 | <220 | U | 5.1 | 220 | <240 | U | 5.49 | 240 | <230 | U | 5.49 | 230 |
| Naphthalene | 91-20-3 | N | -- | 1.6E+05 | 2.0E+06 | 1.5E+02 | 100 | 4 | J | 3.58 | 220 | 6 | J | 3.58 | 220 | <270 | U | 4.4 | 270 | <220 | U | 3.58 | 220 | <240 | U | 3.85 | 240 | <230 | U | 3.85 | 230 |
| Phenanthrene[5] | 85-01-8 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | 27 | J | 2.99 | 220 | 50 | J | 2.99 | 220 | <270 | U | 3.68 | 270 | <220 | U | 2.99 | 220 | <240 | U | 3.22 | 240 | <230 | U | 3.22 | 230 |
| Pyrene | 129-00-0 | N | -- | 2.3E+05 | 3.1E+06 | 6.8E+05 | 100 | 40 | J | 1.92 | 220 | 44 | J | 1.92 | 220 | <270 | U | 2.37 | 270 | <220 | U | 1.92 | 220 | <240 | U | 2.07 | 240 | <230 | U | 2.07 | 230 |
| **SVOC TICs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (Z)-9-Octadecenamide | 301-02-0 | -- | -- | -- | -- | -- | -- | 1,300 | E,NJ,t | 0 | 100 | 760 | E,NJ,t | 0 | 100 | -- | | | | 60 | E,NJ,t | 0 | 100 | -- | | | | -- | | | |
| 1-Heptadecanol | 1454-85-9 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | 37 | E,NJ,t | 0 | 10 | -- | | | | -- | | | |
| 1-Hexadecanol | 36653-82-4 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | 48 | E,NJ,t | 0 | 100 |
| 1-Octadecanol | 112-92-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | 31 | E,NJ,t | 0 | 100 | -- | | | |
| 1-Pentadecanol | 629-76-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 1,1'-Biphenyl, 2,3,3',4,4'-pentachloro- | 32598-14-4 | -- | -- | -- | -- | -- | -- | 390 | E,NJ,t | 0 | 10 | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 1,2-Benzenedicarboxylicacid, bis(2-methy | 84-69-5 | -- | -- | -- | -- | -- | -- | -- | | | | 530 | E,NJ,t | 0 | 100 | 56 | E,B,x | 0 | 100 | 32 | E,NJ,t | 0 | 100 | 41 | E,B,x | 0 | 100 | -- | | | |
| 1,2-Benzenedicarboxylic acid, butyl 2-me | 17851-53-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | 160 | E,NJ,t | 0 | 10 |
| 1,2-Benzenedicarboxylic acid, butyl 8-me | 89-18-9 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 1,2-Benzenedicarboxylic acid, butyl cycl | 84-64-0 | -- | -- | -- | -- | -- | -- | 330 | E,NJ,t | 0 | 1 | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 2(5H)-Furanone, 5,5-dimethyl- | 20019-64-1 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| 2,4,6-Triallyloxy-1,3,5-triazine | 101-37-1 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | 110 | E,NJ,t | 0 | 100 | -- | | | | 65 | E,NJ,t | 0 | 100 | 58 | E,NJ,t | 0 | 100 |
| 7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6, | 10001-439-24 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | 28 | E,NJ,t | 0 | 1 | -- | | | | -- | | | | -- | | | |

**Table 7-3**
**Detected Analytes for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| Sample ID / Sample Date / Sample Depth (ft bgs) | CAS # | C/N | Facility-Wide Background Point Estimate[A] | Adjusted Soil RBC (Residential) | Adjusted Soil RBC (Industrial) | SSL DAF 20 | Draft BTAG Screening Level | 57SB3A 10/7/2003 0-1 | | MDL | RL | 57SB3A-DUP(SBD6) 10/7/2003 0-1 | | MDL | RL | 57SB3B 10/7/2003 14-16 | | MDL | RL | 57SB3C 10/7/2003 29-31 | | MDL | RL | 57SB4A 10/7/2003 0.5 | | MDL | RL | 57SB4B 10/7/2003 1.5 | | MDL | RL |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | | Result | LQ, VQ, r | | |
| Bis(2-ethylhexyl)maleate | 142-16-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | | -- | | | |
| Erucylamide | 112-84-5 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | 630 | E,B,x | 0 | 10 | 340 | E,B,x | 0 | 10 | 320 | E,B,x | 0 | 10 | -- | | | |
| Oxirane, hexadecyl- | 7390-81-0 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | 58 | E,NJ,t | 0 | 10 | -- | | | |
| Phenol, (1,1,3,3-tetramethylbutyl)- | 27193-28-8 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | 29 | E,NJ,t | 0 | 10 | -- | | | |
| Phosphoric acid, tris (3-methylphenyl) e | 78-30-8 | -- | -- | -- | -- | -- | -- | -- | | | | 1,400 | E,NJ,t | 0 | 100 | -- | | -- | | -- | | | | -- | | | | -- | | | |
| Phsophoric acid, tris(3-methylphenyl) es | 563-04-2 | -- | -- | -- | -- | -- | -- | -- | | | | 560 | E,NJ,t | 0 | 100 | -- | | -- | | -- | | | | -- | | | | -- | | | |
| Stearic Acid | 57-11-4 | -- | -- | -- | -- | -- | -- | -- | | | | -- | | | | -- | | | | -- | | | | 40 | E,NJ,t | 0 | 1 | -- | | | |
| **PAHs (µg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Anthracene | 120-12-7 | N | -- | 2.3E+06 | 3.1E+07 | 4.7E+05 | 100 | 1.6 | J | 0.77 | 24 | 3 | J,L,s | 0.91 | 28 | <33 | U,UL,s | 1.12 | 33 | <28 | U | 0.91 | 28 | <30 | U | 0.98 | 30 | <28 | U | 0.98 | 28 |
| Benzo(a)anthracene | 56-55-3 | C | -- | 2.2E+02 | 3.9E+03 | 4.8E+02 | 100 | <24 | U | 0.88 | 24 | <28 | U,UL,s | 1.04 | 28 | <33 | U,UL,s | 1.28 | 33 | <28 | U | 1.04 | 28 | <30 | U | 1.12 | 30 | <28 | U | 1.12 | 28 |
| Benzo(a)pyrene | 50-32-8 | C | -- | 2.2E+01 | 3.9E+02 | 1.2E+02 | 100 | <24 | U | 1.1 | 24 | <28 | U,UL,s | 1.3 | 28 | <33 | U,UL,s | 1.6 | 33 | <28 | U | 1.3 | 28 | <30 | U | 1.4 | 30 | <28 | U | 1.4 | 28 |
| Benzo(b)fluoranthene | 205-99-2 | C | -- | 2.2E+02 | 3.9E+03 | 1.5E+03 | 100 | <24 | U | 1.43 | 24 | <28 | U,UL,s | 1.69 | 28 | <33 | U,UL,s | 2.08 | 33 | <28 | U | 1.69 | 28 | <30 | U | 1.82 | 30 | <28 | U | 1.82 | 28 |
| Benzo(g,h,i)perylene (5) | 191-24-2 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | <24 | U | 13.8 | 24 | <28 | U,UL,s | 16.3 | 28 | <33 | U,UL,s | 20 | 33 | <28 | U | 16.3 | 28 | <30 | U | 17.5 | 30 | <28 | U | 17.5 | 28 |
| Benzo(k)fluoranthene | 207-08-9 | C | -- | 2.2E+03 | 3.9E+04 | 1.5E+04 | 100 | <24 | U | 1.1 | 24 | <28 | U,UL,s | 1.3 | 28 | <33 | U,UL,s | 1.6 | 33 | <28 | U | 1.3 | 28 | <30 | U | 1.4 | 30 | <28 | U | 1.4 | 28 |
| Chrysene | 218-01-9 | C | -- | 2.2E+04 | 3.9E+05 | 4.8E+04 | 100 | 5.2 | J | 1.32 | 24 | 12 | J,L,s | 1.56 | 28 | <33 | U,UL,s | 1.92 | 33 | <28 | U | 1.56 | 28 | <30 | U | 1.68 | 30 | <28 | U | 1.68 | 28 |
| Fluoranthene | 206-44-0 | N | -- | 3.1E+05 | 4.1E+06 | 6.3E+06 | 100 | 46 | | 1.87 | 24 | 84 | ,L,s | 2.21 | 28 | <33 | U,UL,s | 2.72 | 33 | <28 | U | 2.21 | 28 | <30 | U | 2.38 | 30 | <28 | U | 2.38 | 28 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | C | -- | 2.2E+02 | 3.9E+03 | 4.2E+03 | 100 | <24 | U | 0.77 | 24 | <28 | U,UL,s | 0.91 | 28 | <33 | U,UL,s | 1.12 | 33 | <28 | U | 0.91 | 28 | <30 | U | 0.98 | 30 | <28 | U | 0.98 | 28 |
| Phenanthrene (5) | 85-01-8 | N | -- | 2.3E+05 | 3.1E+06 | -- | 100 | 18 | J | 0.66 | 24 | 30 | ,L,s | 0.78 | 28 | <33 | U,UL,s | 0.96 | 33 | <28 | U | 0.78 | 28 | <30 | U | 0.84 | 30 | <28 | U | 0.84 | 28 |
| Pyrene | 129-00-0 | N | -- | 2.3E+05 | 3.1E+06 | 6.8E+05 | 100 | 31 | | 0.99 | 24 | 54 | ,L,s | 1.17 | 28 | <33 | U,UL,s | 1.44 | 33 | <28 | U | 1.17 | 28 | <30 | U | 1.26 | 30 | <28 | U | 1.26 | 28 |
| **Cyanide (mg/kg)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Cyanide | 57-12-5 | N | -- | 1.6E+02 | 2.0E+03 | 1.5E+02 | 0.005 | 0.17 | J | 0.0356 | 0.5 | 0.16 | J | 0.0356 | 0.5 | 0.08 | J | 0.0356 | 0.5 | <0.5 | U | 0.0356 | 0.5 | 0.05 | J | 0.0356 | 0.5 | <0.5 | U | 0.0356 | 0.5 |
| **Percent Solids (%)** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Percent Solids | -- | -- | -- | -- | -- | -- | -- | 77 | | 0.1 | 0.1 | 76 | | 0.1 | 0.1 | 63 | | 0.1 | 0.1 | 75 | | 0.1 | 0.1 | 71 | | 0.1 | 0.1 | 74 | | 0.1 | 0.1 |

**Notes:**
CAS = Chemical Abstracts Service
ft bgs = Feet Below Ground Surface
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyl
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
TIC = Tentatively Identified Compound
MDL = Method Detection Limit
RL = Reporting Limit
NT = Not Tested
NI = Not Identified
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
NA = Not Applicable
(1) = Chromium VI RBC value was used
(2) = Lead criteria are Action Levels; see USEPA Region III guidance
(3) = Mercuric chloride soil RBC value used
(4) = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
(5) = RBC value for pyrene was used for these compounds
[A] = Facility-Wide Background Point Estimate as Reported in the Facility-Wide Background Study Report (IT 2001a)
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 31, 2006, RBC Table and October 10, 2006, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C = Carcinogenic per EPA RBC Table (October 2006)
N = Noncarcinogenic per EPA RBC Table (October 2006)
SSL DAF20 = Soil Screening Level at a Dilution Attenuation Factor of 20
BTAG = Biological Technical Assistance Group Screening Level, Draft 1995

[double-bordered box] = Concentration Exceeds Adjusted Soil Residential RBC
[thick-bordered box] = Concentration Exceeds Adjusted Soil Industrial RBC
underline = Concentration Exceeds Site Background Values
***bold italic*** = Concentration Exceeds SSL DAF20
[grey shaded box] = Concentration Exceeds BTAG Screening Level

**Laboratory Qualifiers**
U The compound was analyzed for but not detected. The reporting limit will be adjusted to reflect any dilution, and for soil, the percent moisture.
J Estimated value.
B Analyte found in associated blank as well as in the sample.
E Concentration exceeded the upper level of the calibration range of the instrument for that specific analysis. For TICs, compound not present in calibration standard, calculated using total peak areas ion chromatographs and response factor of 1.

**Validation Qualifiers**
B Not detected substantially above the level reported in laboratory or field blanks.
N Tentative Identification. Consider present. Special methods may be needed to confirm its presence or absence in future sampling efforts.
J Analyte present. Reported value may not be accurate or precise.
L Analyte present. Reported value may be biased low. Actual value is expected to be higher.
UL Not detected, quantitation limit is probably higher.

**Reason Codes**

GC/MS Organics
l MS/MSD recovery failure
q Concentration exceeded the linear range
s Surrogate failure
t Tentatively identified Compound
x Field and/or equipment blank contamination
z Method blank and/or storage blank contamination

GC and HPLC Organics
l MS/MSD recovery failure
q linearity (%RSD or r) failure in initial calibration
s No confirmation column
x Trip blank contamination
z Method blank and/or storage blank contamination

Inorganics and Conventionals
f Field duplicate imprecision
m MS/MSD recovery failure
p Preparation blank contamination
s Serial dilution failure
x CRDL standard recovery failure

**Table 7-4**
**HHRS COPC Selection (Surface Soil) for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | C/N | Adjusted RBC Residential | Adjusted RBC Industrial | COPC Flag (Y/N) | Rationale for Selection or Deletion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals (mg/kg)** | | | | | | | | | | | | |
| 7429905 | Aluminum | 11,900 | 32,200 | mg/kg | 57SB2A | 4/4 | 1.83 - 9.15 | 32,200 | -- | -- | -- | Y | NSV |
| 7440360 | Antimony | 1.20 | 103 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0518 - 1.3 | 103.0 | N | 3.13 | 40.88 | Y | ***ARES/IND*** |
| 7440382 | Arsenic | 1.6 | 5.2 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0232 - 0.0232 | 5.2 | C | 0.43 | 1.91 | Y | ***ARES/IND*** |
| 7440393 | Barium | 80 | 149 | mg/kg | 57SB4A | 4/4 | 0.106 - 0.106 | 149 | N | 1,564 | 20,440 | N | BSL |
| 7440417 | Beryllium | 0.42 | 0.6 | mg/kg | 57SB4A | 4/4 | 0.0391 - 0.0391 | 0.60 | N | 15.6 | 204 | N | BSL |
| 7440439 | Cadmium | 1.50 | 34 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.182 - 0.182 | 34.00 | N | 3.91 | 51 | Y | **ARES** |
| 7440702 | Calcium | 1,420 | 4,440 | mg/kg | 57SB1A | 4/4 | 16.6 - 16.6 | 4,440 | -- | Nutrient | Nutrient | N | Nutrient |
| 7440473 | Chromium[1] | 20.0 | 361 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.912 - 4.56 | 361 | N | 23.5 | 307 | Y | ***ARES/IND*** |
| 7440484 | Cobalt | 5.8 | 42 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.208 - 0.208 | 42 | -- | -- | -- | Y | NSV |
| 7440508 | Copper | 4.9 | 33 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.368 - 0.368 | 33 | N | 313 | 4,088 | N | BSL |
| 7439896 | Iron | 13,400 | 78,700 | mg/kg | 57SB4A | 4/4 | 17.9 - 71.6 | 78,700 | N | 2,346 | 30,660 | Y | ***ARES/IND*** |
| 7439921 | Lead[2] | 19.0 | 222 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0218 - 0.545 | 222 | -- | 400 | 750 | N | BSL |
| 7439954 | Magnesium | 923 | 2,700 | mg/kg | 57SB1A | 4/4 | 3.21 - 3.21 | 2,700 | -- | Nutrient | Nutrient | N | Nutrient |
| 7439965 | Manganese | 361 | 3,200 | mg/kg | 57SB4A | 4/4 | 0.264 - 1.32 | 3,200 | N | 156 | 2,044 | Y | ***ARES/IND*** |
| 7439976 | Mercury[3] | 0.049 | 0.160 | mg/kg | 57SB2A | 4/4 | 0.0077 - 0.0077 | 0.16 | -- | 0.78 | 10.22 | N | BSL |
| 7440020 | Nickel | 6 | 14 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0356 - 0.0356 | 14 | N | 156 | 2,044 | N | BSL |
| 7440097 | Potassium | 528 | 1,014 | mg/kg | 57SB3A-DUP AVG | 4/4 | 5 - 5 | 1,014 | -- | Nutrient | Nutrient | N | Nutrient |
| 7782492 | Selenium | 0.51 | 0.69 | mg/kg | 57SB2A | 4/4 | 0.0502 - 0.0502 | 0.69 | N | 39.1 | 511 | N | BSL |
| 7440224 | Silver | 0.054 | 0.13 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0044 - 0.0044 | 0.13 | N | 39.1 | 511 | N | BSL |
| 7440235 | Sodium | 33 | 312 | mg/kg | 57SB2A | 4/4 | 8.92 - 8.92 | 312 | -- | Nutrient | Nutrient | N | Nutrient |
| 7440280 | Thallium | 0.17 | 0.3 | mg/kg | 57SB4A | 4/4 | 0.027 - 0.027 | 0.30 | N | 0.55 | 7.15 | N | BSL |
| 7440622 | Vanadium | 29 | 84 | mg/kg | 57SB4A | 4/4 | 0.207 - 0.207 | 84 | N | 7.82 | 102 | Y | **ARES** |
| 7440666 | Zinc | 52.0 | 1,133 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.517 - 5.17 | 1,133 | N | 2,346 | 30,660 | N | BSL |
| | **TCL Pesticides/PCBs (µg/kg)** | | | | | | | | | | | | |
| 11097691 | Aroclor 1254[4] | 1.2E+01 | 1.2E+01 | µg/kg | 57SB4A | 1/1 | 4.2 - 4.2 | 1.2E+01 | C | 1.6E+02 | 1.4E+03 | N | BSL |
| | **TCL VOCs (µg/kg)** | | | | | | | | | | | | |
| 78933 | 2-Butanone | 2.9E+01 | 3.0E+01 | µg/kg | 57SB2A | 4/4 | 5.8 - 7.05 | 3.0E+01 | N | 4.7E+06 | 6.1E+07 | N | BSL |
| 67641 | Acetone | 5.5E+01 | 1.3E+02 | µg/kg | 57SB3A-DUP AVG | 4/4 | 5.8 - 7.05 | 1.3E+02 | N | 7.0E+06 | 9.2E+07 | N | BSL |
| 100414 | Ethylbenzene | 4.7E-01 | 4.7E-01 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0.491 - 0.596 | 4.7E-01 | N | 7.8E+05 | 1.0E+07 | N | BSL |
| 75092 | Methylene chloride | 3.6E+00 | 6.0E+00 | µg/kg | 57SB2A | 3/4 | 3.26 - 3.96 | 6.0E+00 | C | 8.5E+04 | 3.8E+05 | N | BSL |
| 108883 | Toluene | 2.0E+00 | 2.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0.538 - 0.654 | 2.0E+00 | N | 6.3E+05 | 8.2E+06 | N | BSL |
| 79016 | Trichloroethene | 1.8E+00 | 1.8E+00 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0.785 - 0.955 | 1.8E+00 | C | 1.6E+03 | 7.2E+03 | N | BSL |
| | **VOC TICs (µg/kg)** | | | | | | | | | | | | |
| 66251 | Hexanal | 7.0E+00 | 2.8E+01 | µg/kg | 57SB2A | 2/4 | 0 - 0 | 2.8E+01 | -- | -- | -- | Y | NSV |
| | **TCL SVOCs (µg/kg)** | | | | | | | | | | | | |
| 91576 | 2-Methylnaphthalene | 9.0E+00 | 9.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/4 | 3.29 - 3.84 | 9.0E+00 | N | 3.1E+04 | 4.1E+05 | N | BSL |
| 59507 | 4-Chloro-3-Methylphenol | 1.7E+01 | 4.2E+01 | µg/kg | 57SB3A-DUP AVG | 4/4 | 6.25 - 7.29 | 4.2E+01 | -- | -- | -- | Y | NSV |
| 208968 | Acenaphthylene[5] | 2.0E+00 | 6.5E+00 | µg/kg | 57SB3A-DUP AVG | 2/4 | 1.8 - 2.1 | 6.5E+00 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 98862 | Acetophenone | 5.6E+01 | 5.6E+01 | µg/kg | 57SB3A-DUP AVG | 1/4 | 2.28 - 2.66 | 5.6E+01 | N | 7.8E+05 | 1.0E+07 | N | BSL |
| 120127 | Anthracene | 9.0E+00 | 9.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/4 | 5.54 - 6.47 | 9.0E+00 | N | 2.3E+06 | 3.1E+07 | N | BSL |
| 50328 | Benzo(a)pyrene | 1.2E+01 | 3.0E+01 | µg/kg | 57SB2A | 3/4 | 6.85 - 7.99 | 3.0E+01 | C | 2.2E+01 | 3.9E+02 | Y | **ARES** |
| 205992 | Benzo(b)fluoranthene | 2.3E+01 | 5.5E+01 | µg/kg | 57SB2A | 3/4 | 11.7 - 13.7 | 5.5E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 191242 | Benzo(g,h,i)perylene[5] | 1.0E+01 | 1.0E+01 | µg/kg | 57SB3A-DUP AVG | 1/4 | 10.5 - 12.2 | 1.0E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 117817 | Bis(2-ethylhexyl)phthalate | 2.1E+01 | 2.7E+02 | µg/kg | 57SB3A-DUP AVG | 4/4 | 2.48 - 2.9 | 2.7E+02 | C | 4.6E+04 | 2.0E+05 | N | BSL |
| 85687 | Butylbenzylphthalate | 4.4E+01 | 4.4E+01 | µg/kg | 57SB2A | 1/4 | 5.38 - 6.27 | 4.4E+01 | N | 1.6E+06 | 2.0E+07 | N | BSL |
| 105602 | Caprolactam | 1.5E+01 | 3.4E+01 | µg/kg | 57SB3A-DUP AVG | 2/4 | 7.66 - 8.93 | 3.4E+01 | N | 3.9E+06 | 5.1E+07 | N | BSL |
| 218019 | Chrysene | 1.7E+01 | 2.3E+01 | µg/kg | 57SB3A-DUP AVG | 2/4 | 12.2 - 14.3 | 2.3E+01 | C | 2.2E+04 | 3.9E+05 | N | BSL |
| 84662 | Diethylphthalate | 7.0E+00 | 2.0E+01 | µg/kg | 57SB3A-DUP AVG | 4/4 | 2.28 - 2.66 | 2.0E+01 | N | 6.3E+06 | 8.2E+07 | N | BSL |
| 84742 | Di-n-butylphthalate | 4.1E+01 | 3.3E+02 | µg/kg | 57SB1A | 4/4 | 4.58 - 5.35 | 3.3E+02 | N | 7.8E+05 | 1.0E+07 | N | BSL |
| 206440 | Fluoranthene | 2.6E+01 | 4.3E+01 | µg/kg | 57SB3A-DUP AVG | 3/4 | 2.82 - 3.29 | 4.3E+01 | N | 3.1E+05 | 4.1E+06 | N | BSL |
| 86737 | Fluorene | 3.0E+00 | 3.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/4 | 2.02 - 2.35 | 3.0E+00 | N | 3.1E+05 | 4.1E+06 | N | BSL |
| 193395 | Indeno(1,2,3-cd)pyrene | 7.0E+00 | 4.2E+01 | µg/kg | 57SB2A | 3/4 | 4.7 - 5.49 | 4.2E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 91203 | Naphthalene | 5.0E+00 | 5.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/4 | 3.3 - 3.85 | 5.0E+00 | N | 1.6E+05 | 2.0E+06 | N | BSL |
| 85018 | Phenanthrene[5] | 1.3E+01 | 3.9E+01 | µg/kg | 57SB3A-DUP AVG | 3/4 | 2.76 - 3.22 | 3.9E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 129000 | Pyrene | 2.9E+01 | 4.2E+01 | µg/kg | 57SB3A-DUP AVG | 3/4 | 1.78 - 2.07 | 4.2E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |

**Table 7-4**
**HHRS COPC Selection (Surface Soil) for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | C/N | Adjusted RBC Residential | Adjusted RBC Industrial | COPC Flag (Y/N) | Rationale for Selection or Deletion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **SVOC TICs (µg/kg)** | | | | | | | | | | | | |
| 301020 | (Z)-9-Octadecenamide | 1.0E+03 | 1.0E+03 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0 - 0 | 1.0E+03 | -- | -- | -- | Y | NSV |
| 112925 | 1-Octadecanol | 3.1E+01 | 3.1E+01 | µg/kg | 57SB4A | 1/4 | 0 - 0 | 3.1E+01 | -- | -- | -- | Y | NSV |
| 32598144 | 1,1'-Biphenyl, 2,3,3',4,4'-pentachloro- | 3.9E+02 | 3.9E+02 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0 - 0 | 3.9E+02 | -- | -- | -- | Y | NSV |
| 84695 | 1,2-Benzenedicarboxylicacid, bis(2-methy | 4.1E+01 | 5.3E+02 | µg/kg | 57SB3A-DUP AVG | 3/4 | 0 - 0 | 5.3E+02 | -- | -- | -- | Y | NSV |
| 17851535 | 1,2-Benzenedicarboxylic acid, butyl 2-me | 5.1E+01 | 5.1E+01 | µg/kg | 57SB2A | 1/4 | 0 - 0 | 5.1E+01 | -- | -- | -- | Y | NSV |
| 84640 | 1,2-Benzenedicarboxylic acid, butyl cycl | 3.3E+02 | 3.3E+02 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0 - 0 | 3.3E+02 | -- | -- | -- | Y | NSV |
| 20019641 | 2(5H)-Furanone, 5,5-dimethyl- | 2.6E+02 | 2.6E+02 | µg/kg | 57SB1A | 1/4 | 0 - 0 | 2.6E+02 | -- | -- | -- | Y | NSV |
| 101371 | 2,4,6-Triallyloxy-1,3,5-triazine | 6.5E+01 | 9.4E+01 | µg/kg | 57SB1A | 2/4 | 0 - 0 | 9.4E+01 | -- | -- | -- | Y | NSV |
| 112845 | Erucylamide | 3.2E+02 | 6.0E+02 | µg/kg | 57SB2A | 2/4 | 0 - 0 | 6.0E+02 | -- | -- | -- | Y | NSV |
| 7390810 | Oxirane, hexadecyl- | 5.8E+01 | 5.8E+01 | µg/kg | 57SB4A | 1/4 | 0 - 0 | 5.8E+01 | -- | -- | -- | Y | NSV |
| 27193288 | Phenol, (1,1,3,3-tetramethylbutyl)- | 2.9E+01 | 2.9E+01 | µg/kg | 57SB4A | 1/4 | 0 - 0 | 2.9E+01 | -- | -- | -- | Y | NSV |
| 78308 | Phosphoric acid, tris (3-methylphenyl) e | 1.4E+03 | 1.4E+03 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0 - 0 | 1.4E+03 | -- | -- | -- | Y | NSV |
| 563042 | Phsophoric acid, tris(3-methylphenyl) es | 5.6E+02 | 5.6E+02 | µg/kg | 57SB3A-DUP AVG | 1/4 | 0 - 0 | 5.6E+02 | -- | -- | -- | Y | NSV |
| 57114 | Stearic Acid | 4.0E+01 | 4.0E+01 | µg/kg | 57SB4A | 1/4 | 0 - 0 | 4.0E+01 | -- | -- | -- | Y | NSV |
| | **PAHs (µg/kg)** | | | | | | | | | | | | |
| 120127 | Anthracene | 1.5E+00 | 2.3E+00 | µg/kg | 57SB3A-DUP AVG | 3/4 | 0.77 - 0.98 | 2.3E+00 | N | 2.3E+06 | 3.1E+07 | N | BSL |
| 56553 | Benzo(a)anthracene | 7.1E+00 | 7.1E+00 | µg/kg | 57SB2A | 1/4 | 0.88 - 1.12 | 7.1E+00 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 50328 | Benzo(a)pyrene | 1.0E+01 | 1.8E+01 | µg/kg | 57SB1A | 2/4 | 1.1 - 1.4 | 1.8E+01 | C | 2.2E+01 | 3.9E+02 | N | BSL |
| 205992 | Benzo(b)fluoranthene | 1.4E+01 | 1.4E+01 | µg/kg | 57SB1A | 1/4 | 1.43 - 1.82 | 1.4E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 191242 | Benzo(g,h,i)perylene[5] | 2.7E+01 | 2.7E+01 | µg/kg | 57SB1A | 1/4 | 13.8 - 17.5 | 2.7E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 207089 | Benzo(k)fluoranthene | 8.5E+00 | 8.5E+00 | µg/kg | 57SB1A | 1/4 | 1.1 - 1.4 | 8.5E+00 | C | 2.2E+03 | 3.9E+04 | N | BSL |
| 218019 | Chrysene | 8.6E+00 | 1.1E+01 | µg/kg | 57SB1A | 3/4 | 1.32 - 1.68 | 1.1E+01 | C | 2.2E+04 | 3.9E+05 | N | BSL |
| 206440 | Fluoranthene | 2.9E+01 | 6.5E+01 | µg/kg | 57SB3A-DUP AVG | 3/4 | 1.87 - 2.38 | 6.5E+01 | N | 3.1E+05 | 4.1E+06 | N | BSL |
| 193395 | Indeno(1,2,3-cd)pyrene | 7.2E+00 | 1.1E+01 | µg/kg | 57SB1A | 2/4 | 0.77 - 0.98 | 1.1E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 85018 | Phenanthrene[5] | 1.1E+01 | 2.4E+01 | µg/kg | 57SB1A | 3/4 | 0.66 - 0.84 | 2.4E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 129000 | Pyrene | 2.0E+01 | 8.2E+01 | µg/kg | 57SB1A | 3/4 | 0.99 - 1.26 | 8.2E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| | **Cyanide (mg/kg)** | | | | | | | | | | | | |
| 57125 | Cyanide | 5.0E-02 | 1.7E-01 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0356 - 0.0356 | 1.7E-01 | N | 1.6E+02 | 2.0E+03 | N | BSL |

**Notes:**
CAS = Chemical Abstracts Service
COPC = Chemical of Potential Concern
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyls
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Compound
TIC = Tentatively Identified Compound
[1] = Chromium VI RBC value was used
[2] = Lead criteria are Action Levels; see USEPA Region III guidance
[3] = Mercuric chloride soil RBC value used
[4] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
[5] = RBC value for pyrene was used for these compounds

DUP AVG = results for duplicate samples averaged
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the October 31, 2006,
RBC Table and October 10, 2006, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C = Carcinogenic per EPA RBC Table (October 2006)
N = Noncarcinogenic per EPA RBC Table (October 2006)

**ARES** = Above Residential RBC
***ARES/IND*** = Above Residential RBC/Industrial RBC
BSL = Below Residential/Industrial RBC Screening Levels
NSV = No Screening Value Available

**Table 7-5**
**HHRS COPC Selection (Total Soil) for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | C/N | Adjusted RBC Residential | Adjusted RBC Industrial | COPC Flag (Y/N) | Rationale for Selection or Deletion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals (mg/kg)** | | | | | | | | | | | | |
| 7429905 | Aluminum | 11,900 | 38,900 | mg/kg | 57SB1C | 11/11 | 1.83 - 9.15 | 38,900 | -- | -- | -- | Y | NSV |
| 7440360 | Antimony | 0.07 | 103 | mg/kg | 57SB3A-DUP AVG | 9/11 | 0.0518 - 1.3 | 103.00 | N | 3.13 | 40.9 | Y | ***ARES/IND*** |
| 7440382 | Arsenic | 1.1 | 12 | mg/kg | 57SB3B | 11/11 | 0.0232 - 0.0232 | 12 | C | 0.43 | 1.91 | Y | ***ARES/IND*** |
| 7440393 | Barium | 39 | 149 | mg/kg | 57SB4A | 11/11 | 0.106 - 0.106 | 149 | N | 1,564 | 20,440 | N | BSL |
| 7440417 | Beryllium | 0.42 | 3.2 | mg/kg | 57SB2C | 11/11 | 0.0333 - 0.0391 | 3.20 | N | 15.6 | 204 | N | BSL |
| 7440439 | Cadmium | 0.46 | 34 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.182 - 0.182 | 34.00 | N | 3.91 | 51 | Y | **ARES** |
| 7440702 | Calcium | 207 | 4,440 | mg/kg | 57SB1A | 8/11 | 16.6 - 16.6 | 4,440 | -- | Nutrient | Nutrient | N | Nutrient |
| 7440473 | Chromium[1] | 9.3 | 361 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.912 - 4.56 | 361 | N | 23 | 307 | Y | ***ARES/IND*** |
| 7440484 | Cobalt | 5.8 | 42 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.208 - 0.208 | 42 | -- | -- | -- | Y | NSV |
| 7440508 | Copper | 4.9 | 38 | mg/kg | 57SB3B | 11/11 | 0.368 - 0.368 | 38 | N | 313 | 4,088 | N | BSL |
| 7439896 | Iron | 13,400 | 78,700 | mg/kg | 57SB4A | 11/11 | 17.9 - 71.6 | 78,700 | N | 2,346 | 30,660 | Y | ***ARES/IND*** |
| 7439921 | Lead[2] | 2.6 | 222 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.0218 - 0.545 | 222 | -- | 400 | 750 | N | BSL |
| 7439954 | Magnesium | 487 | 35,000 | mg/kg | 57SB3C | 11/11 | 3.21 - 16.1 | 35,000 | -- | Nutrient | Nutrient | N | Nutrient |
| 7439965 | Manganese | 264 | 3,200 | mg/kg | 57SB4A | 11/11 | 0.264 - 1.32 | 3,200 | N | 156 | 2,044 | Y | ***ARES/IND*** |
| 7439976 | Mercury[3] | 0.013 | 0.16 | mg/kg | 57SB2A | 9/11 | 0.0077 - 0.0077 | 0.16 | -- | 0.78 | 10.22 | N | BSL |
| 7440020 | Nickel | 6 | 75 | mg/kg | 57SB2C | 11/11 | 0.0356 - 0.356 | 75 | N | 156 | 2,044 | N | BSL |
| 7440097 | Potassium | 528 | 5,900 | mg/kg | 57SB3C | 11/11 | 5 - 5 | 5,900 | -- | Nutrient | Nutrient | N | Nutrient |
| 7782492 | Selenium | 0.33 | 0.88 | mg/kg | 57SB3C | 11/11 | 0.0502 - 0.0502 | 0.88 | N | 39.1 | 511 | N | BSL |
| 7440224 | Silver | 0.028 | 0.15 | mg/kg | 57SB3C | 11/11 | 0.0044 - 0.0044 | 0.15 | N | 39.1 | 511 | N | BSL |
| 7440235 | Sodium | 33 | 497 | mg/kg | 57SB4B | 11/11 | 8.92 - 18.1 | 497 | -- | Nutrient | Nutrient | N | Nutrient |
| 7440280 | Thallium | 0.11 | 0.3 | mg/kg | 57SB4A | 11/11 | 0.027 - 0.027 | 0.30 | N | 0.55 | 7.15 | N | BSL |
| 7440622 | Vanadium | 18 | 84 | mg/kg | 57SB4A | 11/11 | 0.207 - 0.207 | 84 | N | 7.82 | 102 | Y | **ARES** |
| 7440666 | Zinc | 9.3 | 1,133 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.517 - 5.17 | 1,133 | N | 2,346 | 30,660 | N | BSL |
| | **TCL Pesticides/PCBs (µg/kg)** | | | | | | | | | | | | |
| 11097691 | Aroclor 1254[4] | 1.2E+01 | 1.2E+01 | µg/kg | 57SB4A | 1/1 | 4.2 - 4.2 | 1.2E+01 | C | 1.6E+02 | 1.4E+03 | N | BSL |
| | **TCL VOCs (µg/kg)** | | | | | | | | | | | | |
| 78933 | 2-Butanone | 2.1E+01 | 3.0E+01 | µg/kg | 57SB2A | 11/11 | 5.8 - 7.95 | 3.0E+01 | N | 4.7E+06 | 6.1E+07 | N | BSL |
| 67641 | Acetone | 3.7E+01 | 1.3E+02 | µg/kg | 57SB3A-DUP AVG | 11/11 | 5.8 - 7.95 | 1.3E+02 | N | 7.0E+06 | 9.2E+07 | N | BSL |
| 75274 | Bromodichloromethane | 1.2E+00 | 1.2E+00 | µg/kg | 57SB2C | 1/11 | 0.581 - 0.797 | 1.2E+00 | C | 1.0E+04 | 4.6E+04 | N | BSL |
| 67663 | Chloroform | 1.1E+00 | 2.4E+01 | µg/kg | 57SB1C | 4/11 | 0.517 - 0.709 | 2.4E+01 | N | 7.8E+04 | 1.0E+06 | N | BSL |
| 100414 | Ethylbenzene | 4.7E-01 | 4.7E-01 | µg/kg | 57SB3A-DUP AVG | 1/11 | 0.491 - 0.673 | 4.7E-01 | N | 7.8E+05 | 1.0E+07 | N | BSL |
| 75092 | Methylene chloride | 3.6E+00 | 6.8E+00 | µg/kg | 57SB3B | 9/11 | 3.26 - 4.47 | 6.8E+00 | C | 8.5E+04 | 3.8E+05 | N | BSL |
| 108883 | Toluene | 2.0E+00 | 2.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/11 | 0.538 - 0.738 | 2.0E+00 | N | 6.3E+05 | 8.2E+06 | N | BSL |
| 79016 | Trichloroethene | 1.8E+00 | 1.8E+00 | µg/kg | 57SB3A-DUP AVG | 1/11 | 0.785 - 1.08 | 1.8E+00 | C | 1.6E+03 | 7.2E+03 | N | BSL |
| | **VOC TICs (µg/kg)** | | | | | | | | | | | | |
| 66251 | Hexanal | 7.0E+00 | 2.8E+01 | µg/kg | 57SB2A | 2/11 | 0 - 0 | 2.8E+01 | -- | -- | -- | Y | NSV |
| | **TCL SVOCs (µg/kg)** | | | | | | | | | | | | |
| 91576 | 2-Methylnaphthalene | 9.0E+00 | 9.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/11 | 3.29 - 4.38 | 9.0E+00 | N | 3.1E+04 | 4.1E+05 | N | BSL |
| 59507 | 4-Chloro-3-Methylphenol | 1.6E+01 | 4.4E+01 | µg/kg | 57SB1C | 9/11 | 6.25 - 8.34 | 4.4E+01 | -- | -- | -- | Y | NSV |
| 208968 | Acenaphthylene[5] | 2.0E+00 | 6.5E+00 | µg/kg | 57SB3A-DUP AVG | 2/11 | 1.8 - 2.4 | 6.5E+00 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 98862 | Acetophenone | 5.6E+01 | 5.6E+01 | µg/kg | 57SB3A-DUP AVG | 1/11 | 2.28 - 3.04 | 5.6E+01 | N | 7.8E+05 | 1.0E+07 | N | BSL |
| 120127 | Anthracene | 9.0E+00 | 9.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/11 | 5.54 - 7.39 | 9.0E+00 | N | 2.3E+06 | 3.1E+07 | N | BSL |
| 50328 | Benzo(a)pyrene | 1.2E+01 | 3.0E+01 | µg/kg | 57SB2A | 3/11 | 6.85 - 9.14 | 3.0E+01 | C | 2.2E+01 | 3.9E+02 | Y | **ARES** |
| 205992 | Benzo(b)fluoranthene | 2.3E+01 | 5.5E+01 | µg/kg | 57SB2A | 3/11 | 11.7 - 15.6 | 5.5E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 191242 | Benzo(g,h,i)perylene[5] | 1.0E+01 | 1.0E+01 | µg/kg | 57SB3A-DUP AVG | 1/11 | 10.5 - 14 | 1.0E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 117817 | Bis(2-ethylhexyl)phthalate | 2.0E+01 | 2.7E+02 | µg/kg | 57SB3A-DUP AVG | 11/11 | 2.48 - 3.31 | 2.7E+02 | C | 4.6E+04 | 2.0E+05 | N | BSL |
| 85687 | Butylbenzylphthalate | 1.0E+01 | 4.4E+01 | µg/kg | 57SB2A | 3/11 | 5.38 - 7.17 | 4.4E+01 | N | 1.6E+06 | 2.0E+07 | N | BSL |
| 105602 | Caprolactam | 1.1E+01 | 3.6E+01 | µg/kg | 57SB1C | 4/11 | 7.66 - 10.2 | 3.6E+01 | N | 3.9E+06 | 5.1E+07 | N | BSL |
| 218019 | Chrysene | 1.7E+01 | 2.3E+01 | µg/kg | 57SB3A-DUP AVG | 2/11 | 12.2 - 16.3 | 2.3E+01 | C | 2.2E+04 | 3.9E+05 | N | BSL |
| 84662 | Diethylphthalate | 5.0E+00 | 2.0E+01 | µg/kg | 57SB3A-DUP AVG | 10/11 | 2.28 - 3.04 | 2.0E+01 | N | 6.3E+06 | 8.2E+07 | N | BSL |
| 84742 | Di-n-butylphthalate | 3.8E+01 | 4.3E+02 | µg/kg | 57SB1B | 11/11 | 4.58 - 6.11 | 4.3E+02 | N | 7.8E+05 | 1.0E+07 | N | BSL |
| 206440 | Fluoranthene | 2.6E+01 | 4.3E+01 | µg/kg | 57SB3A-DUP AVG | 3/11 | 2.82 - 3.76 | 4.3E+01 | N | 3.1E+05 | 4.1E+06 | N | BSL |
| 86737 | Fluorene | 3.0E+00 | 3.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/11 | 2.02 - 2.69 | 3.0E+00 | N | 3.1E+05 | 4.1E+06 | N | BSL |
| 193395 | Indeno(1,2,3-cd)pyrene | 7.0E+00 | 4.2E+01 | µg/kg | 57SB2A | 3/11 | 4.7 - 6.27 | 4.2E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 91203 | Naphthalene | 5.0E+00 | 5.0E+00 | µg/kg | 57SB3A-DUP AVG | 1/11 | 3.3 - 4.4 | 5.0E+00 | N | 1.6E+05 | 2.0E+06 | N | BSL |
| 85018 | Phenanthrene[5] | 1.3E+01 | 3.9E+01 | µg/kg | 57SB3A-DUP AVG | 3/11 | 2.76 - 3.68 | 3.9E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 129000 | Pyrene | 2.9E+01 | 4.2E+01 | µg/kg | 57SB3A-DUP AVG | 3/11 | 1.78 - 2.37 | 4.2E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |

**Table 7-5**
**HHRS COPC Selection (Total Soil) for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | C/N | Adjusted RBC Residential | Adjusted RBC Industrial | COPC Flag (Y/N) | Rationale for Selection or Deletion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **SVOC TICs (µg/kg)** | | | | | | | | | | | | |
| 301020 | (Z)-9-Octadecenamide | 6.0E+01 | 1.0E+03 | µg/kg | 57SB3A-DUP AVG | 5/11 | 0 - 0 | 1.0E+03 | -- | -- | -- | Y | NSV |
| 1454859 | 1-Heptadecanol | 3.7E+01 | 3.7E+01 | µg/kg | 57SB3C | 1/11 | 0 - 0 | 3.7E+01 | -- | -- | -- | Y | NSV |
| 36653824 | 1-Hexadecanol | 3.1E+01 | 4.8E+01 | µg/kg | 57SB4B | 2/11 | 0 - 0 | 4.8E+01 | -- | -- | -- | Y | NSV |
| 112925 | 1-Octadecanol | 3.1E+01 | 3.1E+01 | µg/kg | 57SB4A | 1/11 | 0 - 0 | 3.1E+01 | -- | -- | -- | Y | NSV |
| 629765 | 1-Pentadecanol | 5.2E+01 | 5.2E+01 | µg/kg | 57SB2C | 1/11 | 0 - 0 | 5.2E+01 | -- | -- | -- | Y | NSV |
| 32598144 | 1,1'-Biphenyl, 2,3,3',4,4'-pentach | 3.9E+02 | 3.9E+02 | µg/kg | 57SB3A-DUP AVG | 1/11 | 0 - 0 | 3.9E+02 | -- | -- | -- | Y | NSV |
| 84695 | 1,2-Benzenedicarboxylicacid, bis | 3.2E+01 | 5.4E+02 | µg/kg | 57SB1B | 7/11 | 0 - 0 | 5.4E+02 | -- | -- | -- | Y | NSV |
| 17851535 | 1,2-Benzenedicarboxylic acid, bu | 5.1E+01 | 1.6E+02 | µg/kg | 57SB4B | 2/11 | 0 - 0 | 1.6E+02 | -- | -- | -- | Y | NSV |
| 89189 | 1,2-Benzenedicarboxylic acid, bu | 3.4E+01 | 3.4E+01 | µg/kg | 57SB2C | 1/11 | 0 - 0 | 3.4E+01 | -- | -- | -- | Y | NSV |
| 84640 | 1,2-Benzenedicarboxylic acid, bu | 3.3E+02 | 4.7E+02 | µg/kg | 57SB1C | 2/11 | 0 - 0 | 4.7E+02 | -- | -- | -- | Y | NSV |
| 20019641 | 2(5H)-Furanone, 5,5-dimethyl- | 2.6E+02 | 2.6E+02 | µg/kg | 57SB1A | 1/11 | 0 - 0 | 2.6E+02 | -- | -- | -- | Y | NSV |
| 101371 | 2,4,6-Triallyloxy-1,3,5-triazine | 5.8E+01 | 1.3E+02 | µg/kg | 57SB1B | 6/11 | 0 - 0 | 1.3E+02 | -- | -- | -- | Y | NSV |
| 1000143924 | 7,9-Di-tert-butyl-1-oxaspiro(4,5)d | 2.8E+01 | 2.8E+01 | µg/kg | 57SB3B | 1/11 | 0 - 0 | 2.8E+01 | -- | -- | -- | Y | NSV |
| 142165 | Bis(2-ethylhexyl)maleate | 1.2E+02 | 1.2E+02 | µg/kg | 57SB1C | 1/11 | 0 - 0 | 1.2E+02 | -- | -- | -- | Y | NSV |
| 112845 | Erucylamide | 3.2E+02 | 6.3E+02 | µg/kg | 57SB3B | 5/11 | 0 - 0 | 6.3E+02 | -- | -- | -- | Y | NSV |
| 7390810 | Oxirane, hexadecyl- | 5.8E+01 | 5.8E+01 | µg/kg | 57SB4A | 1/11 | 0 - 0 | 5.8E+01 | -- | -- | -- | Y | NSV |
| 27193288 | Phenol, (1,1,3,3-tetramethylbuty | 2.9E+01 | 2.9E+01 | µg/kg | 57SB4A | 1/11 | 0 - 0 | 2.9E+01 | -- | -- | -- | Y | NSV |
| 78308 | Phosphoric acid, tris (3-methylph | 1.4E+03 | 1.4E+03 | µg/kg | 57SB3A-DUP AVG | 1/11 | 0 - 0 | 1.4E+03 | -- | -- | -- | Y | NSV |
| 563042 | Phsophoric acid, tris(3-methylph | 5.6E+02 | 5.6E+02 | µg/kg | 57SB3A-DUP AVG | 1/11 | 0 - 0 | 5.6E+02 | -- | -- | -- | Y | NSV |
| 57114 | Stearic Acid | 4.0E+01 | 1.1E+02 | µg/kg | 57SB1C | 3/11 | 0 - 0 | 1.1E+02 | -- | -- | -- | Y | NSV |
| | **PAHs (µg/kg)** | | | | | | | | | | | | |
| 120127 | Anthracene | 1.5E+00 | 2.3E+00 | µg/kg | 57SB3A-DUP AVG | 3/11 | 0.77 - 1.12 | 2.3E+00 | N | 2.3E+06 | 3.1E+07 | N | BSL |
| 56553 | Benzo(a)anthracene | 7.1E+00 | 7.1E+00 | µg/kg | 57SB2A | 1/11 | 0.88 - 1.28 | 7.1E+00 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 50328 | Benzo(a)pyrene | 1.0E+01 | 1.8E+01 | µg/kg | 57SB1A | 2/11 | 1.1 - 1.6 | 1.8E+01 | C | 2.2E+01 | 3.9E+02 | N | BSL |
| 205992 | Benzo(b)fluoranthene | 1.4E+01 | 1.4E+01 | µg/kg | 57SB1A | 1/11 | 1.43 - 2.08 | 1.4E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 191242 | Benzo(g,h,i)perylene[5] | 2.7E+01 | 2.7E+01 | µg/kg | 57SB1A | 1/11 | 13.8 - 20 | 2.7E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 207089 | Benzo(k)fluoranthene | 8.5E+00 | 8.5E+00 | µg/kg | 57SB1A | 1/11 | 1.1 - 1.6 | 8.5E+00 | C | 2.2E+03 | 3.9E+04 | N | BSL |
| 218019 | Chrysene | 8.6E+00 | 1.1E+01 | µg/kg | 57SB1A | 3/11 | 1.32 - 1.92 | 1.1E+01 | C | 2.2E+04 | 3.9E+05 | N | BSL |
| 206440 | Fluoranthene | 2.9E+01 | 6.5E+01 | µg/kg | 57SB3A-DUP AVG | 3/11 | 1.87 - 2.72 | 6.5E+01 | N | 3.1E+05 | 4.1E+06 | N | BSL |
| 193395 | Indeno(1,2,3-cd)pyrene | 7.2E+00 | 1.1E+01 | µg/kg | 57SB1A | 2/11 | 0.77 - 1.12 | 1.1E+01 | C | 2.2E+02 | 3.9E+03 | N | BSL |
| 85018 | Phenanthrene[5] | 1.1E+01 | 2.4E+01 | µg/kg | 57SB1A | 3/11 | 0.66 - 0.96 | 2.4E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| 129000 | Pyrene | 2.0E+01 | 8.2E+01 | µg/kg | 57SB1A | 3/11 | 0.99 - 1.44 | 8.2E+01 | N | 2.3E+05 | 3.1E+06 | N | BSL |
| | **Cyanide (mg/kg)** | | | | | | | | | | | | |
| 57125 | Cyanide | 5.0E-02 | 1.7E-01 | mg/kg | 57SB3A-DUP AVG | 6/11 | 0.0356 - 0.0356 | 1.7E-01 | N | 1.6E+02 | 2.0E+03 | N | BSL |

**Notes:**

CAS = Chemical Abstracts Service
COPC = Chemical of Potential Concern
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyls
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Compound
TIC = Tentatively Identified Compound
[1] = Chromium VI RBC value was used
[2] = Lead criteria are Action Levels; see USEPA Region III guidance
[3] = Mercuric chloride soil RBC value used
[4] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening
[5] = RBC value for pyrene was used for these compounds

DUP AVG = results for duplicate samples averaged
RBC = USEPA Region III Risk-Based Concentration
(RBC) values from the October 31, 2006,
RBC Table and October 10, 2006, Alternate RBC Table
Adjusted RBCs = a Hazard Quotient (HQ) of 0.1 applied to non-carcinogens
C = Carcinogenic per EPA RBC Table (October 2006)
N = Noncarcinogenic per EPA RBC Table (October 2006)

**ARES** = Above Residential RBC
***ARES/IND*** = Above Residential RBC/Industrial RBC
BSL = Below Residential/Industrial RBC Screening Levels
NSV = No Screening Value Available

**Table 7-6**
**Cumulative HHRS for SWMU 57 (Surface Soil)**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Units | MDC | C/N | RBC Residential | RBC Industrial | Non Carcinogenic HI ($RBC_{Res}$) | Excess Cancer Risk ($RBC_{Res}$) | Non Carcinogenic HI ($RBC_{Ind}$) | Excess Cancer Risk ($RBC_{Ind}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals** | | | | | | | | | |
| 7429905 | Aluminum | mg/kg | 3.22E+04 | -- | -- | -- | -- | -- | -- | -- |
| 7440360 | Antimony | mg/kg | 1.03E+02 | N | 3.13E+01 | 4.09E+02 | 3.E+00 | -- | 3.E-01 | -- |
| 7440382 | Arsenic | mg/kg | 5.20E+00 | C | 4.26E-01 | 1.91E+00 | -- | 1.E-05 | -- | 3.E-06 |
| 7440382 | Arsenic | mg/kg | 5.20E+00 | N | 2.35E+01 | 3.07E+02 | 2.E-01 | -- | 2.E-02 | -- |
| 7440439 | Cadmium | mg/kg | 3.40E+01 | N | 3.91E+01 | 5.11E+02 | 9.E-01 | -- | 7.E-02 | -- |
| 7440473 | Chromium[1] | mg/kg | 3.61E+02 | N | 2.35E+02 | 3.07E+03 | 2.E+00 | -- | 1.E-01 | -- |
| 7440484 | Cobalt | mg/kg | 4.15E+01 | -- | -- | -- | -- | -- | -- | -- |
| 7439896 | Iron | mg/kg | 7.87E+04 | N | 2.35E+04 | 3.07E+05 | 3.E+00 | -- | 3.E-01 | -- |
| 7439965 | Manganese | mg/kg | 3.20E+03 | N | 1.56E+03 | 2.04E+04 | 2.E+00 | -- | 2.E-01 | -- |
| 7440622 | Vanadium | mg/kg | 8.40E+01 | N | 7.82E+01 | 1.02E+03 | 1.E+00 | -- | 8.E-02 | -- |
| | **VOC TICs** | | | | | | | | | |
| 66251 | Hexanal | µg/kg | 2.80E+01 | -- | -- | -- | -- | -- | -- | -- |
| | **TCL SVOCs** | | | | | | | | | |
| 59507 | 4-Chloro-3-Methylphenol | µg/kg | 4.20E+01 | -- | -- | -- | -- | -- | -- | -- |
| 50328 | Benzo(a)pyrene | µg/kg | 3.00E+01 | C | 2.20E+01 | 3.92E+02 | -- | 1.E-06 | -- | 8.E-08 |
| | **SVOC TICs** | | | | | | | | | |
| 301020 | (Z)-9-Octadecenamide | µg/kg | 1.03E+03 | -- | -- | -- | -- | -- | -- | -- |
| 112925 | 1-Octadecanol | µg/kg | 3.10E+01 | -- | -- | -- | -- | -- | -- | -- |
| 32598144 | 1,1'-Biphenyl, 2,3,3',4,4'-pentachloro- | µg/kg | 3.90E+02 | -- | -- | -- | -- | -- | -- | -- |
| 84695 | 1,2-Benzenedicarboxylicacid, bis(2-methy | µg/kg | 5.30E+02 | -- | -- | -- | -- | -- | -- | -- |
| 17851535 | 1,2-Benzenedicarboxylic acid, butyl 2-me | µg/kg | 5.10E+01 | -- | -- | -- | -- | -- | -- | -- |
| 84640 | 1,2-Benzenedicarboxylic acid, butyl cycl | µg/kg | 3.30E+02 | -- | -- | -- | -- | -- | -- | -- |
| 20019641 | 2(5H)-Furanone, 5,5-dimethyl- | µg/kg | 2.60E+02 | -- | -- | -- | -- | -- | -- | -- |
| 101371 | 2,4,6-Triallyloxy-1,3,5-triazine | µg/kg | 9.40E+01 | -- | -- | -- | -- | -- | -- | -- |
| 112845 | Erucylamide | µg/kg | 6.00E+02 | -- | -- | -- | -- | -- | -- | -- |
| 7390810 | Oxirane, hexadecyl- | µg/kg | 5.80E+01 | -- | -- | -- | -- | -- | -- | -- |
| 27193288 | Phenol, (1,1,3,3-tetramethylbutyl)- | µg/kg | 2.90E+01 | -- | -- | -- | -- | -- | -- | -- |
| 78308 | Phosphoric acid, tris (3-methylphenyl) e | µg/kg | 1.40E+03 | -- | -- | -- | -- | -- | -- | -- |
| 563042 | Phsophoric acid, tris(3-methylphenyl) es | µg/kg | 5.60E+02 | -- | -- | -- | -- | -- | -- | -- |
| 57114 | Stearic Acid | µg/kg | 4.00E+01 | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | **Cumulative Risk** | 1.E+01 | 1E-05 | 9.E-01 | 3.E-06 |

**Notes:**

CAS = Chemical Abstracts Service
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
TAL = Target Analyte List
TCL = Target Compound List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
[1] = Chromium VI RBC value was used

MDC = Maximum Detected Concentration
HI = Hazard Index
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 31, 2006, RBC Table and October 10, 2006, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2006)
N = Noncarcinogenic per EPA RBC Table (October 2006)

## Table 7-7
## Exposure Point Concentration Summary for SWMU 57
## SSP Report
## Radford Army Ammunition Plant, Radford, Virginia

| | |
|---|---|
| Scenario Timeframe: | Future |
| Medium: | Total Soil |
| Exposure Medium: | Total Soil |

| Exposure Point | Chemical of Potential Concern | Units | Arithmetic Mean | 95% UCL | Maximum Concentration (Qualifier) | Exposure Point Concentration | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Value | Units | Statistic (1) | Rationale (2) |
| **Total Soil** | Aluminum | mg/kg | 2.76E+04 | 3.25E+04 | 3.9E+04 | 3.25E+04 | mg/kg | 95% UCL (Student's t) | 85% < FOD, Normal |
| | Antimony | mg/kg | 1.30E+00 | 6.22E+00 | 1.0E+02 | 6.22E+00 | mg/kg | 95%UCL (Land's) | 85% < FOD, Lognormal |
| | Arsenic | mg/kg | 4.35E+00 | 6.11E+00 | 1.2E+01 | 6.11E+00 | mg/kg | 95% UCL (Student's t) | 85% < FOD, Normal |
| | Cadmium | mg/kg | 5.08E+00 | 1.86E+01 | 3.4E+01 | 1.86E+01 | mg/kg | 95%UCL (Chebyshev) | 85% < FOD, Lognormal |
| | Chromium | mg/kg | 7.01E+01 | 1.54E+02 | 3.6E+02 | 1.54E+02 | mg/kg | 95%UCL (Land's) | 85% < FOD, Lognormal |
| | Cobalt | mg/kg | -- | -- | 4.2E+01 | 4.15E+01 | mg/kg | -- | -- |
| | Iron | mg/kg | 4.35E+04 | 5.25E+04 | 7.9E+04 | 5.25E+04 | mg/kg | 95% UCL (Student's t) | 85% < FOD, Normal |
| | Manganese | mg/kg | 7.95E+02 | 1.36E+03 | 3.2E+03 | 1.36E+03 | mg/kg | 95%UCL (Land's) | 85% < FOD, Lognormal |
| | Vanadium | mg/kg | 5.78E+01 | 6.85E+01 | 8.4E+01 | 6.85E+01 | mg/kg | 95% UCL (Student's t) | 85% < FOD, Normal |
| | Benzo(a)pyrene | mg/kg | 1.01E+01 | 1.17E+01 | 3.0E+01 | 1.17E+01 | ug/kg | 95% UCL (Bounding) | FOD < 50% |

**Notes:**
UCL = Upper Confidence Limit
mg/kg = Milligram Per Kilogram

(1) See Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites (OSWER Directive 9285.6-10, December 2002) for details on the following methods for calculating the 95% UCL:
95% UCL (Bounding) = The frequency of detection is less than 50%; therefore, the 95% UCL is calculated by the bounding method.
95% UCL (Student's t, adj) = The frequency of detection is between 50% and 85%, and the underlying distribution (detects only) is normal; therefore, Aitchison's Method is used to adjust the detects-only mean and standard deviaiton, and the 95% UCL is calculated using the Student's t method.
95% UCL (Land, adj) = The frequency of detection is between 50% and 85%, and the underlying distribution (detects only) is lognormal; therefore, Aitchison's Method is used to adjust the detects-only mean and standard deviation, and the 95% UCL is calculated using Land's method.
95% UCL (Student's t) = The frequency of detection is greater than 85%, and the distribution is normal.; therefore, the 95% UCL is calculated using the Student's t method.
95% UCL (Bootstrap) = The frequency of detection is between 50% and 85% and the underlying distribution (detects only) is neither normal nor lognormal, OR the frequency of detection is greater than 85% and the distribution (with non-detects represented by half of the detection limit) is neither normal nor lognormal; therefore, the 95% UCL is calculated using Hall's bootstrap method.
Maximum: The 95% UCL exceeds the maximum detected concentration; therefore, the maximum detected concentration is used to represent the 95% UCL.

(2) FOD = Frequency of detection
FOD < 50%: Frequency of detection is less than 50%
50% < FOD < 85%, Normal: Frequency of detection is between 50% and 85%, and the underlying distribution (detects only) is normal.
50% < FOD < 85%, Lognormal: Frequency of detection is between 50% and 85%, and the underlying distribution (detects only) is lognormal.
50% < FOD < 85%, Unknown: Frequency of detection is between 50% and 85%, and the underlying distribution (detects only) is neither normal nor lognormal.
85% < FOD, Normal: Frequency of detection is greater than 85%, and the distribution is normal.
85% < FOD, Lognormal: Frequency of detection is greater than 85%, and the distribution is lognormal.
85% < FOD, Unknown: Frequency of detection is greater than 85%, and the distribution is neither normal nor lognormal.

**Table 7-8**
**Cumulative HHRS for SWMU 57 (Total Soil)**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Units | Maximum EPC | C/N | RBC Residential | RBC Industrial | Non Carcinogenic HI ($RBC_{Res}$) | Excess Cancer Risk ($RBC_{Res}$) | Non Carcinogenic HI ($RBC_{Ind}$) | Excess Cancer Risk ($RBC_{Ind}$) |
|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals** | | | | | | | | | |
| 7429905 | Aluminum | mg/kg | 3.25E+04 | -- | -- | -- | -- | -- | -- | -- |
| 7440360 | Antimony | mg/kg | 6.22E+00 | N | 3.13E+01 | 4.09E+02 | 2.E-01 | -- | 2.E-02 | -- |
| 7440382 | Arsenic | mg/kg | 6.11E+00 | C | 4.26E-01 | 1.91E+00 | -- | 1.E-05 | -- | 3.E-06 |
| 7440382 | Arsenic | mg/kg | 6.11E+00 | N | 2.35E+01 | 3.07E+02 | 3.E-01 | -- | 2.E-02 | -- |
| 7440439 | Cadmium | mg/kg | 1.86E+01 | N | 3.91E+01 | 5.11E+02 | 5.E-01 | -- | 4.E-02 | -- |
| 7440473 | Chromium[1] | mg/kg | 1.54E+02 | N | 2.35E+02 | 3.07E+03 | 7.E-01 | -- | 5.E-02 | -- |
| 7440484 | Cobalt | mg/kg | 1.55E+02 | -- | -- | -- | -- | -- | -- | -- |
| 7439896 | Iron | mg/kg | 5.25E+04 | N | 2.35E+04 | 3.07E+05 | 2.E+00 | -- | 2.E-01 | -- |
| 7439965 | Manganese | mg/kg | 1.36E+03 | N | 1.56E+03 | 2.04E+04 | 9.E-01 | -- | 7.E-02 | -- |
| 7440622 | Vanadium | mg/kg | 6.85E+01 | N | 7.82E+01 | 1.02E+03 | 9.E-01 | -- | 7.E-02 | -- |
| | **VOC TICs** | | | | | | | | | |
| 66251 | Hexanal | µg/kg | 2.80E+01 | -- | -- | -- | -- | -- | -- | -- |
| | **TCL SVOCs** | | | | | | | | | |
| 59507 | 4-Chloro-3-Methylphenol | µg/kg | 4.40E+01 | -- | -- | -- | -- | -- | -- | -- |
| 50328 | Benzo(a)pyrene | µg/kg | 1.17E+01 | C | 2.20E+01 | 3.92E+02 | -- | 5.E-07 | -- | 3.E-08 |
| | **SVOC TICs** | | | | | | | | | |
| 301020 | (Z)-9-Octadecenamide | µg/kg | 1.03E+03 | -- | -- | -- | -- | -- | -- | -- |
| 1454859 | 1-Heptadecanol | µg/kg | 3.70E+01 | -- | -- | -- | -- | -- | -- | -- |
| 36653824 | 1-Hexadecanol | µg/kg | 4.80E+01 | -- | -- | -- | -- | -- | -- | -- |
| 112925 | 1-Octadecanol | µg/kg | 3.10E+01 | -- | -- | -- | -- | -- | -- | -- |
| 629765 | 1-Pentadecanol | µg/kg | 5.20E+01 | -- | -- | -- | -- | -- | -- | -- |
| 32598144 | 1,1'-Biphenyl, 2,3,3',4,4'-pentachloro- | µg/kg | 3.90E+02 | -- | -- | -- | -- | -- | -- | -- |
| 84695 | 1,2-Benzenedicarboxylicacid, bis(2-methy | µg/kg | 5.40E+02 | -- | -- | -- | -- | -- | -- | -- |
| 17851535 | 1,2-Benzenedicarboxylic acid, butyl 2-me | µg/kg | 1.60E+02 | -- | -- | -- | -- | -- | -- | -- |
| 89189 | 1,2-Benzenedicarboxylic acid, butyl 8-me | µg/kg | 3.40E+01 | -- | -- | -- | -- | -- | -- | -- |
| 84640 | 1,2-Benzenedicarboxylic acid, butyl cycl | µg/kg | 4.70E+02 | -- | -- | -- | -- | -- | -- | -- |
| 20019641 | 2(5H)-Furanone, 5,5-dimethyl- | µg/kg | 2.60E+02 | -- | -- | -- | -- | -- | -- | -- |
| 101371 | 2,4,6-Triallyloxy-1,3,5-triazine | µg/kg | 1.30E+02 | -- | -- | -- | -- | -- | -- | -- |
| 1000143924 | 7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6, | µg/kg | 2.80E+01 | -- | -- | -- | -- | -- | -- | -- |
| 142165 | Bis(2-ethylhexyl)maleate | µg/kg | 1.20E+02 | -- | -- | -- | -- | -- | -- | -- |
| 112845 | Erucylamide | µg/kg | 6.30E+02 | -- | -- | -- | -- | -- | -- | -- |
| 7390810 | Oxirane, hexadecyl- | µg/kg | 5.80E+01 | -- | -- | -- | -- | -- | -- | -- |
| 27193288 | Phenol, (1,1,3,3-tetramethylbutyl)- | µg/kg | 2.90E+01 | -- | -- | -- | -- | -- | -- | -- |
| 78308 | Phosphoric acid, tris (3-methylphenyl) e | µg/kg | 1.40E+03 | -- | -- | -- | -- | -- | -- | -- |
| 563042 | Phsophoric acid, tris(3-methylphenyl) es | µg/kg | 5.60E+02 | -- | -- | -- | -- | -- | -- | -- |
| 57114 | Stearic Acid | µg/kg | 1.10E+02 | -- | -- | -- | -- | -- | -- | -- |
| | | | | | | **Cumulative Risk** | 6.E+00 | 1.E-05 | 4.E-01 | 3.E-06 |

**Notes:**
CAS = Chemical Abstracts Service
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
TAL = Target Analyte List
TCL = Target Compound List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
[1] = Chromium VI RBC value was used

MDC = Maximum Detected Concentration
HI = Hazard Index
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 31, 2006, RBC Table and October 10, 2006, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2006)
N = Noncarcinogenic per EPA RBC Table (October 2006)

**Table 7-9**
**HHRS SSL Comparison for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | Soil to Groundwater SSL (DAF 20) | COPC Flag (Y/N) | Rationale for Selection or Deletion |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals (mg/kg)** | | | | | | | | | | |
| 7429905 | Aluminum | 13,900 | 38,900 | mg/kg | 57SB1C | 7/7 | 1.83 - 9.15 | 38,900 | -- | Y | NSV |
| 7440360 | Antimony | 0.07 | 10 | mg/kg | 57SB4B | 5/7 | 0.0518 - 0.0518 | 9.70 | 13.2 | N | BSL |
| 7440382 | Arsenic | 1.1 | 12 | mg/kg | 57SB3B | 7/7 | 0.0232 - 0.0232 | 12.00 | 0.026 | Y | **ASSL** |
| 7440393 | Barium | 39 | 73 | mg/kg | 57SB1C | 7/7 | 0.106 - 0.106 | 73 | 6,015.2 | N | BSL |
| 7440417 | Beryllium | 0.45 | 3.2 | mg/kg | 57SB2C | 7/7 | 0.0333 - 0.0391 | 3.20 | 1,153.7 | N | BSL |
| 7440439 | Cadmium | 0.46 | 4 | mg/kg | 57SB1C | 7/7 | 0.182 - 0.182 | 4.00 | 27.4 | N | BSL |
| 7440702 | Calcium | 207 | 1,030 | mg/kg | 57SB1B | 4/7 | 16.6 - 16.6 | 1,030 | Nutrient | N | Nutrient |
| 7440473 | Chromium[1] | 9.3 | 88 | mg/kg | 57SB1C | 7/7 | 0.912 - 0.912 | 88 | 42 | Y | **ASSL** |
| 7440484 | Cobalt | 8.7 | 26 | mg/kg | 57SB2B | 7/7 | 0.208 - 0.208 | 26 | -- | Y | NSV |
| 7440508 | Copper | 13.0 | 38 | mg/kg | 57SB3B | 7/7 | 0.368 - 0.368 | 38 | 10,517.8 | N | BSL |
| 7439896 | Iron | 34,500 | 59,000 | mg/kg | 57SB4B | 7/7 | 35.8 - 71.6 | 59,000 | -- | Y | NSV |
| 7439921 | Lead [2] | 2.6 | 29 | mg/kg | 57SB1B | 7/7 | 0.0218 - 0.0218 | 29 | -- | Y | NSV |
| 7439954 | Magnesium | 487 | 35,000 | mg/kg | 57SB3C | 7/7 | 3.21 - 16.1 | 35,000 | Nutrient | N | Nutrient |
| 7439965 | Manganese | 264 | 1,090 | mg/kg | 57SB2B | 7/7 | 0.264 - 1.32 | 1,090 | 951.9 | Y | **ASSL** |
| 7439976 | Mercury [3] | 0.013 | 0.053 | mg/kg | 57SB1C | 5/7 | 0.0077 - 0.0077 | 0.05 | -- | Y | NSV |
| 7440020 | Nickel | 11 | 75 | mg/kg | 57SB2C | 7/7 | 0.0356 - 0.356 | 75 | -- | Y | NSV |
| 7440097 | Potassium | 999 | 5,900 | mg/kg | 57SB3C | 7/7 | 5 - 5 | 5,900 | Nutrient | N | Nutrient |
| 7782492 | Selenium | 0.33 | 0.88 | mg/kg | 57SB3C | 7/7 | 0.0502 - 0.0502 | 0.88 | 18.98 | N | BSL |
| 7440224 | Silver | 0.028 | 0.15 | mg/kg | 57SB3C | 7/7 | 0.0044 - 0.0044 | 0.15 | 31.03 | N | BSL |
| 7440235 | Sodium | 74 | 497 | mg/kg | 57SB4B | 7/7 | 8.92 - 18.1 | 497 | Nutrient | N | Nutrient |
| 7440280 | Thallium | 0.11 | 0.3 | mg/kg | 57SB3B | 7/7 | 0.027 - 0.027 | 0.28 | 3.64 | N | BSL |
| 7440622 | Vanadium | 18 | 69 | mg/kg | 57SB1B | 7/7 | 0.207 - 0.207 | 69 | 730 | N | BSL |
| 7440666 | Zinc | 9.3 | 97 | mg/kg | 57SB1C | 7/7 | 0.517 - 0.517 | 97 | 13,622 | N | BSL |
| | **TCL Pesticides/PCBs (µg/kg) *** | | | | | | | | | | |
| 11097691 | Aroclor 1254 [4] | 1.2E+01 | 1.2E+01 | µg/kg | 57SB4A | 1/1 | 4.2 - 4.2 | 1.2E+01 | 1.1E+03 | N | BSL |
| | **TCL VOCs (µg/kg)** | | | | | | | | | | |
| 78933 | 2-Butanone | 2.1E+01 | 2.9E+01 | µg/kg | 57SB3B | 7/7 | 6.6 - 7.95 | 2.9E+01 | 2.9E+04 | N | BSL |
| 67641 | Acetone | 3.7E+01 | 7.7E+01 | µg/kg | 57SB3B | 7/7 | 6.6 - 7.95 | 7.7E+01 | 2.2E+04 | N | BSL |
| 75274 | Bromodichloromethane | 1.2E+00 | 1.2E+00 | µg/kg | 57SB2C | 1/7 | 0.661 - 0.797 | 1.2E+00 | 1.1E+00 | Y | **ASSL** |
| 67663 | Chloroform | 1.1E+00 | 2.4E+01 | µg/kg | 57SB1C | 4/7 | 0.589 - 0.709 | 2.4E+01 | 9.1E-01 | Y | **ASSL** |
| 75092 | Methylene chloride | 4.8E+00 | 6.8E+00 | µg/kg | 57SB3B | 6/7 | 3.71 - 4.47 | 6.8E+00 | 1.9E+01 | N | BSL |
| | **TCL SVOCs (µg/kg)** | | | | | | | | | | |
| 59507 | 4-Chloro-3-Methylphenol | 1.6E+01 | 4.4E+01 | µg/kg | 57SB1C | 5/7 | 6.77 - 8.34 | 4.4E+01 | -- | Y | NSV |
| 117817 | Bis(2-ethylhexyl)phthalate | 2.0E+01 | 6.3E+01 | µg/kg | 57SB1C | 7/7 | 2.69 - 3.31 | 6.3E+01 | 2.9E+06 | N | BSL |
| 85687 | Butylbenzylphthalate | 1.0E+01 | 3.0E+01 | µg/kg | 57SB1C | 2/7 | 5.82 - 7.17 | 3.0E+01 | 1.7E+07 | N | BSL |
| 105602 | Caprolactam | 1.1E+01 | 3.6E+01 | µg/kg | 57SB1C | 2/7 | 8.29 - 10.2 | 3.6E+01 | -- | Y | NSV |
| 84662 | Diethylphthalate | 5.0E+00 | 1.2E+01 | µg/kg | 57SB1C | 6/7 | 2.47 - 3.04 | 1.2E+01 | 4.5E+05 | N | BSL |
| 84742 | Di-n-butylphthalate | 3.8E+01 | 4.3E+02 | µg/kg | 57SB1B | 7/7 | 4.97 - 6.11 | 4.3E+02 | 5.0E+06 | N | BSL |
| | **SVOC TICs (µg/kg)** | | | | | | | | | | |
| 301020 | (Z)-9-Octadecenamide | 6.0E+01 | 8.1E+02 | µg/kg | 57SB1B | 4/7 | 0 - 0 | 8.1E+02 | -- | Y | NSV |
| 1454859 | 1-Heptadecanol | 3.7E+01 | 3.7E+01 | µg/kg | 57SB3C | 1/7 | 0 - 0 | 3.7E+01 | -- | Y | NSV |
| 36653824 | 1-Hexadecanol | 3.1E+01 | 4.8E+01 | µg/kg | 57SB4B | 2/7 | 0 - 0 | 4.8E+01 | -- | Y | NSV |
| 629765 | 1-Pentadecanol | 5.2E+01 | 5.2E+01 | µg/kg | 57SB2C | 1/7 | 0 - 0 | 5.2E+01 | -- | Y | NSV |
| 84695 | 1,2-Benzenedicarboxylicacid, bis(2-methy | 3.2E+01 | 5.4E+02 | µg/kg | 57SB1B | 4/7 | 0 - 0 | 5.4E+02 | -- | Y | NSV |
| 17851535 | 1,2-Benzenedicarboxylic acid, butyl 2-me | 1.6E+02 | 1.6E+02 | µg/kg | 57SB4B | 1/7 | 0 - 0 | 1.6E+02 | -- | Y | NSV |
| 89189 | 1,2-Benzenedicarboxylic acid, butyl 8-me | 3.4E+01 | 3.4E+01 | µg/kg | 57SB2C | 1/7 | 0 - 0 | 3.4E+01 | -- | Y | NSV |
| 84640 | 1,2-Benzenedicarboxylic acid, butyl cycl | 4.7E+02 | 4.7E+02 | µg/kg | 57SB1C | 1/7 | 0 - 0 | 4.7E+02 | -- | Y | NSV |
| 101371 | 2,4,6-Triallyloxy-1,3,5-triazine | 5.8E+01 | 1.3E+02 | µg/kg | 57SB1B | 4/7 | 0 - 0 | 1.3E+02 | -- | Y | NSV |

**Table 7-9**
**HHRS SSL Comparison for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | Soil to Groundwater SSL (DAF 20) | COPC Flag (Y/N) | Rationale for Selection or Deletion |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1000143924 | 7,9-Di-tert-butyl-1-oxaspiro(4,5)deca-6, | 2.8E+01 | 2.8E+01 | µg/kg | 57SB3B | 1/7 | 0 - 0 | 2.8E+01 | -- | Y | NSV |
| 142165 | Bis(2-ethylhexyl)maleate | 1.2E+02 | 1.2E+02 | µg/kg | 57SB1C | 1/7 | 0 - 0 | 1.2E+02 | -- | Y | NSV |
| 112845 | Erucylamide | 3.3E+02 | 6.3E+02 | µg/kg | 57SB3B | 3/7 | 0 - 0 | 6.3E+02 | -- | Y | NSV |
| 57114 | Stearic Acid | 6.4E+01 | 1.1E+02 | µg/kg | 57SB1C | 2/7 | 0 - 0 | 1.1E+02 | -- | Y | NSV |
| | **Cyanide (mg/kg)** | | | | | | | | | | |
| 57125 | Cyanide | 8.0E-02 | 8.0E-02 | mg/kg | 57SB2B | 2/7 | 0.0356 - 0.0356 | 8.0E-02 | 1.5E+02 | N | BSL |

**Notes:**
CAS = Chemical Abstracts Service
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
TAL = Target Analyte List
TCL = Target Compound List
PCB = Polychlorinated Biphenyls
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
[1] = Chromium VI SSL DAF20 value was used
[2] = Lead criteria are Action Levels; see USEPA Region III guidance
[3] = Mercuric chloride soil RBC value used
[4] = Noncarcinogenic Residential RBC value for Aroclor 1254 was used for screening

DUP AVG = results for duplicate samples averaged
SSL DAF20 = Soil Screening Levels at a Dilution Attenuation Factor of 20
Per (SSL) values from the October 31, 2006, RBC Table

**ASSL** = Above Soil Screening Level
BSL = Below Soil Screening Levels
NSV = No Screening Value Available
* = Surface Soil Detections used for SSL Screening due to testing of
one surface soil sample for PCB/Pesticides/Herbicides

**Table 7-10**
**COPC/Background Comparison for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

**Surface Soil COPC/Background Comparison**

| CAS # | Chemical | Minimum Concentration Surface Soil | Maximum Concentration Surface Soil | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | Background Point Estimate[A] | Background Comparison |
|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals (mg/kg)** | | | | | | | | | |
| 7429905 | Aluminum | 11,900 | 32,200 | mg/kg | 57SB2A | 4/4 | 1.83 - 9.15 | 32,200 | 40,041 | N |
| 7440360 | Antimony | 1.2 | 103 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0518 - 1.3 | 103 | -- | NBE |
| 7440382 | Arsenic | 1.6 | 5.2 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.0232 - 0.0232 | 5.2 | 16 | N |
| 7440439 | Cadmium | 1.5 | 34 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.182 - 0.182 | 34 | 0.69 | **Y** |
| 7440473 | Chromium | 20 | 361 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.912 - 4.56 | 361 | 65 | **Y** |
| 7440484 | Cobalt | 5.8 | 42 | mg/kg | 57SB3A-DUP AVG | 4/4 | 0.208 - 0.208 | 42 | 72 | N |
| 7439896 | Iron | 13,400 | 78,700 | mg/kg | 57SB4A | 4/4 | 17.9 - 71.6 | 78,700 | 50,962 | **Y** |
| 7439965 | Manganese | 361 | 3,200 | mg/kg | 57SB4A | 4/4 | 0.264 - 1.32 | 3,200 | 2,543 | **Y** |
| 7440622 | Vanadium | 29 | 84 | mg/kg | 57SB4A | 4/4 | 0.207 - 0.207 | 84 | 108 | N |

**Total Soil COPC/Background Comparison**

| CAS # | Chemical | Minimum Concentration Total Soil | Maximum Concentration Total Soil | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening | Background Point Estimate[A] | Background Comparison |
|---|---|---|---|---|---|---|---|---|---|---|
| | **TAL Metals (mg/kg)** | | | | | | | | | |
| 7429905 | Aluminum | 11,900 | 38,900 | mg/kg | 57SB1C | 11/11 | 1.83 - 9.15 | 38,900 | 40,041 | N |
| 7440360 | Antimony | 0.073 | 103 | mg/kg | 57SB3A-DUP AVG | 9/11 | 0.0518 - 1.3 | 103 | -- | NBE |
| 7440382 | Arsenic | 1.1 | 12 | mg/kg | 57SB3B | 11/11 | 0.0232 - 0.0232 | 12 | 16 | N |
| 7440439 | Cadmium | 0.46 | 34 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.182 - 0.182 | 34 | 0.69 | **Y** |
| 7440473 | Chromium | 9.3 | 361 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.912 - 4.56 | 361 | 65 | **Y** |
| 7440484 | Cobalt | 5.8 | 42 | mg/kg | 57SB3A-DUP AVG | 11/11 | 0.208 - 0.208 | 42 | 72 | N |
| 7439896 | Iron | 13,400 | 78,700 | mg/kg | 57SB4A | 11/11 | 17.9 - 71.6 | 78,700 | 50,962 | **Y** |
| 7439965 | Manganese | 264 | 3,200 | mg/kg | 57SB4A | 11/11 | 0.264 - 1.32 | 3,200 | 2,543 | **Y** |
| 7440622 | Vanadium | 18 | 84 | mg/kg | 57SB4A | 11/11 | 0.207 - 0.207 | 84 | 108 | N |

**Notes:**

CAS = Chemical Abstracts Service
TAL = Target Analyte List
mg/kg = Milligram Per Kilogram
[A] = Facility-Wide Background Point Estimate as
Reported in the Facility-Wide Background Study Report (IT 2001a)
DUP AVG = results for duplicate samples averaged
NBE = No Background Point Estimate

**Table 7-11**
**Detected Chemicals Occurrence for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening |
|---|---|---|---|---|---|---|---|---|
| | **TAL Metals (mg/kg)** | | | | | | | |
| 7429905 | Aluminum | 11,900 | 32,200 | mg/kg | 57SB2A | 4/4 | 1.83 - 9.15 | 32,200 |
| 7440360 | Antimony | 1.2 | 102 | mg/kg | 57SB3A | 4/4 | 0.0518 - 1.3 | 102 |
| 7440382 | Arsenic | 1.6 | 5.1 | mg/kg | 57SB3A | 4/4 | 0.0232 - 0.0232 | 5 |
| 7440393 | Barium | 80.00 | 149 | mg/kg | 57SB4A | 4/4 | 0.106 - 0.106 | 149 |
| 7440417 | Beryllium | 0.44 | 0.6 | mg/kg | 57SB4A | 4/4 | 0.0391 - 0.0391 | 0.60 |
| 7440439 | Cadmium | 1.5 | 27 | mg/kg | 57SB3A | 4/4 | 0.182 - 0.182 | 27.00 |
| 7440702 | Calcium | 1,420 | 4,440 | mg/kg | 57SB1A | 4/4 | 16.6 - 16.6 | 4,440 |
| 7440473 | Chromium | 20 | 268 | mg/kg | 57SB3A | 4/4 | 0.912 - 4.56 | 268 |
| 7440484 | Cobalt | 5.8 | 75 | mg/kg | 57SB3A | 4/4 | 0.208 - 0.208 | 75 |
| 7440508 | Copper | 4.9 | 27 | mg/kg | 57SB3A | 4/4 | 0.368 - 0.368 | 27 |
| 7439896 | Iron | 13,400 | 78,700 | mg/kg | 57SB4A | 4/4 | 17.9 - 71.6 | 78,700 |
| 7439921 | Lead | 19 | 175 | mg/kg | 57SB3A | 4/4 | 0.0218 - 0.545 | 175 |
| 7439954 | Magnesium | 923 | 2,700 | mg/kg | 57SB1A | 4/4 | 3.21 - 3.21 | 2,700 |
| 7439965 | Manganese | 361 | 3,200 | mg/kg | 57SB4A | 4/4 | 0.264 - 1.32 | 3,200 |
| 7439976 | Mercury | 0.05 | 0.16 | mg/kg | 57SB2A | 4/4 | 0.0077 - 0.0077 | 0.16 |
| 7440020 | Nickel | 6 | 13 | mg/kg | 57SB3A | 4/4 | 0.0356 - 0.0356 | 13 |
| 7440097 | Potassium | 528 | 968 | mg/kg | 57SB2A | 4/4 | 5 - 5 | 968 |
| 7782492 | Selenium | 0.51 | 0.69 | mg/kg | 57SB2A | 4/4 | 0.0502 - 0.0502 | 0.69 |
| 7440224 | Silver | 0.05 | 0.11 | mg/kg | 57SB3A | 4/4 | 0.0044 - 0.0044 | 0.11 |
| 7440235 | Sodium | 33 | 312 | mg/kg | 57SB2A | 4/4 | 8.92 - 8.92 | 312 |
| 7440280 | Thallium | 0.17 | 0.3 | mg/kg | 57SB4A | 4/4 | 0.027 - 0.027 | 0.30 |
| 7440622 | Vanadium | 29 | 84 | mg/kg | 57SB4A | 4/4 | 0.207 - 0.207 | 84 |
| 7440666 | Zinc | 52 | 895 | mg/kg | 57SB3A | 4/4 | 0.517 - 5.17 | 895 |
| | **TCL Pesticides/PCBs (µg/kg)** | | | | | | | |
| 11097691 | Aroclor 1254 | 1.2E+01 | 1.2E+01 | µg/kg | 57SB4A | 1/4 | 4.2 - 4.2 | 1.2E+01 |
| | **TCL VOCs (µg/kg)** | | | | | | | |
| 78933 | 2-Butanone | 2.8E+01 | 3.0E+01 | µg/kg | 57SB2A | 4/4 | 5.8 - 7.05 | 3.0E+01 |
| 67641 | Acetone | 5.5E+01 | 1.0E+02 | µg/kg | 57SB1A | 4/4 | 5.8 - 7.05 | 1.0E+02 |
| 100414 | Ethylbenzene | 6.6E-01 | 6.6E-01 | µg/kg | 57SB3A | 1/4 | 0.491 - 0.596 | 6.6E-01 |
| 75092 | Methylene chloride | 3.6E+00 | 6.5E+00 | µg/kg | 57SB3A | 3/4 | 3.26 - 3.96 | 6.5E+00 |
| 108883 | Toluene | 1.3E+00 | 1.3E+00 | µg/kg | 57SB3A | 1/4 | 0.538 - 0.654 | 1.3E+00 |
| 79016 | Trichloroethene | 1.9E+00 | 1.9E+00 | µg/kg | 57SB3A | 1/4 | 0.785 - 0.955 | 1.9E+00 |

**Table 7-11**
**Detected Chemicals Occurrence for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Chemical | Minimum Concentration | Maximum Concentration | Units | Location of Maximum Concentration | Detection Frequency | Range of Detection Limits | Concentration Used for Screening |
|---|---|---|---|---|---|---|---|---|
| | **TCL SVOCs[1] (µg/kg)** | | | | | | | |
| 91576 | 2-Methylnaphthalene | 6.0E+00 | 6.0E+00 | µg/kg | 57SB3A | 1/4 | 3.29 - 3.84 | 6.0E+00 |
| 59507 | 4-Chloro-3-Methylphenol | 1.7E+01 | 4.6E+01 | µg/kg | 57SB3A | 4/4 | 6.25 - 7.29 | 4.6E+01 |
| 208968 | Acenaphthylene | 2.0E+00 | 4.0E+00 | µg/kg | 57SB3A | 2/4 | 1.8 - 2.1 | 4.0E+00 |
| 98862 | Acetophenone | 3.6E+01 | 3.6E+01 | µg/kg | 57SB3A | 1/4 | 2.28 - 2.66 | 3.6E+01 |
| 117817 | Bis(2-ethylhexyl)phthalate | 2.1E+01 | 4.8E+02 | µg/kg | 57SB3A | 4/4 | 2.48 - 2.9 | 4.8E+02 |
| 85687 | Butylbenzylphthalate | 4.4E+01 | 4.4E+01 | µg/kg | 57SB2A | 1/4 | 5.38 - 6.27 | 4.4E+01 |
| 105602 | Caprolactam | 1.5E+01 | 4.3E+01 | µg/kg | 57SB3A | 2/4 | 7.66 - 8.93 | 4.3E+01 |
| 84662 | Diethylphthalate | 7.0E+00 | 1.9E+01 | µg/kg | 57SB3A | 4/4 | 2.28 - 2.66 | 1.9E+01 |
| 84742 | Di-n-butylphthalate | 4.1E+01 | 3.6E+02 | µg/kg | 57SB3A | 4/4 | 4.58 - 5.35 | 3.6E+02 |
| 91203 | Naphthalene | 4.0E+00 | 4.0E+00 | µg/kg | 57SB3A | 1/4 | 3.3 - 3.85 | 4.0E+00 |
| | **PAHs[2] (µg/kg)** | | | | | | | |
| 120127 | Anthracene | 1.5E+00 | 1.9E+00 | µg/kg | 57SB1A | 3/4 | 0.77 - 0.98 | 1.9E+00 |
| 56553 | Benzo(a)anthracene | 7.1E+00 | 7.1E+00 | µg/kg | 57SB2A | 1/4 | 0.88 - 1.12 | 7.1E+00 |
| 50328 | Benzo(a)pyrene | 1.0E+01 | 1.8E+01 | µg/kg | 57SB1A | 2/4 | 1.1 - 1.4 | 1.8E+01 |
| 205992 | Benzo(b)fluoranthene | 1.4E+01 | 1.4E+01 | µg/kg | 57SB1A | 1/4 | 1.43 - 1.82 | 1.4E+01 |
| 191242 | Benzo(g,h,i)perylene | 2.7E+01 | 2.7E+01 | µg/kg | 57SB1A | 1/4 | 13.8 - 17.5 | 2.7E+01 |
| 207089 | Benzo(k)fluoranthene | 8.5E+00 | 8.5E+00 | µg/kg | 57SB1A | 1/4 | 1.1 - 1.4 | 8.5E+00 |
| 218019 | Chrysene | 5.2E+00 | 1.1E+01 | µg/kg | 57SB1A | 3/4 | 1.32 - 1.68 | 1.1E+01 |
| 206440 | Fluoranthene | 2.9E+01 | 5.7E+01 | µg/kg | 57SB1A | 3/4 | 1.87 - 2.38 | 5.7E+01 |
| 193395 | Indeno(1,2,3-cd)pyrene | 7.2E+00 | 1.1E+01 | µg/kg | 57SB1A | 2/4 | 0.77 - 0.98 | 1.1E+01 |
| 85018 | Phenanthrene | 1.1E+01 | 2.4E+01 | µg/kg | 57SB1A | 3/4 | 0.66 - 0.84 | 2.4E+01 |
| 129000 | Pyrene | 2.0E+01 | 8.2E+01 | µg/kg | 57SB1A | 3/4 | 0.99 - 1.26 | 8.2E+01 |
| | **Cyanide (mg/kg)** | | | | | | | |
| 57125 | Cyanide | 5.0E-02 | 1.7E-01 | mg/kg | 57SB3A | 4/4 | 0.0356 - 0.0356 | 1.7E-01 |

**Notes:**

CAS = Chemical Abstracts Sevice
TAL = Target Analyte List
TCL = Target Compound List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon

mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
[1] = SVOCs analyzed by USEPA SW-846 8270 Method 8270C
[2] = PAHs analyzed by USEPA SW-846 Method8310

**Table 7-12**
**Non-detected Chemicals for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Parameter Name | Units | Number of Samples | Minimum MDL | Maximum MDL | TSV | Maximum Detection Limit Exceeds TSV |
|---|---|---|---|---|---|---|---|
| ***Pesticides/Herbicides*** | | | | | | | |
| 72548 | 4,4'-DDD | µg/kg | 1 | 0.357 | 0.357 | -- | NS |
| 72559 | 4,4'-DDE | µg/kg | 1 | 0.263 | 0.263 | 100 | **Y** |
| 50293 | 4,4'-DDT | µg/kg | 1 | 0.27 | 0.27 | 100 | N |
| 309002 | Aldrin | µg/kg | 1 | 0.456 | 0.456 | 100 | N |
| 319846 | alpha-BHC | µg/kg | 1 | 0.455 | 0.455 | 100 | N |
| 5103719 | alpha-Chlordane | µg/kg | 1 | 0.651 | 0.651 | 100 | N |
| 319857 | beta-BHC | µg/kg | 1 | 1.7 | 1.7 | 100 | N |
| 319868 | delta-BHC | µg/kg | 1 | 1.23 | 1.23 | 100 | N |
| 60571 | Dieldrin | µg/kg | 1 | 0.464 | 0.464 | 100 | N |
| 959988 | Endosulfan I | µg/kg | 1 | 1.37 | 1.37 | -- | NS |
| 33213659 | Endosulfan II | µg/kg | 1 | 0.321 | 0.321 | -- | NS |
| 1031078 | Endosulfan Sulfate | µg/kg | 1 | 0.755 | 0.755 | -- | NS |
| 72208 | Endrin | µg/kg | 1 | 0.447 | 0.447 | 100 | N |
| 7421934 | Endrin aldehyde | µg/kg | 1 | 1.67 | 1.67 | -- | NS |
| 53494705 | Endrin ketone | µg/kg | 1 | 0.413 | 0.413 | -- | NS |
| 58899 | gamma-BHC (Lindane) | µg/kg | 1 | 0.291 | 0.291 | 100 | N |
| 5103742 | gamma-Chlordane | µg/kg | 1 | 1.05 | 1.05 | 100 | N |
| 76448 | Heptachlor | µg/kg | 1 | 1.06 | 1.06 | -- | NS |
| 1024573 | Heptachlor epoxide | µg/kg | 1 | 0.683 | 0.683 | 100 | N |
| 72435 | Methoxychlor | µg/kg | 1 | 0.42 | 0.42 | 100 | N |
| 8001352 | Toxaphene | µg/kg | 1 | 35 | 35 | -- | NS |
| 93765 | 2,4,5-T | µg/kg | 1 | 2.8 | 2.8 | -- | NS |
| 93721 | 2,4,5-TP (Silvex) | µg/kg | 1 | 5.6 | 5.6 | -- | NS |
| 94757 | 2,4-D | µg/kg | 1 | 22.4 | 22.4 | -- | NS |
| 94826 | 2,4-DB | µg/kg | 1 | 86.8 | 86.8 | -- | NS |
| 75990 | Dalapon | µg/kg | 1 | 79.8 | 79.8 | -- | NS |
| 1918009 | Dicamba | µg/kg | 1 | 2.8 | 2.8 | -- | NS |
| 120365 | Dichlorprop | µg/kg | 1 | 23.8 | 23.8 | -- | NS |
| 88857 | Dinoseb | µg/kg | 1 | 29.4 | 29.4 | -- | NS |
| 94746 | MCPA | µg/kg | 1 | 1950 | 1950 | -- | NS |
| 93652 | MCPP | µg/kg | 1 | 7080 | 7080 | -- | NS |
| ***PCBs*** | | | | | | | |
| 12674112 | Aroclor 1016 | µg/kg | 1 | 22.4 | 22.4 | -- | NS |
| 11104282 | Aroclor 1221 | µg/kg | 1 | 2.8 | 2.8 | -- | NS |
| 11141165 | Aroclor 1232 | µg/kg | 1 | 7 | 7 | -- | NS |
| 53469219 | Aroclor 1242 | µg/kg | 1 | 4.2 | 4.2 | -- | NS |
| 12672296 | Aroclor 1248 | µg/kg | 1 | 7 | 7 | -- | NS |
| 11096825 | Aroclor 1260 | µg/kg | 1 | 9.8 | 9.8 | 371 | N |
| ***VOCs*** | | | | | | | |
| 71556 | 1,1,1-Trichloroethane | µg/kg | 4 | 0.494 | 0.601 | 300 | N |
| 79345 | 1,1,2,2-Tetrachloroethane | µg/kg | 4 | 0.757 | 0.921 | 300 | N |
| 76131 | 1,1,2-Trichloro-1,2,2-trifluoroethane | µg/kg | 4 | 0.88 | 1.07 | -- | NS |
| 79005 | 1,1,2-Trichloroethane | µg/kg | 4 | 0.688 | 0.836 | 300 | N |
| 75343 | 1,1-Dichloroethane | µg/kg | 4 | 0.84 | 1.02 | 300 | N |
| 75354 | 1,1-Dichloroethene | µg/kg | 4 | 0.85 | 1.03 | -- | NS |
| 87616 | 1,2,3-Trichlorobenzene | µg/kg | 4 | 0.631 | 0.767 | -- | NS |
| 120821 | 1,2,4-Trichlorobenzene | µg/kg | 4 | 0.476 | 0.578 | 100 | N |
| 96128 | 1,2-Dibromo-3-chloropropane | µg/kg | 4 | 2.41 | 2.93 | -- | NS |
| 106934 | 1,2-Dibromoethane | µg/kg | 4 | 0.795 | 0.966 | -- | NS |
| 95501 | 1,2-Dichlorobenzene | µg/kg | 4 | 0.561 | 0.682 | 100 | N |
| 107062 | 1,2-Dichloroethane | µg/kg | 4 | 0.5 | 0.608 | 870,000 | N |
| 78875 | 1,2-Dichloropropane | µg/kg | 4 | 0.68 | 0.826 | 700,000 | N |
| 541731 | 1,3-Dichlorobenzene | µg/kg | 4 | 0.311 | 0.378 | -- | NS |

**Table 7-12**
**Non-detected Chemicals for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Parameter Name | Units | Number of Samples | Minimum MDL | Maximum MDL | TSV | Maximum Detection Limit Exceeds TSV |
|---|---|---|---|---|---|---|---|
| 106467 | 1,4-Dichlorobenzene | µg/kg | 4 | 0.824 | 1 | 100 | N |
| 591786 | 2-Hexanone | µg/kg | 4 | 2.62 | 3.19 | -- | NS |
| 108101 | 4-Methyl-2-pentanone | µg/kg | 4 | 1.69 | 2.06 | -- | NS |
| 71432 | Benzene | µg/kg | 4 | 0.611 | 0.743 | 100 | N |
| 74975 | Bromochloromethane | µg/kg | 4 | 0.883 | 1.07 | -- | NS |
| 75274 | Bromodichloromethane | µg/kg | 4 | 0.581 | 0.706 | 450,000 | N |
| 75252 | Bromoform | µg/kg | 4 | 0.67 | 0.815 | -- | NS |
| 74839 | Bromomethane | µg/kg | 4 | 1.74 | 2.12 | -- | NS |
| 75150 | Carbon disulfide | µg/kg | 4 | 1.68 | 2.04 | -- | NS |
| 56235 | Carbon tetrachloride | µg/kg | 4 | 0.541 | 0.657 | 300 | N |
| 108907 | Chlorobenzene | µg/kg | 4 | 0.767 | 0.932 | 100 | N |
| 75003 | Chloroethane | µg/kg | 4 | 1.57 | 1.9 | -- | NS |
| 67663 | Chloroform | µg/kg | 4 | 0.517 | 0.629 | 300 | N |
| 74873 | Chloromethane | µg/kg | 4 | 0.967 | 1.18 | -- | NS |
| 156592 | cis-1,2-Dichloroethene | µg/kg | 4 | 0.824 | 1 | 300 | N |
| 10061015 | cis-1,3-Dichloropropene | µg/kg | 4 | 0.57 | 0.692 | -- | NS |
| 110827 | Cyclohexane | µg/kg | 4 | 0.367 | 0.446 | -- | NS |
| 124481 | Dibromochloromethane | µg/kg | 4 | 0.6 | 0.729 | -- | NS |
| 75718 | Dichlorodifluoromethane | µg/kg | 4 | 0.775 | 0.942 | -- | NS |
| 100414 | Ethylbenzene | µg/kg | 3 | 0.491 | 0.596 | 100 | N |
| 98828 | Isopropylbenzene | µg/kg | 4 | 0.633 | 0.77 | -- | NS |
| 79209 | Methyl acetate | µg/kg | 4 | 4.03 | 4.89 | -- | NS |
| 1634044 | methyl tert-Butyl ether | µg/kg | 4 | 0.744 | 0.904 | -- | NS |
| 108872 | Methylcyclohexane | µg/kg | 4 | 0.98 | 1.19 | -- | NS |
| 75092 | Methylene chloride | µg/kg | 1 | 3.96 | 3.96 | 300 | N |
| 100425 | Styrene | µg/kg | 4 | 0.513 | 0.623 | 100 | N |
| 127184 | Tetrachloroethene | µg/kg | 4 | 0.711 | 0.864 | 300 | N |
| 108883 | Toluene | µg/kg | 3 | 0.538 | 0.654 | 100 | N |
| 156605 | trans-1,2-Dichloroethene | µg/kg | 4 | 0.815 | 0.991 | 300 | N |
| 10061026 | trans-1,3-Dichloropropene | µg/kg | 4 | 0.604 | 0.735 | -- | NS |
| 79016 | Trichloroethene | µg/kg | 3 | 0.785 | 0.955 | 300 | N |
| 75694 | Trichlorofluoromethane | µg/kg | 4 | 0.862 | 1.05 | -- | NS |
| 75014 | Vinyl Chloride | µg/kg | 4 | 0.429 | 0.522 | 300 | N |
| 1330207 | Xylenes | µg/kg | 4 | 0.488 | 0.594 | 100 | N |
| ***SVOCs*** | | | | | | | |
| 92524 | 1,1'-Biphenyl | µg/kg | 4 | 2.95 | 3.44 | -- | NS |
| 95943 | 1,2,4,5-Tetrachlorobenzene | µg/kg | 4 | 34.4 | 40.2 | -- | NS |
| 108601 | 2,2'-oxybis(1-Chloropropane) | µg/kg | 4 | 1.58 | 1.85 | -- | NS |
| 95954 | 2,4,5-Trichlorophenol | µg/kg | 4 | 4.01 | 4.68 | 100 | N |
| 88062 | 2,4,6-Trichlorophenol | µg/kg | 4 | 3.14 | 3.67 | 100 | N |
| 120832 | 2,4-Dichlorophenol | µg/kg | 4 | 4.22 | 4.93 | 100 | N |
| 105679 | 2,4-Dimethylphenol | µg/kg | 4 | 9.53 | 11.1 | 100 | N |
| 51285 | 2,4-Dinitrophenol | µg/kg | 4 | 3.84 | 4.48 | 20,000 | N |
| 121142 | 2,4-Dinitrotoluene | µg/kg | 4 | 3.78 | 4.41 | -- | NS |
| 606202 | 2,6-Dinitrotoluene | µg/kg | 4 | 33.2 | 38.8 | -- | NS |
| 91587 | 2-Chloronaphthalene | µg/kg | 4 | 2.76 | 3.22 | -- | NS |
| 95578 | 2-Chlorophenol | µg/kg | 4 | 2.41 | 2.81 | 100 | N |
| 91576 | 2-Methylnaphthalene | µg/kg | 3 | 3.29 | 3.84 | -- | NS |
| 95487 | 2-Methylphenol | µg/kg | 4 | 5.81 | 6.78 | 100 | N |
| 88744 | 2-Nitroaniline | µg/kg | 4 | 5.52 | 6.44 | -- | NS |
| 88755 | 2-Nitrophenol | µg/kg | 4 | 2.04 | 2.38 | -- | NS |
| 91941 | 3,3'-Dichlorobenzidine | µg/kg | 4 | 66.5 | 86.7 | -- | NS |
| 99092 | 3-Nitroaniline | µg/kg | 4 | 22 | 43.3 | -- | NS |
| 534521 | 4,6-Dinitro-2-methylphenol | µg/kg | 4 | 5.41 | 6.31 | -- | NS |

**Table 7-12**
**Non-detected Chemicals for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Parameter Name | Units | Number of Samples | Minimum MDL | Maximum MDL | TSV | Maximum Detection Limit Exceeds TSV |
|---|---|---|---|---|---|---|---|
| 101553 | 4-Bromophenyl-phenylether | µg/kg | 4 | 4.06 | 4.73 | -- | NS |
| 106478 | 4-Chloroaniline | µg/kg | 4 | 1.51 | 1.76 | -- | NS |
| 7005723 | 4-Chlorophenyl-phenylether | µg/kg | 4 | 3.92 | 4.58 | -- | NS |
| 106445 | 4-Methylphenol | µg/kg | 4 | 7.64 | 8.92 | 100 | N |
| 100016 | 4-Nitroaniline | µg/kg | 4 | 8.7 | 10.2 | -- | NS |
| 100027 | 4-Nitrophenol | µg/kg | 4 | 3.4 | 3.96 | 100 | N |
| 83329 | Acenaphthene | µg/kg | 4 | 2.06 | 2.41 | 100 | N |
| 208968 | Acenaphthylene | µg/kg | 2 | 1.8 | 2.1 | 100 | N |
| 98862 | Acetophenone | µg/kg | 3 | 2.28 | 2.66 | -- | NS |
| 120127 | Anthracene | µg/kg | 4 | 5.54 | 6.47 | 100 | N |
| 1912249 | Atrazine | µg/kg | 4 | 8.26 | 9.63 | -- | NS |
| 100527 | Benzaldehyde | µg/kg | 4 | 4.86 | 5.67 | -- | NS |
| 56553 | Benzo(a)anthracene | µg/kg | 4 | 16 | 18.6 | 100 | N |
| 50328 | Benzo(a)pyrene | µg/kg | 1 | 7.99 | 7.99 | 100 | N |
| 205992 | Benzo(b)fluoranthene | µg/kg | 1 | 13.7 | 13.7 | 100 | N |
| 191242 | Benzo(g,h,i)perylene | µg/kg | 4 | 10.5 | 12.2 | 100 | N |
| 207089 | Benzo(k)fluoranthene | µg/kg | 4 | 16.1 | 18.8 | 100 | N |
| 111911 | Bis(2-chloroethoxy)methane | µg/kg | 4 | 3.77 | 4.4 | -- | NS |
| 111444 | Bis(2-chloroethyl)ether | µg/kg | 4 | 2.08 | 2.42 | -- | NS |
| 85687 | Butylbenzylphthalate | µg/kg | 3 | 5.38 | 6.27 | -- | NS |
| 105602 | Caprolactam | µg/kg | 2 | 8.29 | 8.93 | -- | NS |
| 86748 | Carbazole | µg/kg | 4 | 7.32 | 8.54 | -- | NS |
| 218019 | Chrysene | µg/kg | 2 | 13.3 | 14.3 | 100 | N |
| 53703 | Dibenz(a,h)anthracene | µg/kg | 4 | 7.08 | 8.26 | 100 | N |
| 132649 | Dibenzofuran | µg/kg | 4 | 3.79 | 4.42 | -- | NS |
| 131113 | Dimethylphthalate | µg/kg | 4 | 3.97 | 4.63 | 200,000 | N |
| 117840 | Di-n-octylphthalate | µg/kg | 4 | 3.72 | 4.34 | -- | NS |
| 206440 | Fluoranthene | µg/kg | 1 | 3.29 | 3.29 | 100 | N |
| 86737 | Fluorene | µg/kg | 4 | 2.02 | 2.35 | 100 | N |
| 118741 | Hexachlorobenzene | µg/kg | 4 | 3.01 | 3.51 | 1,000,000 | N |
| 87683 | Hexachlorobutadiene | µg/kg | 4 | 4.64 | 5.42 | -- | NS |
| 77474 | Hexachlorocyclopentadiene | µg/kg | 4 | 2.38 | 2.77 | 10,000 | N |
| 67721 | Hexachloroethane | µg/kg | 4 | 2.8 | 3.27 | -- | NS |
| 193395 | Indeno(1,2,3-cd)pyrene | µg/kg | 1 | 5.49 | 5.49 | 100 | N |
| 78591 | Isophorone | µg/kg | 4 | 2.08 | 2.42 | -- | NS |
| 91203 | Naphthalene | µg/kg | 3 | 3.3 | 3.85 | 100 | N |
| 98953 | Nitrobenzene | µg/kg | 4 | 3.84 | 4.48 | 40,000 | N |
| 621647 | N-Nitrosodi-n-propylamine | µg/kg | 4 | 3.95 | 4.61 | -- | NS |
| 86306 | N-Nitrosodiphenylamine | µg/kg | 4 | 5.7 | 6.65 | 20,000 | N |
| 87865 | Pentachlorophenol | µg/kg | 4 | 5.27 | 6.15 | 100 | N |
| 85018 | Phenanthrene | µg/kg | 1 | 3.22 | 3.22 | 100 | N |
| 108952 | Phenol | µg/kg | 4 | 4.75 | 5.54 | 100 | N |
| 129000 | Pyrene | µg/kg | 1 | 2.07 | 2.07 | 100 | N |
| ***PAHs*** | | | | | | | |
| 83329 | Acenaphthene | µg/kg | 4 | 10.3 | 13.2 | 100 | N |
| 208968 | Acenaphthylene | µg/kg | 4 | 12.8 | 16.2 | 100 | N |
| 120127 | Anthracene | µg/kg | 1 | 0.98 | 0.98 | 100 | N |
| 56553 | Benzo(a)anthracene | µg/kg | 3 | 0.88 | 1.12 | 100 | N |
| 50328 | Benzo(a)pyrene | µg/kg | 2 | 1.1 | 1.4 | 100 | N |
| 205992 | Benzo(b)fluoranthene | µg/kg | 3 | 1.43 | 1.82 | 100 | N |
| 191242 | Benzo(g,h,i)perylene | µg/kg | 3 | 13.8 | 17.5 | 100 | N |
| 207089 | Benzo(k)fluoranthene | µg/kg | 3 | 1.1 | 1.4 | 100 | N |
| 218019 | Chrysene | µg/kg | 1 | 1.68 | 1.68 | 100 | N |
| 53703 | Dibenz(a,h)anthracene | µg/kg | 4 | 1.54 | 1.96 | 100 | N |

**Table 7-12**
**Non-detected Chemicals for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| CAS # | Parameter Name | Units | Number of Samples | Minimum MDL | Maximum MDL | TSV | Maximum Detection Limit Exceeds TSV |
|---|---|---|---|---|---|---|---|
| 206440 | Fluoranthene | µg/kg | 1 | 2.38 | 2.38 | 100 | N |
| 86737 | Fluorene | µg/kg | 4 | 1.43 | 1.82 | 100 | N |
| 193395 | Indeno(1,2,3-cd)pyrene | µg/kg | 2 | 0.77 | 0.98 | 100 | N |
| 91203 | Naphthalene | µg/kg | 4 | 8.69 | 11.1 | 100 | N |
| 85018 | Phenanthrene | µg/kg | 1 | 0.84 | 0.84 | 100 | N |
| 129000 | Pyrene | µg/kg | 1 | 1.26 | 1.26 | 100 | N |
| ***Explosives*** | | | | | | | |
| 99354 | 1,3,5-Trinitrobenzene | mg/kg | 4 | 0.14 | 0.14 | -- | NS |
| 99650 | 1,3-Dinitrobenzene | mg/kg | 4 | 0.159 | 0.159 | -- | NS |
| 118967 | 2,4,6-Trinitrotoluene | mg/kg | 4 | 0.167 | 0.167 | -- | NS |
| 121142 | 2,4-Dinitrotoluene | mg/kg | 4 | 0.142 | 0.142 | -- | NS |
| 606202 | 2,6-Dinitrotoluene | mg/kg | 4 | 0.25 | 0.25 | -- | NS |
| 35572782 | 2-Amino-4,6-dinitrotoluene | mg/kg | 4 | 0.151 | 0.151 | -- | NS |
| 88722 | 2-Nitrotoluene | mg/kg | 4 | 0.266 | 0.266 | -- | NS |
| 99081 | 3-Nitrotoluene | mg/kg | 4 | 0.184 | 0.184 | -- | NS |
| 1946510 | 4-Amino-2,6-dinitrotoluene | mg/kg | 4 | 0.162 | 0.162 | -- | NS |
| 99990 | 4-Nitrotoluene | mg/kg | 4 | 0.251 | 0.251 | -- | NS |
| 2691410 | HMX (Octahydro-1,3,5,7-tetranitro-1,3,5, | mg/kg | 4 | 0.229 | 0.229 | -- | NS |
| 98953 | Nitrobenzene | mg/kg | 4 | 0.102 | 0.102 | 40,000 | N |
| 121824 | RDX (Hexahydro-1,3,5-trinitro-1,3,5-tria | mg/kg | 4 | 0.131 | 0.131 | -- | NS |
| ***Nitroglycerin/PETN*** | | | | | | | |
| 628966 | Nitroglycerin | mg/kg | 4 | 0.181 | 0.247 | -- | NS |
| 78115 | PETN | mg/kg | 4 | 0.249 | 0.339 | -- | NS |

**Notes:**
CAS = Chemical Abstracts Service
TAL = Target Analyte List
TCL = Target Compound List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
PAH = Polynuclear Aromatic Hydrocarbon
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
NS = No screening value
TSV = Toxicity Screening Value
MDL = Method Detection Limit

**Table 7-13**
**Preliminary Soil Invertebrate Risk Characterization for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| Chemicals | CAS # | MDC for Surface Soil | Direct Contact TRV | TRV Source[A] | HQ |
|---|---|---|---|---|---|
| **TAL Metals (mg/kg)** | | | | | |
| Aluminum | 7429-90-5 | 32,200 | 1 | BTAG 1995 | **32,200** |
| Antimony | 7440-36-0 | 102 | 78 | ECO SSL 2005 | **1.3** |
| Arsenic | 7440-38-2 | 5 | 328 | BTAG 1995 | <1 |
| Barium | 7440-39-3 | 149 | 330 | ECO SSL 2005 | <1 |
| Beryllium | 7440-41-7 | 0.60 | 40 | ECO SSL 2005 | <1 |
| Calcium | 7440-70-2 | 4,440 | NV | -- | NC |
| Chromium | 7440-47-3 | 268 | 0.0075 | BTAG 1995 | **35,733** |
| Cobalt | 7440-48-4 | 75 | 200 | BTAG 1995 | <1 |
| Copper | 7440-50-8 | 27 | 50 | ORNL 1997a | <1 |
| Iron | 7439-89-6 | 78,700 | 12 | BTAG 1995 | **6,558** |
| Lead | 7439-92-1 | 175 | 1,700 | ECO SSL 2005 | <1 |
| Manganese | 7439-96-5 | 3,200 | 330 | BTAG 1995 | **10** |
| Mercury | 7439-97-6 | 0.16 | 0.058 | BTAG 1995 | **3** |
| Nickel | 7440-02-0 | 13 | 100 | ORNL 1997a | <1 |
| Selenium | 7782-49-2 | 0.69 | 1.8 | BTAG 1995 | <1 |
| Silver | 7440-22-4 | 0.11 | 20 | CCME 2004 | <1 |
| Thallium | 7440-28-0 | 0.30 | 1 | CCME 2004 | <1 |
| Vanadium | 7440-62-2 | 84 | 58 | BTAG 1995 | **1.4** |
| Zinc | 7440-66-6 | 895 | 100 | ORNL 1997a | **9** |
| **TCL Pesticides/PCBs (µg/kg)** | | | | | |
| Aroclor 1254 | 11097-69-1 | 12 | 500 | CCME 2004 | <1 |
| **TCL VOCs (µg/kg)** | | | | | |
| 2-Butanone | 78-93-3 | 30 | NV | -- | NC |
| Acetone | 67-64-1 | 100 | NV | -- | NC |
| Ethylbenzene | 100-41-4 | 0.66 | 100 | BTAG 1995 | <1 |
| Methylene chloride | 75-09-2 | 6.5 | 300 | BTAG 1995 | <1 |
| Toluene | 108-88-3 | 1.3 | 100 | BTAG 1995 | <1 |
| Trichloroethene | 79-01-6 | 1.9 | 300 | BTAG 1995 | <1 |
| **TCL SVOCs (µg/kg)** | | | | | |
| 2-Methylnaphthalene | 91-57-6 | 6 | NV | -- | NC |
| 4-Chloro-3-Methylphenol | 59-50-7 | 46 | NV | -- | NC |
| Acenaphthylene | 208-96-8 | 4 | 100 | BTAG 1995 | <1 |
| Acetophenone | 98-86-2 | 36 | NV | -- | NC |
| Bis(2-ethylhexyl)phthalate | 117-81-7 | 480 | NV | -- | NC |
| Butylbenzylphthalate | 85-68-7 | 44 | NV | -- | NC |
| Caprolactam | 105-60-2 | 43 | NV | -- | NC |
| Diethylphthalate | 84-66-2 | 19 | NV | -- | NC |
| Di-n-butylphthalate | 84-74-2 | 360 | NV | -- | NC |
| Naphthalene | 91-20-3 | 4 | 100 | BTAG 1995 | <1 |
| **PAHs (µg/kg)** | | | | | |
| Anthracene | 120-12-7 | 1.9 | 100 | BTAG 1995 | <1 |
| Benzo(a)anthracene | 56-55-3 | 7.1 | 100 | BTAG 1995 | <1 |
| Benzo(a)pyrene | 50-32-8 | 18 | 100 | BTAG 1995 | <1 |
| Benzo(b)fluoranthene | 205-99-2 | 14 | 100 | BTAG 1995 | <1 |
| Benzo(g,h,i)perylene | 191-24-2 | 27 | 100 | BTAG 1995 | <1 |
| Benzo(k)fluoranthene | 207-08-9 | 8.5 | 100 | BTAG 1995 | <1 |
| Chrysene | 218-01-9 | 11 | 100 | BTAG 1995 | <1 |
| Fluoranthene | 206-44-0 | 57 | 100 | BTAG 1995 | <1 |
| Indeno(1,2,3-cd)pyrene | 193-39-5 | 11 | 100 | BTAG 1995 | <1 |
| Phenanthrene | 85-01-8 | 24 | 100 | BTAG 1995 | <1 |
| Pyrene | 129-00-0 | 82 | 100 | BTAG 1995 | <1 |
| **Cyanide (mg/kg)** | | | | | |
| Cyanide | 57-12-5 | 0.17 | 0.005 | BTAG 1995 | **34** |

**Table 7-13**
**Preliminary Soil Invertebrate Risk Characterization for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

**Notes:**

CAS = Chemical Abstracts Service
TAL = Target Analyte List
TCL = Target Compound List
VOC = Volatile Organic Compound
SVOC = Semivolatile Organic Compound
mg/kg = Milligram Per Kilogram
µg/kg = Microgram Per Kilogram
MDC = Maximum Detected Concentration
TRV = Toxicity Reference Value
HQ = Hazard Quotient

NV = No value
NC = Not Calculated no TRV available
BTAG = Biological Technical Assistance Group Screening Level, Draft 1995

[A] =
Region III BTAG (USEPA 1995)
Oak Ridge National Laboratory (Efroymson et al. 1997a)
USEPA Ecological SSL (ECO-SSL 2005)
Canadian Environmental Quality Guidelines (CCME 2004)

**Table 7-14**
**Inorganic COPEC/Background Comparison for SWMU 57**
**SSP Report**
**Radford Army Ammunition Plant, Radford, Virginia**

| Measured Analytes | CAS-Number | MDC for Surface Soil | Background Point Estimate [A] | Maximum Concentration Exceeds Background Point Estimate |
|---|---|---|---|---|
| **TAL METALS (mg/kg)** | | | | |
| ALUMINUM | 7429-90-5 | 32,200 | 40,041 | N |
| ANTIMONY | 7440-36-0 | 102.00 | -- | NBE |
| ARSENIC | 7440-38-2 | 5.10 | 16 | N |
| CADMIUM | 7440-43-9 | 27.00 | 0.69 | **Y** |
| CHROMIUM | 7440-47-3 | 268 | 65 | **Y** |
| IRON | 7439-89-6 | 78,700 | 50,962 | **Y** |
| LEAD | 7439-92-1 | 175 | 27 | **Y** |
| MANGANESE | 7439-96-5 | 3,200 | 2,543 | **Y** |
| MERCURY | 7439-97-6 | 0.16 | 0.13 | **Y** |
| NICKEL | 7440-02-0 | 13 | 63 | N |
| SELENIUM | 7782-49-2 | 0.69 | -- | NBE |
| VANADIUM | 7440-62-2 | 84 | 108 | N |
| ZINC | 7440-66-6 | 895 | 202 | **Y** |

**Notes:**
CAS = Chemical Abstracts Service
mg/kg = Milligram Per Kilogram
MDC = Maximum Detected Concentration
[A] = Facility-Wide Background Point Estimate as
Reported in the Facility-Wide Background Study Report (IT 2001a)
NBE = No Background Point Estimate Available

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**Table 7-15**
**Preliminary/Refined Wildlife Risk Characterization**
**Screening Level Ecological Risk Assessment**
**SSP Report - SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

**Preliminary Assessment**

| Parameter | Maximum Soil Concentration (mg/kg) | Wildlife TRV-Based Soil Concentrations | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | American Robin | | | | Red-tailed Hawk | | | | Meadow Vole | | | | Red Fox | | | | Short-tailed Shrew | | | |
| | | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ |
| **Metals** | | | | | | | | | | | | | | | | | | | | | |
| ARSENIC | 5 | 1.39E+01 | <1 | 3.46E+01 | <1 | 3.89E+02 | <1 | 9.71E+02 | <1 | 8.99E+00 | <1 | 8.99E+01 | <1 | 1.34E+00 | 3.7 | 1.34E+01 | <1 | 3.02E-01 | 16.6 | 3.02E+00 | 1.7 |
| CADMIUM | 27 | 6.75E-01 | 40.0 | 9.31E+00 | 2.9 | 3.91E+02 | <1 | 5.40E+03 | <1 | 1.50E+01 | 1.8 | 1.50E+02 | <1 | 1.48E+01 | 1.8 | 1.48E+02 | <1 | 1.16E+00 | 23.3 | 1.16E+01 | 2.3 |
| CHROMIUM | 268 | 5.27E+00 | 50.8 | 2.64E+01 | 10.2 | 2.70E+01 | 9.9 | 1.35E+02 | 2.0 | 8.65E+05 | <1 | 8.65E+06 | <1 | 2.38E+04 | <1 | 2.38E+05 | <1 | 1.78E+04 | <1 | 1.78E+05 | <1 |
| COPPER | 27 | 1.38E+02 | <1 | 1.82E+02 | <1 | 7.11E+02 | <1 | 9.33E+02 | <1 | 8.34E+02 | <1 | 1.10E+03 | <1 | 7.43E+01 | <1 | 9.78E+01 | <1 | 9.57E+01 | <1 | 1.26E+02 | <1 |
| LEAD | 175 | 5.18E+00 | 33.8 | 5.18E+01 | 3.4 | 5.69E+02 | <1 | 5.69E+03 | <1 | 1.05E+03 | <1 | 1.05E+04 | <1 | 4.97E+02 | <1 | 4.97E+03 | <1 | 5.45E+01 | 3.2 | 5.45E+02 | <1 |
| MERCURY | 0.16 | 6.08E-01 | <1 | 1.22E+00 | <1 | 2.62E-01 | <1 | 5.23E-01 | <1 | 4.27E-01 | <1 | 1.74E+00 | <1 | 3.93E-03 | 40.7 | 1.60E-02 | 10.0 | 8.31E-02 | 1.9 | 3.39E-01 | <1 |
| NICKEL | 13 | 3.86E+02 | <1 | 5.33E+02 | <1 | 1.95E+03 | <1 | 2.70E+03 | <1 | 5.54E+03 | <1 | 1.11E+04 | <1 | 3.23E+02 | <1 | 6.46E+02 | <1 | 2.86E+02 | <1 | 5.71E+02 | <1 |
| SELENIUM | 0.69 | 3.13E-01 | 2.2 | 6.27E-01 | 1.1 | 4.03E+00 | <1 | 8.06E+00 | <1 | 2.73E+00 | <1 | 4.50E+00 | <1 | 6.09E-01 | 1.1 | 1.00E+00 | <1 | 5.27E-01 | 1.3 | 8.70E-01 | <1 |
| SILVER | 0.11 | 2.31E+01 | <1 | 1.73E+02 | <1 | 8.34E+02 | <1 | 6.26E+03 | <1 | 1.72E+03 | <1 | 1.72E+04 | <1 | 2.89E+02 | <1 | 2.89E+03 | <1 | 5.85E+01 | <1 | 5.85E+02 | <1 |
| ZINC | 895 | 1.40E+01 | 64.0 | 1.26E+02 | 7.1 | 2.19E+01 | 40.8 | 1.98E+02 | 4.5 | 3.38E+03 | <1 | 6.75E+03 | <1 | 8.28E+01 | 10.8 | 1.66E+02 | 5.4 | 4.22E+02 | 2.1 | 8.44E+02 | 1.1 |
| **PCBs** | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1254 | 0.012 | 8.69E-03 | 1.4 | 8.69E-02 | <1 | 1.53E+00 | <1 | 1.53E+01 | <1 | 1.17E+01 | <1 | 1.17E+02 | <1 | 5.33E-02 | <1 | 5.33E-01 | <1 | 3.42E-03 | 3.5 | 3.42E-02 | <1 |
| **SVOCs/PAHs** | | | | | | | | | | | | | | | | | | | | | |
| ACENAPHTHYLENE | 0.004 | NC | | NC | | NC | | NC | | 1.38E+04 | <1 | 6.90E+04 | <1 | 9.71E+03 | <1 | 4.85E+04 | <1 | 9.32E+02 | <1 | 4.66E+03 | <1 |
| ANTHRACENE | 0.0019 | NC | | NC | | NC | | NC | | 5.23E+04 | <1 | 5.23E+05 | <1 | 2.14E+04 | <1 | 2.14E+05 | <1 | 2.20E+03 | <1 | 2.20E+04 | <1 |
| BENZO(A)ANTHRACENE | 0.0071 | NC | | NC | | NC | | NC | | 4.78E+01 | <1 | 4.78E+02 | <1 | 2.55E+00 | <1 | 2.55E+01 | <1 | 1.43E+00 | <1 | 1.43E+01 | <1 |
| BENZO(A)PYRENE | 0.018 | 3.56E+00 | <1 | 1.78E+01 | <1 | 9.73E+00 | <1 | 4.87E+01 | <1 | 1.66E+02 | <1 | 1.66E+03 | <1 | 3.48E+00 | <1 | 3.48E+01 | <1 | 4.23E+00 | <1 | 4.23E+01 | <1 |
| BENZO(B)FLUORANTHENE | 0.014 | NC | | NC | | NC | | NC | | 1.68E+02 | <1 | 1.68E+03 | <1 | 2.87E+00 | <1 | 2.87E+01 | <1 | 5.12E+00 | <1 | 5.12E+01 | <1 |
| BENZO(G,H,I)PERYLENE | 0.027 | NC | | NC | | NC | | NC | | 8.86E+01 | <1 | 4.43E+02 | <1 | 1.87E-01 | <1 | 9.34E-01 | <1 | 2.84E+00 | <1 | 1.42E+01 | <1 |
| BENZO(K)FLUORANTHENE | 0.0085 | NC | | NC | | NC | | NC | | 1.85E+03 | <1 | 1.85E+04 | <1 | 3.16E+01 | <1 | 3.16E+02 | <1 | 5.65E+01 | <1 | 5.65E+02 | <1 |
| CHRYSENE | 0.011 | NC | | NC | | NC | | NC | | 2.37E+03 | <1 | 2.37E+04 | <1 | 1.24E+02 | <1 | 1.24E+03 | <1 | 5.65E+01 | <1 | 5.65E+02 | <1 |
| FLUORANTHENE | 0.057 | NC | | NC | | NC | | NC | | 4.11E+03 | <1 | 2.05E+04 | <1 | 7.02E+02 | <1 | 3.51E+03 | <1 | 1.24E+02 | <1 | 6.22E+02 | <1 |
| INDENO(1,2,3-CD)PYRENE | 0.011 | NC | | NC | | NC | | NC | | 1.92E+03 | <1 | 1.92E+04 | <1 | 1.15E+01 | <1 | 1.15E+02 | <1 | 4.26E+01 | <1 | 4.26E+02 | <1 |
| PHENANTHRENE | 0.024 | 8.17E+00 | <1 | 4.08E+01 | <1 | 7.63E+02 | <1 | 3.81E+03 | <1 | 7.32E+02 | <1 | 3.66E+03 | <1 | 2.98E+02 | <1 | 1.49E+03 | <1 | 3.22E+01 | <1 | 1.61E+02 | <1 |
| PYRENE | 0.082 | NC | | NC | | NC | | NC | | 1.07E+03 | <1 | 5.35E+03 | <1 | 1.85E+02 | <1 | 9.25E+02 | <1 | 3.17E+01 | <1 | 1.58E+02 | <1 |

**Refined Assessment**

| Parameter | Maximum Soil Concentration (mg/kg) | Wildlife TRV-Based Soil Concentrations | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | American Robin | | | | Red-tailed Hawk | | | | Meadow Vole | | | | Red Fox | | | | Short-tailed Shrew | | | |
| | | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ | NOAEL | HQ | LOAEL | HQ |
| **Metals** | | | | | | | | | | | | | | | | | | | | | |
| ARSENIC | 5.0 | 6.04E+01 | <1 | 1.51E+02 | <1 | 8.09E+05 | <1 | 2.02E+06 | <1 | 1.65E+01 | <1 | 1.65E+02 | <1 | 8.23E+02 | <1 | 8.23E+03 | <1 | 1.03E+00 | 4.9 | 1.03E+01 | <1 |
| CADMIUM | 27 | 3.08E+00 | 8.8 | 4.25E+01 | <1 | 8.15E+05 | <1 | 1.12E+07 | <1 | 2.75E+01 | <1 | 2.75E+02 | <1 | 9.95E+03 | <1 | 9.95E+04 | <1 | 4.06E+00 | 6.6 | 4.06E+01 | <1 |
| CHROMIUM | 268 | 2.18E+01 | 12.3 | 1.09E+02 | 2.5 | 5.62E+04 | <1 | 2.81E+05 | <1 | 1.59E+06 | <1 | 1.59E+07 | <1 | 1.45E+07 | <1 | 1.45E+08 | <1 | 5.98E+04 | <1 | 5.98E+05 | <1 |
| LEAD | 175 | 2.17E+01 | 8.1 | 2.17E+02 | <1 | 1.19E+06 | <1 | 1.19E+07 | <1 | 1.92E+03 | <1 | 1.92E+04 | <1 | 3.11E+05 | <1 | 3.11E+06 | <1 | 1.83E+02 | <1 | 1.83E+03 | <1 |
| MERCURY | 0.16 | 2.72E+00 | <1 | 5.45E+00 | <1 | 5.45E+02 | <1 | 1.09E+03 | <1 | 7.83E-01 | <1 | 3.20E+00 | <1 | 2.40E+00 | <1 | 9.78E+00 | <1 | 2.84E-01 | <1 | 1.16E+00 | <1 |
| SELENIUM | 0.69 | 1.42E+00 | <1 | 2.84E+00 | <1 | 8.39E+03 | <1 | 1.68E+04 | <1 | 5.00E+00 | <1 | 8.25E+00 | <1 | 3.79E+02 | <1 | 6.25E+02 | <1 | 1.82E+00 | <1 | 3.01E+00 | <1 |
| ZINC | 895 | 6.32E+01 | 14.2 | 5.71E+02 | 1.6 | 4.56E+04 | <1 | 4.12E+05 | <1 | 6.19E+03 | <1 | 1.24E+04 | <1 | 5.06E+04 | <1 | 1.01E+05 | <1 | 1.46E+03 | <1 | 2.92E+03 | <1 |
| **PCBs** | | | | | | | | | | | | | | | | | | | | | |
| Aroclor 1254 | 0.012 | 4.00E-02 | <1 | 4.00E-01 | <1 | 3.18E+03 | <1 | 3.18E+04 | <1 | 2.14E+01 | <1 | 2.14E+02 | <1 | 3.25E+01 | <1 | 3.25E+02 | <1 | 1.21E-02 | <1 | 1.21E-01 | <1 |

**Notes:**
NC = Not Calculated no TRV available
TRV = Toxicity Reference Value
HQ = Hazard Quotient
LOAEL = Lowest observable adverse effects level
NOAEL = No observable adverse effects level
mg/kg = Milligram Per Kilogram
PCB = Polychlorinated Biphenyls
SVOC = Semi-Volatile Organic Compound
PAH = Poly-Aromatic Hydrocarbon

[shaded box] = Indicate HQs greater than 1.0

Refer to Appendix I for detailed description of model parameters and results

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# APPENDIX E

# FORMS

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**Form E-1**
**Work Plan Revision Form**
**MWP Addendum 021 – RFI for SWMU 57**
**Radford Army Ammunition Plant, Radford, Virginia**

| | |
|---|---|
| SITE DESIGNATION / LOCATION: | Section: ____________________ |
| Radford Army Ammunition Plant | Addendum: ____________________ |
| Radford, VA | Version: ____________________ |
| | Effective Date: ____________________ |
| SUBJECT: | Approved by: |
| | Field Operations Leader |
| | ____________________ |
| | Date: ____________________ |
| | Concurrence: |
| | Project Manager |
| | ____________________ |
| | Date ____________________ |
| | Sheet ______ of ______ |

**Form E-2**
**Worker Acknowledgement Form**
**SWMU 57 RCRA Facility Investigation**
**Radford Army Ammunition Plant, Radford, Virginia**

**Document:** Master Work Plan/QAP/HSP and Work Plan Addendum 021

**Version:** Final

**Project:** Radford Army Ammunition Plant

**Location:** Pond by Buildings 4931 and 4928, SWMU 57

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

**Site Personnel:**

| Name (please print) | Signature | Date |
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