RADFORD ARMY AMMUNITION PLANT, VIRGINIA

SWMU 54 Monitored Natural Attenuation Sampling
Year Three Report

Prepared for:
USACE, Baltimore District
10 South. Howard St.
Baltimore, MD 21201

Prepared by:
CB&I Federal Services LLC.
4696 Millennium Drive
Belcamp, MD 21017

Draft Document

October 2014

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

June 16, 2015

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

William Barnett
Environmental Manager
BAE Systems Ordnance Systems, Inc.
Radford Army Ammunition Plant
P.O. Box 1
Radford, VA 24141-0100

VIA Electronic Mail

Re: Radford Army Ammunition Plant, Radford, Virginia
SWMU 54 Monitored Natural Attenuation Sampling
Year Three Report

Dear Mr. McKenna and Mr. Barnett:

The U.S. Environmental Protection Agency (EPA) and Virginia Department of Environmental Quality (VDEQ) have reviewed the U.S. Army's (Army's) SWMU 54, Monitored Natural Attenuation (MNA) Sampling Year Three Report. SWMU 54 is located at the Radford Army Ammunition Plant (RFAAP) in Radford, Virginia. Based upon our review, the MNA Report is approved, and in accordance with Part II. (E)(5) of RFAAP's Corrective Action Permit, the MNA Report is considered final. If you have any questions, please call me at 410-305-2779.

Sincerely,

Erich Weissbart

Erich Weissbart, P.G.
RCRA Project Manager
Office of Remediation (3LC20)

c: James Cutler, VDEQ

BAE SYSTEMS

ORDNANCE SYSTEMS INC.
Radford Army Ammunition Plant
4050 Pepper's Ferry Road
Radford Virginia 24141

November 7, 2014

Mr. Erich Weissbart, P.G.
U. S. Environmental Protection Agency, Region III
Land and Chemicals Division (3LC20)
1650 Arch Street
Philadelphia, PA 19103-2029

Mr. James L. Cutler, Jr.
Virginia Department of Environmental Quality
629 East Main Street
Richmond, VA 23219

Subject: With Certification, SWMU 54 Monitored Natural Attenuation Sampling Year Three Report
Draft Document, October 2014
EPA ID# VA1210020730

Dear Mr. Weissbart and Mr. Cutler:

Enclosed is the certification for the subject documents that were sent to you on November 4, 2014. Also enclosed is the November 4, 2014 transmittal email.

Please coordinate with and provide any questions or comments to myself at 540 639 7785 or Mr. Jim McKenna, ACO Staff at 540 731 5782.

Sincerely,

Jay Stewart
Environmental Manager
BAE Systems, Ordnance Systems Inc

c: Aziz Farahmand
Virginia Department of Environmental Quality
Blue Ridge Regional Office
3019 Peters Creek Road
Roanoke, VA 24019

Rich Mendoza
U.S. Army Environmental Command
Cleanup and Munitions Response Division
2450 Connell Road, Bldg 2264, 1st Floor, Room 126
Fort Sam Houston, TX 78234-7664

14-0900-143

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

bc: Administrative File
J. McKenna, ACO Staff
Rob Davie-ACO Staff

Coordination: J. McKenna

Concerning the following:

Radford Army Ammunition Plant
SWMU 54
Monitored Natural Attenuation
Sampling Year Three Report
Draft Document, October 2014

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: Luis A. Ortiz
TITLE: Lieutenant Colonel, US Army
Commanding

SIGNATURE: _____

PRINTED NAME: William M. Barnett
TITLE: General Manager
BAE Systems

Alberts, Matt (US SSA)

From: Mckenna, James J CIV (US) <james.j.mckenna16.civ@mail.mil>
Sent: Tuesday, November 04, 2014 2:50 PM
To: Weissbart.Erich@epamail.epa.gov; Cutler,Jim
Cc: Meyer, Tom NAB02; Mendoza, Richard R Jr CIV (US); aziz.farahmand@deq.virginia.gov; Bogucki, MaryAnn (US SSA); Alberts, Matt (US SSA); Stewart, Jay (US SSA); Davie, Robert N.; Ortiz, Luis (RFAAP); Leahy, Timothy
Subject: FW: Draft SWMU 54 Year 3 MNA Report

Erich, Jim C., All:

Note the contractor will ship the subject document with a copy of this email to the POCs and tracking numbers below. Certification will follow by separate letter.

Jim McKenna	1Z66V7170192081740
Tom Meyer	1Z66V7170195410656
Rich Mendoza	1Z66V7170198915061
Erich Weissbart-Ft. Meade	1Z66V7170198417073
Erich Weissbart-Philadelphia	1Z66V7170195652681
Jim Cutler	1Z66V7170198317896
Aziz Farahmand	1Z66V7170195668709
Mary-Ann Bogucki	1Z66V7170195121110

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

Jim McKenna

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LIST OF APPENDICES

The Appendices are included on a CD.

LIST OF ACRONYMS AND ABBREVIATIONS

°C .....degrees Celsius
µg/L.....micrograms per liter
2,4,6-TNT 2,4,6-trinitrotoluene
2ADNT 2-amino-4,6-dinitrotoluene
4ADNT 4-amino-2,6-dinitrotoluene
CMO .....Corrective Measures Objective
CMS .....Corrective Measures Study
COC .....Chain-of-Custody
COI.....Contaminant of Interest
COPC .....Chemical of Potential Concern
DIC.....Dissolved Inorganic Carbon
DIUF .....De-ionized Ultra-filtered
DNT .....Dinitrotoluene
DNX.....hexahydro-1,3,5-dinitroso-5-nitro-1,3,5-triazine
DO.....Dissolved Oxygen
ft .....foot or feet
ft/day .....feet per day
ft/year .....feet per year
HHRA .....Human Health Risk Assessment
HI .....Hazard Index
IM.....Interim Measure
IMWP.....Interim Measures Work Plan
MCL.....Maximum Contaminant Level
mg/kg .....milligrams per kilogram
mg/L.....milligrams per liter
mL/min.....milliliters per minute
MNA .....Monitored Natural Attenuation
MNX hexahydro-1-nitroso-3,5-dinitro-1,2,5-triazine
MS.....Matrix Spike
mS/cm .....millisiemens per centimeter
MSD.....Matrix Spike Duplicate
msl.....mean sea level
mV.....millivolts
MWP.....Master Work Plan
NG.....Nitroglycerin
NTU .....Nephelometric Turbidity Unit
ORP.....Oxidation-Reduction Potential
PID .....Photoionization Detector
QA/QC .....Quality Assurance/Quality Control
QC.....Quality Control
RCRA.....Resource Conservation and Recovery Act
RDX .....cyclotrimethylenetrinitramine
RFAAP.....Radford Army Ammunition Plant
RFI .....RCRA Facility Investigation
RG.....Remedial Goal
Shaw.....Shaw Environmental, Inc.
SL.....Screening Level
SOP .....Standard Operating Procedure
SWMU .....Solid Waste Management Unit
TNT.....Trinitrotoluene
TNX hexhydro-1,3,5-trinitroso-1,3,5-triazine
TOC.....Total Organic Carbon
URS.....URS Corporation
USEPA.....U.S. Environmental Protection Agency
VI .....Verification Investigation

1.0 INTRODUCTION

Shaw Environmental, Inc. (Shaw) was contracted by the U.S. Army Corps of Engineers to perform a Monitored Natural Attenuation (MNA) at Solid Waste Management Unit (SWMU) 54 (RAAP-014), the Propellant Burning Ash Disposal Area, at Radford Army Ammunition Plant (RFAAP), Radford, VA. This report contains a description of the activities involved in the ninth through twelfth quarterly rounds of groundwater sampling conducted in 2013 through 2014. This report includes an analysis of the results of the ninth through twelfth quarter's data and a summary of the third year of sampling.

1.1 Purpose and Scope

Based on the *Final SWMU 54 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) / Corrective Measures Study (CMS) Report* (URS, 2008), soil interim measures (IMs) were performed at SWMU 54. The IMs were conducted to mitigate the threat of a contaminant release, migration, and/or exposure to the public and the environment in accordance with Part II(D)(11-21) IM of the *RFAAP Corrective Action Permit* (USEPA, 2000). The IMs included:

1. Site Preparation.
2. Excavation.
3. Waste Characterization & Off-site Disposal.
4. Confirmation Sampling.
5. Site Restoration.

The soil IMs have been completed, and this report details the implementation of the groundwater MNA IMs approved in the *Final SWMU 54 MNA Interim Measures Work Plan (IMWP)* (Shaw, 2011a) including:

Periodic sampling from existing groundwater monitoring wells.

The Corrective Measures Objectives (CMOs) and Remedial Goals (RGs) were developed in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). The site-specific CMOs for SWMU 54 Area A are to mitigate further leaching of explosives constituents from soil-to-groundwater at levels that would potentially increase observed concentrations and adversely impact future beneficial use of groundwater; and to the extent practicable, a goal of restoring site groundwater to the most beneficial use. The site-specific CMOs for SWMU 54 Area B are to mitigate the potential hypothetical future risks that have been identified for exposure to soil under a future construction worker scenario; and to prevent leaching of contaminants of concern from soil-to-groundwater at levels that would potentially adversely impact future beneficial use of groundwater. The site-specific CMOs for Area A and Area B have been met through the soil excavation and off-site disposal completed in 2010.

The objectives of the MNA program are to:

- Measure and track the reduction of:
  - 2,4,6-trinitrotoluene (2,4,6-TNT), dinitrotoluene (DNT)-mixture, cyclotrimethylenetrinitramine (RDX), and perchlorate to levels below the RGs as defined in **Table 1-1**.

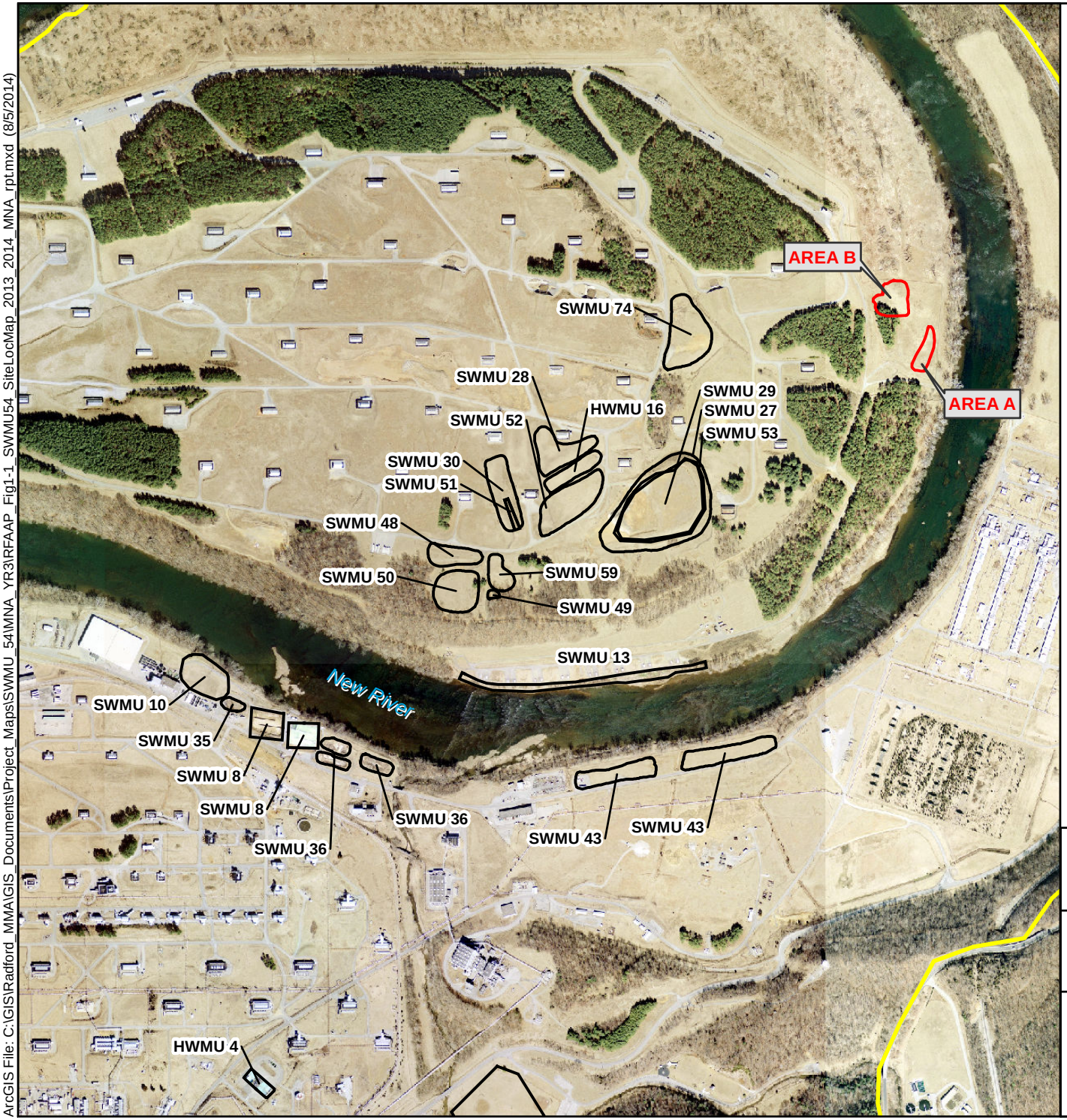
Table 1-1
SWMU 54 Groundwater Remedial Goals

Chemical of Interest	Groundwater RG (mg/L)	Groundwater RG Source(*)
2,4,6-TNT	0.00782	RG
DNT Mixture	0.000932	RG
RDX	0.0061	RG
Perchlorate	0.0109	RG

*RGs were calculated using target risk 1E-5 for the lifetime resident and a target hazard of 1 for the adult and child resident (see URS, 2008).

1.2 Site Description and Background

SWMU 54 is located within the easternmost portion of the Horseshoe Area at RFAAP. SWMU 54 consists of two contiguous disposal areas: Area A is an approximately 0.58-acre triangular shaped area in the southern portion of SWMU 54, and Area B is an approximately 1.09-acre area in the northern portion of SWMU 54 (**Figure 1-1**). SWMU 54 was reportedly used as a disposal area in the late 1970s for ash from propellant burning activities located at the Waste Propellant Burning Grounds. The site is currently undeveloped. The RFAAP Installation security fence is located along the northern and eastern boundaries of SWMU 54.



LEGEND

- SWMU 54 Boundary
- Other SWMU Boundary
- Installation Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

0 500 1,000 2,000 Feet

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FIGURE 1-1
SWMU 54
Site Location Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig1-1_SWMU54_SiteLocMap_2013_2014_MNA_rpt.mxd (8/5/2014)

2.0 PHYSICAL CHARACTERISTICS

2.1 Topography

As illustrated on **Figure 2-1**, SWMU 54 is situated on a gently sloping terrace ranging from approximately 1,716 to 1,696 feet (ft) mean sea level (msl) from east to west, respectively. The SWMU is positioned within the 100-year floodplain on a terrace feature of the New River. East of the site, the ground surface slopes steeply towards the New River (approximately 1,676 ft msl).

2.2 Surface Water

SWMU 54 is located within the easternmost portion of the Horseshoe Area at RFAAP. The SWMU is located within the floodplain of the New River. Any runoff from the SWMU will flow overland east, into the New River.

2.3 Geology

2.3.1 Regional Geology

SWMU 54 is located in the New River Valley, which crosses the Valley and Ridge Province approximately perpendicular to the regional strike of bedrock, and cross cuts Cambrian and Ordovician limestone or dolostone. Deep clay-rich residuum is prevalent in areas underlain by carbonate rocks. The valley is covered by river floodplain and terrace deposits; karst topography is dominant throughout the area. A more detailed description of the regional geology is presented in the *RFAAP MWP* (URS, 2003).

2.3.2 Site-Specific Geology

Lithologic characterization of the subsurface at SWMU 54 was performed during the advancement of soil borings and monitoring well borings at the site. Two geologic cross-sections were developed based on the logging descriptions recorded during the advancement of the soil borings. A plan view of the cross-sectional lines (Line A-A' and Line B-B') is presented on **Figure 2-1**. The geologic cross-sections are presented on **Figures 2-2 and 2-3**.

Borings advanced at the site ranged from 10 to 60 ft in depth. Depths to bedrock were directly measured at the monitoring well borings. Bedrock elevations ranged from approximately 1,716 to 1,670 ft msl, with the bedrock surface sloping to the east.

Depth to competent bedrock at the site ranges from 17 to 24 ft. A saprolitic layer, formed from *in situ* weathering of the carbonate bedrock, immediately overlies the competent bedrock. The saprolite is up to 2.5 ft in thickness.

The bedrock under the site is the Cambrian-aged Elbrook Formation, which is a thickly-bedded, blue-gray dolostone interspersed with blue-gray to white limestone. It is locally described in nearby well borings as interbedded green and maroon shale and yellowish-brown dolostone and greenish- to grayish-brown limestone and dolostone.

The unconsolidated sediment immediately overlying the saprolite consists of alluvial deposits. Alluvial deposits, consisting primarily of silty sand overly channel deposits of fine- to coarse-grained sand and gravel (river jack). These Paleo-channel deposits rest directly on the saprolite. Portions of the disposal areas contain fill material to depths of 9 to 10 ft below ground surface. A more detailed discussion of the geology and soil at RFAAP is presented in Sections 3.4 through 3.7 of the *RFAAP MWP* (URS, 2003) and in the *Facility-Wide Background Study Report* (IT, 2001).

2.4 Hydrogeology

2.4.1 Regional Hydrogeology

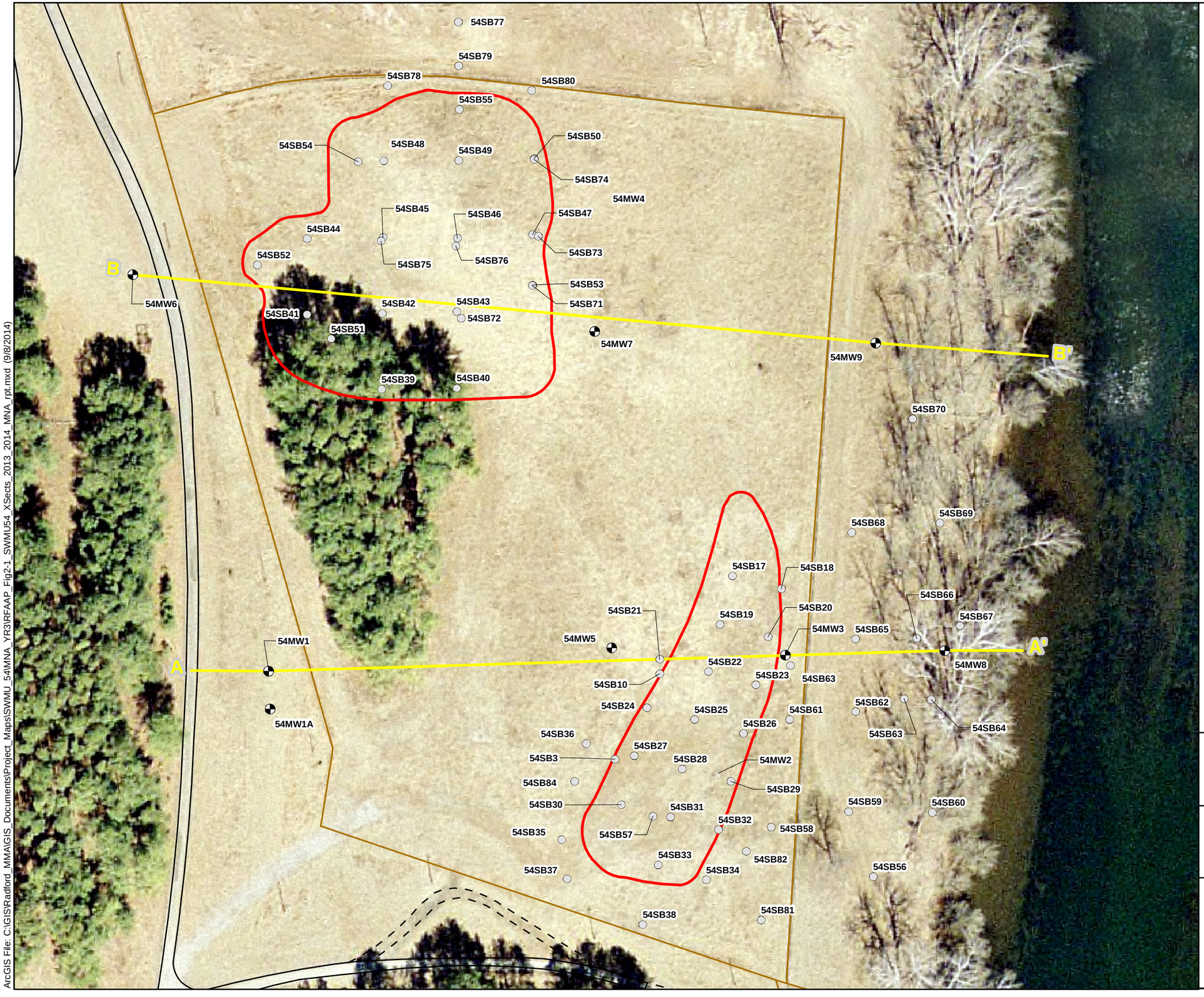
Geologically, the Appalachian Plateaus and Valley and Ridge Province encompass two major tectonic domains: the southern Appalachian Basin and the southeastern part of the Eastern Interior Basin. The hydrogeologic framework is based on generalized stratigraphic succession, with indurated sedimentary rocks of the Paleozoic age forming predominant units.

Groundwater flow paths are typically short, commonly extending no more than several miles in their longest dimension. The largest groundwater supplies are produced from the carbonate rocks, especially where they are associated with thick regolith, an important storage reservoir throughout the entire area. The regolith stores recharge that would be otherwise rapidly diverted to overland flow. It also slowly releases water to underlying carbonate aquifers. Because of the widespread distribution of carbonate rocks and associated regolith, abundant precipitation in a humid climate, and relatively steep hydraulic gradients, this region (and locally) is one of the major karstlands in the eastern United States.

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

2.4.2 Site-Specific Hydrogeology

Monitoring wells installed at SWMU 54 were screened in both the shallow, surficial aquifer, and shallow bedrock. Water levels were measured in the wells to calculate the groundwater flow direction at the site. Groundwater contour maps have been prepared using water level data collected prior to each round of groundwater sampling. The maps for the third year of monitoring are presented on **Figures 4-2**, **4-3**, **4-4, and 4-5**. Contour lines shown on the figures represent lines of equal elevation of the water table; consequently, groundwater flow direction is always perpendicular to the contour lines. Groundwater at the site tends to flow east and appears to discharge to the New River along the eastern side of the site.



ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig2-1_SWMU54_XSects_2013_2014_MNA_rpt.mxd (9/8/2014)

LEGEND

- Soil Sample Location
- Monitoring Well
- Cross Section Line
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary
- Other SWMU Boundary

N

Scale:

0 37.5 75 150 Feet

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

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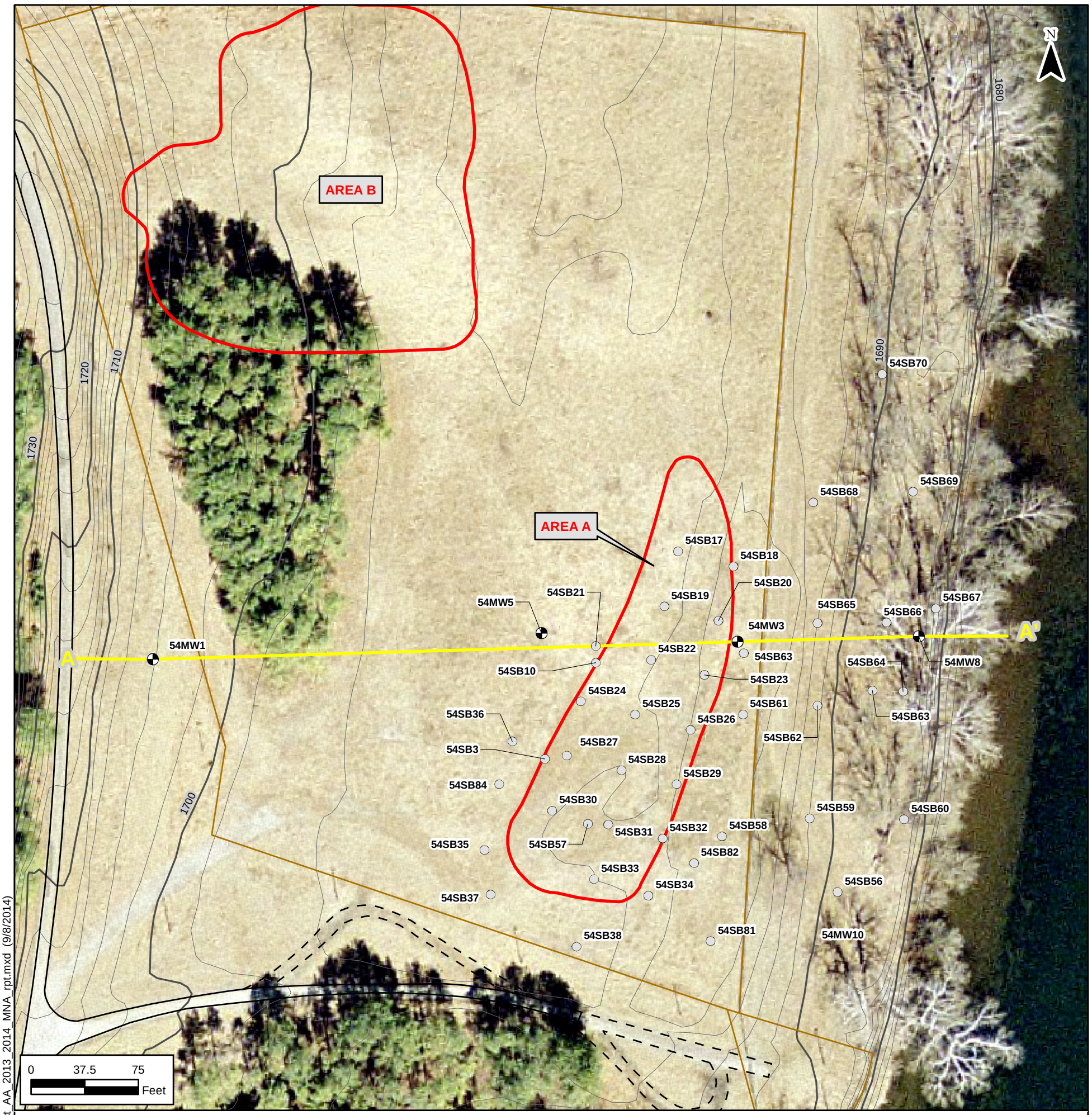
FIGURE 2-1
SWMU 54
Topography and Cross Sections
Radford Army Ammunition Plant,
Radford, VA



LEGEND

- Soil Sample Location
- Monitoring Well
- Dirt Road
- Paved Road
- Railroad
- Fence
- Cross Section Line
- 10 ft Contour Line
- SWMU 54 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Cross section A-A' profile and soil sample locations were obtained from SWMU 54 Final RCRA Facility Investigation/Corrective Measures Study Report, Volume I (September 2008, URS). Distance and elevation units are in feet. Vertical exaggeration = 5.

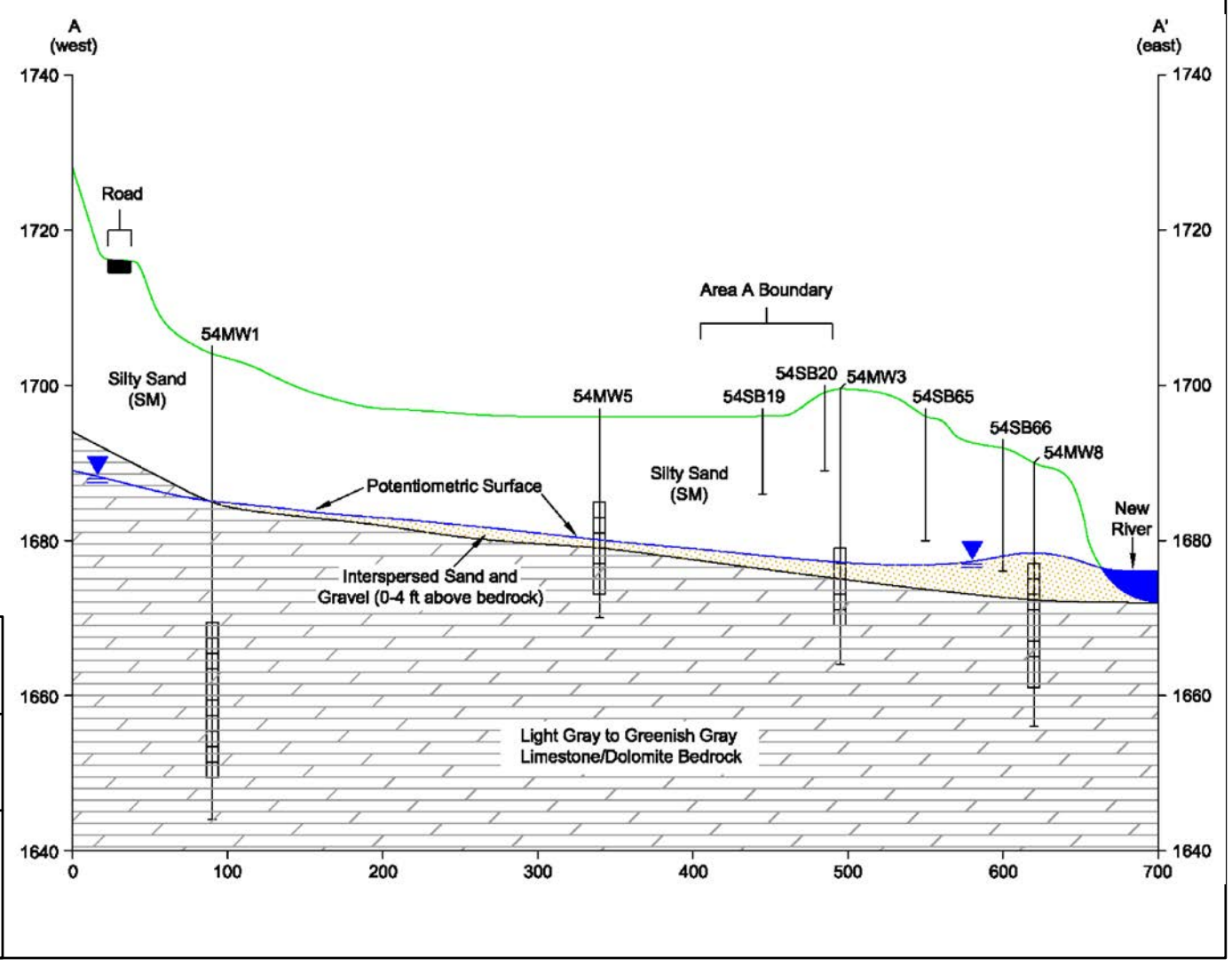


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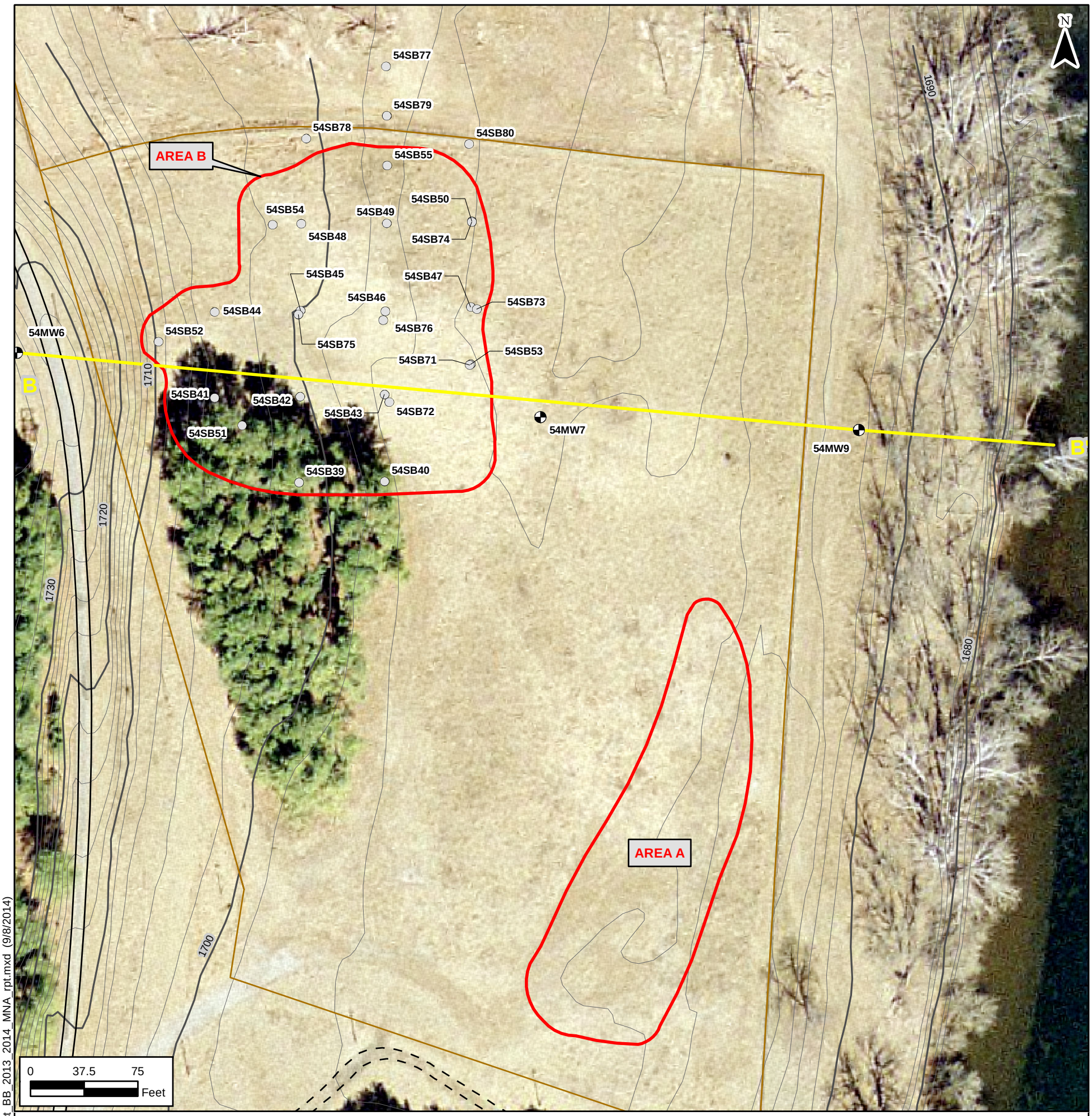
FIGURE 2-2
SWMU 54
Cross Section A-A'
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig2-2_SWMU54_XSect_AA_2013_2014_MNA_rpt.mxd (9/8/2014)



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LEGEND

- Soil Sample Location
- Monitoring Well
- Cross Section Line
- Dirt Road
- Paved Road
- Railroad
- 10 ft Contour Line
- Fence
- SWMU 54 Boundary
- Other SWMU Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County, VA Planning & GIS Services.
2) Cross section B-B' profile and soil sample locations were obtained from SWMU 54 Final RCRA Facility Investigation/Corrective Measures Study Report, Volume I (September 2008, URS). Distance and elevation units are in feet. Vertical exaggeration = 5.

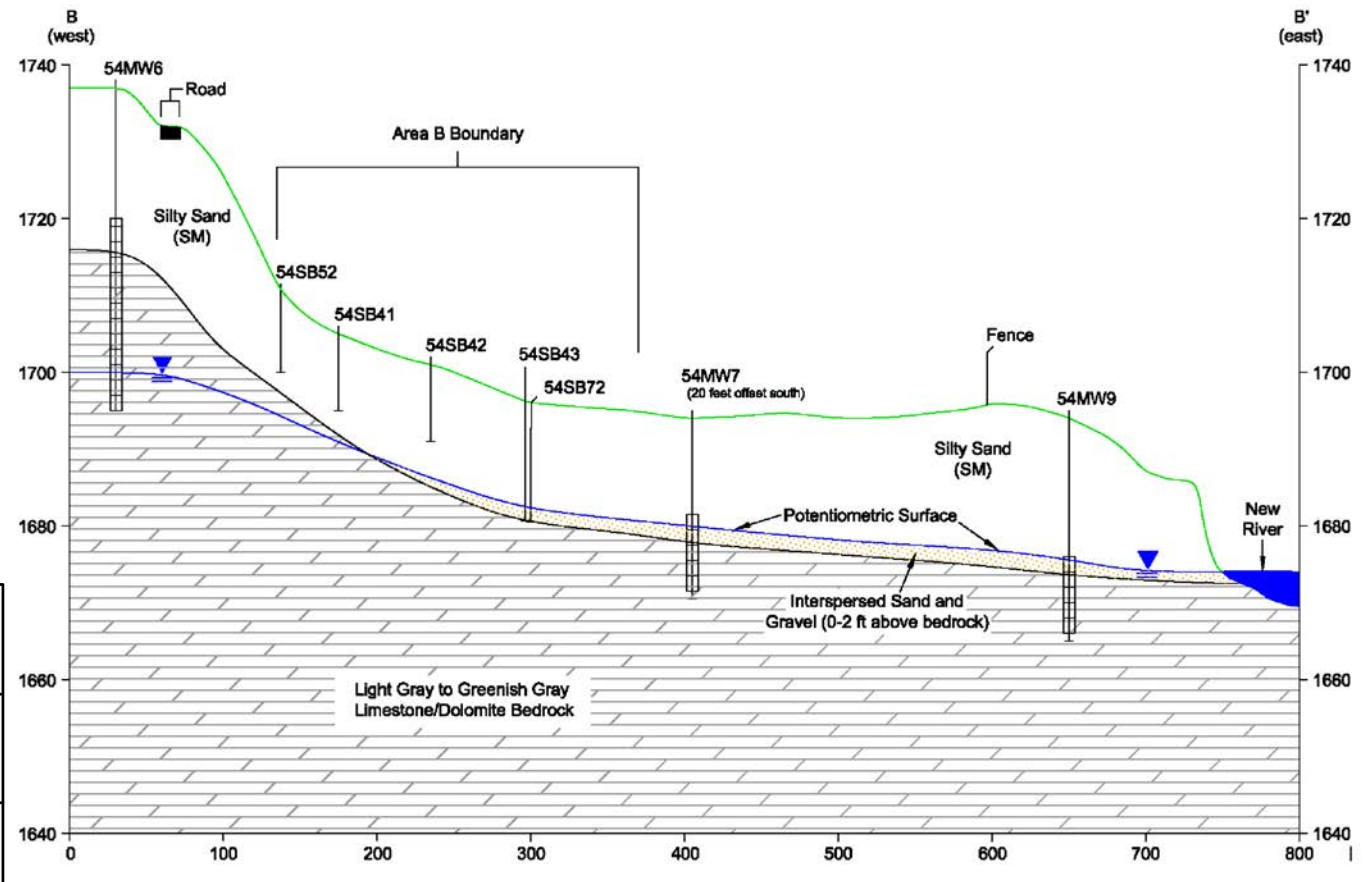

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FIGURE 2-3
SWMU 54
Cross Section B-B'
Radford Army Ammunition Plant,
Radford, VA

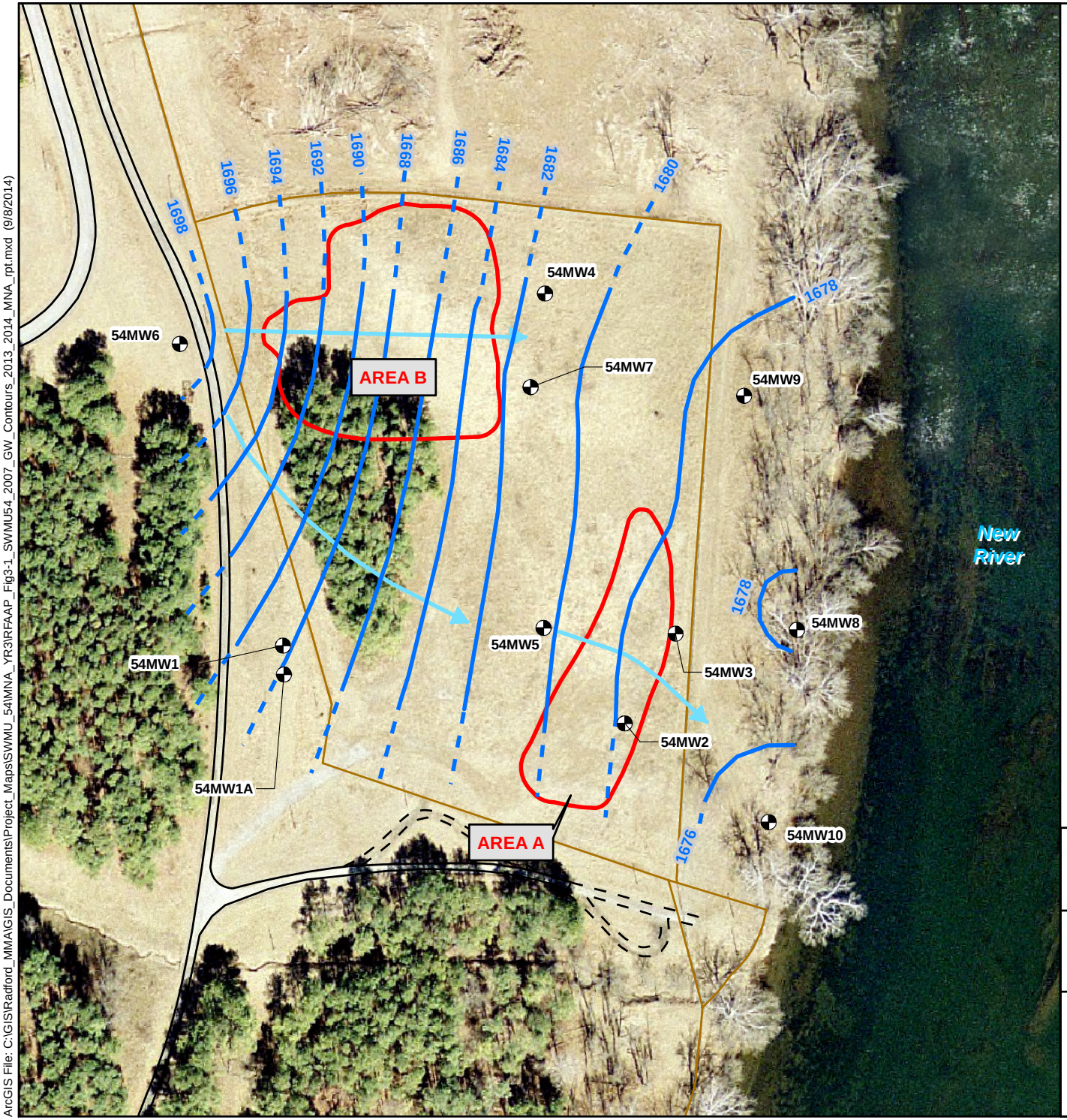
3.0 PREVIOUS INVESTIGATIONS

Four previous investigations have been conducted at this site prior to completion of an interim removal measure in 1999 by Parallax, Inc. Data obtained from previous site investigations prior to the IM were used to identify site boundaries and characteristics, and identify chemicals of potential concern (COPCs). In 1992, the Environmental Photographic Interpretation Center provided aerial photographic analysis of SWMU 54, under the direction of the U.S. Environmental Protection Agency (USEPA). Also in 1992, under authority of the 1984 Hazardous and Solid Waste Amendments, Dames & Moore conducted a RCRA Verification Investigation (VI) at the site to identify the ash disposal at Area A. As a follow-up to the 1992 VI, Parsons completed an RFI in 1996, as part of a multiple site investigation to "define the extent of ash and the limits of soil contamination." In 1998, a Supplemental RFI/CMS was conducted to investigate a flat grassy area ringed by mature pine trees northwest of Area A. This area was defined as Area B within SWMU 54. The purpose of the supplemental RFI was to "characterize the nature and extent of contamination within SWMU 54." In 1999, Parallax, Inc. completed IMs at Area A and Area B of SWMU 54 consisting of excavation of selected "hot spot" areas of lead and explosives in soil.

In 2008, URS Corporation (URS) conducted an RFI/CMS investigating both Area A and Area B to confirm the effectiveness of the IM as well as evaluate and assess current conditions at the sites and provide recommendations regarding potential corrective measure requirements at the sites. Direct push soil borings with chemical sampling were used to: characterize the nature and extent of constituents in soil at SWMU 54, identify the lateral and vertical extent of any waste material present, and characterize soil lithology and depth to groundwater and bedrock. Additionally, monitoring wells were installed at the site and groundwater samples were collected and analyzed. Details of these investigations are described in Section 3.0 (Field Investigation Program) of the *Final SWMU 54 RFI/CMS Report* (URS, 2008). A potentiometric map, portraying the groundwater levels measured in 2007 is provided as **Figure 3-1**. Historical data listing Chemicals of Interest (COI) concentrations in the on-site groundwater, New River surface water and New River sediment pore water can be found in **Tables 3-1 through 3-6**.

The nature and extent assessment indicated that the main concern at the site is the fill material and grossly-contaminated soil directly below the material. Areas A and B were evaluated separately for the soil and groundwater nature and extent assessments given the 200-ft separation between the areas, their topographic cross-gradient position, the lack of mobility of the chemicals in soil, and observed distributions of chemicals.

The main parameters of concern in Area A soil are lead, 2,4,6-TNT, DNT, RDX, amino DNTs, nitroglycerin (NG), heptachlor epoxide, and dioxins/furans. The main parameters of concern in groundwater at Area A are explosives and perchlorate. Concentrations of COIs 2,4,6-TNT, DNT, , RDX, and perchlorate in groundwater have decreased since RFI monitoring began in 2003 and 2004. The lateral extent of explosives and perchlorate in groundwater extends from Area A eastward to the New River. Sampling of the groundwater/surface water interface (sediment pore water) and surface water of the New River did not indicate detectable impacts to sediment pore water or surface water from COPCs in groundwater.



LEGEND

- Monitoring Well Location
- Groundwater Contour
- Inferred Groundwater Contour
- Groundwater Flow Direction
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

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FIGURE 3-1
SWMU 54
June 5, 2007 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig3-1_SWMU54_2007_GW_Contours_2013_2014_MNA_rpt.mxd (9/8/2014)

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
Page 1 of 5

Sample ID / Sample Date	CAS	C/N	RG	Units	54DPW1 12/11/2002		MDL	RL	54DPW2 12/11/2002		MDL	RL	54DPW3 12/11/2002		MDL	RL	54GP77 10/13/2004		MDL	RL	54GP78 10/11/2004		MDL	RL	54GP78-DUP(DUP-1) 10/11/2004		MDL	RL	54GP79 10/11/2004		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			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	<7.2	U,R,I	0.73	7.2	1.5	JB,B,z	0.33	3.3	<2.1	U,R,I	0.21	2.1	NT				NT				NT				NT			
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	<7.2	U,R,I	1	7.2	<3.3	U,R,I	0.48	3.3	<2.1	U,R,I	0.31	2.1	NT				NT				NT				NT			
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	5.5		0.54	1	27.7		0.54	1	2		0.54	1	3.5		0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
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Sample ID / Sample Date	CAS	C/N	RG	Units	54GP80 10/13/2004		MDL	RL	54GP81 10/11/2004		MDL	RL	54GP82 10/11/2004		MDL	RL	54GP83 10/11/2004		MDL	RL	54GP84 10/13/2004		MDL	RL	54GP85 10/14/2004		MDL	RL	54GP86 10/13/2004		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			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	NT				NT				NT				NT				NT				NT				NT			
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	NT				NT				NT				NT				NT				NT				NT			
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	<1	U	0.1	1	1		0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1	<1	U	0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
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Sample ID / Sample Date	CAS	C/N	RG	Units	54GP87 10/14/2004		MDL	RL	54GW56 8/18/2004		MDL	RL	54GW57 8/17/2004		MDL	RL	54GW58 8/24/2004		MDL	RL	54GW59 8/18/2004		MDL	RL	54GW59-DUP(DUP-3) 8/18/2004		MDL	RL	54GW60 8/24/2004		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			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	NT				160		0.15	1.3	1.7	,J,g	0.0749	0.65	15		0.0749	0.65	4.2	,L,f	0.0749	0.65	11	,J,g	0.0749	0.65	9.3		0.0749	0.65
DNT mixture*			**0.932**		ND				ND				ND	U			ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	NT				35	,J,g	0.164	0.65	0.69		0.164	0.65	3.7		0.164	0.65	1		0.164	0.65	1.7		0.164	0.65	0.8		0.164	0.65
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	<1	U	0.1	1	13.5		0.1	1	2		0.1	1	25.8		0.1	1	4		0.1	1	3.6		0.1	1	1.7		0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
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Sample ID / Sample Date	CAS	C/N	RG	Units	54GW61 8/24/2004		MDL	RL	54GW62 8/23/2004		MDL	RL	54GW63 8/23/2004		MDL	RL	54GW64 8/23/2004		MDL	RL	54GW64-DUP(DUP-9) 8/23/2004		MDL	RL	54GW65 8/20/2004		MDL	RL	54GW66 8/20/2004		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			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	74		0.0749	0.65	9		0.0749	0.65	<0.65	U	0.0749	0.65	0.82	,J,g	0.0749	0.65	0.76	,J,g	0.0749	0.65	3		0.0749	0.65	NT			
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	<0.65	U	0.164	0.65	1.6		0.164	0.65	<0.65	U	0.164	0.65	0.75	,J,g	0.164	0.65	0.73	,J,g	0.164	0.65	0.7		0.164	0.65	NT			
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	3		0.1	1	5.3		0.1	1	<1	U	0.1	1	1.1		0.1	1	0.97	B	0.1	1	1.7		0.1	1	0.94	B,J,m	0.1	1

Table 3-1
2002 Area A Direct Push Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia
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Sample ID / Sample Date	CAS	C/N	RG	Units	54GW66 8/23/2004		MDL	RL	54GW67 8/20/2004		MDL	RL	54GW67 8/23/2004		MDL	RL	54GW68 8/20/2004		MDL	RL	54GW69 8/20/2004		MDL	RL	54GW69 8/23/2004		MDL	RL	54GW70 8/20/2004		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			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	<0.65	U	0.0749	0.65	NT				<0.65	U	0.0749	0.65	2.6	,J,g	0.0749	0.65	NT				1.4		0.0749	0.65	<0.65	U	0.0749	0.65
DNT mixture*			**0.932**		ND				ND				ND				ND				ND				ND				ND			
RDX	121-82-4	C	**6.1**	ug/L	<0.65	U	0.164	0.65	NT				<0.65	U	0.164	0.65	<0.65	U	0.164	0.65	NT				0.51	J	0.164	0.65	<0.65	U	0.164	0.65
Perchlorate																																
Perchlorate	14797-73-0	N	**10.9**	ug/L	NT				0.59	B,J,m	0.1	1	NT				<1	U	0.1	1	0.65	B,J,m	0.1	1	NT				0.76	B	0.1	1

Notes:
µg/L = Microgram Per Liter
TAL = Target Analyte List
TCL = Target Compound List
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
NI = Not Identified
NT = Not Tested
ND = Not Detected
*The results of 2,4-DNT and 2,6-DNT were added together to get the DNT mixture result.

C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)

=Exceeds RG

Data Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blanks.
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.
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.
N = Sample spike recovery is outside of control limits.
P = Greater than 40% difference for detected concentrations between the two GC or HPLC columns.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
UL = Not detected, quantitation limit is probably higher.
g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.
o = Calibration blank contamination.
p = Preparation blank contamination.
s = Serial dilution failure.
w = Field and/or equipment blank contamination.
x = Trip blank contamination.
z = Method blank and/or storage blank contamination.

Table 3-2
2003-2004 Area A Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Sample ID / Sample Date	CAS	C/N	RG	Units	54MW2 3/4/2003		MDL	RL	54MW3 3/4/2003		MDL	RL	54MW5 3/4/2003		MDL	RL	54MW-8 12/21/2004		MDL	RL	54MW-9 12/21/2004		MDL	RL	54MW-10 12/21/2004		MDL	RL	54MW10-DUP(DUP-1) 12/21/2004		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			Result	LQ, VQ, r		
Explosives				ug/L																												
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	ug/L	<3.6	U	0.365	3.6	38		0.365	3.6	<4.2	U	0.43	4.2	<0.65	U	0.0749	0.65	<0.65	U	0.0749	0.65	62		0.15	1.3	65		0.15	1.3
DNT mix*			**0.932**	ug/L	ND				ND				ND				ND				ND				ND				ND			
RDX (Hexahydro-1,3,5-trinitro-1,3,5-tria	121-82-4	C	**6.1**	ug/L	<3.6	U	0.526	3.6	32		0.526	3.6	<4.2	U	0.61	4.2	0.2	J,J,g	0.164	0.65	1.1	,J,g	0.164	0.65	28		0.164	0.65	29		0.164	0.65
Perchlorate																																
Perchlorate	14797-73-0	N	**10.90**	ug/L	12		0.54	1	59.2		0.54	1	1.6		0.54	1	0.22	B	0.1	1	0.21	B	0.1	1	9.8		0.1	1	9.1		0.1	1
Field Parameters																																
Dissolved Oxygen	--	--	--	mg/L	6.97				5.18				2.88				0.25				2.56				1.25				1.25			
Oxidation Reduction Potential	--	--	--	mV	159.5				119.0				95.1				215				234				208				208			
pH	--	--	--	SU	6.37				6.65				7.00				7.20				7.53				7.06				7.06			
Conductivity	--	--	--	mS	0.191				0.341				0.310				0.627				0.706				0.760				0.760			
Temperature	--	--	--	°C	16.24				15.97				12.91				13.6				13.2				13.8				13.8			
Turbidity	--	--	--	NTU	0.80				1.93				12.0				4.17				4.13				3.52				3.52			

*DNT mixture result is the result of the adding together of 2,4-DNT and 2,6-DNT.

Notes:

CAS = Chemical Abstracts Service
µg/L = Microgram Per Liter
TAL = Target Analyte List
TCL = Target Compound List
SVOC = Semivolatile Organic Compound
TIC = Tentatively Identified Compound
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
ND = Not Detected
NT = Not Tested
mV = millivolt

SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity
RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
MCL = Maximum Contaminant Level

= detected above Remedial Goal (RG)

Data Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blanks.
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.
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.
N = Sample spike recovery is outside of control limits.
P = Greater than 40% difference for detected concentrations between the two GC or HPLC columns.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
UL = Not detected, quantitation limit is probably higher.

g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.
o = Calibration blank contamination.
p = Preparation blank contamination.
s = Serial dilution failure.
w = Field and/or equipment blank contamination.
x = Trip blank contamination.
z = Method blank and/or storage blank contamination.

Table 3-3
2006-2007 Area A Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

First Quarter - November/December 2006

Sample ID / Sample Date	CAS	C/N	RG	54MW1 11/29/2006 Result	LQ, VQ, r	MDL	RL	54MW2 11/29/2006 Result	LQ, VQ, r	MDL	RL	54MW3 12/5/2006 Result	LQ, VQ, r	MDL	RL	54MW5 11/29/2006 Result	LQ, VQ, r	MDL	RL	54MW8 12/1/2006 Result	LQ, VQ, r	MDL	RL	54MW9 12/1/2006 Result	LQ, VQ, r	MDL	RL	54MW10 12/1/2006 Result	LQ, VQ, r	MDL	RL
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.075	5	5.6		0.075	5	0.85	J	0.075	5	0.29	J	0.075	5	<5	U	0.075	5	<5	U	0.075	5	2.1	J	0.075	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	3.3	J	0.16	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	11.95				10.29				11.94				10.1				8.94				8.51				8.13			
Oxidation Reduction Potential (mV)	--	--	--	153				159				171				231				32				53				36			
pH (SU)	--	--	--	7.86				7.15				7.26				7.2				7.53				7.65				7.39			
Conductivity (mS)	--	--	--	0.44				0.533				0.580				0.557				0.605				0.790				0.733			
Temperature (°C)	--	--	--	18.6				17.7				18.3				18.5				17.1				19.1				16.3			
Turbidity (NTU)	--	--	--	4.47				1.16				0.07				16.6				11.83				23.5				10.31			

Second Quarter - March 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-1 3/28/2007 Result	LQ, VQ, r	MDL	RL	54MW-2 3/28/2007 Result	LQ, VQ, r	MDL	RL	54MW-3 3/28/2007 Result	LQ, VQ, r	MDL	RL	54MW-5 3/28/2007 Result	LQ, VQ, r	MDL	RL	54MW-8 3/27/2007 Result	LQ, VQ, r	MDL	RL	54MW-9 3/27/2007 Result	LQ, VQ, r	MDL	RL	54MW10 DUP AVG 3/27/2007 Result	LQ, VQ, r	MDL	RL
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	0.25	J,J,d	0.1	5	<5	U	0.1	5	0.84	J,J,g	0.1	5	14		0.1	5	<5	U	0.1	5	6.018		0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				1.146				<5				<5				<5				<5				0.898			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	8.1		0.092	5	<5	U	0.092	5	3.87		0.092	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.036	0.2	3.6		0.036	0.2	<0.2	U	0.036	0.2	0.52		0.036	0.2	0.26		0.036	0.2	0.24		0.036	0.2	2.9		0.036	0.2
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	8.06				7.75				6.12				8.38				6.68				6.51				8			
Oxidation Reduction Potential (mV)	--	--	--	-5				44				-11				53				-17				-10				11			
pH (SU)	--	--	--	7.63				6.45				6.94				6.51				7.05				7.18				6.88			
Conductivity (mS)	--	--	--	0.199				0.183				0.311				0.167				0.267				0.960				0.334			
Temperature (°C)	--	--	--	13.44				15.8				15.22				12.73				13.92				14.43				15.95			
Turbidity (NTU)	--	--	--	1.82				0.37				2.13				1.22				13.96				7.71				3.64			

Table 3-3
2006-2007 Area A Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Third Quarter - June 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-1 6/5/2007		MDL	RL	54MW-2 6/5/2007		MDL	RL	54MW-3 6/5/2007		MDL	RL	54MW-5 6/5/2007		MDL	RL	54MW-8 6/5/2007		MDL	RL	54MW-9 6/5/2007		MDL	RL	54MW-10 6/5/2007		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			Result	LQ, VQ, r		
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	3.9	J	0.1	5	1	J	0.1	5	0.49	J	0.1	5	<5	U	0.1	5	<5	U	0.1	5	2.4	J	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	ND				ND				ND				ND				ND				0.466				ND			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	6.3		0.092	5	<5	U	0.092	5	1.6	J	0.092	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	2		0.08	0.2	0.88		0.08	0.2	0.58		0.08	0.2	0.7		0.08	0.2	0.23		0.08	0.2	0.37		0.08	0.2
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	7.57				8.46				5.06				8.44				8.82				5.21				7.35			
Oxidation Reduction Potential (mV)	--	--	--	297				268				109				236				285				94				187			
pH (SU)	--	--	--	7.33				6.78				6.2				6.24				6.9				6.25				6.87			
Conductivity (mS)	--	--	--	0.192				0.225				0.003				0.163				0.245				0.003				0.353			
Temperature (°C)	--	--	--	13.58				13.48				15.66				21.68				13.4				15.44				14.51			
Turbidity (NTU)	--	--	--	0.48				0.29				0.36				0.67				0.06				1.67				9.37			

Fourth Quarter - September 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-1 9/19/2007		MDL	RL	54MW-2 9/19/2007		MDL	RL	54MW-3 9/19/2007		MDL	RL	54MW-5 9/19/2007		MDL	RL	54MW-8 9/18/2007		MDL	RL	54MW-9 9/18/2007		MDL	RL	54MW-10 9/18/2007		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			Result	LQ, VQ, r		
Explosives (ug/L)																															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	0.78	J	0.1	5	1.2	J	0.1	5	0.38	J,J,g	0.1	5	<5	U	0.1	5	<5	U	0.1	5	17		0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	ND				ND				ND				ND				ND				ND				0.696			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5	8		0.092	5
Perchlorate (ug/L)																															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	0.57		0.08	0.2	0.31		0.08	0.2	0.34		0.08	0.2	0.37		0.08	0.2	<0.2	U	0.08	0.2	2.9		0.08	0.2
Field Parameters																															
Dissolved Oxygen (mg/L)	--	--	--	4.03				2.37				6.34				5.53				4.06				3.78				3.89			
Oxidation Reduction Potential (mV)	--	--	--	233				172				205				228				288				237				239			
pH (SU)	--	--	--	8.2				7.01				5.67				6.89				6.82				7.11				6.76			
Conductivity (mS)	--	--	--	0.487				0.637				0.57				0.647				0.711				0.833				0.844			
Temperature (°C)	--	--	--	19.79				15.91				15.6				17.36				14.41				18.05				17.27			
Turbidity (NTU)	--	--	--	0.79				2.19				2.02				1.62				0.43				2.19				7.19			

Notes:

CAS = Chemical Abstracts Service
ug/L = Microgram Per Liter
ng/L = Nanograms Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

ND = Not Detected
NT = Not Tested
mV = millivolt
SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
MCL = Maximum Contaminant Level

=Exceeds RG

Data Qualifiers:
J = Analyte present. Reported value may not be accurate or precise.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
c = Calibration failure.
d = MS/MSD or LCS/LCSD RPD imprecision.
g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.

Table 3-4
2003 Area B Groundwater Analytical Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Sample ID / Sample Date	RG	Units	54MW4 3/4/2003		MDL	RL	54MW6 3/3/2003		MDL	RL	54MW7 3/4/2003		MDL	RL	54MW7-DUP(GW-DUP-1) 3/4/2003		MDL	RL
			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Perchlorate																		
Perchlorate[1]	**10.9**	µg/L	<1	U	0.54	1	<1	U	0.54	1	<1	U	0.54	1	<1	U	0.54	1
Explosives																		
2,4,6-Trinitrotoluene	**7.82**	µg/L	<5.4	U	0.55	5.4	<4.2	U	0.43	4.2	<3.6	U	0.365	3.6	<4.8	U	0.487	4.8
DNT Mixture	**0.932**	ug/L	ND				ND				ND				ND			
RDX (Hexahydro-1,3,5-trinitro-1,3,5-tria	**6.1**	µg/L	<5.4	U	0.79	5.4	<4.2	U	0.61	4.2	<3.6	U	0.526	3.6	<4.8	U	0.701	4.8

Notes:

CAS = Chemical Abstracts Service
µg/L = Microgram Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
ND = Not Detected

mV = millivolt
SU = Standard Units
mS = miliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

=Exceeds RG

Data Qualifiers:
B = Not detected substantially above the level reported in laboratory or field blanks.
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.
J = Analyte present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
L = Analyte present. Reported value may be biased low. Actual value is expected to be higher.
N = Sample spike recovery is outside of control limits.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.
UJ = Not detected, quantitation limit may be inaccurate or imprecise.
UL = Not detected, quantitation limit is probably higher.
g = Dual column confirmation imprecision.
l = LCS recovery failure.
m = MS/MSD recovery failure.
o = Calibration blank contamination.
p = Preparation blank contamination.
s = Serial dilution failure.
w = Field and/or equipment blank contamination.
x = Trip blank contamination.
z = Method blank and/or storage blank contamination.

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

First Quarter - November/December 2006

Sample ID / Sample Date	CAS	C/N	Adjusted Tap Water RBC	54MW4 11/30/2006		MDL	RL	54MW6 11/29/2006		MDL	RL	54MW7 12/5/2006		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	9.9				11.63				10.46			
Oxidation Reduction Potential (mV)	--	--	--	-92				181				170			
pH (SU)	--	--	--	7.77				8				7.56			
Conductivity (mS)	--	--	--	1.13				0.297				0.729			
Temperature (°C)	--	--	--	15				16.6				15.9			
Turbidity (NTU)	--	--	--	2.66				4.87				5.91			

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Second Quarter - March 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW-4 3/27/2007		MDL	RL	54MW-6 3/27/2007		MDL	RL	54MW-7 3/27/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	<5	U	0.1	5	<5	U	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.036	0.2	<0.2	U	0.036	0.2	<0.2	U	0.036	0.2
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	5.97				8.8				6			
Oxidation Reduction Potential (mV)	--	--	--	-95				135				-44			
pH (SU)	--	--	--	7.16				8.21				7			
Conductivity (mS)	--	--	--	1.11				0.314				0.323			
Temperature (°C)	--	--	--	15.68				17.77				14.25			
Turbidity (NTU)	--	--	--	1.54				31.1				6.59			

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Third Quarter - June 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW4 DUP AVG 6/5/2007		MDL	RL	54MW-6 6/5/2007		MDL	RL	54MW-7 6/5/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	<5	U	0.1	5	<5	U	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	<0.2	U	0.08	0.2	<0.2	U	0.08	0.2
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	5.15				4.5				7.72			
Oxidation Reduction Potential (mV)	--	--	--	91				76				225			
pH (SU)	--	--	--	6.39				6.03				6.97			
Conductivity (mS)	--	--	--	0.003				0.003				0.302			
Temperature (°C)	--	--	--	14.54				19.28				3.03			
Turbidity (NTU)	--	--	--	0.67				9.96				0.71			

Table 3-5
2006-2007 Area B Quarterly Groundwater Monitoring Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Fourth Quarter - September 2007

Sample ID / Sample Date	CAS	C/N	RG	54MW4 9/19/2007		MDL	RL	54MW6 9/19/2007		MDL	RL	54MW7 DUP AVG 9/19/2007		MDL	RL
				Result	LQ, VQ, r			Result	LQ, VQ, r			Result	LQ, VQ, r		
Explosives (ug/L)															
2,4,6-Trinitrotoluene	118-96-7	N	**7.82**	<5	U	0.1	5	<5	U	0.1	5	<5	U	0.1	5
Dinitrotoluene Mixture	--	C	**0.932**	ND				ND				ND			
RDX	121-82-4	C	**6.100**	<5	U	0.092	5	<5	U	0.092	5	<5	U	0.092	5
Perchlorate (ug/L)															
Perchlorate	14797-73-0	N	**10.90**	<0.2	U	0.08	0.2	0.1	J	0.08	0.2	<0.2	U	0.08	0.2
Field Parameters															
Dissolved Oxygen (mg/L)	--	--	--	4.03				7.47				4.56			
Oxidation Reduction Potential (mV)	--	--	--	-1				236				266			
pH (SU)	--	--	--	7.91				8.13				6.97			
Conductivity (mS)	--	--	--	1.1				0.267				0.766			
Temperature (°C)	--	--	--	16.08				16.69				16.83			
Turbidity (NTU)	--	--	--	0.43				4.37				0.39			

Notes:

CAS = Chemical Abstracts Service
ug/L = Microgram Per Liter
ng/L = Nanogram Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code
ND = Not Detected

mV = millivolt
SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

=Exceeds RG

See Table 6-3D (December 2006) and Table 6-3E (June 2007) for Total 2,3,7,8-TCDD TEQ Calculations

C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)

Data Qualifiers:
J = Analyte present. Reported value may not be accurate or precise.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.

Table 3-6
2006 New River Surface Water and Sediment Pore Water Sample Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Surface Water

Sample ID / Sample Date	CAS	C/N	RG	NR-SW-1 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-2 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-3 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-4 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-5 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-6 11/30/2006 Result	LQ, VQ, r	MDL	RL
Explosives (ug/L)																											
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																											
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																											
Dissolved Oxygen (mg/L)	--	--	--	17.05				15.83				14.64				12.93				14.83				15.11			
Oxidation Reduction Potential (mV)	--	--	--	219				118				47				53				32				35			
pH (SU)	--	--	--	8.9				8.1				7.96				7.81				7.67				8.3			
Conductivity (mS)	--	--	--	0.116				0.113				0.118				0.174				0.117				0.155			
Temperature (°C)	--	--	--	10.1				9.9				10.1				10.3				10.2				10.4			
Turbidity (NTU)	--	--	--	71.3				13.7				17.48				9.94				7.66				6.21			

Pore Water

Sample ID / Sample Date	CAS	C/N	RG	NR-PW-1 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-2 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-3 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-4 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-5 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-6 11/30/2006 Result	LQ, VQ, r	MDL	RL
Explosives (ug/L)																											
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																											
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																											
Dissolved Oxygen (mg/L)	--	--	--	10.38				10.46				12.2				9.35				10.82				11.34			
Oxidation Reduction Potential (mV)	--	--	--	-109				-174				20				-182				-44				-58			
pH (SU)	--	--	--	7.33				7.21				7.47				7.57				7.44				7.2			
Conductivity (mS)	--	--	--	0.307				0.344				0.248				0.38				0.553				0.353			
Temperature (°C)	--	--	--	12.8				10.7				10.8				10.6				13.2				11.9			
Turbidity (NTU)	--	--	--	16.35				37.9				22.7				4.86				3.63				11.85			

Table 3-6
2006 New River Surface Water and Sediment Pore Water Sample Results with Remedial Goals
SWMU 54
Radford Army Ammunition Plant, Radford, Virginia

Surface Water

Sample ID / Sample Date	CAS	C/N	RG	NR-SW-7 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-8 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-8-DUP(DUP-4) 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-9 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-SW-10 12/1/2006 Result	LQ, VQ, r	MDL	RL
Explosives (ug/L)																							
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																							
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																							
Dissolved Oxygen (mg/L)	--	--	--	13.13				13.27				13.27				13.76				14.69			
Oxidation Reduction Potential (mV)	--	--	--	10				41				41				51				52			
pH (SU)	--	--	--	8.11				7.8				7.8				7.62				7.83			
Conductivity (mS)	--	--	--	0.140				0.124				0.124				0.131				0.114			
Temperature (°C)	--	--	--	11.7				12.5				12.5				11.8				11			
Turbidity (NTU)	--	--	--	148				13.8				13.8				20.5				11.46			

Pore Water

Sample ID / Sample Date	CAS	C/N	RG	NR-PW-6-DUP(DUP-3) 11/30/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-7 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-8 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-9 12/1/2006 Result	LQ, VQ, r	MDL	RL	NR-PW-10 12/1/2006 Result	LQ, VQ, r	MDL	RL
Explosives (ug/L)																							
2,4,6-Trinitrotoluene	118-96-7	C	**7.82**	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5	<5	U	0.075	5
2,4-Dinitrotoluene	121-14-2	N		<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5	<5	U	0.12	5
2,6-Dinitrotoluene	606-20-2	N		<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5	<5	U	0.27	5
DNT mixture*			**0.932**	<5				<5				<5				<5				<5			
RDX	121-82-4	C	**6.100**	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5	<5	U	0.16	5
Perchlorate (ug/L)																							
Perchlorate	14797-73-0	--	**10.900**	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10	<10	U	1.84	10
Field Parameters																							
Dissolved Oxygen (mg/L)	--	--	--	11.34				9.25				9.74				10.55				10.18			
Oxidation Reduction Potential (mV)	--	--	--	-58				-194				-173				-173				-157			
pH (SU)	--	--	--	7.2				7.54				7.36				7.23				7.47			
Conductivity (mS)	--	--	--	0.353				0.517				0.660				0.533				0.479			
Temperature (°C)	--	--	--	11.9				13				12.9				13.2				13.1			
Turbidity (NTU)	--	--	--	11.85				3.72				5.6				15.87				1.66			

Notes:

CAS = Chemical Abstracts Service
mg/L = Milligram Per Liter
ug/L = Microgram Per Liter
MDL = Method Detection Limit
RL = Reporting Limit
LQ = Laboratory Qualifier
VQ = Validation Qualifier
r = Reason Code

mV = millivolt
SU = Standard Units
mS = milliSiemen
°C = degrees Celcius
NTU = Nephelometric Turbidity

*DNT mixture results are obtained by adding together the results of 2,4-DNT and 2,6-DNT.

RBC = USEPA Region III Risk-Based Concentration (RBC) values from the October 11, 2007, RBC Table and October 11, 2007, Alternate RBC Table
C = Carcinogenic per EPA RBC Table (October 2007)
N = Noncarcinogenic per EPA RBC Table (October 2007)
BTAG = Biological Technical Assistance Group Water - BTAG Freshwater Screening Values, 2006a

=Exceeds Remedial Goal (RG)

Data Qualifiers:
J = Analyte present. Reported value may not be accurate or precise.
U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.

Parameters of concern in Area B soils include lead, DNT, amino DNT, NG, RDX, dieldrin, Aroclor 1254, heptachlor epoxide, and dioxins/furans. No COIs were identified for Area B Groundwater.

The Human Health Risk Assessment (HHRA) identified eight COIs at Area A (2,4,6-TNT, DNT, RDX, perchlorate, amino DNTs, NG, heptachlor epoxide, and 2,3,7,8-TCDD) and ten COIs at Area B (2,4,6-TNT, DNT, RDX, amino DNTs, NG, lead, Aroclor 1254, heptachlor epoxide, dieldrin, and 2,3,7,8-TCDD) under both an industrial and residential future-use scenario for total soil at SWMU 54. The HHRA determined that unacceptable risks to potential future residential and industrial receptors were associated with the COIs. Based on the results from the HHRA, it was concluded that based on the levels detected in the soil hot spot areas, COIs could potentially leach from soil to groundwater at levels of concern, although groundwater impacts at levels of concern have not yet been identified at Area B. Because the RFI demonstrated that COI contamination is present at concentrations associated with unacceptable human health concerns, a CMS was performed to address the propellant ash material and grossly-contaminated soil under the ash material at SWMU 54. The alternatives evaluated were as follows:

- Alternative One: No Further Action.
- Alternative Two: Excavation of Soil at Area A and Area B, Off-site Disposal, and MNA of Groundwater.
- Alternative Three: Excavation of Soil at Area A and Area B, Off-site Disposal, and Enhanced *In Situ* Bioremediation of Groundwater.

These three alternatives were evaluated using the selection criteria: effectiveness, implementability, and cost. The site-specific CMO for SWMU 54 is to mitigate further leaching of explosives constituents from soil to groundwater at levels that would potentially increase observed concentrations and adversely impact future beneficial use of groundwater, and to eliminate the potential threats to human health and the environment that exist within materials found in SWMU 54. Observations from the SWMU 54 soil investigations indicate that the propellant ash consisted of a black, ashy material that was very evident when encountered. Therefore, identification and removal of the propellant ash and grossly-contaminated soil was partially based on visual observations during excavation, with analytical samples collected to confirm the observations.

Alternative Two, which entails excavation and off-site disposal as the primary remediation process, was found to achieve the CMO. Therefore, Alternative Two was selected as the final alternative for SWMU 54 because it is implementable and provides a greater level of protection to human health and the environment not provided by other alternatives. In addition, Alternative Two is the sole alternative that facilitates RGs without potential adverse effects to groundwater (i.e., degradation of secondary water quality parameters) from remedial implementation activities, which would occur with implementation of Alternative Three.

The CMOs and RGs were developed in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). The following is a summary of the findings from that process.

The site-specific CMO for SWMU 54 Area A is to mitigate further leaching of explosives constituents from soil-to-groundwater at levels that would potentially increase observed concentrations and adversely impact future beneficial use of groundwater; and to the extent

practicable, a goal of restoring site groundwater to the most beneficial use. The soil CMOs for Area A have been met, and the purpose of this Report is to implement the groundwater IMs to meet the CMOs for groundwater.

The site-specific CMO for SWMU 54 Area B is to mitigate the potential hypothetical future risks that have been identified for exposure to soil under a future construction worker scenario; and to prevent leaching of contaminants of concern from soil-to-groundwater at levels that would potentially adversely impact future beneficial use of groundwater. The site-specific CMOs have been met through the soil excavation and off-site disposal completed in 2010.

RGs for SWMU 54 groundwater, shown in **Table 1-1** of this report, were used at SWMU 54 to confirm that all COIs were removed from soil to levels that are safe for human health and the environment. Results from the soil remedial action at SWMU 54 can be found in the approved *Final Interim Measures Completion Report for SWMU 54* (Shaw, 2011b). The groundwater RGs will be used to compare results from groundwater monitoring wells to assess the progress of the MNA process.

4.0 FIELD ACTIVITIES

The following sections provide a discussion of field activities conducted by Shaw in the third year of monitoring at SWMU 54.

The third year of groundwater monitoring consisted of four sampling events conducted in August 2013 (ninth quarter), November 2013 (tenth quarter), February 2014 (eleventh quarter), and May 2014 (twelfth quarter). Field activities were conducted in accordance with the *Final SWMU 54 MNA IMWP* (Shaw, 2011a). Copies of the field log entries are presented in **Appendix A**.

4.1 Groundwater Sampling – Ninth Quarter

Groundwater elevation measurements and groundwater samples were collected from 13 groundwater monitoring wells. Monitoring well 54MW6 could not be measured or sampled because it was dry. The ninth quarter of groundwater sampling was conducted August 5-8, 2013. Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.1.1 Groundwater Elevation Measurements

A round of synoptic water levels was conducted at SWMU 54 prior to each sampling event in the third year of sampling. Water levels were recorded at 13 monitoring wells. **Table 4-1** presents the measured depth to water levels and groundwater elevations above msl collected on August 5 prior to the ninth quarter sampling event. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the ninth quarter and is presented on **Figure 4-2**.

Estimated groundwater flow velocities were calculated for Area A and Area B based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 8.5 ft, resulting in a calculated hydraulic gradient of 0.016 ft/ft. Using an average K value for Area A of 4.86 feet per day (ft/day) and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.39 ft/day [142.0 feet per year (ft/year)].

The Area B flow path of approximately 225 ft had a groundwater elevation difference of 3.88 ft, resulting in a calculated hydraulic gradient of 0.017 ft/ft. Using an average K value for Area B of 4.55 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area B is approximately 0.39 ft/day (142.00 ft/year), similar to the Area A value.

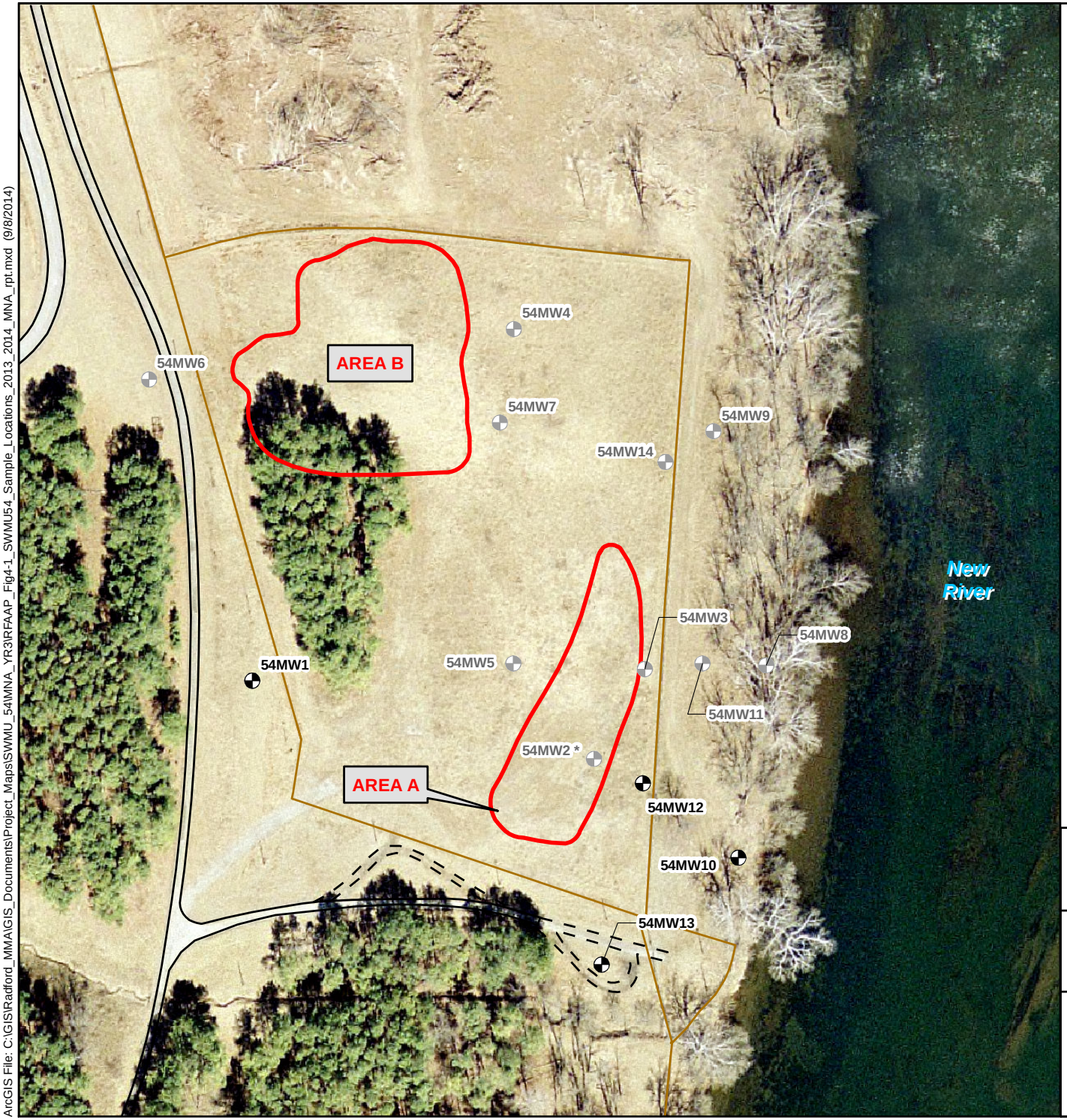
4.1.2 Groundwater Sampling

Groundwater samples were collected from 13 monitoring wells on August 5-8, 2013. Groundwater samples from the ninth through twelfth quarters of sampling were analyzed for the following analyte classes: Explosives and perchlorate. In addition, the following indicator parameters were also collected: Total Organic Carbon (TOC), Dissolved Inorganic Carbon (DIC), dissolved ferrous iron, dissolved manganese, chloride, nitrate, sulfate, pH, temperature, specific conductance, dissolved oxygen (DO), oxidation-reduction potential (ORP), and turbidity. The analysis list is presented in **Table 4-2**.

Table 4-1
Ninth Quarter Groundwater Elevations at SWMU 54

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	18.64	1689.14	62
54MW2	1701.41	19.96	1681.45	32
54MW3	1702.15	21.41	1680.74	36
54MW4	1696.14	15.62	1680.52	47.5
54MW5	1698.11	15.81	1682.3	25
54MW6	1739.19	Dry	NA	42
54MW7	1696.58	13.6	1682.98	23
54MW8	1692.64	12.00	1680.64	34
54MW9	1696.04	16.94	1679.1	28.5
54MW10	1691.1	14.31	1676.79	35
54MW11	1696.27	16.62	1679.65	31
54MW12	1702.42	20.68	1681.74	30
54MW13	1698.9	18.92	1679.98	22
54MW14	1700.66	20.12	1680.54	31.5

Notes:
TOC – Top of casing
DTW – Depth to water



LEGEND

- Monitoring Well (Current MNA Network)
- Monitoring Well (Removed From Network After 9th Quarter)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) * = 54MW2 was also sampled in the 10th quarter.

N

Scale:

0 75 150 300 Feet

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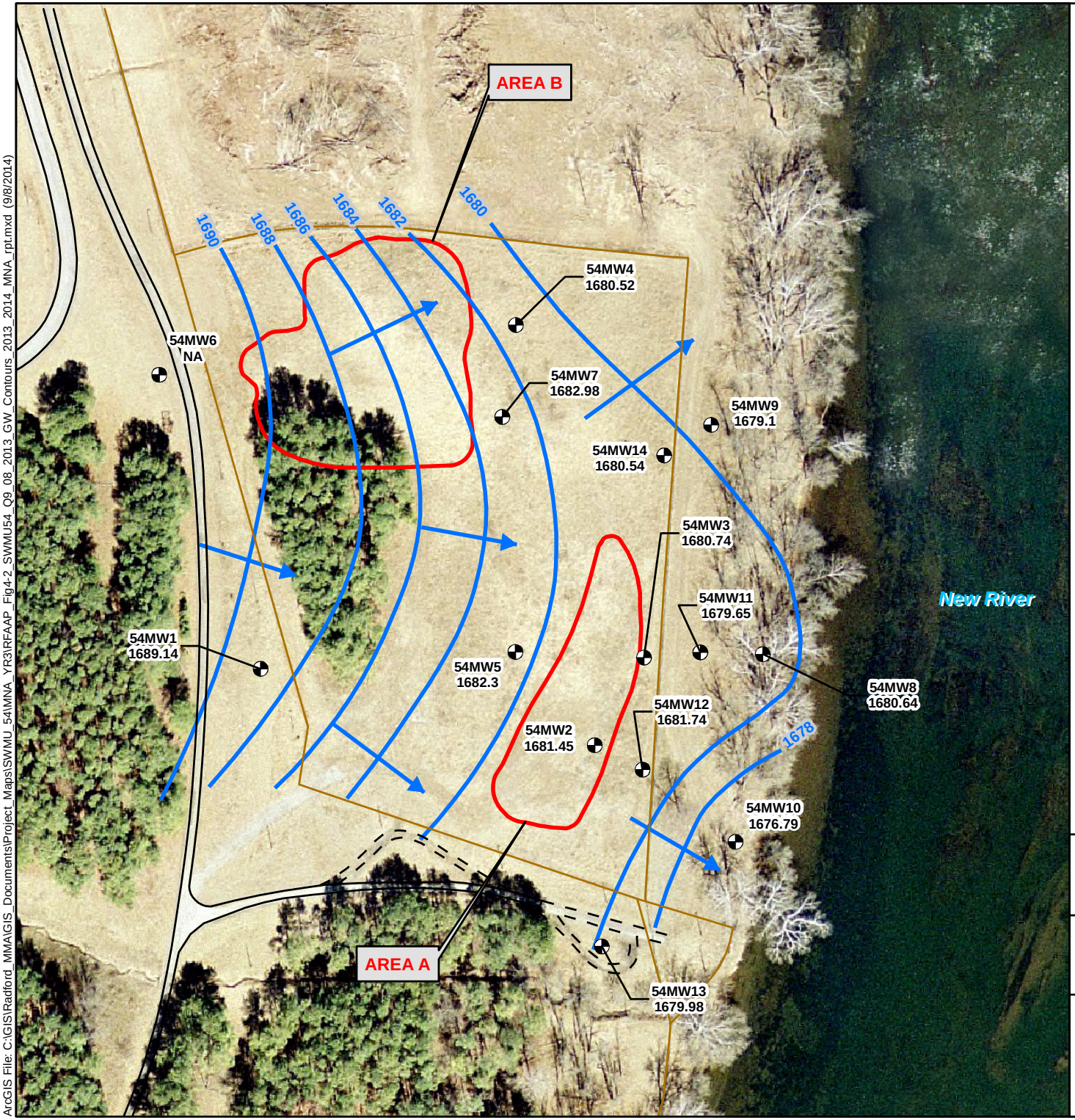
FIGURE 4-1
SWMU 54
Sample Locations
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig4-1_SWMU54_Sample_Locations_2013_2014_MNA_rpt.mxd (9/8/2014)



ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig4-2_SWMU54_Q9_08_2013_GW_Contours_2013_2014_MNA_rpt.mxd (9/8/2014)

LEGEND

- Monitoring Well
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

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FIGURE 4-2
SWMU 54
August 2013 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

Table 4-2
Sample Analysis for SWMU 54 Groundwater Monitoring – Ninth Quarter

Site ID	Sample ID	Frequency	Explosives	Perchlorate	MNA Indicator Parameters
54MW01	54MW01	Quarterly	X	X	X
54MW02	54MW02	Quarterly	X	X	X
54MW03	54MW03	Quarterly	X	X	X
54MW04	54MW04	Quarterly	X	X	X
54MW05	54MW05	Quarterly	X	X	X
54MW06	N/A	Quarterly	X	X	X
54MW07	54MW07	Quarterly	X	X	X
54MW08	54MW08	Quarterly	X	X	X
54MW09	54MW09	Quarterly	X	X	X
54MW10	54MW10	Quarterly	X	X	X
54MW11	54MW11	Quarterly	X	X	X
54MW12	54MW12	Quarterly	X	X	X
54MW13	54MW13	Quarterly	X	X	X
54MW14	54MW14	Quarterly	X	X	X

N/A – Not applicable. 54MW06 was dry and could not be sampled in ninth quarter.

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A photoionization detector (PID) reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screen. Monitoring wells were initially pumped at a rate of approximately 300-350 milliliters per minute (mL/min) on average. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-3** presents a summary of the final, stabilized reading for each well from the ninth quarter.

Measurements conducted for SWMU 54 generally showed aerobic conditions for groundwater. Due to the poor correlation between DO and ORP, the assessment of aerobic conditions is based on the ORP for this event. Levels of DO in the wells ranged from 0.39 to 6.57 milligrams per liter (mg/L). ORP measurements in the wells ranged from -13 to 146 millivolts (mV). Levels of pH were generally in the neutral range with measurements

Table 4-3
SWMU 54 Ninth Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	7.38	0.398	1.2	4.13	122	13.43	<0.05	<0.2
54MW2	6.91	0.592	0.0	0.80	84	15.25	NM	NM
54MW3	6.75	0.617	0.0	1.69	96	15.08	<0.05	<0.2
54MW4	6.96	0.937	0.0	0.39	-18	13.22	0.05	<0.2
54MW5	6.28	0.333	0.0	6.28	129	15.49	0.05	<0.2
54MW6*	NA	NA	NA	NA	NA	NA	NA	NA
54MW7	6.71	0.478	7.2	2.40	86	13.05	<0.05	<0.2
54MW8	6.95	0.559	0.0	0.67	42	13.40	<0.05	<0.2
54MW9	7.12	0.419	6.1	2.36	-13	13.25	0.05	0.2
54MW10	6.48	0.496	0.0	0.86	35	14.51	<0.05	<0.2
54MW11	7.04	0.637	0.0	4.65	68	13.46	0.05	<0.2
54MW12	6.36	0.491	7.0	2.85	91	15.70	0.05	<0.2
54MW13	6.57	0.351	0.0	6.57	146	13.89	0.15	<0.2
54MW14	6.84	0.554	0.0	0.52	50	13.21	0.05	<0.2

N/A – Not applicable. 54MW06 was dry. Water quality parameters were not measured
NM – Not measured

ranging from 6.28 to 7.38 standard units. Specific conductance measurements in the wells ranged from 0.333 to 0.937 millisiemens per centimeter (mS/cm).

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained at 300 mL/min during sample collection. Samples were collected, preserved, and packed in ice until shipment to the laboratory. Chain-of-custody (COC) forms and temperature blanks accompanied the samples at all times. Copies of the COCs are provided in **Appendix B**.

4.1.3 Quality Control Samples

Quality control (QC) samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 10 percent, with two duplicate groundwater samples [54TM01 and 54TM14 taken at well locations 54MW01 and 54MW14, respectively (see **Table 4-2** for analytes)] obtained during the ninth quarter of groundwater sampling. Matrix spike/matrix spike duplicates (MS/MSDs) were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW2. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected per sampling quarter. Equipment rinse blanks were collected by pouring de-ionized ultra-filtered (DIUF) water over decontaminated sampling equipment and into laboratory supplied bottles. Rinse blanks are collected for the same suite of parameters as the samples. Results of the quality assurance/quality control (QA/QC) sample analysis are presented in **Appendix B**.

4.2 Groundwater Sampling – Tenth Quarter

Groundwater elevation measurements and groundwater samples were collected from 4 groundwater monitoring wells (54MW2, 54MW10, 54MW12, and 54MW13). All wells that had no detections above RGs during the first two and a quarter (2-1/4) years (nine quarterly sampling events) were eliminated from future sampling events. All wells associated with Area B have been eliminated from the MNA sampling program. The four wells sampled are located within and downgradient of Area A. The tenth quarter of groundwater sampling was conducted on November 5, 2013. Groundwater elevation measurements were collected from the four wells prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.2.1 Groundwater Elevation Measurements

Table 4-4 presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the reduced groundwater elevation data set collected during the tenth quarter and is presented on **Figure 4-3**.

Estimated groundwater flow velocities were calculated for Area A based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 180 ft had a groundwater elevation difference of 5.75 ft, resulting in a calculated hydraulic gradient of 0.032 ft/ft. Using an average K value for Area A of 4.86 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.78 ft/day (282.6 ft/year).

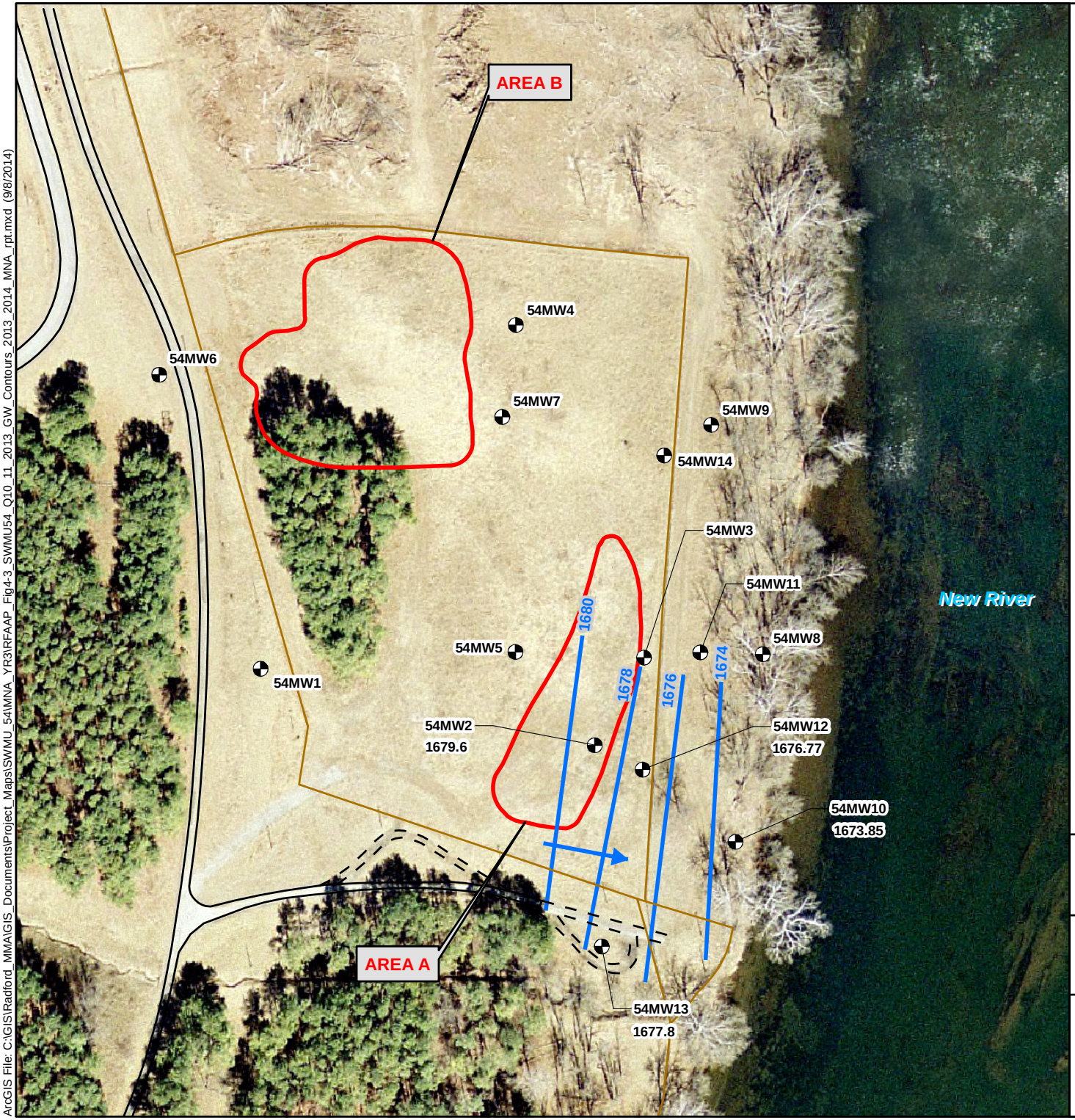
Table 4-4
SWMU 54 Tenth Quarter Groundwater Elevations

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW2	1701.41	21.81	1679.6	32
54MW10	1691.1	17.25	1673.85	35
54MW12	1702.42	25.65	1676.77	30
54MW13	1698.9	21.1	1677.8	22

Notes:
TOC – Top of casing
DTW – Depth to water

4.2.2 Groundwater Sampling

Groundwater samples were collected from four monitoring wells on November 5, 2013. Samples from the tenth quarter were tested for the analyte list presented in **Table 4-5**. The RDX MNA parameters include hexahydro-1,3,5-dinitroso-5-nitro-1,3,5-triazine (DNX), hexahydro-1-nitroso-3,5-dinitro-1,2,5-triazine (MNX), and hexhydro-1,3,5-trinitroso-1,3,5-triazine (TNX), which are explosive break-down products of RDX.



LEGEND

- Monitoring Well
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

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FIGURE 4-3
SWMU 54
November 2013 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig4-3_SWMU54_Q10_11_2013_GW_Contours_2013_2014_MNA_rpt.mxd (9/8/2014)

Table 4-5
Sample Analysis for SWMU 54 Groundwater Monitoring

Site ID	Sample ID	Frequency	Explosives	Perchlorate	MNA Indicator Parameters	RDX MNA Indicators
54MW02	54MW02	Quarterly	X	X	X	X
54MW10	54MW10	Quarterly	X	X	X	X
54MW12	54MW12	Quarterly	X	X	X	X
54MW13	54MW13	Quarterly	X	X	X	X

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A PID reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screen. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-6** presents a summary of the final, stabilized reading for each well.

Table 4-6
SWMU 54 Tenth Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW2	7.45	0.635	0.0	2.70	51	14.09	<0.05	<0.2
54MW10	6.89	0.615	0.0	2.45	18	15.25	<0.05	<0.2
54MW12	NM	0.469	4.6	1.17	108	14.96	0.05	<0.2
54MW13	7.29	0.643	0.4	1.32	25	15.96	0.05	<0.2

NM – Not measured

Measurements conducted for the tenth quarter of SWMU 54 monitoring generally showed aerobic conditions for groundwater. Levels of DO in the wells ranged from 1.17 to 2.70 mg/L. ORP measurements in the wells ranged from 18 to 108 mV. Levels of pH were generally in the neutral range with measurements ranging from 6.89 to 7.45 standard units. Specific conductance measurements in the wells ranged from 0.469 to 0.643 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to

the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the tenth quarter are provided in **Appendix B**.

4.2.3 Quality Control Samples

QC samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 25 percent, with one duplicate groundwater sample [54TM12 (see **Table 4-5** for analytes)] obtained during the tenth quarter of groundwater sampling. MS/MSDs were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW12 during the tenth quarter. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected during the sampling event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, 54RB11513, was collected on November 5, 2013, by pouring DIUF water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

4.3 Groundwater Sampling – Eleventh Quarter

Groundwater elevation measurements and groundwater samples were collected from 4 groundwater monitoring wells. The eleventh quarter of groundwater sampling was conducted February 19, 2014 (54MW1, 54MW10, 54MW12, and 54MW13). Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

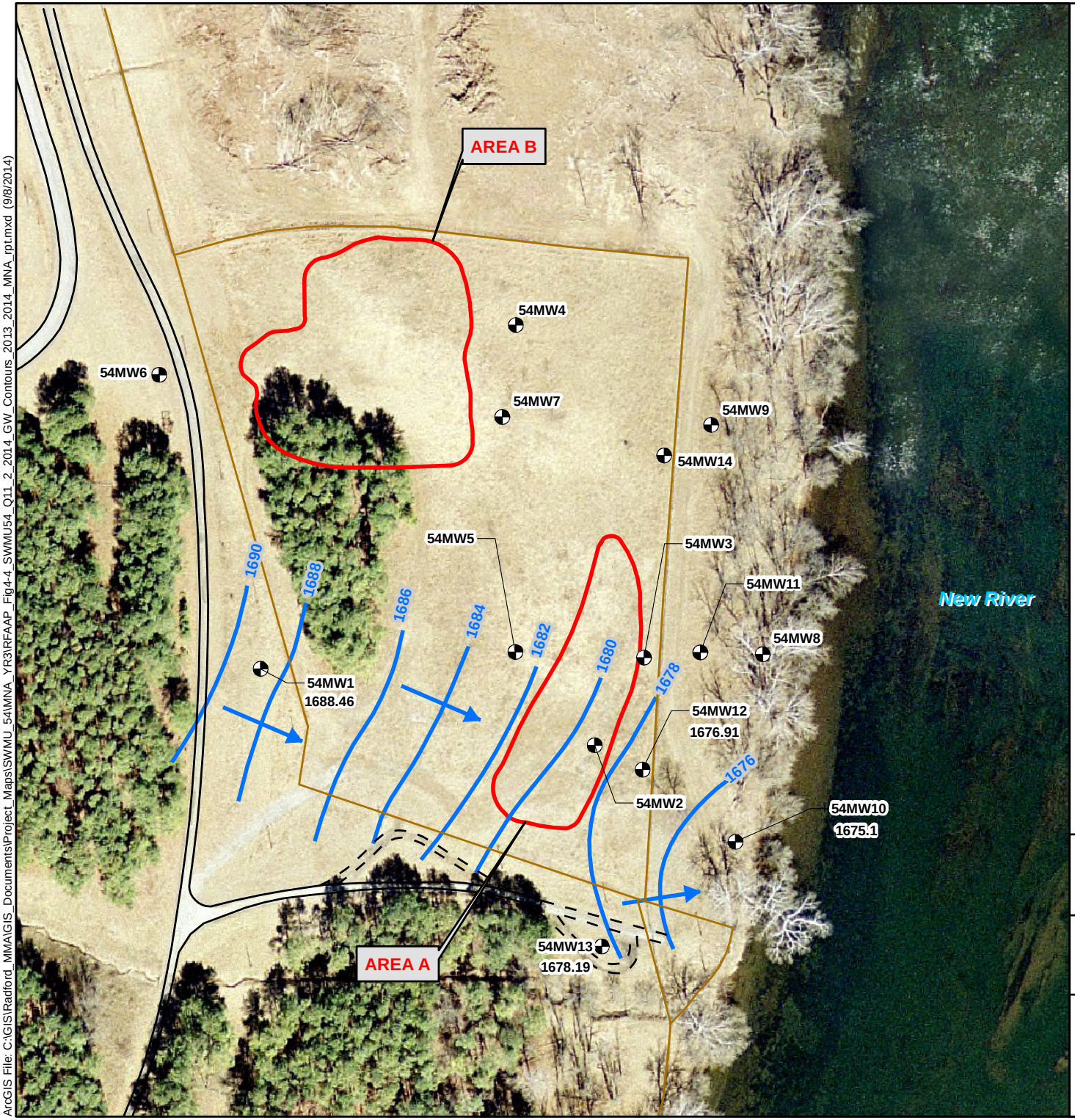
4.3.1 Groundwater Elevation Measurements

Water levels were recorded at each of the four monitoring wells. **Table 4-7** presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the eleventh quarter and is presented on **Figure 4-4**.

Table 4-7
SWMU 54 Eleventh Quarter Groundwater Elevations

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	19.32	1688.46	62
54MW10	1691.1	16	1675.1	35
54MW12	1702.42	25.51	1676.91	30
54MW13	1698.9	20.71	1678.19	22

Notes:
TOC – Top of casing
DTW – Depth to water



ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig4-4_SWMU54_Q11_2_2014_GW_Contours_2013_2014_MNA_rpt.mxd (9/8/2014)

LEGEND

- Monitoring Well
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

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FIGURE 4-4
SWMU 54
February 2014 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

Estimated groundwater flow velocities were calculated for Area A and Area B based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 13.36 ft, resulting in a calculated hydraulic gradient of 0.025 ft/ft. Using an average K value for Area A of 4.86 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.61 ft/day (221.7 ft/year).

4.3.2 Groundwater Sampling

Groundwater samples were collected from each of the four monitoring wells on February 19, 2014. Samples from the eleventh quarter were analyzed for the analyte list presented in **Table 4-5**.

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A PID reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screened interval. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-8** presents a summary of the final, stabilized reading for each well.

Table 4-8
SWMU 54 Eleventh Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	8.10	0.410	0.0	1.32	127	12.34	<0.05	<0.2
54MW10	6.89	0.587	0.0	1.43	153	13.20	<0.05	0.2
54MW12	7.21	0.643	3.8	0.70	150	14.11	<0.05	0.2
54MW13	7.21	0.481	14.0	2.09	142	12.04	0.05	<0.2

*Readings exhibited very high, unchanging turbidity.

Measurements conducted for the eleventh quarter of SWMU 54 monitoring generally showed aerobic conditions for groundwater. Levels of DO in the wells ranged from 0.70 to 2.09 mg/L. ORP measurements in the wells ranged from 127 to 153 mV. Levels of pH were generally in the neutral range with measurements ranging from 6.89 to 7.21 standard units. Specific conductance measurements in the wells ranged from 0.410 to 0.643 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the eleventh quarter are provided in **Appendix B**.

4.3.3 Quality Control Samples

QC samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 25 percent, with one duplicate groundwater sample [54TM12 collected from 54MW12 (see **Table 4-5** for analytes)] obtained during the eleventh quarter of groundwater sampling. MS/MSDs were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW1 during the eleventh quarter. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected during the sample event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, 54RB021914, was collected on February 19, 2014, by pouring DIUF water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

4.4 Groundwater Sampling – Twelfth Quarter

Groundwater elevation measurements and groundwater samples were collected from four groundwater monitoring wells (54MW1, 54MW10, 54MW12, and 54MW13). The twelfth quarter of groundwater sampling was conducted May 28, 2014. Groundwater elevation measurements were collected prior to sampling activities. The locations of the wells are displayed on **Figure 4-1**.

4.4.1 Groundwater Elevation Measurements

Water levels were recorded at each of the four monitoring wells. **Table 4-9** presents the measured depth to water levels and groundwater elevations above msl. A groundwater elevation contour map was constructed from the groundwater elevation data collected during the twelfth quarter and is presented on **Figure 4-5**.

Table 4-9
SWMU 54 Twelfth Quarter Groundwater Elevations

Well ID	Elevation of TOC	DTW (ft TOC)	Water Level (ft msl)	Total Depth (ft TOC)
54MW1	1707.78	20.63	1687.15	62
54MW10	1691.1	16.71	1674.39	35
54MW12	1702.42	27.5	1674.92	30
54MW13	1698.9	22.21	1676.69	22

Notes:
TOC – Top of casing
DTW – Depth to water

The estimated groundwater flow velocity was calculated for Area A based on parameters used in the *SWMU 54 RFI/CMS Report* (URS, 2008). The Area A flow path of approximately 525 ft had a groundwater elevation difference of 12.8 ft, resulting in a calculated hydraulic gradient of

0.024 ft/ft. Using an average K value for Area A of 4.86 ft/day and an estimated effective porosity of 0.20, the groundwater flow velocity for Area A is approximately 0.59 ft/day (215.0 ft/year).

4.4.2 Groundwater Sampling

Groundwater samples were collected from each of the four monitoring wells on May 28, 2014. Samples from the twelfth quarter were analyzed for the full analyte list presented in **Table 4-5**.

Groundwater samples were collected via low-flow sampling techniques to obtain representative groundwater samples and minimize waste purge water. The following procedures were followed during the groundwater sampling event. A PID reading was taken upon opening the well to determine if potentially hazardous levels of volatiles were present. All PID readings were within acceptable levels. Depth to water and total depth measurements were recorded to determine the amount of water in the well casing and sandpack. A submersible pump was lowered into the well until the pump inlet was within the screened section of the well. Water quality parameters, including temperature, pH, DO, redox potential, turbidity, and conductivity, were monitored continuously through a flow cell during well purging, and final stabilized readings were recorded. Upon completion of the stabilization, dissolved manganese and dissolved ferrous iron were tested via a field kit. **Table 4-10** presents a summary of the final, stabilized reading for each well.

Table 4-10
SWMU 54 Twelfth Quarter Water Quality Parameters

Well ID	pH	Conductivity (mS/cm)	Turbidity (NTU)	Dissolved Oxygen (mg/kg)	ORP	Temperature (^{o}C)	Dissolved Manganese	Dissolved Ferrous Iron
54MW1	7.79	0.469	3.0	1.65	222.3	16.61	0.05	0.2
54MW10	6.93	0.582	3.8	1.56	127.4	12.81	0.10	<0.2
54MW12	NM	0.453	10.0	2.25	272.1	14.61	0.10	0.2
54MW13	NM	0.470	9.0	1.14	71.3	16.57	0.05	0.2

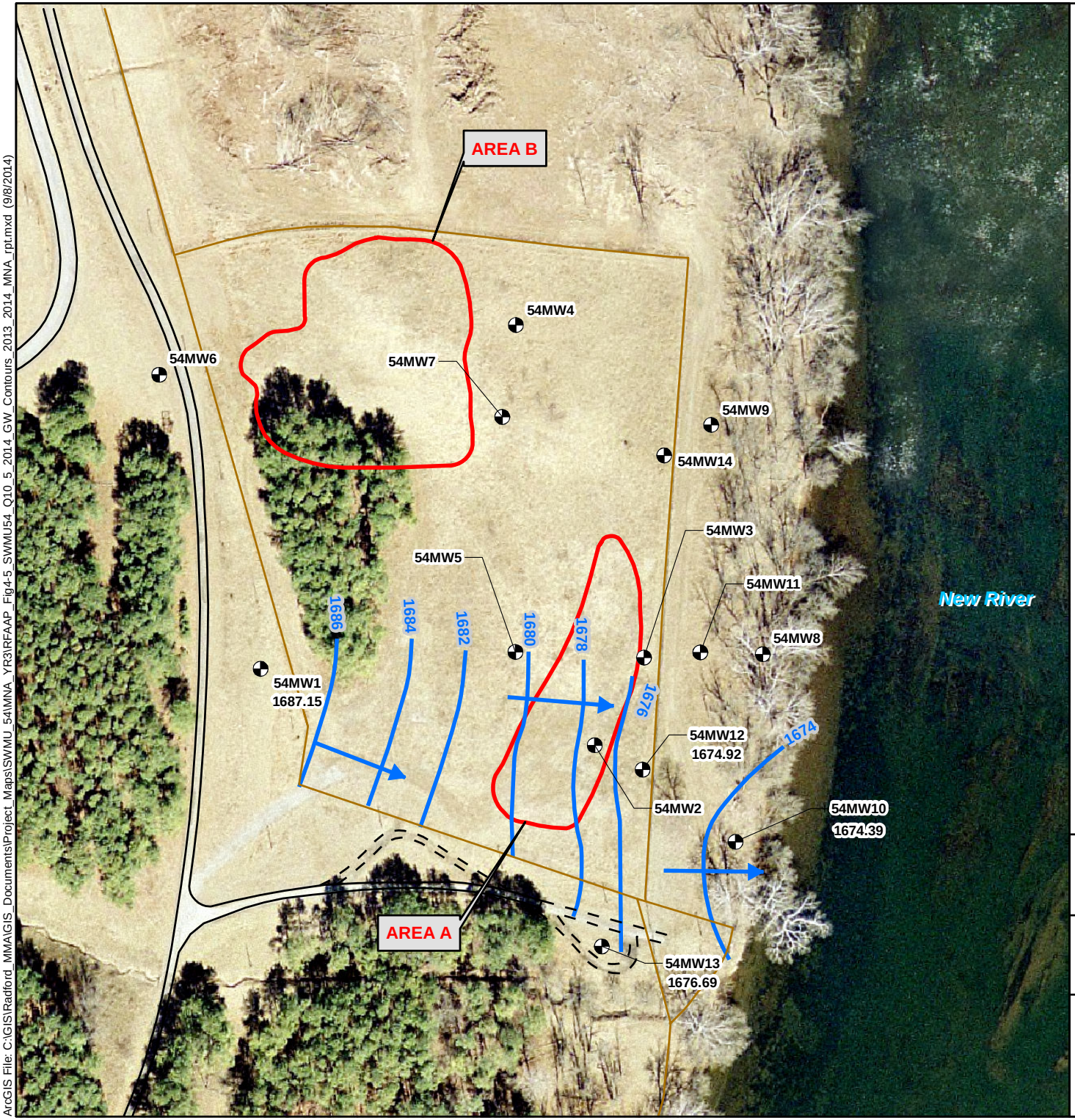
Measurements conducted for the twelfth quarter of SWMU 54 monitoring generally showed aerobic conditions for groundwater. Levels of DO in the wells ranged from 1.14 to 2.25 mg/L. ORP measurements in the wells ranged from 71.3 to 272.1 mV. Levels of pH were typically in the neutral range with measurements reading from 6.93 to 7.79 standard units. Specific conductance measurements in the wells ranged from 0.453 to 0.582 mS/cm.

Prior to sampling, the flow cell was disconnected and the groundwater flow rate was maintained during sample collection. Samples were collected, preserved, and packed in ice until shipment to the laboratory. COCs and temperature blanks accompanied the samples at all times. Copies of the COCs for the twelfth quarter are provided in **Appendix B**.

4.4.3 Quality Control Samples

QC samples, including rinse blanks and duplicates, were collected during this field event.

Duplicate samples were collected at a rate of 25 percent, with one duplicate groundwater sample [54TM12 was collected from sample location 54MW12 (see **Table 4-5** for analytes)] obtained



ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig4-5_SWMU54_Q10_5_2014_GW_Contours_2013_2014_MNA_rpt.mxd (9/8/2014)

LEGEND

- Monitoring Well
- Dirt Road
- Paved Road
- Railroad
- Fence
- Groundwater Contour
- Groundwater Flow Direction
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 4-5
SWMU 54
May 2014 Groundwater Contour Map
Radford Army Ammunition Plant,
Radford, VA

during the twelfth quarter of groundwater sampling. MS/MSDs were collected at a rate of 5 percent. One MS/MSD was collected for each analyte class at well 54MW01 during the twelfth quarter. Duplicate and MS/MSD samples were collected by homogenizing a large sample volume and splitting it into two samples for a duplicate and three samples for an MS/MSD.

One equipment rinse blank was collected during the sample event. Rinse blanks are collected for the same suite of parameters as the samples. Rinse blank sample, 54RB052814, was collected on May 28, 2014, by pouring DIUF water over decontaminated sampling equipment and into laboratory supplied bottles. Results of the QA/QC sample analysis are presented in **Appendix B**.

5.0 CHEMICAL ANALYTICAL RESULTS

5.1 Selection of Comparison Criteria

The chemical data collected during this investigation were compared to RGs selected in the *Final SWMU 54 RFI/CMS Report* (URS, 2008). Groundwater chemical data were compared to current USEPA Maximum Contaminant Levels (MCLs) (USEPA, 2011). Screening levels (SLs) are calculated values that are derived from theoretical risk scenarios. Compounds are grouped as carcinogens or noncarcinogens, and carcinogen SL values are calculated to represent an increase of 10^{-6} in cancer risk. Noncarcinogen SLs are calculated to a Hazard Index (HI) of 1. In order to account for potential cumulative effects of exposure to noncarcinogenic compounds, values for noncarcinogens have been recalculated to an HI of 0.1. **Tables 5-1 through 5-10** present the sample results and summaries of the ninth through twelfth quarter data, including number of RG and MCL exceedances, frequency of detection, the minimum and maximum detected concentrations, and the location of the maximum concentration.

5.2 Ninth Quarter Groundwater Results

Thirteen (13) groundwater monitoring wells were sampled during the ninth quarterly sampling event with well location 54MW6 being dry at the time of sampling. Sample locations are shown on **Figure 4-1**. Duplicate samples were collected from monitoring wells 54MW1 and 54MW14 and analyzed for explosives, perchlorate, and MNA indicator parameters. Groundwater samples were analyzed for explosives, perchlorate, and MNA indicator parameters. Detected constituents are summarized in **Table 5-1** and presented in **Table 5-2**.

Explosives

Four explosives were detected in the groundwater samples. 2,4,6-TNT was detected in three wells (54MW02, 54MW12, 54MW13) at concentrations of 0.974 micrograms per liter (µg/L), 65.9 µg/L, and 3.81 µg/L, respectively. The 2,4,6-TNT concentration in 54MW12 exceeded the RG of 7.8 µg/L.

2-amino-4,6-dinitrotoluene (2ADNT) was detected in three wells on site (54MW2, 54MW12, and 54MW13). 4-amino-2,6-dinitrotoluene (4ADNT) was detected in the same three wells.

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX was detected at levels below RGs in samples 54MW10 and 54MW13. The detected concentration in 54MW12 exceeded the RG for RDX (6.1 µg/L) with a concentration of 14.6 µg/L.

The locations of detected explosives were typically consistent with earlier sampling rounds. **Figure 5-1** depicts RG exceedances measured during the ninth quarter of groundwater sampling.

Perchlorate

Perchlorate was detected in 11 samples (54MW2, 54MW3, 54MW5, 54MW7, 54MW8 through 54MW14) collected in the ninth quarter MNA sampling. Perchlorate detections did not exceed the RG.

Miscellaneous Analytes

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, chloride, nitrate, and sulfate) for the purposes of evaluating the effectiveness of the MNA process.

Table 5-1
SWMU 54 Summary of Ninth Quarter Groundwater Samples

	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
2,4,6-Trinitrotoluene	7.82	1	3	15	0.974	65.9	54MW12
2-amino-4,6-Dinitrotoluene	na	na	3	15	0.798	8.67	54MW12
4-amino-2,6-Dinitrotoluene	na	na	3	15	0.639	4.99	54MW12
RDX	6.1	1	3	15	1.46	14.6	54MW12
Misc. (ug/L)							
Perchlorate	10.9	0	12	15	0.132	9.88	54MW12
Total Organic Carbon	na	na	15	15	822	4280	54MW10
Chloride	na	na	15	15	1640	7830	54MW05
Nitrate (as N)	na	na	11	15	120	4800	54MW12
Sulfate	na	na	15	15	15000	322000	54MW04

na - not applicable

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples

Analyte	Sample ID Sample Date	54MW01 8/5/13					54MW02 8/8/13					54MW03 8/8/13					54MW04 8/5/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.82	1.06	U		*0.266*	*1.06*	0.974	J	J	*0.278*	*1.11*	1.11	U		*0.278*	*1.11*	1.19	U		*0.298*	*1.19*
2-amino-4,6-Dinitrotoluene	na	1.06	U		*0.266*	*1.06*	1.53			*0.278*	*1.11*	1.11	U		*0.278*	*1.11*	1.19	U		*0.298*	*1.19*
4-amino-2,6-Dinitrotoluene	na	1.06	U		*0.266*	*1.06*	0.981	J	J	*0.278*	*1.11*	1.11	U		*0.278*	*1.11*	1.19	U		*0.298*	*1.19*
RDX	6.1	1.06	U		*0.266*	*1.06*	1.11	U		*0.278*	*1.11*	1.11	U		*0.278*	*1.11*	1.19	U		*0.298*	*1.19*
Misc. (ug/L)																					
Perchlorate	10.9	0.2	U		*0.1*	*0.2*	1		L	*0.1*	*0.2*	0.446			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*
Total Organic Carbon	na	3320		J	*500*	*1000*	1500		B	*500*	*1000*	1110		B	*500*	*1000*	2700		B	*500*	*1000*
Dissolved Inorganic Carbon	na	39300		J	*1000*	*2000*	42100		J	*1000*	*2000*	53100		J	*1000*	*2000*	44800		J	*1000*	*2000*
Total Inorganic Carbon	na	20400		J	*500*	*1000*	735	J	J	*500*	*1000*	597	J	J	*500*	*1000*	20600		J	*500*	*1000*
Chloride	na	1640			*100*	*200*	6060			*100*	*200*	4840			*100*	*200*	2120			*100*	*200*
Nitrate (as N)	na	600	U		*100*	*600*	326	J	J	*100*	*600*	521	J	J	*100*	*600*	600	U		*100*	*600*
Sulfate	na	26700			*500*	*1000*	30800			*500*	*1000*	26100			*500*	*1000*	322000			*2500*	*5000*

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples

Analyte	Sample ID Sample Date	54MW05 8/8/13					54MW07 8/8/13					54MW08 8/7/13					54MW09 8/7/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.82	1.2	U		*0.301*	*1.2*	1.12	U		*0.281*	*1.12*	1.25	U		*0.313*	*1.25*	1.14	U		*0.284*	*1.14*
2-amino-4,6-Dinitrotoluene	na	1.2	U		*0.301*	*1.2*	1.12	U		*0.281*	*1.12*	1.25	U		*0.313*	*1.25*	1.14	U		*0.284*	*1.14*
4-amino-2,6-Dinitrotoluene	na	1.2	U		*0.301*	*1.2*	1.12	U		*0.281*	*1.12*	1.25	U		*0.313*	*1.25*	1.14	U		*0.284*	*1.14*
RDX	6.1	1.2	U		*0.301*	*1.2*	1.12	U		*0.281*	*1.12*	1.25	U		*0.313*	*1.25*	1.14	U		*0.284*	*1.14*
Misc. (ug/L)																					
Perchlorate	10.9	0.389			*0.1*	*0.2*	0.37			*0.1*	*0.2*	0.334			*0.1*	*0.2*	0.327			*0.1*	*0.2*
Total Organic Carbon	na	908	J	B	*500*	*1000*	822	J	B	*500*	*1000*	2300		B	*500*	*1000*	4170		J	*500*	*1000*
Dissolved Inorganic Carbon	na	36000		J	*1000*	*2000*	17900		J	*1000*	*2000*	58000		J	*1000*	*2000*	38000		J	*1000*	*2000*
Total Inorganic Carbon	na	1750		J	*500*	*1000*	825	J	J	*500*	*1000*	36500		J	*500*	*1000*	18400		J	*500*	*1000*
Chloride	na	7830			*100*	*200*	2350			*100*	*200*	4540			*100*	*200*	5320			*100*	*200*
Nitrate (as N)	na	849			*100*	*600*	600	U		*100*	*600*	273	J	J	*100*	*600*	194	J	J	*100*	*600*
Sulfate	na	15000			*500*	*1000*	27300			*500*	*1000*	38000			*500*	*1000*	39200			*500*	*1000*

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples

Analyte	Sample ID Sample Date	54MW10 8/7/13					54MW11 8/7/13					54MW12 8/7/13					54MW13 8/5/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																					
2,4,6-Trinitrotoluene	7.82	1.25	U		*0.313*	*1.25*	1.11	U		*0.278*	*1.11*	65.9			*1.45*	*5.81*	3.81			*0.263*	*1.05*
2-amino-4,6-Dinitrotoluene	na	1.25	U		*0.313*	*1.25*	1.11	U		*0.278*	*1.11*	8.67			*0.291*	*1.16*	0.798	J	J	*0.263*	*1.05*
4-amino-2,6-Dinitrotoluene	na	1.25	U		*0.313*	*1.25*	1.11	U		*0.278*	*1.11*	4.99			*0.291*	*1.16*	0.639	J	J	*0.263*	*1.05*
RDX	6.1	2.23			*0.313*	*1.25*	1.11	U		*0.278*	*1.11*	14.6			*0.291*	*1.16*	1.46			*0.263*	*1.05*
Misc. (ug/L)																					
Perchlorate	10.9	0.365			*0.1*	*0.2*	0.132	J	J	*0.1*	*0.2*	9.88			*1*	*2*	0.477			*0.1*	*0.2*
Total Organic Carbon	na	4280		J	*500*	*1000*	3110		J	*500*	*1000*	3270		J	*1000*	*2000*	2350		B	*500*	*1000*
Dissolved Inorganic Carbon	na	51400		J	*1000*	*2000*	59900		J	*1000*	*2000*	48100		J	*1000*	*2000*	38100		J	*1000*	*2000*
Total Inorganic Carbon	na	39300		J	*500*	*1000*	37600		J	*500*	*1000*	3740		J	*1000*	*2000*	24500		J	*500*	*1000*
Chloride	na	4830			*100*	*200*	4130			*100*	*200*	5030			*100*	*200*	2580			*100*	*200*
Nitrate (as N)	na	206	J	J	*100*	*600*	120	J	J	*100*	*600*	4800			*100*	*600*	591	J	J	*100*	*600*
Sulfate	na	44300			*500*	*1000*	91800			*500*	*1000*	39600			*500*	*1000*	23300			*500*	*1000*

Table 5-2
SWMU 54 Detected Analytes in Fifth Quarter Groundwater Samples

Analyte	Sample ID / Sample Date / RG	54MW14 8/5/13					54TM01 8/5/13					54TM14 8/5/13				
		Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																
2,4,6-Trinitrotoluene	7.82	1.18	U		*0.294*	*1.18*	1.05	U		*0.263*	*1.05*	1.14	U		*0.284*	*1.14*
2-amino-4,6-Dinitrotoluene	na	1.18	U		*0.294*	*1.18*	1.05	U		*0.263*	*1.05*	1.14	U		*0.284*	*1.14*
4-amino-2,6-Dinitrotoluene	na	1.18	U		*0.294*	*1.18*	1.05	U		*0.263*	*1.05*	1.14	U		*0.284*	*1.14*
RDX	6.1	1.18	U		*0.294*	*1.18*	1.05	U		*0.263*	*1.05*	1.14	U		*0.284*	*1.14*
Misc. (ug/L)																
Perchlorate	10.9	0.456			*0.1*	*0.2*	0.2	U		*0.1*	*0.2*	0.489			*0.1*	*0.2*
Total Organic Carbon	na	3640		J	*500*	*1000*	2380		B	*500*	*1000*	4000			*500*	*1000*
Dissolved Inorganic Carbon	na	51300		J	*1000*	*2000*	37700		J	*1000*	*2000*	45400		J	*1000*	*2000*
Total Inorganic Carbon	na	29600		J	*500*	*1000*	16800		J	*500*	*1000*	30300		J	*500*	*1000*
Chloride	na	4010			*100*	*200*	1670			*100*	*200*	4050			*100*	*200*
Nitrate (as N)	na	290	J	J	*100*	*600*	600	U		*100*	*600*	343	J	J	*100*	*600*
Sulfate	na	28200			*500*	*1000*	27000			*500*	*1000*	28000			*500*	*1000*

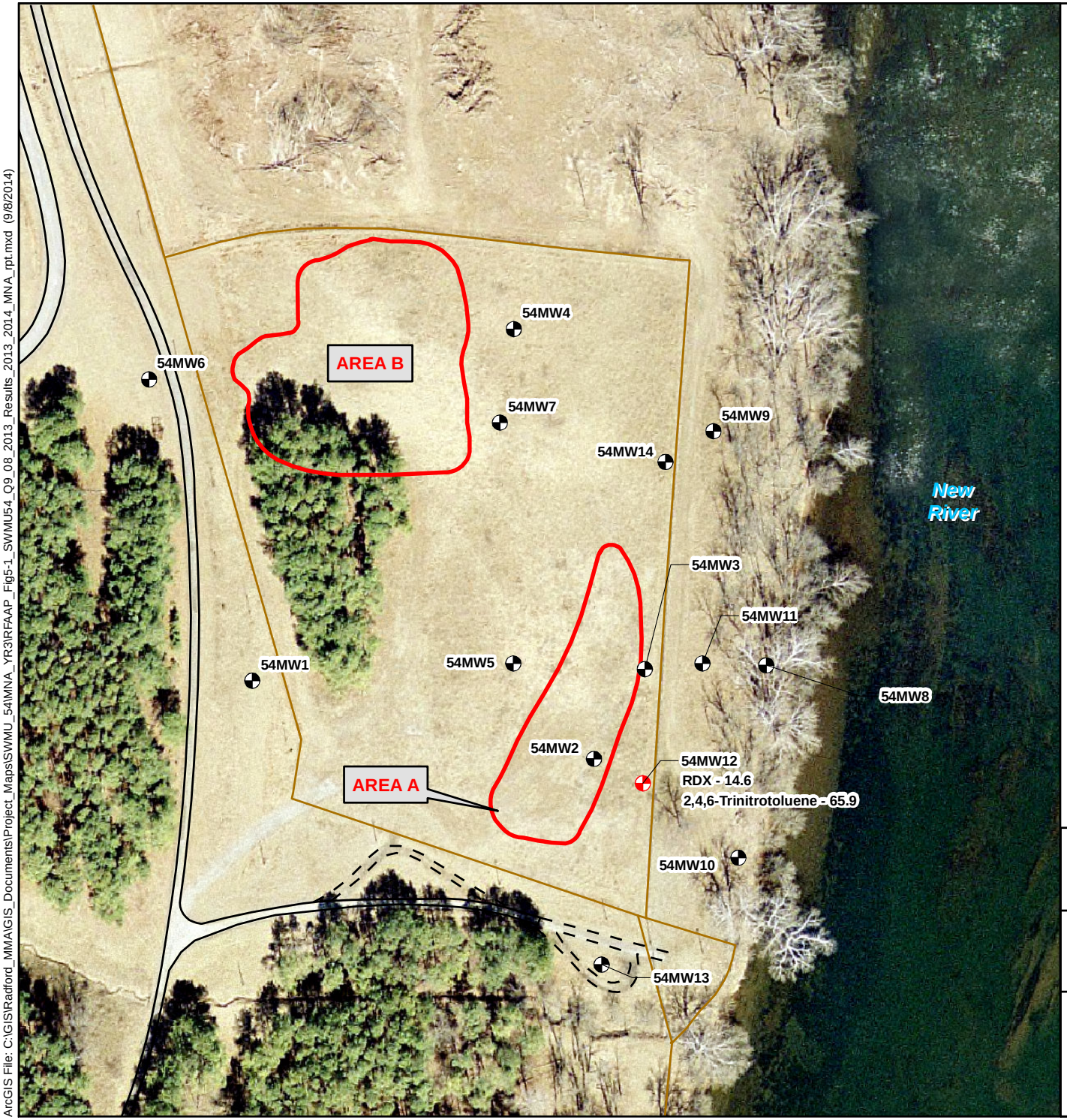
12 J Shading and black font indicates an RG exceedance

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 5-1
SWMU 54
August 2013 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig5-1_SWMU54_Q9_08_2013_Results_2013_2014_MNA_rpt.mxd (9/8/2014)

Levels of TOC in the wells ranged from 3.11 to 4.28 mg/L. Levels of DIC ranged from 17.9 to 59.9 mg/L. Dissolved ferrous iron levels were equal to or below 0.2 mg/L and dissolved manganese ranged from <0.05 to 0.15 mg/L. Chloride concentrations ranged from 1.64 mg/L to 7.83 mg/L. Nitrate was detected between 0.120 and 4.80 mg/L. Finally, sulfate detections ranged from 15.0 to 322 mg/L.

MNA indicators are displayed in **Table 4-3** and **Table 5-2**.

5.3 Tenth Quarter Groundwater Results

Four groundwater monitoring wells were sampled during the tenth quarterly sampling event. Sample locations are shown on **Figure 4-1**. A duplicate sample was collected from monitoring well 54MW12 (54TM12). Groundwater samples were analyzed for explosives, perchlorate, MNA indicator parameters and RDX breakdown by-products DNX, MNX and TNX. Detected constituents are summarized in **Table 5-3** and presented in **Table 5-4**.

Explosives

Eleven explosives were detected in the groundwater samples. 2,4,6-TNT was detected in all four wells (54MW2, 54MW10, 54MW12, and 54MW13). 2,4,6-TNT concentrations exceeded its RG of 7.8 µg/L at 54MW10 (50 µg/L), 54MW12 (17 µg/L) and 54MW13 (9.8 µg/L).

2ADNT and 4ADNT were detected in all four wells. 2,4-DNT and 2,6-DNT were detected in two wells and one well, respectively. The 2,4-DNT and 2.6-DNT detections did not exceed the DNT mixture RG of 0.932 µg/L. 1,3-Dinitrobenzene (1,3-DNB) was detected in all four wells, and 2-nitrotoluene was detected in two wells. There are no RGs for these two compounds.

RDX was detected in all four wells. RDX concentrations exceeded the RG in 54MW10, with a concentration of 21.0 µg/L.

Figure 5-2 depicts explosives concentrations for the wells where explosives have exceeded RGs.

Perchlorate

Perchlorate was detected in all four wells in the tenth quarter MNA sampling. Perchlorate concentrations did not exceed the RG in the tenth quarter of MNA sampling.

Miscellaneous Analyses

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, chloride, nitrate, and sulfate) for the purposes of evaluating the effectiveness of the MNA process. Three RDX breakdown byproducts - DNX, MNX, and TNX -were added to the sampling program in the tenth quarter to assess whether natural attenuation processes were affecting RDX.

Levels of TOC in the wells ranged from 0.50 to 2.5 mg/L. Levels of DIC ranged from 54.0 to 76.0 mg/L. Dissolved ferrous iron was measured at levels below 0.2 mg/L and dissolved manganese levels were equal to or <0.05 mg/L. Chloride concentrations ranged from 4.3 mg/L to 5.6 mg/L. Nitrate was detected between 0.25 and 1.1 mg/L. Finally, sulfate detections ranged from 26 to 57 mg/L. DNX, MNX and TNX were each detected in the same three wells where RDX was detected. (54MW10, 54MW12 and 54MW13).

MNA indicators are displayed in **Table 4-5** and **Table 5-4**.

Table 5-3
SWMU 54 Summary of Tenth Quarter Groundwater Samples

	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
1,3-Dinitrobenzene	na	na	5	5	0.064	2.2	54MW10
2,4,6-Trinitrotoluene	7.82	4	5	5	0.46	50	54MW10
2,4-Dinitrotoluene	na	na	2	5	0.2	0.2	54MW10
2,6-Dinitrotoluene	na	na	1	5	0.11	0.11	54MW13
DNT Mixture*	0.932	0	3	5	0.11	0.2	54MW10
2-amino-4,6-Dinitrotoluene	na	na	5	5	0.73	8.1	54TM12
2-Nitrotoluene	na	na	2	5	0.065	0.19	54MW12
4-amino-2,6-Dinitrotoluene	na	na	5	5	0.45	4.5	54TM12
RDX	6.1	1	5	5	0.075	21	54MW10
DNX	na	na	4	5	0.17	0.25	54MW12
MNX	na	na	4	5	0.064	0.41	54MW10
TNX	na	na	4	5	0.2	0.59	54TM12
Misc. (ug/L)							
Perchlorate	10.9	0	5	5	0.26	2.3	54MW10
Total Organic Carbon	na	na	3	5	500	2500	54MW2
Dissolved Inorganic Carbon	na	na	5	5	54000	76000	54MW13
Dissolved Organic Carbon	na	na	1	5	2400	2400	54MW2
Total Inorganic Carbon	na	na	5	5	57000	80000	54MW13
Chloride	na	na	5	5	4300	5600	54MW2
Nitrate (as N)	na	na	5	5	250	1100	54MW12
Sulfate	na	na	5	5	26000	57000	54MW10

*DNT Mixture is the sum of 2,4- and 2,6- DNT

Table 5-4
SWMU 54 Detected Analytes in Tenth Quarter Groundwater Samples

Analyte	Sample ID / Sample Date	54MW2 11/5/13					54MW10 11/5/13				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
1,3-Dinitrobenzene	na	0.064	J	J	*0.028*	*0.048*	2.2	J	J	*0.028*	*0.048*
2,4,6-Trinitrotoluene	7.82	0.46			*0.023*	*0.048*	50			*0.069*	*0.14*
2,4-Dinitrotoluene	na	0.048	U		*0.046*	*0.048*	0.2			*0.046*	*0.048*
2,6-Dinitrotoluene	na	0.048	U		*0.039*	*0.048*	0.048	U		*0.039*	*0.048*
DNT Mixture*	0.932	0.096	U		*0.085*	*0.096*	0.2			*0.085*	*0.096*
2-amino-4,6-Dinitrotoluene	na	0.73			*0.021*	*0.048*	4.5			*0.021*	*0.048*
2-Nitrotoluene	na	0.048	U		*0.032*	*0.048*	0.048	U		*0.032*	*0.048*
4-amino-2,6-Dinitrotoluene	na	0.45			*0.022*	*0.024*	4.3			*0.022*	*0.024*
RDX	6.1	0.075	J	J	*0.044*	*0.048*	21			*0.13*	*0.14*
DNX	na	0.048	U		*0.029*	*0.048*	0.21	J	J	*0.029*	*0.048*
MNX	na	0.048	U		*0.018*	*0.048*	0.41			*0.018*	*0.048*
TNX	na	0.048	U		*0.031*	*0.048*	0.3	J	J	*0.031*	*0.048*
Misc. (ug/L)											
Perchlorate	10.9	0.26			*0.019*	*0.04*	2.3			*0.019*	*0.04*
Total Organic Carbon	na	2500			*500*	*500*	680	J	J	*500*	*500*
Dissolved Inorganic Carbon	na	74000			*1000*	*1000*	66000			*1000*	*1000*
Dissolved Organic Carbon	na	2400			*1000*	*1000*	1000	U		*1000*	*1000*
Total Inorganic Carbon	na	75000			*1000*	*1000*	70000			*1000*	*1000*
Chloride	250000	5600			*250*	*250*	4600			*250*	*250*
Nitrate (as N)	10000	250			*25*	*25*	670			*25*	*25*
Sulfate	250000	29000			*250*	*250*	57000			*500*	*500*

*DNT Mixture is the sum of 2,4- and 2,6- DNT

Table 5-4
SWMU 54 Detected Analytes in Tenth Quarter Groundwater Samples

Analyte	Sample ID / Sample Date / RG	54MW12 11/5/13					54MW13 11/5/13				
		Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
1,3-Dinitrobenzene	na	1.4	J	L	*0.028*	*0.048*	0.74	J	J	*0.028*	*0.048*
2,4,6-Trinitrotoluene	7.82	17			*0.023*	*0.048*	9.8			*0.023*	*0.048*
2,4-Dinitrotoluene	na	0.2	J	J	*0.046*	*0.048*	0.048	U		*0.046*	*0.048*
2,6-Dinitrotoluene	na	0.048	U		*0.039*	*0.048*	0.11	J	B	*0.039*	*0.048*
DNT Mixture*	0.932	0.2	J		*0.085*	*0.096*	0.11	J	B		
2-amino-4,6-Dinitrotoluene	na	8			*0.021*	*0.048*	1.6			*0.021*	*0.048*
2-Nitrotoluene	na	0.19	J	J	*0.032*	*0.048*	0.048	U		*0.032*	*0.048*
4-amino-2,6-Dinitrotoluene	na	4.4			*0.022*	*0.024*	1.3			*0.022*	*0.024*
RDX	6.1	0.54	J	K	*0.044*	*0.048*	4	J	J	*0.044*	*0.048*
DNX	na	0.25	J	J	*0.029*	*0.048*	0.17	J	J	*0.029*	*0.048*
MNX	na	0.092	J	J	*0.018*	*0.048*	0.064	J	J	*0.018*	*0.048*
TNX	na	0.58	J	K	*0.031*	*0.048*	0.2	J	J	*0.031*	*0.048*
Misc. (ug/L)											
Perchlorate	10.9	1.1			*0.019*	*0.04*	0.43			*0.019*	*0.04*
Total Organic Carbon	na	500	J	J	*500*	*500*	500	U		*500*	*500*
Dissolved Inorganic Carbon	na	55000			*1000*	*1000*	76000			*1000*	*1000*
Dissolved Organic Carbon	na	1000	U		*1000*	*1000*	1000	U		*1000*	*1000*
Total Inorganic Carbon	na	58000			*1000*	*1000*	80000			*1000*	*1000*
Chloride	250000	5400			*250*	*250*	4300			*250*	*250*
Nitrate (as N)	10000	1100			*25*	*25*	450			*50*	*50*
Sulfate	250000	26000			*250*	*250*	39000			*250*	*250*

Table 5-4
SWMU 54 Detected Analytes in Tenth Quarter Groundwater Samples

Analyte	Sample ID / Sample Date	54TM12 11/5/13				
	RG	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)						
1,3-Dinitrobenzene	na	1.4	J	J	*0.028*	*0.048*
2,4,6-Trinitrotoluene	7.82	18			*0.023*	*0.048*
2,4-Dinitrotoluene	na	0.048	U		*0.046*	*0.048*
2,6-Dinitrotoluene	na	0.048	U		*0.039*	*0.048*
DNT Mixture*	0.932	0.096	U		*0.085*	*0.096*
2-amino-4,6-Dinitrotoluene	na	8.1			*0.021*	*0.048*
2-Nitrotoluene	na	0.065	J	J	*0.032*	*0.048*
4-amino-2,6-Dinitrotoluene	na	4.5			*0.022*	*0.024*
RDX	6.1	0.51	J	J	*0.044*	*0.048*
DNX	na	0.25	J	J	*0.029*	*0.048*
MNX	na	0.096	J	J	*0.018*	*0.048*
TNX	na	0.59			*0.031*	*0.048*
Misc. (ug/L)						
Perchlorate	10.9	1.1			*0.019*	*0.04*
Total Organic Carbon	na	500	U		*500*	*500*
Dissolved Inorganic Carbon	na	54000			*1000*	*1000*
Dissolved Organic Carbon	na	1000	U		*1000*	*1000*
Total Inorganic Carbon	na	57000			*1000*	*1000*
Chloride	250000	5400			*250*	*250*
Nitrate (as N)	10000	1100			*25*	*25*
Sulfate	250000	26000			*250*	*250*

12 J Shading and black font indicates an RG exceedance

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

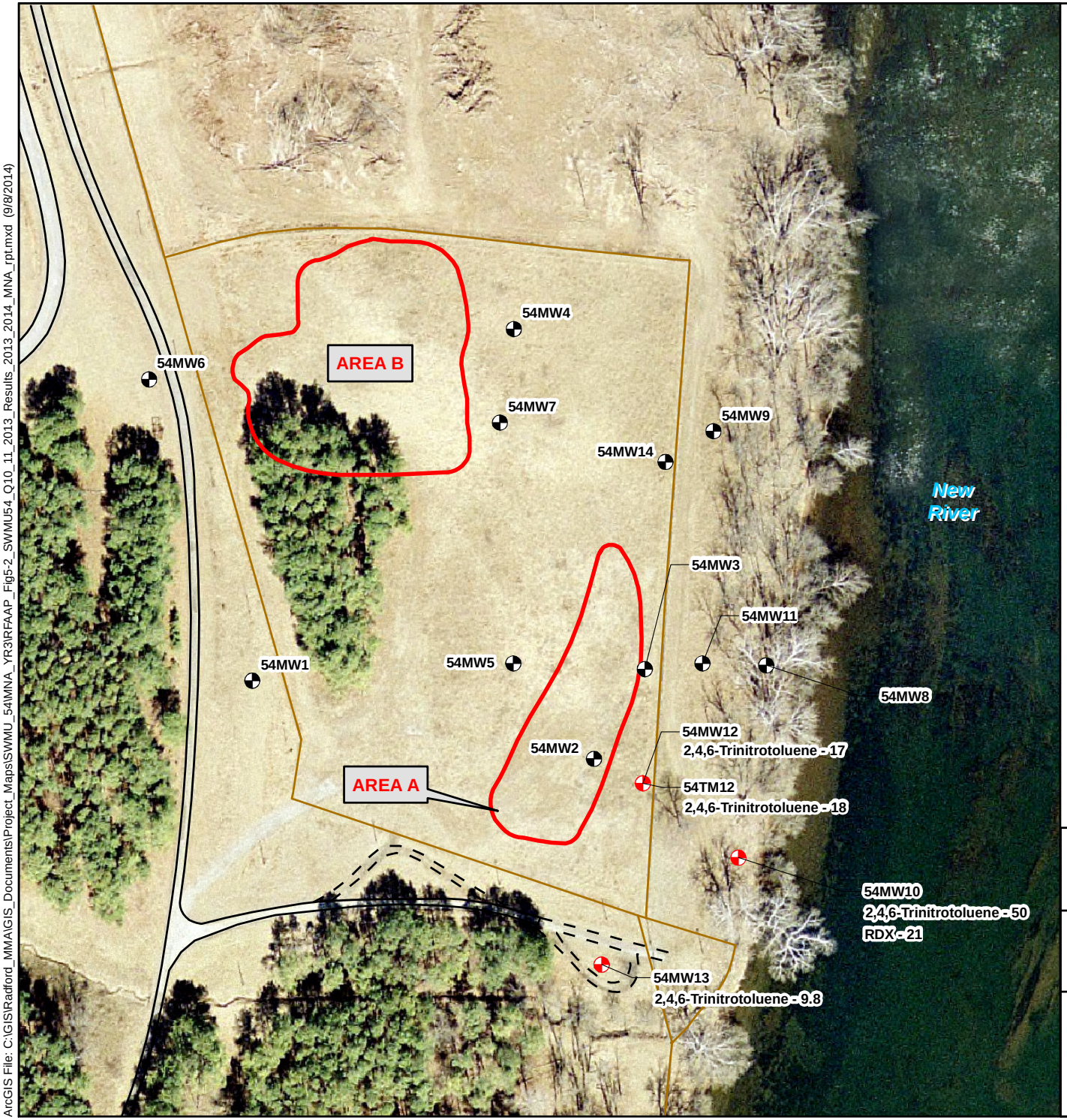
Data Qualifiers:

B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration bias high.

L = Analyte present. Reported value may be biased low. U = Undetected.



LEGEND

- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 5-2
SWMU 54
November 2013 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig5-2_SWMU54_Q10_11_2013_Results_2013_2014_MNA_rpt.mxd (9/8/2014)

5.4 Eleventh Quarter Groundwater Results

Four groundwater monitoring wells were sampled during the eleventh quarterly sampling event. Sample locations are shown on **Figure 4-1**. A duplicate sample was collected from monitoring well 54MW12 (54TM12). Groundwater samples were analyzed for explosives, perchlorate, MNA indicator parameters, and RDX breakdown by-products. Detected constituents are summarized in **Table 5-5** and presented in **Table 5-6**.

Explosives

Ten explosives were detected in the groundwater samples. 2,4,6-TNT was detected in three wells (54MW10, 54MW12, and 54MW13). 2,4,6-TNT concentrations exceeded the RG of 7.82 µg/L in wells 54MW10 (13 µg/L) and 54MW12 (29 µg/L) during the eleventh quarter of groundwater sampling.

2ADNT was detected in three wells (54MW10, 54MW12 and 54MW13). 4ADNT was detected in two wells (54MW10, and 54MW12). 2,4-DNT was also identified in 54MW10, and 54MW12. 1,3-DNB was detected in three wells (54MW10, 54MW12 and 54MW13). 2-Nitrotoluene was detected in two wells (54MW10 and 54MW12); nitroglycerin was also detected in the same two wells.

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX concentrations exceeded the RG of 6.1 µg/L in well 54MW12 (8.7 µg/L) during the eleventh quarter of groundwater sampling. **Figure 5-3** depicts explosives concentrations for the wells where explosives have been detected, as compared to RGs.

Perchlorate

Perchlorate was detected in three wells (54MW10, 54MW12, and 54MW13). Perchlorate concentrations did not exceed the RG in the eleventh quarter MNA sampling.

Miscellaneous Analyses

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, chloride, nitrate, and sulfate) for the purposes of evaluating the effectiveness of the MNA process.

Levels of TOC in the wells ranged from non-detect to 1.0 mg/L. Levels of DIC ranged from 59 to 85 mg/L. Dissolved ferrous iron was measured at levels equal to or below 0.2 mg/L and dissolved manganese ranged from <0.05 to 0.05 mg/L. Nitrate levels ranged between non-detect and 3.1 mg/L. Chloride concentrations ranged from 1.4 mg/L to 5.6 mg/L. Finally, sulfate detections ranged from 30 to 89 mg/L.

DNX and TNX were each detected in the same three wells where RDX was detected (54MW10, 54MW12, and 54MW13). MNX was not detected in the groundwater samples.

MNA indicators are displayed in **Table 4-7** and **Table 5-6**.

Table 5-5
SWMU 54 Summary of Eleventh Quarter Groundwater Samples

	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
1,3-Dinitrobenzene	na	na	4	5	0.19	5.5	54TM12
2,4,6-Trinitrotoluene	7.82	3	4	5	2.5	29	54MW12
2,4-Dinitrotoluene	na	na	3	5	0.068	0.31	54MW12
DNT Mixture*	0.932	0	3	5	0.068	0.31	54MW12
2-amino-4,6-Dinitrotoluene	na	na	4	5	0.068	6.4	54MW12
2-Nitrotoluene	na	na	3	5	1.3	3.1	54MW12
4-amino-2,6-Dinitrotoluene	na	na	4	5	0.52	3.8	54MW12
RDX	6.1	2	4	5	0.88	8.7	54MW12
Nitroglycerin	na	na	3	5	2.4	47	54MW12
DNX	na	na	4	5	0.13	0.36	54MW12
MNX	na	na	3	5	0.13	0.32	54TM12
TNX	na	na	4	5	0.14	0.47	54MW12
Misc. (ug/L)							
Perchlorate	10.9	0	4	5	0.32	4.3	54TM12
Total Organic Carbon	na	na	3	5	530	1000	54MW01
Dissolved Inorganic Carbon	na	na	5	5	59000	85000	54MW10
Dissolved Organic Carbon	na	na	1	5	1000	1000	54TM12
Total Inorganic Carbon	na	na	5	5	59000	91000	54MW10
Chloride	na	na	5	5	1400	5700	54TM12
Nitrate (as N)	na	na	4	5	440	3100	54MW12
Sulfate	na	na	5	5	30000	89000	54MW10

*DNT Mixture is the sum of 2,4- and 2,6- DNT

Table 5-6
SWMU 54 Detected Analytes in Eleventh Quarter Groundwater Samples
Page 1 of 2

Analyte	Sample ID	54MW01					54MW10				
	Sample Date	2/19/14					2/19/14				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
1,3-Dinitrobenzene	na	0.048	U		*0.028*	*0.048*	1.4	J	J	*0.028*	*0.048*
2,4,6-Trinitrotoluene	7.82	0.048	U		*0.023*	*0.048*	13			*0.023*	*0.048*
2,4-Dinitrotoluene	na	0.048	U		*0.046*	*0.048*	0.068	J	B	*0.046*	*0.048*
DNT Mixture*	0.932	0.096	U		*0.085*	*0.096*	0.068	J	B	*0.085*	*0.096*
2-amino-4,6-Dinitrotoluene	na	0.048	U		*0.021*	*0.048*	0.068	J	B	*0.021*	*0.048*
2-Nitrotoluene	na	0.048	U		*0.032*	*0.048*	1.3	J	J	*0.032*	*0.048*
4-amino-2,6-Dinitrotoluene	na	0.024	U		*0.022*	*0.024*	2.3			*0.022*	*0.024*
RDX	6.1	0.048	U		*0.044*	*0.048*	5.3			*0.044*	*0.048*
Nitroglycerin	na	3.6	U		*1.4*	*3.6*	2.4	J	J	*1.4*	*3.6*
DNX	na	0.048	U		*0.029*	*0.048*	0.13	J	J	*0.029*	*0.048*
MNX	na	0.048	U		*0.018*	*0.048*	0.13	J	B	*0.018*	*0.048*
TNX	na	0.048	UJ		*0.031*	*0.048*	0.22			*0.031*	*0.048*
Misc. (ug/L)											
Perchlorate	10.9	0.04	U		*0.019*	*0.04*	0.42			*0.019*	*0.04*
Total Organic Carbon	na	1000			*500*	*500*	530	J	J	*500*	*500*
Dissolved Inorganic Carbon	na	59000			*1000*	*1000*	85000			*1000*	*1000*
Dissolved Organic Carbon	na	1000	U		*1000*	*1000*	1000	U		*1000*	*1000*
Total Inorganic Carbon	na	59000			*1000*	*1000*	91000			*1000*	*1000*
Chloride	na	1400			*250*	*250*	4200			*250*	*250*
Nitrate (as N)	na	25	U		*25*	*25*	470			*25*	*25*
Sulfate	na	30000			*250*	*250*	89000			*500*	*500*

*DNT Mixture is the sum of 2,4- and 2,6- DNT

Table 5-6
SWMU 54 Detected Analytes in Eleventh Quarter Groundwater Samples
Page 2 of 2

Analyte	Sample ID Sample Date	54MW12 2/19/14					54MW13 2/19/14					54TM12 2/19/14				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																
1,3-Dinitrobenzene	na	5.3		K	*0.028*	*0.048*	0.19	J	J	*0.028*	*0.048*	5.5	J	J	*0.028*	*0.048*
2,4,6-Trinitrotoluene	7.82	29			*0.069*	*0.14*	2.5			*0.023*	*0.048*	28			*0.069*	*0.14*
2,4-Dinitrotoluene	na	0.31	J	B	*0.046*	*0.048*	0.048	U		*0.046*	*0.048*	0.3	J	B	*0.046*	*0.048*
DNT Mixture*	0.932	0.31	J	B	*0.085*	*0.096*	0.096	U		*0.085*	*0.096*	0.3	J	B	*0.085*	*0.096*
2-amino-4,6-Dinitrotoluene	na	6.4		K	*0.021*	*0.048*	0.65			*0.021*	*0.048*	6.3		K	*0.021*	*0.048*
2-Nitrotoluene	na	3.1	J	J	*0.032*	*0.048*	0.048	U		*0.032*	*0.048*	3	J	J	*0.032*	*0.048*
4-amino-2,6-Dinitrotoluene	na	3.8		K	*0.022*	*0.024*	0.52		B	*0.022*	*0.024*	3.8		K	*0.022*	*0.024*
RDX	6.1	8.7		K	*0.044*	*0.048*	0.88	J	J	*0.044*	*0.048*	8.6		K	*0.044*	*0.048*
Nitroglycerin	na	47	J	J	*1.4*	*3.6*	3.6	U		*1.4*	*3.6*	46	J	J	*1.4*	*3.6*
DNX	na	0.36	J	J	*0.029*	*0.048*	0.24	J	J	*0.029*	*0.048*	0.35	J	J	*0.029*	*0.048*
MNX	na	0.31		B	*0.018*	*0.048*	0.048	U		*0.018*	*0.048*	0.32		B	*0.018*	*0.048*
TNX	na	0.47	J	J	*0.031*	*0.048*	0.14	J	J	*0.031*	*0.048*	0.47	J	J	*0.031*	*0.048*
Misc. (ug/L)																
Perchlorate	10.9	4			*0.019*	*0.04*	0.32			*0.019*	*0.04*	4.3			*0.019*	*0.04*
Total Organic Carbon	na	1000			*500*	*500*	500	U		*500*	*500*	500	U		*500*	*500*
Dissolved Inorganic Carbon	na	70000			*1000*	*1000*	68000			*1000*	*1000*	70000			*1000*	*1000*
Dissolved Organic Carbon	na	1000	U		*1000*	*1000*	1000	U		*1000*	*1000*	1000			*1000*	*1000*
Total Inorganic Carbon	na	81000			*1000*	*1000*	68000			*1000*	*1000*	72000			*1000*	*1000*
Chloride	na	5600			*250*	*250*	2200			*250*	*250*	5700			*250*	*250*
Nitrate (as N)	na	3100			*100*	*100*	440			*25*	*25*	3100			*100*	*100*
Sulfate	na	36000			*250*	*250*	31000			*250*	*250*	36000			*250*	*250*

12 J Shading and black font indicates an RG exceedance

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

Data Qualifiers:

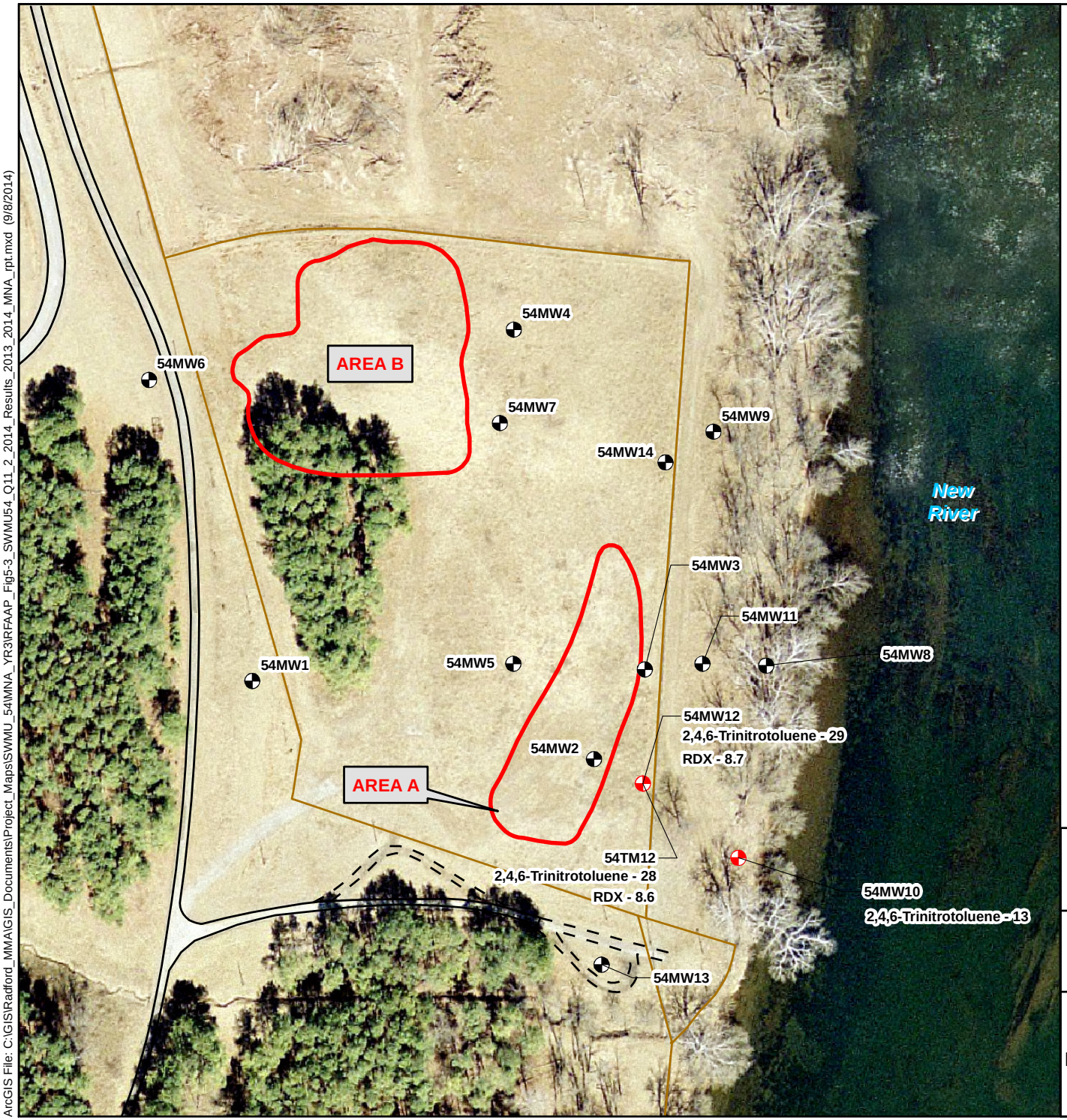
B = Not detected substantially above the level reported in laboratory or field blanks.

J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration biased high.

L = Analyte present. Reported value may be biased low.

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 5-3
SWMU 54
February 2014 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig5-3_SWMU54_Q11_2_2014_Results_2013_2014_MNA_rpt.mxd (9/8/2014)

5.5 Twelfth Quarter Groundwater Results

Four groundwater monitoring wells were sampled during the twelfth quarterly sampling event. Sample locations are shown on **Figure 4-1**. A duplicate sample was collected from monitoring well 54MW12 (54TM12). Groundwater samples were analyzed for explosives, perchlorate, MNA indicator parameters and RDX breakdown by-products. Detected constituents are summarized in **Table 5-7** and presented in **Table 5-8**.

Explosives

Thirteen explosives were detected in the groundwater samples. 2,4,6-TNT was detected in three wells (54MW10, 54MW12, and 54MW13). 2,4,6-TNT exceeded its RG in two wells - 54MW10 with a concentration of 11 µg/L and 54MW12 with a concentration of 10 µg/L.

2ADNT and 4ADNT were detected in three wells (54MW10, 54MW12, and 54MW13). 2,4-DNT and 2,6-DNT were also identified in the same three wells. Concentrations of the DNT mixture of 2,4-DNT and 2,6-DNT did not exceed the RG of 0.932 µg/L.

Additional explosives detected in the wells include 1,3-DNB, 2-nitrotoluene, 4-nitroluene and nitroglycerin. No explosives were reported in the upgradient well 54MW1.

RDX was detected in three wells (54MW10, 54MW12, and 54MW13). RDX concentrations exceeded the RG in 54MW10, with a concentration of 8.7 µg/L.

Figure 5-4 depicts explosives exceedances for the twelfth quarter of groundwater sampling.

Perchlorate

Perchlorate was detected in samples collected from all four wells (54MW1, 54MW10, 54MW12 and 54MW13) in the twelfth quarter MNA sampling. Perchlorate concentrations did not exceed the RG.

Miscellaneous Analyses

Groundwater samples were also analyzed for MNA indicators (TOC, DIC, dissolved ferrous iron, dissolved manganese, chloride, nitrate, and sulfate) for the purposes of evaluating the effectiveness of the MNA process.

Levels of TOC in the wells ranged from non-detect to 62 mg/L. Levels of DIC ranged from 45 to 60 mg/L. Dissolved ferrous iron was measured at levels equal to or below 0.2 mg/L and dissolved manganese ranged from 0.05 to 0.10 mg/L. Chloride concentrations ranged from 1.4 mg/L to 4.7 mg/L. Nitrate levels ranged from non-detect to 1.6 mg/L. Finally, sulfate detections ranged from 27 to 58 mg/L.

DNX, MNX, and TNX were also detected in the same three wells (54MW10, 54MW12, and 54MW13) as RDX.

MNA indicators are displayed in **Table 4-9** and **Table 5-8**.

Table 5-7

SWMU 54 Summary of Twelfth Quarter Groundwater Samples

	RG	# of RG Exceedances	# of Detections	# of Samples	Minimum Concentration	Maximum Concentration	Location of Maximum
Explosives (ug/L)							
1,3-Dinitrobenzene	na	na	4	5	0.66	2.3	54MW12
2,4,6-Trinitrotoluene	7.82	3	4	5	5.8	11	54MW10
2,4-Dinitrotoluene	na	na	4	5	0.038	0.2	54MW12
2,6-Dinitrotoluene	na	na	4	5	0.043	0.73	54MW12
DNT Mixture*	0.932	0	4	5	0.099	0.93	54MW12
2-amino-4,6-Dinitrotoluene	na	na	4	5	0.86	4.8	54TM12
2-Nitrotoluene	na	na	2	5	0.11	0.12	54MW12
4-amino-2,6-Dinitrotoluene	na	na	4	5	0.79	3.6	54MW12
4-Nitrotoluene	na	na	4	5	0.14	0.34	54MW10
RDX	6.1	1	4	5	2	8.7	54MW10
Nitroglycerin	na	na	2	5	1.7	2.3	54MW12
DNX	na	na	4	5	0.051	0.14	54MW13
MNX	na	na	4	5	0.083	0.19	54MW12
TNX	na	na	4	5	0.11	0.57	54TM12
Misc. (ug/L)							
Perchlorate	10.9	0	5	5	0.029	1.7	54MW12
Total Organic Carbon	na	na	2	5	51000	62000	54MW10
Dissolved Inorganic Carbon	na	na	5	5	45000	60000	54MW10
Dissolved Organic Carbon	na	na	2	5	1100	3700	54MW01
Total Inorganic Carbon	na	na	4	5	1700	52000	54TM12
Chloride	na	na	5	5	1400	4700	54MW12
Nitrate (as N)	na	na	5	5	31	1600	54MW12
Sulfate	na	na	5	5	27000	58000	54MW10

* DNT Mixture is the sum of 2,4- and 2,6-DNT

Table 5-8
SWMU 54 Detected Analytes in Twelfth Quarter Groundwater Samples

Analyte	Sample ID Sample Date	54MW01 5/28/14					54MW10 5/28/14				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)											
1,3-Dinitrobenzene	na	0.06	U	UL	*0.032*	*0.06*	0.96	J	J	*0.032*	*0.06*
2,4,6-Trinitrotoluene	7.82	0.06	U	UL	*0.029*	*0.06*	11		L	*0.029*	*0.06*
2,4-Dinitrotoluene	na	0.06	U	UL	*0.026*	*0.06*	0.038	J	J	*0.026*	*0.06*
2,6-Dinitrotoluene	na	0.06	U	UL	*0.042*	*0.06*	0.092	J	J	*0.042*	*0.06*
DNT Mixture*	0.932	0.12	U	UL	*0.068*	*0.12*	0.13	J	J	*0.068*	*0.12*
2-amino-4,6-Dinitrotoluene	na	0.06	U	UL	*0.016*	*0.06*	1.6		L	*0.016*	*0.06*
2-Nitrotoluene	na	0.06	U	UL	*0.038*	*0.06*	0.06	U	UL	*0.038*	*0.06*
4-amino-2,6-Dinitrotoluene	na	0.06	U	UL	*0.017*	*0.06*	1.7		L	*0.017*	*0.06*
4-Nitrotoluene	na	0.06	U	UL	*0.053*	*0.06*	0.34	J	J	*0.053*	*0.06*
RDX	6.1	0.06	U	UL	*0.026*	*0.06*	8.7		L	*0.026*	*0.06*
Nitroglycerin	na	3.6	U		*1.3*	*3.6*	3.6	U		*1.3*	*3.6*
DNX	na	0.048	U	UL	*0.029*	*0.048*	0.09	J	J	*0.029*	*0.048*
MNX	na	0.048	U	UL	*0.018*	*0.048*	0.12	J	J	*0.018*	*0.048*
TNX	na	0.048	UJ	UL	*0.031*	*0.048*	0.19	J	J	*0.031*	*0.048*
Misc. (ug/L)											
Perchlorate	10.9	0.029	J	J	*0.019*	*0.04*	0.44			*0.019*	*0.04*
Total Organic Carbon	na	51000	J	L	*500*	*500*	62000		J	*500*	*500*
Dissolved Inorganic Carbon	na	52000		J	*1000*	*1000*	60000		J	*1000*	*1000*
Dissolved Organic Carbon	na	3700	J	L	*1000*	*1000*	1000	U	UJ	*1000*	*1000*
Total Inorganic Carbon	na	1000	U	UJ	*1000*	*1000*	1700		J	*1000*	*1000*
Chloride	na	1400			*250*	*250*	3900			*250*	*250*
Nitrate (as N)	na	31	JH	B	*25*	*25*	330	H	L	*25*	*25*
Sulfate	na	29000			*250*	*250*	58000			*500*	*500*

* DNT Mixture is the sum of 2,4- and 2,6-DNT

Table 5-8
SWMU 54 Detected Analytes in Twelfth Quarter Groundwater Samples

Analyte	Sample ID	54MW12					54MW13					54TM12				
	Sample Date	5/28/14					5/28/14					5/28/14				
	RG	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL	Result	Lab Q	Val Q	MDL	MRL
Explosives (ug/L)																
1,3-Dinitrobenzene	na	2.3			*0.032*	*0.06*	0.66	J	J	*0.032*	*0.06*	2.2			*0.032*	*0.06*
2,4,6-Trinitrotoluene	7.82	10			*0.029*	*0.06*	5.8			*0.029*	*0.06*	11			*0.029*	*0.06*
2,4-Dinitrotoluene	na	0.2	J	J	*0.026*	*0.06*	0.056	J	J	*0.026*	*0.06*	0.16	J	J	*0.026*	*0.06*
2,6-Dinitrotoluene	na	0.73	J	J	*0.042*	*0.06*	0.043	J	J	*0.042*	*0.06*	0.46	J	J	*0.042*	*0.06*
DNT Mixture*	0.932	0.93	J	J	*0.068*	*0.12*	0.099	J	J	*0.068*	*0.12*	0.62	J	J	*0.068*	*0.12*
2-amino-4,6-Dinitrotoluene	na	4.7			*0.016*	*0.06*	0.86			*0.016*	*0.06*	4.8			*0.016*	*0.06*
2-Nitrotoluene	na	0.12	J	J	*0.038*	*0.06*	0.06	U		*0.038*	*0.06*	0.11	J	J	*0.038*	*0.06*
4-amino-2,6-Dinitrotoluene	na	3.6			*0.017*	*0.06*	0.79			*0.017*	*0.06*	3.6			*0.017*	*0.06*
4-Nitrotoluene	na	0.14	J	J	*0.053*	*0.06*	0.15	J	J	*0.053*	*0.06*	0.24	J	J	*0.053*	*0.06*
RDX	6.1	2			*0.026*	*0.06*	2.5	J	J	*0.026*	*0.06*	2.2			*0.026*	*0.06*
Nitroglycerin	na	2.3	J	B	*1.3*	*3.6*	3.6	U		*1.3*	*3.6*	1.7	J	B	*1.3*	*3.6*
DNX	na	0.051	J	J	*0.029*	*0.048*	0.14	J	J	*0.029*	*0.048*	0.056	J	J	*0.029*	*0.048*
MNX	na	0.19	J	J	*0.018*	*0.048*	0.083	J	J	*0.018*	*0.048*	0.16	J	J	*0.018*	*0.048*
TNX	na	0.5	J	J	*0.031*	*0.048*	0.11	J	J	*0.031*	*0.048*	0.57	J	J	*0.031*	*0.048*
Misc. (ug/L)																
Perchlorate	10.9	1.7			*0.019*	*0.04*	0.37			*0.019*	*0.04*	1.7			*0.019*	*0.04*
Total Organic Carbon	na	500	U		*500*	*500*	500	U		*500*	*500*	500	U		*500*	*500*
Dissolved Inorganic Carbon	na	50000			*1000*	*1000*	45000			*1000*	*1000*	46000			*1000*	*1000*
Dissolved Organic Carbon	na	1000	U		*1000*	*1000*	1100			*1000*	*1000*	1000	U		*1000*	*1000*
Total Inorganic Carbon	na	50000			*1000*	*1000*	46000			*1000*	*1000*	52000			*1000*	*1000*
Chloride	na	4700			*250*	*250*	2200			*250*	*250*	4700			*250*	*250*
Nitrate (as N)	na	1600			*25*	*25*	410			*25*	*25*	1600			*25*	*25*
Sulfate	na	31000			*250*	*250*	27000			*250*	*250*	31000			*250*	*250*

12 J Shading and black font indicates an RG exceedance

RG source: SWMU 54 RFI/CMS Report, Final Document (URS, 2008)

Data Qualifiers:

B = Not detected substantially above the level reported in laboratory or field blanks.

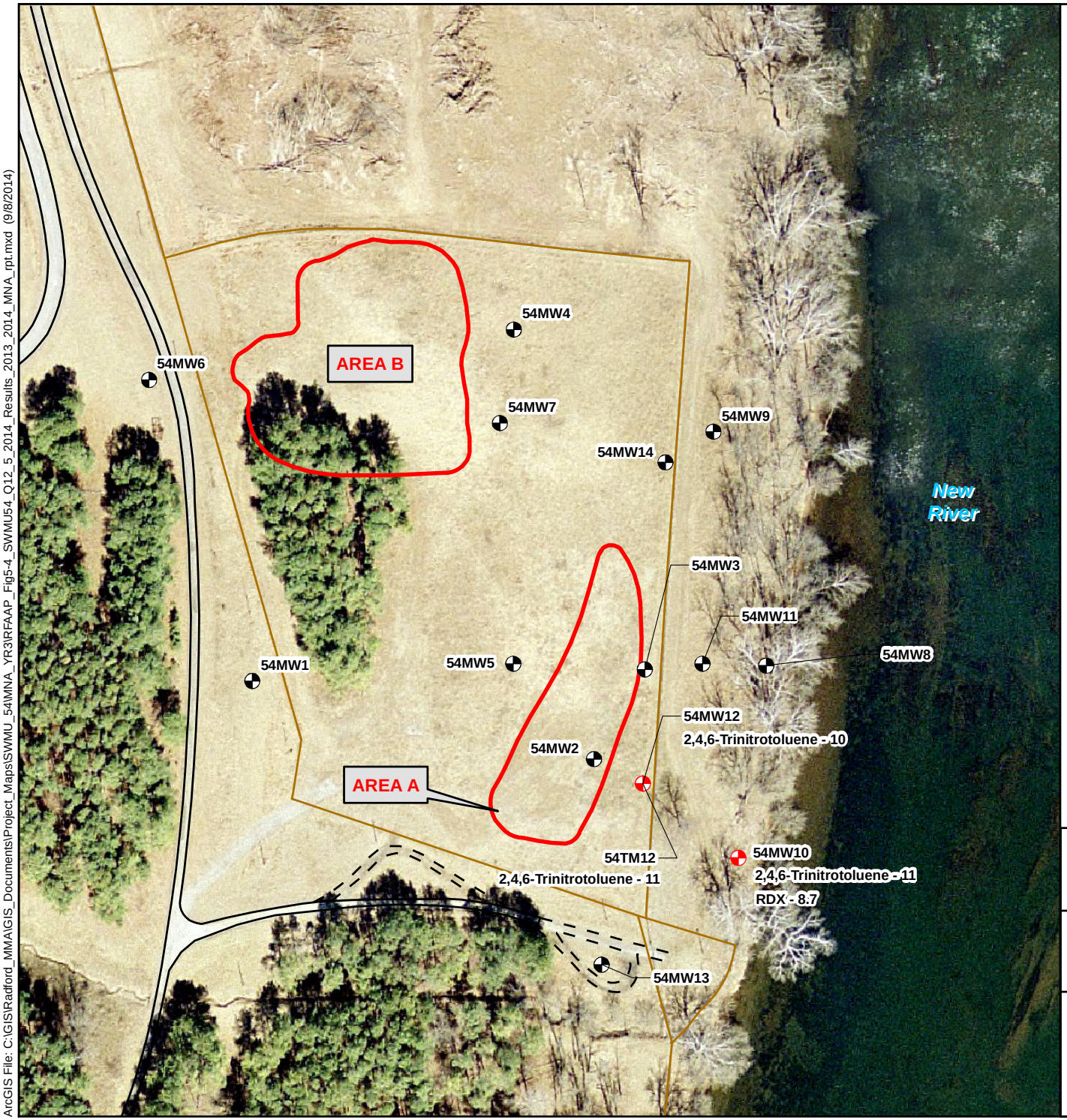
J = Analyte present. Reported value may not be accurate or precise.

K = Estimated concentration bias high.

L = Analyte present. Reported value may be biased low. Actual value is expected to be higher.

P = There is >40% RPD for detected concentrations between the two different columns. Lower of the two values is reported on the Form1

U = Not detected. The associated number indicates the approximate sample concentration necessary to be detected.



LEGEND

- Monitoring Well
- Monitoring Well (Groundwater Sample Result >= RGs)
- Dirt Road
- Paved Road
- Railroad
- Fence
- SWMU 54 Boundary

Notes:
1) Aerial photo, dated 2005, was obtained from Montgomery County Planning, VA Planning & GIS Services.
2) Sample results are in ug/L.
3) RGs = Remedial Goals.
3) Only the results exceeding the RGs are reported.

N

Scale:

0 75 150 300 Feet

U.S. Army Corps of Engineers

CB&I Federal Services LLC
4696 Millennium Drive, Suite 320
Belcamp, Maryland 21017

FIGURE 5-4
SWMU 54
May 2014 Groundwater Sample Results
Radford Army Ammunition Plant,
Radford, VA

ArcGIS File: C:\GIS\Radford_MMA\GIS_Documents\Project_Maps\SWMU_54\MNA_YR3\RFAAP_Fig5-4_SWMU54_Q12_5_2014_Results_2013_2014_MNA_rpt.mxd (9/8/2014)

5.6 Year One Through Year Three Sample Results

This section discusses the results from the first 3 years of MNA sampling. Samples collected during the first two years were analyzed for the full suite of analytical parameters described in **Table 4-2** (explosives, perchlorate, and MNA indicators). The Year 2 MNA Report (CB&I, 2013) recommended elimination of the wells with no COI exceedances for the first two years, based on criteria established in the MNA work plan. The ninth quarter of sampling occurred prior to regulatory approval of the MNA report, and the original parameters were included in that sampling event. After approval of the Year 2 report, the sample plan was modified to include RDX MNA indicators in the analytical suite and reduce the sampling program from 14 monitoring wells to three wells with COI exceedances (54MW10, 12, and 13), and an upgradient well (54MW1) to monitor background conditions. Additionally, the annual surface water and sediment pore water sampling from the New River were eliminated.

5.6.1 Groundwater

Explosives

Samples from the wells within SWMU 54 were analyzed for explosives for twelve quarters of sampling. Thirteen explosives were detected in the samples including DNX, MNX, and TNX, which were added to the sampling program for Quarters 10 to 12.

Explosives concentrations were below selected RGs in all monitoring well locations except 54MW10, 54MW12, and 54MW13. **Figures 5-5 through 5-7** depict the concentrations at these sampling locations throughout the twelve quarters of sampling.

2,4,6-TNT was not detected in monitoring wells 54MW1, 54MW3 through 54MW7, 54MW9, 54MW11, and 54MW14 through eight quarters of sampling. 2,4,6-TNT concentrations have remained below the RG in 54MW2 and 54MW8 throughout the duration of the monitoring. 2,4,6-TNT concentrations were detected at levels above the RG in the fifth quarter of sampling at 54MW10. 2,4,6-TNT concentrations at 54MW10 decreased below the RG in Quarters 6 through 9; however, the 2,4,6,-TNT levels were above the RG for Quarters 10 to 12. At monitoring well 54MW12, 2,4,6-TNT concentrations have consistently been above the RG for all sampling events except Quarters 6 and 7. Quarter 8 recorded the highest concentration of 2,4,6-TNT to date at 108 µg/L. 2,4,6-TNT concentrations at 54MW13 have typically been below the RG with the exception of the fifth and tenth quarters of sampling where it exceeded the RG.

2ADNT and 4ADNT, degradation intermediaries of 2,4,6-TNT, were detected at monitoring wells 54MW2, 54MW3, 54MW5, 54MW8, 54MW10, 54MW12, 54MW13, and 54MW14. An analysis of monitoring locations 54MW10, 54MW12, and 54MW13 shows a correlation in 2,4,6-TNT concentration spikes with increasing concentrations of both 2ADNT and 4ADNT, indicating a limited transformation process from 2,4,6-TNT (**Figures 5-8 through 5-10**, respectively). 2,4,6-TNT degradation leading to amino-DNTs is likely occurring at localized zones within the soil matrix where the conditions are more favorable.

2,4-DNT was encountered at 54MW12 in the fourth quarter sample and samples from recent Quarters 10 through 12. 2,4-DNT was also detected in monitoring well 54MW10 during the tenth through twelfth quarters and 54MW13 in Quarter 12. 2,6-DNT was identified in 54MW10, 54MW12 and 54MW13 during the twelfth quarter. The combined concentrations of 2,4-DNT and 2,6-DNT did not exceed the RG of 0.932 µg/L for DNT mixture.

Additional explosives detected in the groundwater samples include 1,3-dinitrobenzene, nitroglycerin, 2-nitrotoluene and 4-nitrotoluene. There are no RGs for these compounds. These compounds have only been detected in monitoring wells 54MW10, 54MW12 and 54MW13.

RDX was not encountered in monitoring wells 54MW1, 54MW3 through 54MW7, 54MW9, 54MW11, and 54MW14. Concentrations of RDX were found to be below the RG for nine quarters in monitoring wells 54MW2, 54MW8, and below the RG for 12 quarters at 54MW13. RDX concentrations exceeded the RDX RG in the fifth quarter, tenth quarter and twelfth quarter in sample location 54MW10. RDX concentrations measured in 54MW12 exceeded the RG in seven of twelve quarters sampled. It is currently unclear if MNA is the cause of a general downward trend in RDX concentrations site wide, with the exception of Quarters 5, 8, 10 and 12 at monitoring locations 54MW10 and 54MW12 (**Figures 5-5 and 5-7**).

Many of the intermediate and end-products of RDX degradation are relatively short-lived in the environment, and accumulation of these would not be expected. Studies on the fate and transport of explosives in the environment state that the nitroso intermediates of RDX (DNX, MNX, and TNX) have rarely been observed in the field at the few sites where analyses have been conducted for them (Branning and Pennington, 2002). Many of these intermediates are observed only transiently due to their susceptibility to rapid mineralization, typically persisting only on the scale of several hours to several days. Significant observations of the final end-products are also not expected. Hydrazines, dimethylhydrazines, and methanol are not likely to accumulate in the environment, particularly at the low concentrations they would be produced as end-products, because these compounds very rapidly biodegrade. Therefore, the observation of intermediate and end-products of RDX biodegradation (DNX, MNX, and TNX), even at low concentrations, would be considered strong presumptive evidence of active and ongoing degradation processes.

DNX and TNX were identified in 54MW10, 54MW12 and 54MW13 during Quarters 10 through 12. MNX was detected in these wells in Quarters 10 and 12. The concentrations of these compounds were low (less than 1 µg/L), but generally mirrored the RDX concentrations in the wells. Detection of the RDX daughter products in these wells with elevated RDX concentrations suggests degradation and natural attenuation of RDX is a viable, ongoing remedial process at the site. DNX, MNX, and TNX were not detected in the upgradient wells (54MW1 and 54MW2).

In conclusion, concentrations of explosives at SWMU 54 have typically remained below the RGs throughout the site with the exception of 54MW10, 54MW12, and 54MW13.

Perchlorate

Samples from the wells within SWMU 54 were analyzed for perchlorate during all twelve quarters of sampling. Perchlorate was detected in all 14 monitoring wells. Perchlorate concentrations were below the RGs in each monitoring well except for 54MW12, where the concentration exceeded the RG of 10.9 µg/L in the fourth and eighth quarters (**Figure 5-6**). These two exceedances corresponded with spikes in 2,4,6-TNT concentrations at 54MW12.

Site-wide perchlorate levels have typically been steady and below the site specific RG with the exception of the concentrations detected at 54MW12, which appear to mirror 2,4,6-TNT concentration peaks.

Figure 5-5 SWMU 54 54MW10 Explosives Concentrations Q1 through Q12

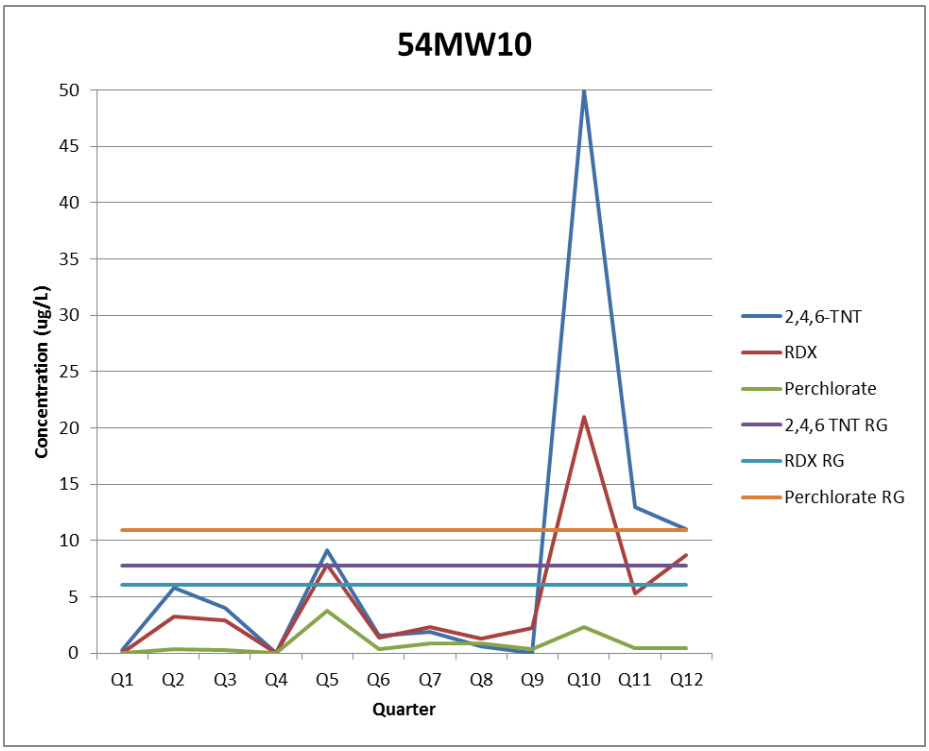


Figure 5-6 SWMU 54 54MW12 Explosives Concentrations Q1 through Q12

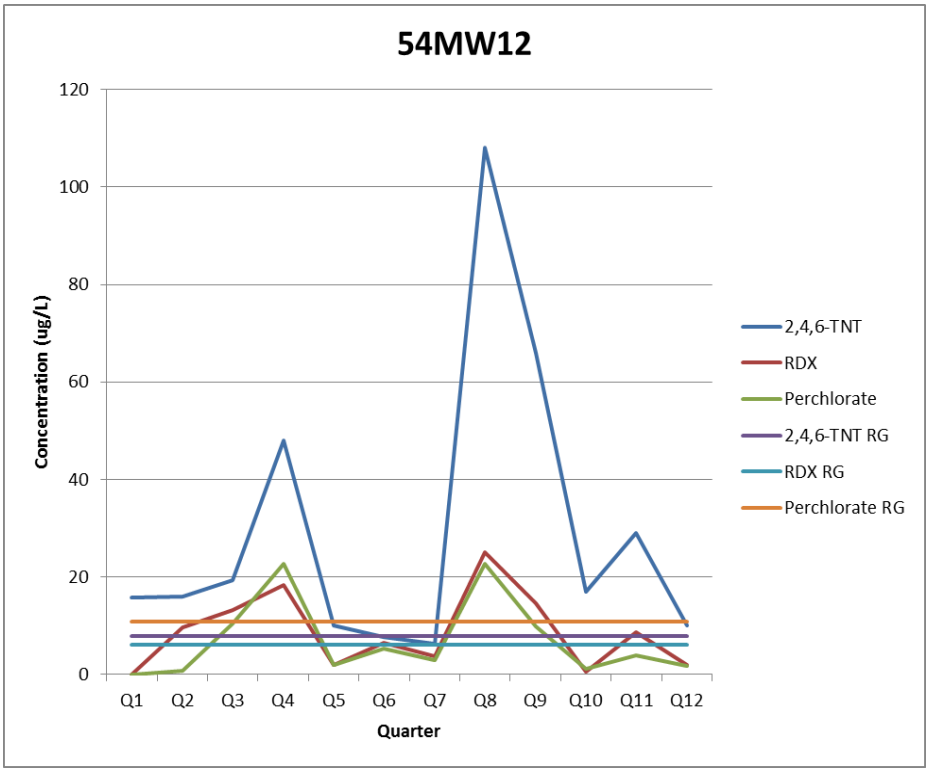


Figure 5-7 SWMU 54 54MW13 Explosives Concentrations Q1 through Q12

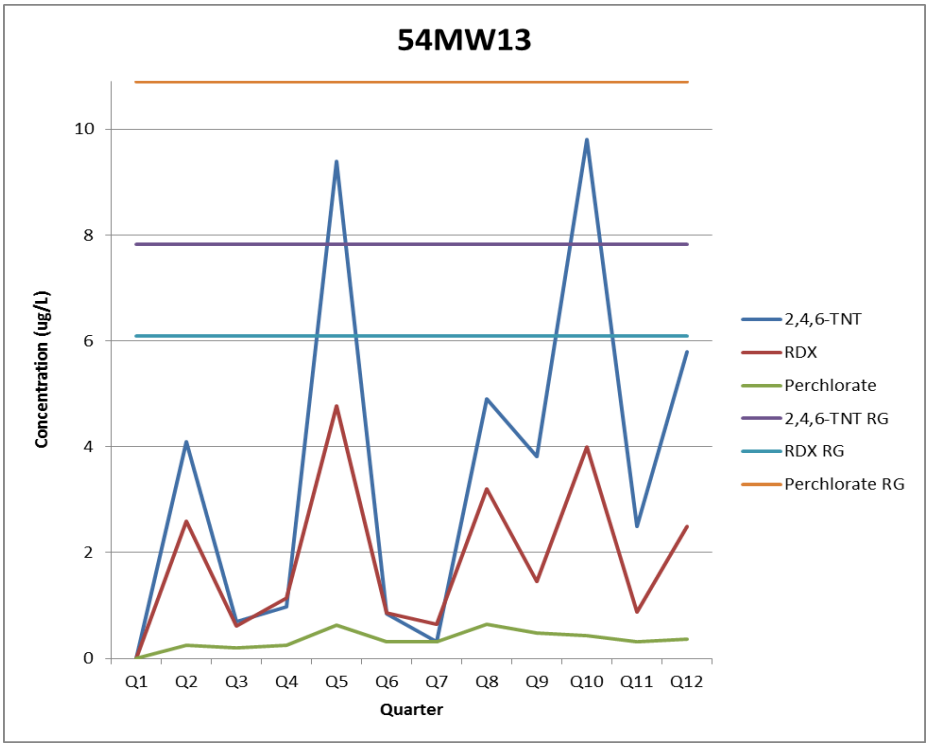


Figure 5-8 SWMU 54 54MW10 2,4,6-TNT to Amino-DNT Correlation

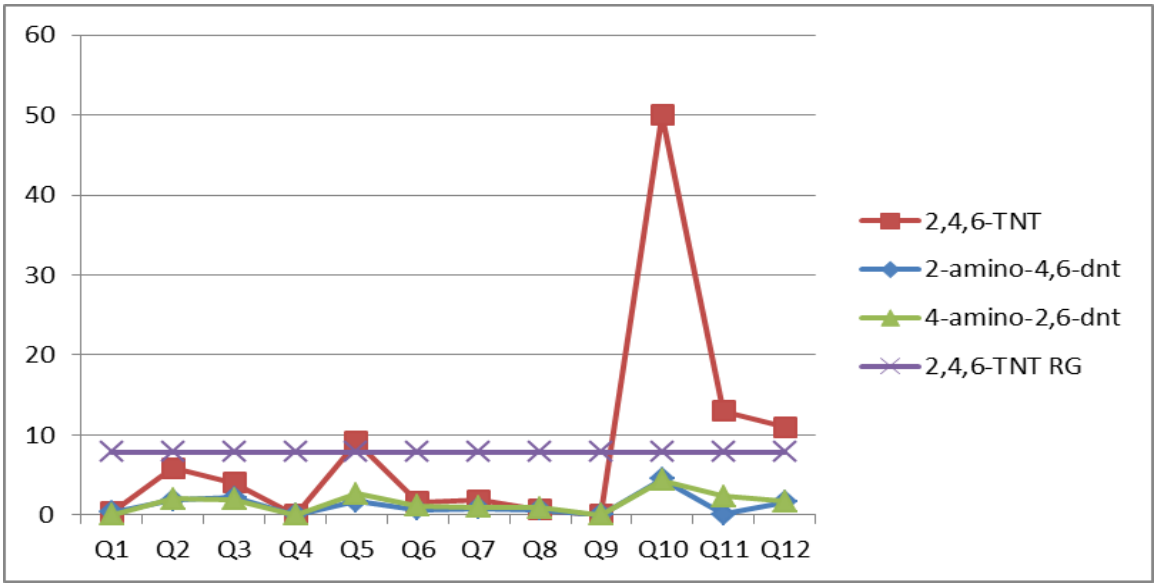


Figure 5-9 SWMU 54 54MW12 2,4,6-TNT to Amino-DNT Correlation

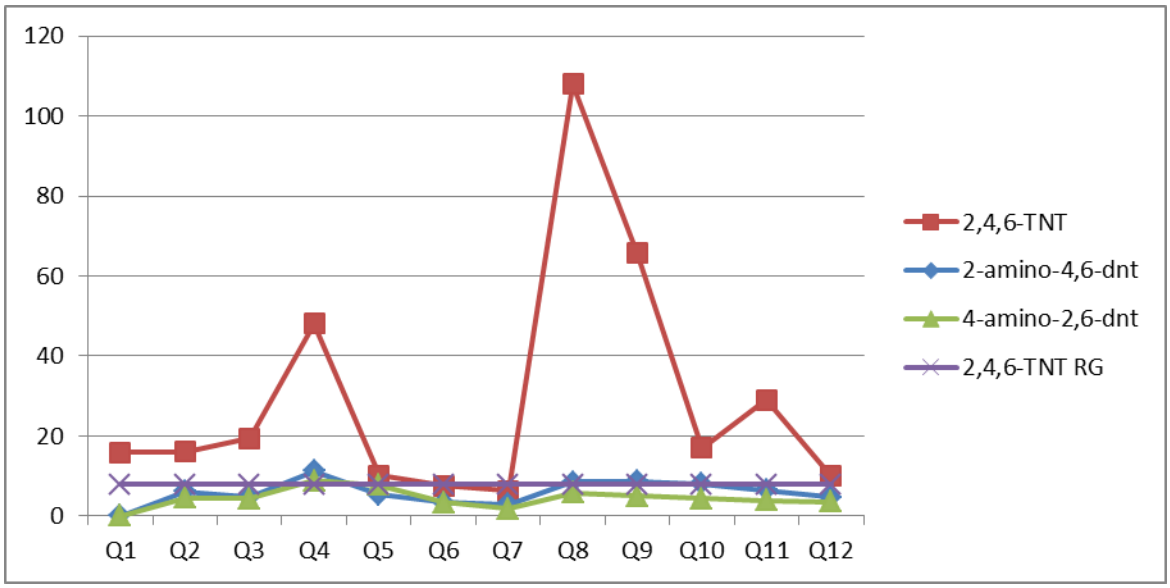
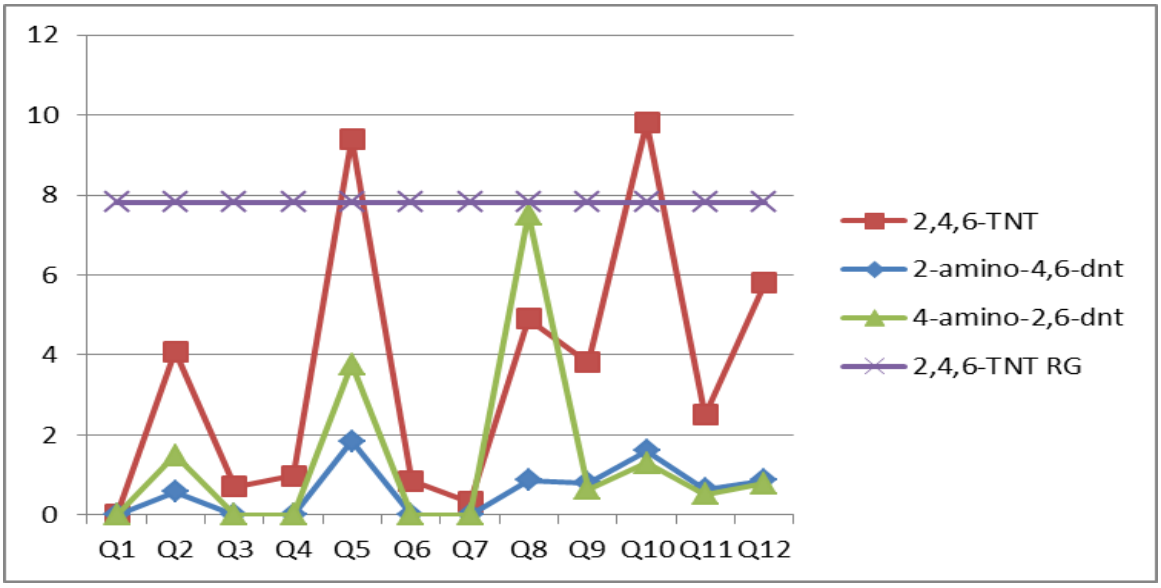


Figure 5-10 SWMU 54 54MW13 2,4,6-TNT to Amino-DNT Correlation



6.0 MNA EVALUATION OF SWMU 54

Monitored natural attenuation (MNA) is a remedial approach in which physical, chemical, and biological processes occur under favorable conditions, without human interferences to reduce the mass, toxicity, volume, concentration, and mobility of contaminants in soil and groundwater. The physical, chemical, and biological processes include biodegradation, dispersion, dilution, sorption, volatilization, and chemical or biological stabilization (USEPA, 1998). Analytical results from multiple groundwater sampling events at RFAAP SWMU 54 were evaluated for qualitative indications of natural attenuation processes that may reduce the levels of nitroaromatics (specifically 2,4,6-TNT and RDX) and perchlorate (ClO_4). The following sections present the results as they pertain to the lines of evidence used to demonstrate the potential for MNA.

6.1 First Line of Evidence: Occurrence of Contaminants

The first line of evidence consists of evaluating contaminant and daughter product concentrations in monitoring wells over time. SWMU 54 contains 14 wells (54MW1, 54MW2, 54MW3, 54MW4, 54MW5, 54MW6, 54MW7, 54MW8, 54MW9, 54MW10, 54MW11, 54MW12, 54MW13, and 54MW14), which targeted areas of potential nitroaromatic and perchlorate contamination. Historical trends and the results of quarterly groundwater sampling are discussed below, and the data is provided in **Table 6-1**.

2,4,6-TNT. Elevated concentrations of 2,4,6-TNT above the RG of 7.82 µg/L were observed in three wells, 54MW10, 54MW12, and 54MW13. 2,4,6-TNT concentrations have fluctuated in these three wells during the twelve quarterly sampling events. At monitoring well 54MW10, the 2,4,6-TNT concentration went from undetected in August 2013 (Q9) to the highest concentration recorded in this well during the three years of monitoring at 50 µg/L in November 2013 (Q10). TNT concentrations decreased in Quarters 11 and 12 but remained above the RG. A similar pattern was detected at monitoring well 54MW13, with a concentration below the RG at 3.81 µg/L in August 2013 (Q9) followed by an increase to the highest TNT concentration detected in this well at 9.8 µg/L in November 2013 (Q10). The TNT concentration decreased below the RG in Quarter 11 at 2.5 µg/L in February 2014 (Q11). The TNT concentration increased to 5.8 µg/L in Quarter 12 but remained below the RG. Monitoring well 54MW12 has generally maintained concentrations of 2,4,6-TNT above the RG; although, a sharp reduction in 2,4,6-TNT was observed from the 108 µg/L in May 2013 (Q8) to 66 µg/L in August 2013 (Q9) and 17 µg/L in November 2013 (Q10). Levels of 2,4,6-TNT detected in Quarters 11 and 12 remained above the RG.

DNT Mixture. DNT was detected in the fourth, tenth, eleventh and twelfth quarters of sampling at monitoring wells 54MW10, 54MW12 and 54MW13. The combined concentrations of 2,4-DNT and 2,6-DNT did not exceed the RG of 0.932 µg/L for DNT mixture.

RDX. Elevated concentrations of RDX above the RG of 6.1 µg/L were observed in two wells, 54MW10 and 54MW12. RDX concentrations have fluctuated in these two wells during the twelve quarterly sampling events. At monitoring well 54MW10, a sharp increase in RDX concentrations from 2.23 µg/L from August 2013 (Q9) to 21 µg/L in November 2013 (Q10) was observed. The 21 µg/L level is the highest concentration reported in this well during the 12 quarters of sampling. However, concentrations were then observed to be below the RG in February 2014 (Q11), but were above the RG at 8.7 µg/L in May 2014 (Q12). Monitoring well

Table 6-1
Analytical Results for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Parameter	Remediation Goal (RG)	July 2011 (Q1)	October 2011 (Q2)	January 2012 (Q3)	April 2012 (Q4)	August 2012 (Q5)	November 2012 (Q6)	February 2013 (Q7)	May 2013 (Q8)	August 2013 (Q9)	November 2013 (Q10)	February 2014 (Q11)	May 2014 (Q12)
		54MW1											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	0	0
RDX	6.1	0	0	0	0	0	0	0	0	0	--	0	0
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	0	0
Perchlorate	10.9	0	0	0	0	0	0	0	0	0	--	0	0.029
		54MW2											
2,4,6-TNT	7.82	2.1	0.9	2.08	2.66	0	0	0	0.749	0.974	0.46	--	--
RDX	6.1	0.572	0	0	0.384	0	0	0	0	0	0.075	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	0	--	--
Perchlorate	10.9	3.07	0.547	1.91	4.02	0	0.842	1.41	1.82	1	0.26	--	--
		54MW3											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0.53	0.18	0	0	0.405	0.303	0.309	0.59	0.446	--	--	--
		54MW4											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0	0	0	0	0	0.141	0	0	0	--	--	--
		54MW5											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0.311	0.393	0.313	0.301	0.42	0.28	0.255	0.309	0.389	--	--	--

Table 6-1
Analytical Results for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Parameter	Remediation Goal (RG)	July 2011 (Q1)	October 2011 (Q2)	January 2012 (Q3)	April 2012 (Q4)	August 2012 (Q5)	November 2012 (Q6)	February 2013 (Q7)	May 2013 (Q8)	August 2013 (Q9)	November 2013 (Q10)	February 2014 (Q11)	May 2014 (Q12)
		54MW6											
2,4,6-TNT	7.82	0	0	0	0	0	Dry	0	0	Dry	--	--	--
RDX	6.1	0	0	0	0	0	Dry	0	0	Dry	--	--	--
DNT Mixture	0.932	0	0	0	0	0	Dry	0	0	Dry	--	--	--
Perchlorate	10.9	0	0.127	0.159	0	0.175	Dry	0.16	0.171	Dry	--	--	--
		54MW7											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0.321	0	0	0.365	0	0.103	0.162	0.103	0.37	--	--	--
		54MW8											
2,4,6-TNT	7.82	0.928	0.433	0	0.301	0	0	0	0	0	--	--	--
RDX	6.1	0.761	0.567	0.493	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0	0.408	0.355	0.388	0.392	0.286	0.484	0.118	0.334	--	--	--
		54MW9											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0	0.229	0.262	0.217	0	0	1.07	0.923	0.327	--	--	--
		54MW10											
2,4,6-TNT	7.82	0.305	5.84	4.05	0	**9.17**	1.59	1.88	0.637	0	**50**	**13**	**11**
RDX	6.1	0	3.24	2.95	0	**7.84**	1.35	2.36	1.29	2.23	**21**	5.3	**8.7**
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	0.2	0.068	0.13
Perchlorate	10.9	0	0.325	0.258	0	3.74	0.344	0.832	0.835	0.365	2.3	0.42	0.44
		54MW11											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0	0	0.239	0	0	0	0.263	0.43	0.132	--	--	--

Table 6-1
Analytical Results for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Parameter	Remediation Goal (RG)	July 2011 (Q1)	October 2011 (Q2)	January 2012 (Q3)	April 2012 (Q4)	August 2012 (Q5)	November 2012 (Q6)	February 2013 (Q7)	May 2013 (Q8)	August 2013 (Q9)	November 2013 (Q10)	February 2014 (Q11)	May 2014 (Q12)
		54MW12											
2,4,6-TNT	7.82	**15.9**	**16.1**	**19.4**	**48**	**10.1**	7.62	6.29	**108**	**65.9**	**17**	**29**	**10**
RDX	6.1	0	**9.77**	**13.2**	**18.4**	1.95	**6.59**	3.79	**25**	**14.6**	0.54	**8.7**	2
DNT Mixture	0.932	0	0	0	0.381	0	0	0	0	0	0.2	0.31	0.93
Perchlorate	10.9	0	0.726	10.5	**22.8**	2	5.31	2.98	**22.7**	9.88	1.1	4	1.7
		54MW13											
2,4,6-TNT	7.82	0	4.09	0.699	0.979	**9.4**	0.843	0.318	4.91	3.81	**9.8**	2.5	5.8
RDX	6.1	0	2.59	0.614	1.14	4.77	0.855	0.642	3.2	1.46	4	0.88	2.5
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	0.11	0	0.099
Perchlorate	10.9	0	0.244	0.206	0.243	0.627	0.308	0.313	0.64	0.477	0.43	0.32	0.37
		54MW14											
2,4,6-TNT	7.82	0	0	0	0	0	0	0	0	0	--	--	--
RDX	6.1	0	0	0	0	0	0	0	0	0	--	--	--
DNT Mixture	0.932	0	0	0	0	0	0	0	0	0	--	--	--
Perchlorate	10.9	0	0.215	0.181	0.214	0.24	0	0	0.195	0.456	--	--	--

Notes:
Bold font indicates exceedance of RG.
-- Indicates well was removed from monitoring program

54MW12 has generally maintained concentrations of RDX above the RG. At this well, the RDX concentration exceeded the RG in August 2013 (Q9) at 14.6 µg/L, but RDX was detected at an estimated level of 0.54 µg/L in Quarter 10. The RDX concentration increased to above the RG in February 2014 (Q11) at 8.7 µg/L but decreased to 2.0 µg/L in Quarter 12.

RDX breakdown products were measured in monitoring wells 54MW10, 54MW12 and 54MW13 during Quarters 10 through 12. The total concentration of DNX, MNX and TNX recorded at 54MW10 in Quarter 10 was 0.92 µg/L. This concentration coincided with a spike in the RDX level at this well in Quarter 10. The concentrations of the RDX by-products decreased during Quarters 11 and 12. Similar correlations with RDX concentrations were observed in 54MW12 and 54MW13. The highest concentrations of DNX, MNX and TNX were identified in 54MW12 and 54MW13 during Quarters 11 and 10, respectively, which coincides with the highest RDX concentrations recorded in these wells during that time period.

Amino DNT. As 2,4,6-TNT is biologically degraded, the two daughter products 2ADNT and 4ADNT are formed. Both of the daughter products were present in four monitoring wells (54MW2, 54MW10, 54MW12, and 54MW13) during the latest sampling (Q9 to Q12). At 54MW12, where the highest levels of 2,4,6-TNT have been observed, both of the daughter products are present and are increasing. At 54MW10, concentrations of both daughter products mirror the 2,4,6-TNT levels. The 2ADNT and 4ADNT concentrations increase with an increase in the 2,4,6-TNT concentration and show a corresponding drop with a decrease in 2,4,6-TNT concentrations. The presence of 2ADNT and 4ADNT along with the decreasing concentrations of 2,4,6-TNT suggest biological degradation of 2,4,6-TNT is occurring at these locations.

Perchlorate. Perchlorate was detected at concentrations above the RG of 10.9 µg/L in one well, 54MW12, during the February 2012 (Q4) and May 2013 (Q8) sampling events. In August 2013 (Q9), perchlorate concentrations decreased to 9.88 µg/L and remained below the RG for the next three sampling events (Q10 to Q12). Chloride is a daughter product of perchlorate degradation. At SWMU 54, chloride is present within groundwater; however, background concentrations are too high to determine any measureable change due to perchlorate reduction. Other breakdown products for perchlorate were not included in the analysis suite for these sampling events.

The first line of evidence indicates decreasing trends in 2,4,6-TNT concentrations and the presence of daughter products, 2ADNT and 4ADNT, suggesting that natural attenuation via biological degradation of 2,4,6-TNT is occurring at SWMU 54. In addition, the identification of RDX daughter products, DNX, MNX and TNX in the wells with RDX detections indicate active degradation of RDX. Overall decreasing trends in RDX and perchlorate and the identification of intermediate by-products suggest natural attenuation of RDX and perchlorate is occurring.

6.2 Second Line of Evidence: Geochemical Conditions

Respiratory substrates are used preferentially during microbial metabolism based on the amount of energy that can be derived from each of them. Respiratory substrates are used in the following order:

$$O_2 > NO_3^- > Fe^{+3} > ClO_4 > SO_4^{-2} > CO_2$$

Geochemical data is available for all twelve quarterly groundwater sampling events at SWMU 54. Field parameters (DO, ORP, pH, temperature, and conductivity) have been collected since 2011 as part of the low-flow sampling procedures. Laboratory analysis for nitrate, sulfate, and

TOC were conducted for all twelve quarterly groundwater sampling events at SWMU 54. These geochemical data are discussed regarding the potential for biodegradation in the groundwater at SWMU 54.

The microbial degradation of nitro-aromatic compounds primarily occurs under nitrate-reducing conditions, whereas perchlorate requires sulfate reducing groundwater conditions.

Dissolved Oxygen (DO). The preferred terminal electron acceptor during aerobic microbial respiration is oxygen, and DO is measured to determine whether the groundwater is under aerobic or anaerobic conditions. Average DO values less than 1 mg/L, are tolerable of anaerobic microbial activities.

DO levels during the twelve quarterly sampling events (early 2011 to May 2014) ranged from 0.0 to 7.81 mg/L indicating both anaerobic and aerobic conditions are present at the site. Values higher than 8 mg/L are considered erroneous records given their relative magnitude to oxygen solubility at field temperatures and are not included in this analysis. In wells where biological degradation products are observed (54MW2, 54MW3, 54MW5, 54MW8, 54MW10, 54MW12, 54MW13, and 54MW14), DO levels (between 0 and 7.81 mg/L) indicate a flux between anaerobic and aerobic conditions, although aerobic conditions appear to be favored (**Table 6-2**). TNT has been known to be reduced under a variety of conditions (aerobic and anaerobic); however, further reduction of TNT breakdown products, including 2ADNT and 4ADNT, and reduction of RDX and perchlorate is more favorable under anaerobic conditions (Spain, 1995).

The sharp increase in explosive concentrations at 54MW10 and 54MW12 in Quarters 9 and 10 occurred during aerobic conditions at these wells. Under aerobic conditions, biodegradation is not as effective in the reduction of explosives and perchlorates. As a result of the subsurface biochemistry, the decreased biological activity may have led to an increase in the explosives and perchlorate concentrations during this period.

Oxidation-Reduction Potential (ORP). ORP values indicate the groundwater's reductive potential and are used to confirm the DO measurements in groundwater. ORP values less than +50 mV typically correspond to mildly reducing, anaerobic conditions, while ORP values less than -200 mV correspond to highly reducing, anaerobic conditions. As mentioned previously, TNT reduction can occur in aerobic systems, but the reduction of TNT breakdown products, RDX, and perchlorate are favored under anaerobic conditions (generally observed when ORP values are between -100 mV and 0 mV).

ORP levels during the twelve quarterly sampling events (early 2011 to May 2014) ranged from -33 to 297 mV indicating both anaerobic and aerobic conditions are present at the site, although oxidating conditions appear to be favored (**Table 6-2**). ORP values and DO readings did not show a clear corresponding trend for samples taken at the same well and same sampling event. At monitoring wells with elevated concentrations of TNT and RDX (54MW10, 54MW12 and 54MW13), ORP readings suggest aerobic conditions.

pH. The pH for optimum microbial activity ranges from 5 to 9 standard units. Microbial activity may decrease at lower pH values. All of the total 133 historical pH data available are within this optimal pH range (**Table 6-2**). In general, the pH environment at SWMU 54 is suitable for microbial activity.

Nitrate. Following oxygen, microorganisms preferentially use nitrate (NO_3^-) as a terminal electron acceptor. Elevated nitrate concentrations may indicate the degradation of nitroaromatics

(including 2,4,6-TNT) into breakdown products and favor nitrate-reducing conditions; however, elevated nitrate (>1 mg/L) is an inhibitor of perchlorate reduction (IRTC, 2008).

Nitrate levels during the twelve sampling events were generally low (overall < 1 mg/L) with concentrations ranging from non-detect to 4.8 mg/L, suggesting that perchlorate reduction is not inhibited (**Table 6-2**).

Monitoring well 54MW12, at which the highest perchlorate concentrations have been identified, nitrate levels have consistently been > 1 mg/L during the twelve quarters of sampling indicating perchlorate degradation may be limited. However, the elevated nitrate concentrations in this well suggest favorable conditions for the reduction of 2,4,6-TNT. The increase in 2,4-DNT and 2,6-DNT levels in this well from Quarter 10 to Quarter 12 also suggest the biodegradation of TNT.

Ferrous Iron. Ferric iron is reduced to soluble ferrous iron in the groundwater where iron-reducing bacteria have been active. An increase in ferrous iron concentrations is indicative of iron-reducing conditions. Biological reduction of TNT is favored in nitrate-reducing conditions and therefore, elevated levels of ferrous iron are an indicator of favorable groundwater conditions for TNT degradation. However, the degradation of TNT breakdown products, 2ADNT and 4ADNT, RDX, and perchlorate are favored in iron-reducing conditions. Ferrous iron concentrations for all wells and all sampling events have been less than 0.2 mg/L (non-detect) or equal to 0.2 mg/L indicating that iron-reducing conditions are not present at this time, or the iron has been reduced previously.

Sulfate. Biological degradation of TNT breakdown products, 2ADNT and 4ADNT, RDX, and perchlorate actively occurs under sulfate-reducing conditions. Sulfate levels greater than 20 µg/L may cause competitive exclusion (USEPA, 2008). Sulfate concentrations were measured in the groundwater during each of the twelve quarterly sampling events and were greater than 20 mg/L (ranging from 15.0 to 403 mg/L), indicating that biological degradation of 2ADNT and 4ADNT may be inhibited at SWMU 54 (**Table 6-2**).

Total Organic Carbon (TOC). Organic carbon is a required source of reduced carbon and energy needed to sustain microbial degradation of nitroaromatics and perchlorate. TOC concentrations greater than 20 mg/L are considered adequate to support microbial activity. Available TOC data from the first eleven quarterly sampling events ranged from less than 0.50 (non-detect) to 7.47 mg/L (**Table 6-2**), suggesting that the area does not have sufficient natural organic carbon to sustain the microbial activity. For the last quarterly sampling event in May 2014 (Quarter 12), TOC data exceeded 20 mg/L in two wells – 54MW1 (51.0 mg/L) and 54MW10 (63.0 mg/L). The TOC levels warrant continued monitoring for a possible increase to potentially improve microbial degradation.

Table 6-2
Water Quality Parameters for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia

Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 First Quarter (July 2011) Water Quality Parameters														
pH	7.7	6.36	6.86	7.19	6.36	7.33	6.6	6.98	6.29	7.13	7.14	6.67	6.75	7.23
Conductivity (mS/cm)	0.357	0.526	0.491	0.949	0.371	0.449	0.419	0.544	0.535	1.68	0.651	0.568	0.676	0.582
Turbidity (NTU)	5.6	0	1.5	1.9	3	0.2	0	4.6	6	89.8	62.6	100	94	16.9
Dissolved Oxygen (mg/L)	4.86	2.35	4.71	0	4.87	0.68	3.91	3.53	1.23	0.51	0	3.52	0.9	1.06
ORP (mV)	130	178	121	-18	178	110	170	134	198	67	96	152	29	73
Temperature (°C)	14.12	17.07	19.82	15.52	19.88	19.32	18.87	17.86	14.3	25.19	14.94	18.38	20.09	23.76
Dissolved Manganese	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.1	<0.05	0.2	<0.05	0.05	<0.05	0.65	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	25.2	1.09	0.967	0	0.613	0	0.119	0.639	0.233	0	0	2.79	0.439	0.242
Sulfate (mg/L)	27.1	39.8	23.6	329	15.1	27.4	61.5	40	62.2	167	93.6	38.1	38.8	33.6
TOC (mg/L)	3.9	3.51	7.26	2.51	6.14	1.95	3.17	6.05	5.1	1.61	5.97	2.64	2.55	6.73
SWMU 54 Second Quarter (October 2011) Water Quality Parameters														
pH	7.49	7.02	7.05	7.27	6.78	7.49	7.3	7.09	7.2	6.83	7.31	6.7	7.05	7.16
Conductivity (mS/cm)	0.432	0.56	0.674	0.912	0.502	0.305	0.734	0.541	0.562	0.677	0.654	0.523	0.831	0.568
Turbidity (NTU)	164	167	160	81.1	231	107	155	104	79.9	236	685	69	--	157
Dissolved Oxygen (mg/L)	0	0	0	2.44	2.68	3.8	0.1	0.05	0.06	0	0	1.72	0.37	0
ORP (mV)	102	117	107	-15	143	122	66	151	146	82	-13	144	126	73
Temperature (°C)	18.04	14.77	14.16	14.32	15.48	13.18	18.01	14.94	14.75	14.75	13.73	14.81	14.63	14.93
Dissolved Manganese (mg/L)	<0.05	<0.05	0.1	0.05	0.1	0.05	0.4	0.05	0.2	0.15	0.3	<0.05	0.35	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0	0.394	0.357	0	0.568	0.167	0	0.514	0.184	0.388	0	2	0.21	0.202
Sulfate (mg/L)	27.1	27	44.4	210	17.4	7.06	216	39.9	46.9	96.7	119	31.8	90.2	34.1
TOC (mg/L)	3.9	3.2	3.22	1.38	1.88	2.68	1.31	7.47	6.78	6.98	3.22	4.71	3.31	4.64
SWMU 54 Third Quarter (January 2011) Water Quality Parameters														
pH	7.59	7.48	7.4	7.36	7.15	7.53	7.43	7.08	7.4	7.46	7.59	6.09	7.45	7.48
Conductivity (mS/cm)	0.498	0.662	0.762	1.11	0.628	0.305	0.905	0.492	0.674	0.707	0.763	0.595	0.687	0.651
Turbidity (NTU)	8.9	15.3	19.2	55.6	32.1	72.4	26.8	66.7	36.8	1.1	6.8	---	226	0
Dissolved Oxygen (mg/L)	0	0	0	0	7.81	12.01	0	16.65	8.48	6.06	5.09	4.02	7.63	1.66
ORP (mV)	100	33	24	5	121	191	3	104	111	118	101	186	25	61
Temperature (°C)	13.2	13.91	13.26	13.04	13.58	11.93	12.73	9.72	9.65	11.16	11.4	12.86	11.53	12.91
Dissolved Manganese (mg/L)	<0.05	<0.05	0.1	0.05	0.1	0.05	0.4	0.05	0.2	0.15	0.3	<0.05	0.35	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0	0.609	0	0	0.578	0.158	0	0.401	0.174	0.572	0.158	1.94	0.237	0.241
Sulfate (mg/L)	26.3	28.2	73.7	480	20.3	4.55	249	41.5	62.5	72.7	93	37.6	53.9	32.2
TOC (mg/L)	2.1	1.8	2.39	1.16	1.42	1.94	2.38	1.66	2.78	1.66	6.71	5.09	6.63	1.68

Table 6-2
Water Quality Parameters for Groundwater Performance Monitoring at SWMU 54
Radford AAP, Radford, Virginia
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Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 Fourth Quarter (April 2012) Water Quality Parameters														
pH	5.42	5.19	5.38	5.33	4.99	5.76	5.57	5.38	5.46	5.48	5.59	5.05	5.32	5.5
Conductivity (mS/cm)	0.958	1.12	1.46	0.001	0.891	0.73	1.58	1.21	1.26	1.73	1.4	1.35	0.981	1.2
Turbidity (NTU)	2.5	4.4	2.4	125	70.1	318	38	3.4	65.3	30.8	94.7	37	312	36
Dissolved Oxygen (mg/L)	7.36	7.18	2.24	23.45	10.47	6.49	2.01	7.43	11.29	2.83	5.8	9.44	7.1	5.55
ORP (mV)	-30	236	225	180	168	132	162	134	145	61	36	267	116	149
Temperature (°C)	13.37	12.44	12.02	11.56	20.98	19.09	12.57	14.69	14.21	15.5	14.11	12.67	15.52	12.69
Dissolved Manganese (mg/L)	<0.05	<0.05	0.1	0.5	<0.05	0.05	0.4	0.05	0.2	0.1	0.3	<0.05	0.35	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0	1.33	0	0	0.677	0.129	0.231	0.483	0.139	0	0	2.65	0.294	0.386
Sulfate (mg/L)	34.9	34.9	80	432	14	14.9	69.4	40.1	56	221	104	37.9	35.4	29.3
TOC (mg/L)	1.8	1.57	1.18	1.82	2.33	5.46	0.99	2.36	3.01	2.4	2.68	2.34	3.51	1.09
SWMU 54 Fifth Quarter (August 2012) Water Quality Parameters														
pH	7.08	6.94	6.71	7.05	6.71	7.47	7.03	6.87	6.84	6.71	7.06	6.61	6.97	7.05
Conductivity (mS/cm)	0.395	0.722	0.644	0.968	0.58	0.363	0.817	0.599	0.752	0.693	0.715	0.665	0.697	0.625
Turbidity (NTU)	4.1	43	19	14	23	0	7.4	19	5.2	0.8	10.8	48	95	9.2
Dissolved Oxygen (mg/L)	5.34	0	0	0.23	3.96	4.84	0	2.78	0.56	0.4	0	0.33	1.75	0
ORP (mV)	212	65	209	-33	200	134	128	125	-10	47	-22	226	135	-13
Temperature (°C)	13.89	13.49	12.93	15.06	13.44	16.52	13.66	13.7	14.09	13.93	13.64	13.71	16.12	14.08
Dissolved Manganese (mg/L)	<0.05	<0.05	0.05	0.05	<0.05	0.05	0.05	0.05	0.2	0.05	0.05	<0.05	0.3	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.600	0.190	0.613	3.00	0.728	0.120	3.00	0.581	1.80	0.594	1.80	1.06	0.681	0.214
Sulfate (mg/L)	26.1	95.5	23.8	378	18.0	15.7	186	41.8	87.2	102	97.6	27.0	38.2	31.8
TOC (mg/L)	0.721	2.00	2.00	1.10	2.00	1.00	1.02	2.00	2.00	1.37	2.00	2.00	1.05	2.04
SWMU 54 Sixth Quarter (November 2012) Water Quality Parameters														
pH	7.63	7.21	6.97	7.03	6.99	Dry	7.31	7.23	7.23	7.29	7.28	7.6	5.72	7.3
Conductivity (mS/cm)	0.443	0.62	0.561	1.01	0.612	Dry	0.826	0.628	0.784	0.779	0.698	0.635	0.918	0.6
Turbidity (NTU)	2.9	11.4	0.2	17	5.5	Dry	46	3.9	27.7	4.7	2.5	2.4	35	43
Dissolved Oxygen (mg/L)	1.44	0.86	4.09	1	1.01	Dry	0.56	2.71	1.14	0.38	1.1	0.26	0.95	0.45
ORP (mV)	148	141	145	72	167	Dry	59	101	-28	43	117	135	209	100
Temperature (°C)	10.03	13.43	12.22	11.27	11.21	Dry	10.83	11.98	11.35	13.61	12.95	13.99	12.26	10.61
Dissolved Manganese (mg/L)	0.05	0.05	0.05	0.05	0.05	Dry	0.05	0.05	0.2	0.05	0.05	0.1	0.3	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	Dry	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.600	0.327	0.656	3.00	0.944	Dry	1.80	0.403	1.80	0.381	0.600	2.86	0.369	0.600
Sulfate (mg/L)	31.3	35.4	22.9	403	21.5	Dry	179	60.3	199	151	99.1	49.8	76.7	39.0
TOC (mg/L)	1.96	2.68	3.29	2.93	4.31	Dry	3.72	4.90	6.73	5.55	5.88	3.41	2.00	2.12

Table 6-2
Water Quality Parameters for Groundwater Performance Monitoring at SWMU 54
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Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 Seventh Quarter (February 2013) Water Quality Parameters														
pH	7.85	6.89	6.76	7.52	6.56	7.08	7.4	7.03	7.04	6.69	7.09	6.36	6.96	7.45
Conductivity (mS/cm)	0.465	0.682	0.504	1.01	0.417	0.293	0.474	0.498	0.487	0.542	0.687	0.464	0.37	0.619
Turbidity (NTU)	0	20	9	16	0	44.3	16	9.2	10.9	13.2	2	14.2	6.8	1.2
Dissolved Oxygen (mg/L)	0.71	1.43	6.97	0.53	9.19	9.28	2.83	5.36	8.28	2.97	0.58	1.27	8.39	0.47
ORP (mV)	-5	156	171	-56	168	72	12	168	194	125	169	168	158	56
Temperature (°C)	12.17	8.28	11.98	12.09	11.18	13.15	11.48	9.89	9.74	11.22	10.14	10.31	7.98	12.26
Dissolved Manganese (mg/L)	0.05	<0.05	0.1	0.05	<0.05	0.05	0.1	0.05	0.2	0.1	0.25	<0.05	0.2	<0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.600	0.315	0.423	3.00	0.636	0.209	0.205	0.336	0.510	0.477	0.346	1.95	0.501	0.600
Sulfate (mg/L)	27.1	36.8	25.3	340	15.5	4.29	34.2	44.6	117	70.1	120	35.8	23.1	41.1
TOC (mg/L)	1.19	0.916	1.07	1.35	1.00	1.50	0.791	1.00	2.09	1.14	1.88	1.21	0.683	1.46
SWMU 54 Eighth Quarter (May 2013) Water Quality Parameters														
pH	7.38	6.52	7.06	7.51	6.83	7.33	7.41	7.47	7.95	6.94	7.59	6.78	6.97	7.31
Conductivity (mS/cm)	0.398	0.315	0.499	1.021	0.4	0.494	0.674	0.596	0.521	0.537	0.592	0.665	0.44	0.608
Turbidity (NTU)	1.2	0.2	1.4	6.2	8.9	7.1	0.5	1.6	5.2	1.4	0.3	3.8	0.2	6.4
Dissolved Oxygen (mg/L)	4.13	2.74	3.55	1.05	3.28	1.29	3.24	0.4	7.58	2.43	1.17	2.54	1.4	4.13
ORP (mV)	122	254.3	273.6	257.1	283.1	128.4	282.7	255.1	244.2	287.8	255.8	292.4	284	296.5
Temperature (°C)	13.43	12.22	13.31	11.73	12.2	13.48	12.74	13.32	11.12	12.89	12.42	13.28	12.84	13.42
Dissolved Manganese (mg/L)	<0.05	0.05	0.05	0.05	<0.05	<0.05	0.05	0.05	0.1	0.05	0.05	<0.05	0.15	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	0.368	0.988	0.911	3.00	1.60	0.600	1.10	0.600	0.637	0.740	0.647	4.03	1.05	0.543
Sulfate (mg/L)	26.1	24.1	29.0	329	15.7	14.0	137	41.1	96.7	48.8	89.4	47.6	29.2	37.0
TOC (mg/L)	0.949	1.68	1.36	0.619	1.06	2.41	0.793	1.00	1.38	1.00	0.635	1.36	0.817	0.583
SWMU 54 Ninth Quarter (August 2013) Water Quality Parameters														
pH	7.82	6.91	6.75	6.96	6.28	Dry	6.71	6.95	7.12	6.48	7.04	6.36	6.57	6.84
Conductivity (mS/cm)	0.452	0.592	0.617	0.937	0.333	Dry	0.478	0.559	0.419	0.496	0.637	0.491	0.351	0.554
Turbidity (NTU)	3	0	0	0	0	Dry	7.2	0	6.1	0	0	7.0	0	0
Dissolved Oxygen (mg/L)	0.136	0.8	1.69	0.39	6.28	Dry	2.4	0.67	2.36	0.86	4.65	2.85	6.57	0.52
ORP (mV)	223.2	84	96	-18	129	Dry	86	42	-13	35	68	91	146	50
Temperature (°C)	14.51	15.25	15.08	13.22	15.49	Dry	13.05	13.4	13.25	14.51	13.46	15.7	13.89	13.21
Dissolved Manganese (mg/L)	0.05	NM	<0.05	0.05	0.05	Dry	<0.05	<0.05	0.05	<0.05	0.05	0.05	0.15	0.05
Dissolved Ferrous Iron (mg/L)	<0.2	NM	<0.2	<0.2	<0.2	Dry	<0.2	<0.2	0.2	<0.2	<0.2	<0.2	<0.2	<0.2
Nitrate (mg/L)	<0.600	0.326	0.521	<0.600	0.849	Dry	<0.600	0.273	0.194	0.206	0.12	4.8	0.591	0.29
Sulfate (mg/L)	26.7	30.8	26.1	322	15.0	Dry	27.3	38.0	39.2	44.3	91.8	39.6	23.3	28.2
TOC (mg/L)	3.32	1.5	1.11	2.7	0.91	Dry	0.822	2.30	4.17	4.28	3.11	3.27	2.35	3.64

Table 6-2
Water Quality Parameters for Groundwater Performance Monitoring at SWMU 54
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Well ID	54MW1	2	3	4	5	6	7	8	9	10	11	12	13	14
SWMU 54 Tenth Quarter (November 2013) Water Quality Parameters														
pH	--	7.45	--	--	--	--	--	--	--	6.89	--	NM	7.29	--
Conductivity (mS/cm)	--	0.635	--	--	--	--	--	--	--	0.615	--	0.469	0.643	--
Turbidity (NTU)	--	0	--	--	--	--	--	--	--	0	--	4.6	0.4	--
Dissolved Oxygen (mg/L)	--	2.7	--	--	--	--	--	--	--	2.45	--	1.17	1.32	--
ORP (mV)	--	51	--	--	--	--	--	--	--	18	--	108	25	--
Temperature (°C)	--	14.09	--	--	--	--	--	--	--	15.25	--	14.96	15.96	--
Dissolved Manganese (mg/L)	--	<0.05	--	--	--	--	--	--	--	<0.05	--	0.05	0.05	--
Dissolved Ferrous Iron (mg/L)	--	<0.2	--	--	--	--	--	--	--	<0.2	--	<0.2	<0.2	--
Nitrate (mg/L)	--	0.25	--	--	--	--	--	--	--	0.670	--	1.1	0.45	--
Sulfate (mg/L)	--	29.0	--	--	--	--	--	--	--	57.0	--	26.0	39.0	--
TOC (mg/L)	--	2.5	--	--	--	--	--	--	--	0.68	--	0.5	<0.50	--
SWMU 54 Eleventh Quarter (February 2014) Water Quality Parameters														
pH	8.1	--	--	--	--	--	--	--	--	6.89	--	7.21	7.21	--
Conductivity (mS/cm)	0.41	--	--	--	--	--	--	--	--	0.587	--	0.643	0.481	--
Turbidity (NTU)	0	--	--	--	--	--	--	--	--	0	--	3.8	14	--
Dissolved Oxygen (mg/L)	1.32	--	--	--	--	--	--	--	--	1.43	--	0.7	2.09	--
ORP (mV)	127	--	--	--	--	--	--	--	--	153	--	150	142	--
Temperature (°C)	12.34	--	--	--	--	--	--	--	--	13.2	--	14.11	12.04	--
Dissolved Manganese (mg/L)	<0.05	--	--	--	--	--	--	--	--	<0.05	--	<0.05	0.05	--
Dissolved Ferrous Iron (mg/L)	<0.2	--	--	--	--	--	--	--	--	0.2	--	0.2	<0.2	--
Nitrate (mg/L)	<0.025	--	--	--	--	--	--	--	--	0.470	--	3.1	0.44	--
Sulfate (mg/L)	30.00	--	--	--	--	--	--	--	--	89.0	--	36.0	31.0	--
TOC (mg/L)	1.00	--	--	--	--	--	--	--	--	0.53	--	1.00	<0.50	--
SWMU 54 Twelfth Quarter (May 2014) Water Quality Parameters														
pH	7.79	--	--	--	--	--	--	--	--	6.93	--	NM	NM	--
Conductivity (mS/cm)	0.469	--	--	--	--	--	--	--	--	0.582	--	0.453	0.47	--
Turbidity (NTU)	3	--	--	--	--	--	--	--	--	3.8	--	10	9	--
Dissolved Oxygen (mg/L)	1.65	--	--	--	--	--	--	--	--	1.56	--	2.25	1.14	--
ORP (mV)	222.3	--	--	--	--	--	--	--	--	127.4	--	272.1	71.3	--
Temperature (°C)	16.61	--	--	--	--	--	--	--	--	12.81	--	14.61	16.57	--
Dissolved Manganese (mg/L)	0.05	--	--	--	--	--	--	--	--	0.1	--	0.1	0.05	--
Dissolved Ferrous Iron (mg/L)	0.2	--	--	--	--	--	--	--	--	<0.2	--	0.2	0.2	--
Nitrate (mg/L)	0.031	--	--	--	--	--	--	--	--	0.330	--	1.6	0.41	--
Sulfate (mg/L)	29.0	--	--	--	--	--	--	--	--	58.0	--	31.0	27.0	--
TOC (mg/L)	51.0	--	--	--	--	--	--	--	--	62.0	--	<0.50	<0.50	--

Notes:
mS/cm - milliseimens per centimeter
NTU - Nephelometric Turbidity Unit
mV - millivolts
°C - degrees Celsius
mg/L - milligrams per liter
NM - not measured
-- - Wells eliminated from monitoring program

7.0 SUMMARY AND CONCLUSIONS

Fourteen (14) groundwater monitoring wells have been sampled on a quarterly basis for over 2 years (nine quarters) at SWMU 54. After Quarter 9, the monitoring program was reduced to the three wells which have had COI concentrations above RGs (54MW10, 54MW12, and 54MW13) and an upgradient well (54MW1). Additionally, in the fourth and eighth quarters of monitoring, five pore water sample locations were monitored in the New River. Samples collected in the first twelve quarters were analyzed for explosives, perchlorate, and MNA indicators. For Quarters 10 through 12, samples were also analyzed for RDX breakdown products. Sample results were compared to RGs and evaluated to determine whether MNA is occurring at the site. This report presents the results of the first through twelfth quarters of sampling and also summarizes the data from the first three years of sampling.

Based on contaminant concentrations and biological indicator parameters measured in groundwater at the site, MNA processes including biodegradation (for 2,4,6-TNT and RDX), sorption, dilution, dispersion, and chemical stabilization are occurring at SWMU 54. The data also suggest that the MNA processes are preserving plume stability and decreasing nitroaromatic and perchlorate mass.

In summary, the following conclusions and recommendations were made regarding the potential for MNA in contaminated groundwater at SWMU 54:

- Presence of 2,4,6-TNT daughter products 2ADNT and 4ADNT suggest that incomplete biological degradation has occurred, which may be aiding in removing mass in the groundwater.
- Identification of RDX breakdown products DNX, MNX, and TNX indicate active degradation of RDX.
- All perchlorate concentrations in the third year of sampling were below the RG and showed a steady decline in concentrations during that period.

Geochemical parameters also indicate that groundwater conditions are generally aerobic, thereby supporting biological degradation of 2,4,6-TNT; however, do not currently support biological degradation of 2ADNT, 4ADNT, RDX, and perchlorate.

The source removal efforts at SWMU 54 appear to have been effective in significantly lowering the site-wide COCs in groundwater. Eleven (11) of the 14 monitoring well locations (54MW1 through 54MW9, 54MW11, and 54MW14) have had concentrations below site selected RGs for eight consecutive quarters for 2,4,6-TNT, DNT mixture, RDX, and perchlorate. As per the *Final SWMU 54 MNA IMWP* (Shaw, 2011a), these wells were removed from the MNA sampling program after Quarter 9 (August 2013).

Pore water samples PW-1, PW-3, PW-5, PW-8, and PW-9 have had no detections of explosives or perchlorate in 2 years of sampling. As per the *Final SWMU 54 MNA IMWP* (Shaw, 2011a), the pore water sample locations were removed from the MNA sampling program after Quarter 9 (August 2013).

Explosives concentrations through twelve quarters of groundwater sampling indicate that limited biodegradation at well locations 54MW10, 54MW12, and 54MW13 (SWMU 54 Area A wells) is occurring. Based on the localized distribution of elevated constituents and the generally

declining concentrations site-wide, a groundwater remedy at SWMU54 does not appear necessary at the time. However, the tenth quarter of sample collection included the most elevated concentrations of explosive COIs reported at monitoring locations 54MW10 and 54MW12, warranting continued monitoring at these locations. The sharp increase in explosive concentrations at 54MW10 and 54MW12 in Quarters 9 and 10 occurred during aerobic conditions at these wells. Under aerobic conditions, biodegradation is not as effective in the reduction of explosives and perchlorates. As a result of the subsurface biochemistry, the decreased biological activity may have led to an increase in the explosives and perchlorate concentrations during this period.

It is our recommendation that groundwater monitoring continues on a quarterly basis at well locations 54MW10, 54MW12, and 54MW13, In addition to monitoring wells 54MW10, 54MW12, and 54MW13, monitoring well 54MW1 will continue to be monitored as an upgradient well, despite meeting the criteria for being removed from the network.

8.0 REFERENCES

Brannon and Pennington, 2002. *Environmental Fate and Transport Process Descriptors For Explosives*. Prepared for U.S. Army Corps of Engineers. May 2002.

Interstate Technology and Regulatory Council (IRTC) (Perchlorate Team), 2008. *Remediation Technologies for Perchlorate Contamination in Water and Soil*. Interstate Technology and Regulatory Council, Washington, DC.

IT Corporation (IT), 2001. *Facility-Wide Background Study*. Radford Army Ammunition Plant, Virginia. Final Report. Delivery Order No. 0008, Contract No. DACA31-94-D-0064.

Parsons Engineering Science, Inc. (Parsons), 1996. *RCRA Facility Investigation for Solid Waste Management Units 17, 31, 48, and 54 at Radford Army Ammunition Plant, Virginia.* Prepared for U.S. Army Environmental Center.

Shaw Environmental, Inc. (Shaw), 2011a. *SWMU 54 Monitored Natural Attenuation Interim Measures Work Plan*. Radford Army Ammunition Plant, Virginia. Final Report.

Shaw Environmental, Inc. (Shaw), 2011b. *SWMU 54 Interim Measures Completion Report*. Radford Army Ammunition Plant, Radford, Virginia. April 2011.

Spain, J.C. 1995. *Biodegradation of nitroaromatic compounds.* Annual Review of Microbiology, 49: 523-555.

URS Corporation (URS), 2003. *Final Master Work Plan, Quality Assurance Plan, Health and Safety Plan*. Radford Army Ammunition Plant, Radford, Virginia. Prepared for the U.S. Army Corps of Engineers, Baltimore District. August 2003.

URS Corporation (URS), 2008. *Solid Waste Management Unit 54 RCRA Facility Investigation/ Corrective Measures Study Report*. Radford Army Ammunition Plant, Radford, Virginia. September 2008.

U.S. Environmental Protection Agency (USEPA), 1998. *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater,* EPA/600/R-98/128, Wiedemeier, T.H., M.A. Swanson, D.E. Moutoux, E.K. Gordon, J.T. Wilson, B.H. Wilson, D.H. Kampbell, P.E. Haas, R.N. Miller, J.E. Hansen, and F.H. Chapelle, Cincinnati, Ohio.

U.S. Environmental Protection Agency (USEPA), 2000. *Permit for Corrective Action and Waste Minimization*: Pursuant to the Resource Conservation and Recovery Act as Amended by the Hazardous and Solid Waste Amendment of 1984, Radford Army Ammunition Plant, Radford, Virginia. VA1210020730.

U.S. Environmental Protection Agency (USEPA), 2011. *Regional Screening Levels (SL) Table.* Developed by Oak Ridge National Laboratory under Interagency Agreement with USEPA. Dated June 2011. On-line: http://www.epa.gov/reg3hwmd/risk/human/SLoncentration_table/Generic_Tables/index.htm

The appendices for this report are included on a CD following this page.

Appendix A-1

Boring Logs

Appendix A-2

Field Sampling Logs

Appendix B-1

Chains of Custody

Appendix B-2

Data Validation Files

Appendix B-3

Laboratory Data