Impact Area Groundwater Study Program

Final
Small Arms Ranges Investigation Report

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

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ACRONYMS AND ABBREVIATIONS

AAATC	Anti-Aircraft Artillery Training Center
bgs	below ground surface
cal	caliber
cm	centimeter
CN	chloroacetophenone
CRREL	Cold Regions Research and Engineering Laboratory
DNT	dinitrotoluene
2,4-DNT	2,4-dinitrotoluene
2,6-DNT	2,6-dinitrotoluene
HA	USEPA Drinking Water Health Advisory
ICP	Inductively Coupled Plasma
MAARNG	Massachusetts Army National Guard
MassDEP	Massachusetts Department of Environmental Protection
MCL	Maximum Contaminant Level (federal)
MMCL	Massachusetts Maximum Contaminant Level
MCP	Massachusetts Contingency Plan
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mL	milliliter
MMR	Massachusetts Military Reservation
MS	Mass Spectroscopy
NGVD	National Geodetic Vertical Datum
OMMP	Operations, Maintenance and Monitoring Plan
PAH	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	tetrachloroethylene
PCNs	polychlorinated naphthalenes
RDX	hexahydro-1,3,5-trinitro-1,3,5-triazine
REP	relative experimental potency
RSL	Regional Screening Level
SPLP	Synthetic Precipitation Leaching Procedure
SSLs	Soil Screening Levels
SVOCs	semivolatile organic compounds
TAL	Target Analyte List
TCE	trichloroethylene
TCLP	Toxicity Characteristic Leaching Procedure
2,4,5-T	2,4,5-trichlorophenoxyacetic acid
µg/L	micrograms per liter
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOCs	volatile organic compounds
XRF	x-ray fluorescence

EXECUTIVE SUMMARY

This Investigation Report summarizes the results of studies undertaken to characterize and evaluate soil and groundwater conditions at the Small Arms Ranges of the Massachusetts Military Reservation (MMR – now known as Joint Base Cape Cod - JBCC). The Small Arms Ranges investigation was conducted under the U.S. Environmental Protection Agency (USEPA) Safe Drinking Water Act Administrative Orders SDWA 1-97-1019 and SDWA 1-2000-0014 and in consideration of the substantive cleanup standards of the Massachusetts Contingency Plan (MCP).

The Small Arms Ranges include 40 locations where small arms ammunition has been used at Camp Edwards. The ranges evaluated in this report have been used for a variety of small arms, including pistols, rifles, shotguns, sub-machine guns, and machine guns. The ranges include ranges that are currently operational and active (6), operational but inactive (14) and non-operational (20).

The Small Arms Ranges are located in a general circumference around the Impact Area. Most of the sites that are currently in use are relatively flat areas cleared of vegetation to accommodate easy acquisition of downrange targets. Many of the remaining sites are largely overgrown. A number of the former and current ranges have overlapped the same areas over time. According to the Archive Search Report (USACE 1999), all known ranges utilizing only small arms ammunition encompass approximately 1,399 acres.

Since 1998, numerous groundwater and soil investigations have been implemented at the Small Arms Ranges. Groundwater beneath the ranges has been monitored as part of the MMR Long-Term Monitoring Program. From 2000 to 2004, a multi-range soil sampling effort was conducted as part of the Phase IIa and IIb Small Arms Range investigation programs. From 2006 to 2009, extensive multiple increment soil sampling was conducted at six ranges (E, J, K, SE, SW and T Ranges). From 2010 to 2012, soil, groundwater and pore water monitoring was conducted at the active J, K and T Ranges under the Small Arms Range Best Management Practices and Operations, Maintenance and Monitoring Plans (OMMP). In 2013, an additional multiple increment soil sampling program was conducted at numerous ranges.

The results of groundwater monitoring investigations at the Small Arms Ranges indicate the presence of Small Arms related metals (lead, tungsten, antimony and copper) below action levels. Explosives were not reported in any monitoring wells associated with these ranges (with the one exception being a well at G Range that intersects the Demo 1 plume). Low levels of metals, including barium, chromium, iron, and zinc, were also detected in some samples from certain wells below action levels. Tungsten has been detected in samples from B Range. In 2006, an elevated detection of tungsten (560 µg/L) was reported in one well (MW-72S) at B Range during a U.S. Army Corps of Engineers (USACE) Cold Regions Research and Engineering Laboratory (CRREL) study. All subsequent groundwater sampling results at B Range have been between <1 and 23 µg/L.

Results of multiple increment soil sampling performed from 2006 to 2012 at six ranges (E, J, K, SE, SW, and T Ranges) indicated that nitroglycerin was the principal propellant-related constituent present in surface soils. This constituent was primarily detected in or near the firing lines. Soil was removed at several of these ranges to reduce the levels of nitroglycerin.

Concentrations of metals that are associated with small arms projectiles (including antimony, copper, lead and tungsten) were variable across the range surface soils and also varied within individual ranges. The highest concentrations of antimony (91.9 mg/Kg), lead (5,800 mg/Kg), and copper (742 mg/Kg) were reported for T Range samples.

Literature, laboratory, and field studies were conducted by the USACE CRREL on propellants (nitroglycerin and 2,4,DNT), lead, and tungsten in surface soils at Small Arms Ranges. The propellant study found that propellants are largely contained within the nitrocellulose propellant fibers and not prone to dissolution in the environment. What little propellant mass is leachable is readily degraded by natural processes before it can reach the groundwater. The literature and field evaluations of lead mobility determined that the nature of the soils at MMR retards lead migration. The studies of tungsten concluded that the chemistry of tungsten in the environment is complex. Overall, the results of these studies indicated that residual soil contaminants from fired propellants and projectiles are currently not a threat to groundwater at properly managed ranges. With the possible exception of tungsten, these study results are consistent with the general absence of propellants and absence of significant concentrations of metals in groundwater at the Camp Edwards Small Arms Ranges.

Groundwater tungsten concentrations have consistently been observed at low to non-detect levels since the high concentration (560 µg/L) detected in MW-72S in 2006. However, elevated tungsten concentrations have recently been observed in pore water at one lysimeter at B Range. Therefore, a transient pulse of tungsten, such as appears to have occurred at well MW-72S in 2006, is possible.

A conceptual site model was developed for the Small Arms Ranges to assess the potential impact of propellant and projectile-related surface soil contamination on groundwater. The evaluations by CRREL concerning the potential for subsurface migration of lead at Small Arms Ranges were considered in developing the conceptual site model.

Several soil remediation projects have been undertaken on the Small Arms Ranges to reduce potential contaminant concentrations and limit mobility. These include the 1998 Berm Maintenance project when soil in the backstop berms on many of the ranges was excavated, sifted to remove bullets, treated with a phosphate binder, and replaced on the ranges. Approximately 56 tons of lead bullets were recovered and recycled under this project. Following that, limited excavations were made in the mid-2000s to remove nitroglycerin from the firings lines of several ranges. In 2006/2007, soil containing elevated levels of tungsten was removed from the ranges where tungsten bullets were fired. This soil was later disposed off-site. In 2009-2010, soil was excavated from several ranges so that lead bullets could be removed. The sifted soil is stockpiled at D Range for later re-use on the ranges.

A risk screening was conducted for the current and former Small Arms Ranges within Camp Edwards to assess whether any of the analytes that were detected in soil or groundwater warranted further consideration. Groundwater monitoring data were available for all but 10 of the ranges for explosives, perchlorate, metals and inorganics, pesticides and herbicides, semivolatile organic compounds (SVOCs), volatile organic compounds (VOCs), and/or polychlorinated biphenyls (PCBs). Of the 219 analytes analyzed for in groundwater, 15 were detected at maximum concentrations that exceeded risk-based groundwater screening criteria: perchlorate, antimony, arsenic, chromium, nitrogen as nitrate-nitrite, thallium, tungsten, zinc, MCPP, bis(2-ethylhexyl)phthalate, naphthalene, chloroform, cis-1,3-dichloropropene, tetrachloroethylene (PCE) and trichloroethylene (TCE). Of these, arsenic and chloroform have been previously associated with other sources, and their presence is not indicated to be related to Small Arms Range activities. In the cases of antimony, thallium, bis(2-ethylhexyl)phthalate, naphthalene, cis-1,3-dichloropropene, PCE and TCE, typically only the maximum detected concentrations of these analytes exceeded their most stringent screening criteria. More importantly, subsequent sampling results for the same wells were non-detect for these analytes. MCPP detections have been associated with false positives obtained using an older analytical method (AMEC 2002a). In addition, bis(2-ethylhexyl)phthalate is a common laboratory contaminant and its presence in these samples is believed to have been a laboratory artifact. Chromium has been sporadically detected in 24 different wells, typically only once or twice, and the maximum detected concentration of chromium was less than the MCL and the MCP Method 1 GW-1 Standard. Only the maximum detected filtered tungsten concentration exceeded the Massachusetts Department of Environmental Protection (MassDEP) Interim Drinking Water Guideline (20 µg/L) and the paired unfiltered result was below the Guideline as were all subsequent samples for tungsten. (A groundwater tungsten concentration [560 µg/L] in excess of the MassDEP Interim Guideline was also reported in 2006, as part of a CRREL research study. This sample was collected prior to the 2007 start date for the risk screening tungsten data set.) Zinc has been sporadically detected in 36 different wells, and the maximum detected concentration of zinc was less than the MCP Method 1 GW-1 Standard (there is no MCL for zinc). Nitrogen (measured as nitrate-nitrite) exceeded the MCL for nitrite, but not the MCL for nitrate. The maximum detected concentration of nitrogen also did not exceed the RSL for either nitrate or nitrite or the HA for nitrate plus nitrite. Finally, the one well (MW-344S) with a perchlorate detection above the screening criteria has been evaluated as part of the Northwest Corner Site as documented in the *Final Northwest Corner Remedial Investigation/Feasibility Study* (Tetra Tech 2009). Therefore, analytes detected in groundwater at the Small Arms Ranges were determined to pose no significant risk to human health.

Soil data for the Small Arms Ranges were available for explosives, perchlorate, PCNs, metals and inorganics, pesticides and herbicides, SVOCs, VOCs, and PCBs. Nitroglycerin and 2,4-DNT were the most frequently detected explosives compounds identified at the Small Arms Ranges. As discussed above, both nitroglycerin and DNT are encapsulated in nitrocellulose and, consequently, are essentially immobile in the environment. Neither compound has been detected in the groundwater samples associated with the ranges. Thus, DNT and nitroglycerin residuals from small arms firing are not believed to pose a threat to groundwater.

With a few possible exceptions like antimony and tungsten, most metals detected in surface soil at the Small Arms Ranges are anticipated to have relatively low mobility and resist rapid migration through the vadose zone. Of the 19 metals detected in soil at concentrations exceeding at least one screening criterion, antimony, lead and tungsten are the most commonly associated with small arms ammunition.

- Although there are exceedances of the MCP S-1/GW-1 Standard for antimony (20 mg/Kg), antimony has not been consistently detected in groundwater. However, antimony has been detected in pore water suggesting mobility in shallow soils.
- Tungsten has been detected in the soil on the ranges where tungsten bullets were used although the most heavily impacted soil has been removed. An impact to groundwater has been observed on B Range. However, since the transient pulse observed in 2006, only the maximum detected tungsten groundwater concentration of 22 µg/L in MW-470S in October 2006 exceeded the MassDEP Interim Drinking Water Guideline (20 µg/L). All other results have been below the MassDEP Interim Guideline.
- There are several sample locations where the lead concentration in the soil exceeds the MassDEP S-1/GW-1 standard of 300 mg/Kg. With the exception of H Range, Former N Range and T Range, the average soil concentrations at these ranges are below this standard. Lead has been detected in groundwater in 3.8 percent of all unfiltered groundwater samples. The maximum detected concentration has always been below the groundwater standard. This finding is consistent with a recent study of the behavior of metallic lead in the environment, which concluded that the nature of the soils at MMR retards lead migration. However, as noted in the Environmental Assessment of Lead at Camp Edwards (CRREL 2007), there is limited data to completely quantify possible lead migration in subsurface soils. Therefore, given its toxicity, range design and maintenance programs, including Best Management Practices are prudent.

There were two Small Arms Ranges at MMR that had not been sampled and did not have available analytical data for use in this risk screening. These were L Range (1950s to 1980s) and Former M-3 Range. During the May 2013 Supplemental Investigation, a visual investigation and metal detector sweep were performed at L Range. No significant metal debris was detected and there was no visual evidence of past use of the area as a range. No samples were collected from Former M-3 Range. In order to qualitatively evaluate the Former M-3 Range, information regarding their operational history, time frame when it was used, size and location was reviewed in order to identify whether there was a similar range that had sampling data that might provide an indication of the possible conditions at these ranges. The reference range for Former M-3 Range is Former M-1 Range. The soil concentrations at Former M-1 Range were found to either be below the detected constituents screening criteria or were found to not present a potential threat to groundwater.

Based on the soil and groundwater data, the contaminants detected in soil at the Small Arms Ranges have not resulted in groundwater contamination above action levels, with the exception of tungsten. The mass of propellant and projectile related contaminants has been greatly reduced at the ranges as the result of several remediation activities and range maintenance. Therefore, the risk of future impacts to groundwater has been reduced. Based upon these investigation findings, recommendations and proposed future actions have been developed in Section 9 for each of the Small Arms Ranges.

1.0 INTRODUCTION

This Investigation Report summarizes the results of studies undertaken to characterize and evaluate soil and groundwater conditions at the Small Arms Ranges of the MMR. The Small Arms Ranges investigation was conducted under the U.S. Environmental Protection Agency (USEPA) Safe Drinking Water Act Administrative Orders SDWA 1-97-1019 and SDWA 1-2000-0014 and in consideration of the substantive cleanup standards of the MCP.

The Small Arms Ranges include 40 ranges or range locations where small arms ammunition was used (Figure 1-1 and Table 1-1). The ranges evaluated in this report have been used for a variety of small arms, including pistols, rifles, shotguns, sub-machine guns, and machine guns.

1.1 Purpose of Report

The purpose of this report is to provide a summary of the results of previously reported soil and groundwater investigations at the Small Arms Ranges, as well as the results of more recent studies. All available analytical data have been used to delineate the nature and extent of the contamination resulting from past activities at the ranges and to complete a risk screening to determine if remedial actions are needed to prevent impacts to the groundwater aquifer. This report considers both soil and groundwater at the ranges.

A significant amount of the work that has been performed at the Small Arms Ranges has been previously reported in the *Final IAGWSP Technical Team Memorandum 02-2 Small Arms Range Report* (AMEC 2003a). Therefore, this Investigation Report focuses on both summarizing the previously reported information and appropriately considering it in conjunction with more recent investigations that were conducted since 2005. In the course of the following discussions, previous reports are referenced as appropriate.

1.2 Investigation Scope and Objectives

Investigations have been conducted at the Small Arms Ranges to evaluate the nature and extent of contamination in soil and groundwater at the ranges. The investigations included the collection and analysis of soil, pore water and groundwater samples.

The objective of this report is to document the results of the soil, pore water and groundwater investigations at the Small Arms Ranges and evaluate their significance through a risk screening, as described in Section 7. Data were collected as part of this investigation to characterize the nature and extent of contamination and provide a basis for the evaluation of risk posed by conditions at the ranges.

1.3 Report Organization

This section provides an introduction to this Investigation Report. Section 2.0 provides an overall description of the Small Arms Ranges, and summarizes past historical uses of the ranges and the environmental setting of the study area. Section 3.0 provides a synopsis of previously reported site investigation activities at the Small Arms Ranges. Section 4.0 summarizes response actions and maintenance activities that have been implemented at the ranges. Section 5.0 discusses the nature and extent of groundwater and soil contamination at the ranges. Section 6.0 presents a conceptual site model for contaminants. Section 7.0 presents a summary of the risk screening evaluation. Section 8.0 presents the investigation findings of this report. Conclusions and recommendations are presented in Section 9.0. References are provided in Section 10.0. Appendix A (CD) presents analytical data for the soil and groundwater sampling programs. Appendix B presents background soil data and relevant regulatory criteria for MMR. Appendix C includes a compilation of aerial photographs for individual ranges. The environmental chemistries of lead, antimony and tungsten are summarized in Appendix D. Appendix E summarizes risk screening information for MassDEP. Additional reports pertinent to the Small Arms Ranges are included in Appendix F (CD).

2.0 SITE BACKGROUND

2.1 Site Description

Forty Small Arms Ranges were evaluated at MMR. Some of the Small Arms Ranges evaluated have existed at multiple locations (e.g., L and M Ranges); some range locations are coincident with other range locations (e.g., E-1 and E-2). Six of the ranges (E, J, K, SE/SW, and T) were the focus of the 2005-2009 multiple increment sampling investigations with multiple increment sampling conducted in 2013 at many additional ranges.

Ranges associated with the Otis Fish and Game Club have not been included in this document since these ranges are being evaluated under a U.S. Air Force remediation program. Certain multi-use ranges at MMR (particularly the IBC and U Ranges) have also not been included in this report, as these ranges are part of the Training Ranges Operable Unit. In addition, this report only evaluates the eastern portion of the KD Range (East). KD Range (West) had a firing line and targets at 100, 200 and 300 yards from the firing line. It was also used for zeroing rifles at 25-meter targets. However, this range was not evaluated because it was used for a variety of munitions, including 40mm high explosive and practice grenades, Dragon HEAT and practice rockets, 90mm recoilless rifle HEAT and practice rounds, and TOW practice missiles, and was addressed under a 2001 response action.

Typical components of most Small Arms Ranges include one or more firing lines, a range floor, target arrays, and an impact berm (Figure 2-1). The impact berms usually include the berm face frequently containing bullet pockets and a trough at the base of the berm. A number of the Small Arms Ranges at MMR (for example Succonsette Pond) do not include the typical range features or a formal backstop berm. For several of these ranges, including Former B and Former C Ranges, natural terrain hillsides were used as backstops in conjunction with or in place of man-made berms. Certain ranges [such as KD (East) and KD (West)] did not have either backstops or hillsides. At these ranges, projectiles traveled until they dropped in the Impact Area.

Some of the range locations (such as E-1 and E-2) have more recently been converted to other uses (Demolition Area 1), and range features are no longer discernible. In addition, some of the ranges have become so overgrown with vegetation that it is difficult to identify details of the actual range location (e.g., Q Range). Generally, the ranges are relatively flat areas cleared of vegetation to accommodate easy acquisition of downrange targets although vegetation has grown back on several of the unused ranges.

2.1.1 Range Status

The Small Arms Ranges have been classified into one of three groups based upon their operational status, as follows:

- Operational Ranges (Active): These are ranges where firing is currently permitted and an Operations, Maintenance and Monitoring Plan (OMMP) is in place (J, K, SE/SW, T and I Ranges).
- Operational Ranges (Inactive): These are ranges that are not currently in use, but, given their configuration and location, could be used again for small arms firing. They would

need to go through an approval process in order to resume firing, including the development and implementation of an OMMP. Some of these ranges will require monitoring and maintenance in order to retain their Operational (Inactive) status (A, B, C, D, E, G, H, KD East, N, O, P, Former N, Q and Former R Ranges).

- Non-operational Ranges: These ranges have not been used for decades and many of them are situated in such a manner where development and activities, which now exist within their firing fans, would preclude their use. It is unlikely that these ranges will be used again for small arms firing (Former B, Former C, Former D, E-1 E-2, GA/GB, Former K, L Range (1940s-1950s), L Range (1950s-1980s), L-1, L-2, L-3, L-4, Former M-1, Former M-2, Former M-3, Former M-4, Skeet Range 1, Skeet Range 2, Succonsette Pond and the 500-yard Rifle Range).

2.2 Site History

Records indicate that the earliest general usage of areas of MMR for the Small Arms Ranges evaluated in this report was in the World War II period starting around 1940. A variety of small arms used at these ranges included pistols, rifles, shotguns, sub-machine guns and machine guns.

Items used on the Small Arms Ranges included small arms ammunition ranging from 5.56mm ball rounds to .50 caliber (cal) machine gun rounds. Table 2-1 summarizes information on ammunition use at the Small Arms Ranges based upon historical data compiled in the Archives Search Report (USACE 2001). As indicated above, a variety of types of ammunition have been used at the Small Arms Ranges such as .22 cal, .30 cal, .30 cal carbine, .38 cal, .45 cal, .50 cal, 5.56mm, 7.62mm, 9mm ball and tracer rounds, and various shotgun ammunition. Ball ammunition is a standard small arms ammunition, typically a lead core bullet with a metal (copper) jacket. A number of the Small Arms Ranges have undergone multiple uses since World War II, including conversion between use as pistol ranges and use as rifle and/or machine gun ranges. Historical information available concerning the numbers of rounds of specific types of ammunition used at each range is largely unavailable. As indicated in Table 2-1, the types of ammunition in most widespread use at multiple ranges included 5.56mm ball, 7.62mm ball, .30 cal, .45 cal and tracer rounds. Individual discussions of each range are presented in Section 5.

Potential sources of Small Arms Range contaminants include propellant-related compounds deposited on the surface in the vicinity of firing lines and projectile-related compounds deposited on the surface at, and in the vicinity of, range backstops. Propellant-related compounds consist, in part, of a suite of SVOCs produced by the combustion of small caliber ammunition propellants. SVOCs used as propellants include nitroglycerin and 2,4-DNT. These compounds are released to the environment and deposited as surface residue via airborne deposition.

Projectile-related residues consist mainly of the metallic constituents of various alloys used in the manufacturing of small caliber rounds (Table 2-2). Lead compounds (including lead antimony alloys) are primary constituents of most small arms ammunition. Lead may comprise in excess of 50 percent of the weight of certain small arms ammunition and is the primary metal of environmental concern (Table 2-3). Certain compounds (including lead azide, lead styphnate and/or antimony sulfide) may also be present in primers. Certain additional metals, including antimony and copper, may be present to increase projectile hardness. Copper and zinc may also be present in the metal jackets of the ammunition.

Table 2-2. Metals Used in Small Arms Ammunition

Constituent	Purpose
Lead	Primary constituent of a projectile
Lead styphnate/lead azide/antimony sulfide	A constituent of primers
Antimony	Increases hardness
Arsenic	Sometimes present in lead. Historically, a small amount may have been used in the production of some small shot since it increases the surface tension of dropped lead, thereby improving lead shot roundness.
Tin	Limited use to increase hardness
Copper	Jacket alloy metal
Zinc	Jacket alloy metal
Iron	Iron tips on penetrator rounds
Tungsten	Constituent of certain projectiles

Table 2-3. Typical Metal Composition of 5.56mm and 7.62mm Projectiles

Ball Type	Weapon	Metal Concentration in Weight Percent			
		Antimony (Sb)	Copper (Cu)	Iron (Fe)	Lead (Pb)
5.56mm	M16	1.4	31.3	–	67.3
7.62mm	M60	1.5	23.2	–	75.3
5.56mm (Hardened tip)	M16	1.0	35.4	12.7	50.9

Source: USACE 1996

At most rifle and pistol ranges, weapons are fired toward fixed or stationary targets placed in front of a backstop berm. This configuration often results in the formation of bullet pockets on the face of the berm. These pockets result from the impact of high-energy projectiles into the berm face. The bullet pocket areas may be potential locations of more elevated lead concentrations within berm faces. By contrast, at shotgun ranges (O Range, Skeet Range 1, and Skeet Range 2), ammunition projectiles are typically more widely dispersed and generally fall to the ground with less impact energy than pistol or rifle bullets, resulting in less projectile fragmentation, but potentially impact a significant surface area due to the hundreds of lead pellets per shotgun shell.

In 1999, following the implementation of a ban on the use of lead-based ammunition, 5.56mm tungsten ammunition (also known as “green” or frangible ammunition) began being used at certain Small Arms Ranges. The tungsten projectiles consisted of a high-density tungsten core and steel penetrator surrounded by a copper-alloy jacket.

Tungsten ammunition was used at fourteen Small Arms Ranges (B, C, D, E, G, H, I, IBC, J, K, KD, SE, SW and T Ranges) at MMR during the time period from 2000-2006. In February 2006, in response to concerns regarding a detection of tungsten in groundwater at MMR, use of tungsten ammunition was suspended. Following suspension of the use of tungsten ammunition, a berm maintenance program was implemented for focused removal of tungsten-contaminated soils at certain ranges.

2.3 Environmental Setting

The following subsections provide further site information regarding geography, cultural setting, ecological setting, climate, geology, hydrology, and hydrogeology.

2.3.1 Geographic Setting

MMR includes Camp Edwards, Otis Air National Guard Base, United States Coast Guard Air Station Cape Cod, Cape Cod Air Force Station, and the Veterans Affairs Cemetery. It is located on the western side of Cape Cod, Massachusetts. The northern non-cantonment area is a wooded area on the Upper Cape that is largely undeveloped, but fringed with highways, homes, and other development (Cape Cod Commission 1998). The predominant land use surrounding MMR is residential or commercial development. MMR is situated adjacent to the towns of Bourne, Sandwich, Falmouth, and Mashpee.

A restricted area surrounded by partial (non-continuous) fencing and guarded gates, the land is controlled by the U.S. Army under a lease with the Commonwealth of Massachusetts until at least 2051. Chapter 47 of the Acts of 2002 established the Upper Cape Water Supply Reserve to protect the water supply and wildlife habitat. Therefore, the potential for human exposure to on-site soil contaminants is limited to occasional trespassers, hunters, site workers, and military personnel. The northern area in which most of the Small Arms Ranges are located is used for military training. It is anticipated that the land use at the Small Arms Ranges will not significantly change over time.

2.3.2 Cultural Setting

Land use near MMR is primarily residential and commercial, and secondarily agricultural and industrial. Portions of MMR are opened for deer and turkey hunting by permit from the Massachusetts Division of Fisheries and Wildlife. The major agricultural land use near MMR is the cultivation of cranberries. Commercial and industrial development in the area includes service industries, landscaping, sand and gravel pit operations, and municipal landfills (USACE 2002).

MMR contains a cantonment area that includes a housing area for approximately 2,000 year-round residents. This area includes a chapel, a golf course, a base exchange, a medical dispensary, and two schools. Areas of MMR are used as airfields and other military support facilities. The MMR resident population increases by as much as several thousand people during the summer training activities. The northern area is used for water supply, wildlife habitat management, and compatible military training.

An archaeological survey covering 72 percent of Camp Edwards was conducted in 1987 to assess its archaeological sensitivity. One historic site and 26 prehistoric sites were identified within Camp Edwards. Findings from these surveys indicate that humans inhabited the Camp Edwards area up to 10,000 years ago.

2.3.3 Ecological Setting

The northern two-thirds of MMR are characterized as undeveloped open area, while the southern one-third is characterized as developed land. The dominant vegetation types vary accordingly. The northern portion of MMR consists of forested uplands dominated by stands of pitch pine and mixed oak species (*Quercus* spp.) with a diverse shrubby understory. Remnant vegetation in the southern portion of MMR consists of open grassland fields interspersed with scattered trees and shrubs. The present composition of these forests is a reflection of eighteenth-century logging practices, replanting strategies, and fire suppression activities. The other dominant cover type in this area consists of pitch pine and scrub oak barrens that are maintained by periodic fires (USACE 2002).

There are 39 state-listed species observed on MMR. About half of these are lepidoptera (i.e., moths), such as Gerhard's underwing moth (*Catocala herodias gerhardi*), the barrens daggermoth (*Acronicta albarufa*), and Melsheimer's sack bearer (*Cicinnus melsheimeri*). State-listed plant species documented on MMR include broad tinker's weed (*Triosteum perfoliatum*), ovate spikerush (*Eleocaris obtusa* var. *ovata*), Torrey's beak-sedge (*Rhynchospora torreyana*), and adder's tongue fern (*Ophioglossum pusillum*). Rare bird species on MMR include the upland sandpiper (*Bartramia longicauda*), the grasshopper sparrow (*Ammodramus savannarum*), the vesper sparrow (*Pooecetes gramineus*), and the northern harrier (*Circus cyaneus*). These species are primarily associated with the grassland fields in the southern cantonment area. No threatened or endangered amphibians, reptiles, fish, or mammals are known to inhabit MMR; however, MMR does support a number of animals that are listed by the state as species of special concern. These include the eastern box turtle (*Terrapene carolina*), the Cooper's hawk (*Accipiter cooperii*), and the sharp-shinned hawk (*Accipiter striatus*) (USACE 2002). Northern harriers are known to nest in the Impact Area and have been seen in that area.

2.3.4 Climate

The climate for Barnstable County, where MMR is located, is defined as humid continental. The neighboring Atlantic Ocean has a moderating influence on the temperature extremes of winter and summer. Winds of 30 miles per hour may be expected on an average of at least one day per month. Gale force winds can be common and more severe in winter. Average daily temperatures range from 29.6 ºF in February to 70.4 ^{o}F in July.

Mean annual rainfall and snow melt water ranges from 45 to 48 inches. The average net recharge to groundwater of this annual rainfall is 27 inches per year. Occasional tropical storms that affect Barnstable County may produce 24-hour rainfall events of five to six inches (NGB 1990). Average snowfall is 24 inches (MAARNG 2001).

2.3.5 Geology

The geology of Upper Cape Cod is comprised of glacial sediments deposited during the retreat of the Wisconsin stage of Holocene glaciation, approximately 15,000 years ago. Four sedimentary units characterize the regional geology: the Buzzards Bay Moraine, the Sandwich Moraine, the Buzzards Bay Outwash, and the Mashpee Pitted Plain. The sedimentary units are underlain by crystalline bedrock. Table 2-4 summarizes the principal sedimentary units underlying each of the Small Arms Ranges. The majority of the Small Arms Ranges are located in the Mashpee Pitted Plain.

The Buzzards Bay and Sandwich Moraines lie along the western and northern edges of Camp Edwards, converging in the vicinity of the Northwest Corner Area of MMR, as shown on Figure 2-2. Masterson et al. (1997) report that the Buzzards Bay Moraine resulted from the meltwater deposition of sorted sediments within a stagnant ice margin overlying a basal till. The surface of the moraine is characterized by an abundance of boulders. The upper part of the Sandwich Moraine resulted from glacial deformation of material; the lower part consists of sandy sediments. The moraine deposits are described as generally consisting of gravel, sand, silt, and clay with locally poorly to moderately sorted sand and gravel. Numerous discontinuous lenses of fine-grained sediments, including laminated silts and unsorted debris flow deposits, are also present in the moraines (Masterson et al. 1997). The till in the lower part of the Buzzards Bay Moraine is comprised of sand, silt, and clay, and scattered gravel in a compacted, unsorted matrix. Both moraines form the hummocky ridges characteristic of the northwest and north side of MMR.

The Mashpee Pitted Plain consists of fine- to coarse-grained sands with gravel forming a broad outwash plain lying to the east and south of the moraines (Figure 2-2) and interior to MMR. Masterson et al. (1997) report that the lower part of the Mashpee Pitted Plain consists of fine-grained, glaciolacustrine sediments comprised of fine sand, silt, and clay. This laterally persistent facies can be encountered underlying the moraines. The Buzzards Bay Outwash can be found along the west MMR boundary to the Cape Cod Canal and Buzzards Bay. Like the Mashpee Pitted Plain, the Buzzards Bay Outwash consists of coarse sand and gravel of deltaic origin with locally interbedded fine sand and silt.

It should be noted that overlying all of these glacial deposits is a thin veneer of fine eolian silt, in some places 2 feet in thickness. This silt layer is normally located directly below topsoil at the Small Arms Ranges.

2.3.6 Hydrology/Hydrogeology

Surface water resources on MMR are scarce. Surface water is not usually retained due to the well-drained, sandy soils of MMR. As a result, approximately 60 percent of the annual rainfall on MMR infiltrates the soil and contributes to the groundwater aquifer (AMEC 2005). The 31 wetlands on the training sites of MMR comprise 55 acres of land. No large lakes, rivers, or streams exist on the property, only small marshy wetlands and ponds. Most of the wetlands and surface waters in the Sandwich and Buzzards Bay Moraines on MMR are considered to be perched (MAARNG 2001). However, Succonsette Pond, which lies immediately southwest of the Central Impact Area, intercepts the water table.

The groundwater beneath MMR is known as the Sagamore Lens, which is a part of the larger Cape Cod Aquifer (MAARNG 2001). The Sagamore Lens is underlain by low permeability crystalline bedrock, which is not a productive source of water. The source of fresh water recharge to this groundwater system is rainfall and snowmelt. Approximately 27 inches of the average annual rainfall infiltrates the soil and recharges groundwater on an annual basis. The top of the groundwater mound of the Sagamore Lens is located within the area of the J-1, J-2, and J-3 Ranges, which are southeast of the Impact Area located in the central portion of MMR (Figure 2-3).

The height of the water table in and around MMR can fluctuate up to 7 feet annually due to seasonal variations in groundwater recharge. Groundwater levels are highest in the spring when recharge rates are high; levels are lowest in the late summer/early autumn when rainfall is minimal.

The Small Arms Ranges are situated over a portion of the Sagamore Lens. The groundwater flow direction beneath most Small Arms Ranges in western and central portions of the site is predominantly to the west and northwest, and the hydraulic gradient steepens with increasing distance from the top of the regional potentiometric groundwater mound. Within the central portions of MMR, groundwater elevations typically range between 65 and 70 feet NGVD, and depth to groundwater ranges from approximately 100 to 140 feet below ground surface (bgs). For Small Arms Ranges located to the south of the groundwater mound, such as K Range, groundwater flow is to the southwest. Based on the observed response of the water table relative to recharge events, the hydraulic travel time through the vadose zone is expected to be three to six months. The thickness of the saturated zone varies between 180 and 280 feet.

3.0 SUMMARY OF INVESTIGATIONS

A series of investigations have been conducted at the Small Arms Ranges to characterize soil and groundwater conditions. These include soil sampling at most of the ranges and installation and sampling of groundwater monitoring wells at many of the ranges.

3.1 Groundwater Characterization Activities

Since 1998, monitoring wells have been installed to evaluate and monitor groundwater beneath the Small Arms Ranges. Many of these wells have been sampled as part of the site-wide Long-Term Monitoring Program. Others have been sampled in conjunction with individual range-related investigations.

An overall discussion of site-wide groundwater monitoring results for the Small Arms Ranges is presented in Section 5.0. Monitoring well locations are included on the associated figures depicting the locations of individual ranges. This section summarizes several of the principal groundwater investigations that have focused on the Small Arms Ranges.

3.1.1 Groundwater Sampling at Former D Range

Monitoring well (MW-174S) was installed at the Former D Range where contaminant concentrations in surface soil were determined to be among the highest of the “unbermed” Small Arms Ranges (see Section 5.2.1.7). (The range does have a low [2-3 foot] residual berm that appears to be a remnant of the original berm.) The well was positioned directly beneath grid 135H, which exhibited significant visual evidence of small caliber projectile fragments and the highest concentrations of lead in soil. This well has been sampled multiple times since its installation for the complete Phase I suite of parameters (i.e., explosives, metals/inorganics, SVOCs, VOCs, pesticides/PCBs, and herbicides) and perchlorate. This well was sampled under the Small Arms Ranges Groundwater Investigation Project Note (IAGWSP 2007a) for metals (RCRA 8), tungsten, SVOCs, and explosives. In addition, this well is sampled for metals on an annual basis under the Small Arms Ranges Interim Environmental Monitoring program.

3.1.2 Tungsten Groundwater Evaluation

Following the February 2006 suspension of the firing of tungsten ammunition at MMR, a comprehensive tungsten berm evaluation was implemented to identify tungsten-impacted soil and groundwater at the Small Arms Ranges. Monitoring wells installed during this investigation were sampled for explosives, metals, and SVOCs. Both filtered (dissolved) and unfiltered (total) metals samples were collected.

In conjunction with characterization of tungsten evaluations in groundwater, an extensive laboratory analytical method development program was implemented to improve laboratory techniques for the low-level determination of tungsten in groundwater. This investigation was implemented due to the lack of an approved EPA method for determination of tungsten in groundwater and concerns that some reported tungsten detections in groundwater at MMR might be false positives. This investigation program is further discussed in Section 5.1.

B Range

Tungsten bullets were used on B Range from approximately 1999 to 2006. B Range was the most heavily used range during this period with over 330,000 tungsten-containing bullets fired. Samples collected from existing monitoring well MW-72S, which is located approximately 25 feet downgradient of the target berm on the range, contained tungsten at concentrations as high as 560 µg/L in 2006. However, six weeks later, in June 2006 following berm soil excavation, the tungsten concentration was 5 µg/L and more recently concentrations have consistently been less than 7 µg/L. In order to further evaluate the tungsten concentrations detected in well MW-72S, new monitoring wells were installed upgradient (MW-538), downgradient (MW-455S and MW-539), cross-gradient (MW-490S), and adjacent to (MW-537M1) this well.

Tungsten was not detected in the new well, MW-537M1, located just 10 feet from MW-72S. Tungsten was also not detected in wells MW-455S, MW-490S, and MW-539M1. Well MW-490S, located 150 feet north of MW-72S, has not had any detections of tungsten despite being located a similar distance downgradient from the berm and screened to intercept shallow groundwater like MW-72S. Tungsten and several other metals were detected in well MW-538M1 located beneath the berm.

C Range

Tungsten bullets were used on this range from approximately 1999 to 2006. C Range was one of the most heavily used ranges during this period with approximately 228,500 tungsten-containing bullets fired. The berm at C Range extends across less than half of the range. Two wells were installed at this range to monitor for the presence of tungsten and other contaminants in groundwater. MW-456S was located downgradient of the backstop berm. In the first sampling event in this well, tungsten was detected at 2.6 µg/L in the filtered sample and non-detect in the unfiltered sample. Tungsten was non-detect in the two subsequent sampling events from this well suggesting that the initial result was a false positive. Thus, a second well (MW-491S) was installed closer to the berm to provide further confirmation that tungsten in the backstop berm has not impacted groundwater. Tungsten was not detected in this second well or in MW-456S since the analytical method improvements were implemented.

E Range

Approximately 16,000 rounds of 9mm frangible pistol ammunition, which contains tungsten, were fired on E Range in 2004. One well, MW-468S, was installed to the west of the range to monitor for tungsten and other contaminants. A trace level of tungsten (0.39 µg/L) was detected in this well in March 2007. All subsequent samples since the improvement of the analytical method have been non-detect for tungsten.

G Range

Approximately 42,500 rounds of tungsten-containing bullets were used on G Range from 2000 through 2004. G Range is situated such that the firing line, target line, and backstop berm are all in line with the direction of groundwater flow. Thus, one well (MW-470S) was installed to assess potential impacts from all of these features. Tungsten was detected twice in this well in

December 2006 (2.6 µg/L) and March 2007 (0.81 µg/L). All subsequent samples since the improvement of the analytical method have been non-detect for tungsten.

J Range

The predominant ammunition fired at J Range from 2002 to 2006 was the 5.56mm tungsten round. Two monitoring wells, MW-471S and MW-472S, were installed on the range to monitor for tungsten and other contaminants. MW-471 is located downgradient of the back of the berm while MW-472 is located downgradient of the firing line. A trace level concentration (0.33 µg/L) of tungsten was detected MW-471S in March 2007. All other samples from these wells since the improvement of the analytical method were non-detect for tungsten.

KD Range East

KD range was used to fire tungsten-containing ammunitions from 2002 to 2005. Over this time period, approximately 68,800 tungsten-containing rounds were fired at this range. In addition, soil from other ranges where tungsten was removed was stockpiled at KD Range West prior to being shipped off-site. Therefore, existing well MW-109S was sampled to determine whether tungsten use on the range or the soil stockpile had impacted groundwater. The results of this sampling were non-detect for tungsten.

K Range

K Range is located south of the impact area and just east of the J Range. It was established in the late 1980s. From 2002 to 2006, the predominant ammunition fired at the range was 5.56mm tungsten rounds. Two shallow monitoring wells (MW-473S and MW-474S) were installed on K Range to monitor for tungsten and other contamination. MW-474S was installed downgradient of the firing line while MW-473S was located downgradient of the target berm. Tungsten has not been detected in either MW-473S or MW-474S.

SE/SW Range

SE/SW Ranges received moderate use over the 2002-2006 timeframe. During this time period essentially all of the ammunition used was 5.56mm tungsten rounds. Two wells, MW-465S and MW-466S, were installed to monitor for the presence of tungsten and other contaminants. These wells were placed to intercept groundwater passing underneath both SE and SW ranges. In 2006 tungsten was detected in both MW-465S and MW-466S at concentrations of 2.4 µg/L and 3.6 µg/L, respectively. Tungsten has not been detected in either well during more recent sampling events since the improvement of the analytical method.

T Range

The use of tungsten bullets was discontinued in 2006 and a backstop berm and bullet collection system was installed at T Range as part of the Massachusetts Army National Guard’s (MAARNG) initiative to return to firing lead bullets on the range. Two monitoring wells (MW-467S and MW-489S) were installed on the range to monitor for tungsten and other contaminants. MW-489S was installed downgradient of the former range floor. MW-467S was installed downgradient of the range firing line. T Range did not have a backstop berm prior to the installation of the STAPP™ bullet capture system in 2007. These wells were located to monitor groundwater impacts immediately downgradient of the range floor and firing line.

Tungsten was detected at a maximum concentration of 2.4 µg/L in MW-467S in October 2006. More recent results for this well since the improvement of the analytical method have been non-detect for tungsten. Tungsten has never been detected in MW-489S.

3.1.3 Other Groundwater Investigations

Former B Range

Former B Range is a small arms range located on the northern side of Monument Beach Road in Training Area B-8. The range, originally referred to as the Monument Beach Road 1000-inch range and the 1000-inch Machine Gun “A” Range, was constructed sometime between 1935 and 1941 for use as a machine gun and pistol training range. It continued to be used in this manner until sometime in the 1950s. This range is one of the oldest on the installation and potential contamination (e.g. lead) would have had a longer time to leach to groundwater than on any other range. Two wells were installed on this range to monitor for contamination. MW-475S was installed downgradient of the hillside while MW-476S was located downgradient of the backstop berm. Both wells were sampled for metals (RCRA 8), tungsten, SVOCs, and explosives.

O Range

O Range was selected for groundwater investigation because it is located on the east side of the base. This range is somewhat unique in that it was used for shotguns, which have smaller-sized lead projectiles than conventional rifles or pistols. Monitoring well MW-492S was installed with the intent to monitor lead leaching to the groundwater from the backstop where most of the lead shot was deposited. MW-492S was positioned directly downgradient of the backstop berm on the range. This well was sampled for RCRA 8 metals plus copper, zinc, iron, and antimony (both filtered and unfiltered).

3.1.4 Best Management Practices and Operations, Maintenance and Monitoring at J, K and T Ranges

From 2010 through 2013 a pilot testing program was implemented at J, K and T Ranges (currently active operational 25-meter ranges) to assess whether lead ammunition could be used at these ranges while still adequately protecting groundwater and the environment. During this time frame environmental monitoring was conducted in support of this program under the Best Management Practices and OMMPs. Bullet traps were installed at the ranges as part of the Best Management Practices. This monitoring program has included sampling for groundwater and soil pore water as well as selected soil sampling at each range. Details of the individual sampling efforts are presented in the semi-annual and annual OMMP Sampling and Analysis Reports.

During this program, groundwater sampling was conducted at two monitoring wells at J Range (MW-471S and MW-472S), two wells at K Range (MW-473S and MW-474S) and one well at T Range (MW-467S). Both filtered and unfiltered groundwater samples were collected and analyzed for selected metals including antimony, copper and lead. Sampling results are included in the overall discussion of groundwater data for the Small Arms Ranges presented in Section 5.1.

In addition, pan lysimeters were installed at each range to evaluate soil pore water with respect to the potential for subsurface (vadose zone) metals leaching and migration. A total of three lysimeters were installed and sampled at J Range, four lysimeters at K Range and three lysimeters at T Range. Lysimeters were sampled and analyzed for selected metals including antimony, copper, lead and tungsten. Overall lysimeter results are discussed in Section 5.1.1.

3.1.5 May 2013 Pore Water Sampling

As part of the May 2013 Small Arms Ranges Supplemental Investigation, lysimeters were installed at several ranges to evaluate pore water metals concentrations. Lysimeters were installed at C, G and KD Ranges. Lysimeters at B and G Ranges were sampled in June 2013. Lysimeters at C and KD Ranges did not yield enough water and therefore could not be sampled during this sampling event. Pore water samples were analyzed for selected metals [antimony, chromium, lead and tungsten]. Results are discussed in Section 5.1.2.

3.1.6 Synthetic Precipitation Leaching Procedure (SPLP) Investigation

As part of the April 2013 Soil Investigation, SPLP leaching studies were conducted by an off-site laboratory on soil samples from three target berms (berms at C, G and KD Ranges) that were previously treated with MAECTITE. The purpose of this investigation was to collect data to evaluate the longer-term effectiveness of the MAECTITE process (discussed in Section 4.1.1.1), which is intended to prevent the aqueous phase migration of lead in the vadose zone. Specific soil sampling locations were selected based upon review of berm XRF soil screening results (as discussed in Section 3.2.7). Soil samples were submitted for total lead analyses and following SPLP leaching, aqueous leachate samples were also analyzed for lead. Results for the SPLP leaching tests are discussed in Section 5.1.3.

3.2 Soil Characterization Activities

The soil investigations that have been conducted at the Small Arms Ranges are summarized below. Additional details of investigations conducted at individual Small Arms Ranges are included in Section 5. A summary of early Phase IIb sampling is included in Table 3-1. A summary of overall range-specific soil sampling is included in Table 3-2.

3.2.1 Initial Soil Investigations

Initial Phase IIb Investigations

Investigation of the contaminants at Small Arms Ranges was originally scoped under the Phase IIb Work Plan (Ogden 2000). Soil sampling was conducted at a limited subset of the Camp Edwards Small Arms Ranges as part of the first round of Phase IIb in 2000 and 2001. Results of the original scope of work were reported in the Phase IIb report (AMEC 2003b).

During initial Phase IIb investigations at the G, I, and SE Ranges, soil sampling followed a live-fire exercise to evaluate potential impacts to soil from airborne deposition of propellant- and projectile-related contaminants. At these locations, composite samples were typically collected from a 9-point grid at one depth and 5-point grid at two depths. Samples were analyzed for SVOCs and metals.

At the Former B Range, discrete samples were collected from 10 hillside backstop locations from two depths and analyzed for metals. At the Former C and Former D Ranges, both firing line and backstop samples were collected. At the firing lines, composite samples were collected from 5-point grids at two or three depths and analyzed for SVOCs and metals. At the backstops, eight to ten discrete samples were collected at two depths and analyzed for metals.

As part of the initial Phase IIb investigation, sampling and analyses were also conducted at the GA/GB Ranges. Soil samples were collected at a soil berm, a drainage ditch, a coal ash deposit, and firing line locations. At all locations, soil samples were collected from two depth intervals (0 to 6 inches bgs and 18 to 24 inches bgs).

The results of these initial Phase IIb investigations are further discussed in Section 5.

Supplemental Phase IIb Investigations

Based on the results of the initial Phase IIb sampling, a follow-up investigation was conducted in 2002 under the Supplemental Phase IIb Work Plan (AMEC 2002b) to investigate most of the remaining Small Arms Ranges and complete investigation at those initially investigated. Under the Supplemental Phase IIb program, soil samples were collected from 25 Small Arms Ranges including operational ranges A, B, C, D, E, G, H, I, J, K, KD, N, O, P, SE, Former R, SW, T and non-operational ranges Former B, Former C, Former D, Former M-1, Former M-2, Succonsette Pond, and Skeet Range 1. In general, firing points were sampled at most of the operational ranges where they were clearly identified (A, B, C, D, E, G, H, I, J, K, KD, N, O, P, SE, SW, and T Ranges). Typically, at each firing line two to five sampling locations were established. Samples were generally collected at three depths (0 to 3 inches, 3 to 6 inches, and 6 to 12 inches) with one composite and one discrete sample collected at each depth. Composite samples were collected utilizing 5-point grids. Samples were analyzed for SVOCs and metals. At certain ranges where backstops were not remediated during the 1998 Berm Maintenance Program (Former M-2 Range) or where characterization of the area beyond the backstop was warranted (G, I and J Ranges), additional samples were collected. At each of these ranges, three to ten backstop or beyond backstop samples were collected as discrete samples and analyzed for metals. At most of the ranges, discrete samples were collected at multiple locations. Several sites, including the L-1, L-4, Former M-3, Former M-4, Q Range, and the 500-yard Rifle Range, were removed from the list to be investigated because no clear range features were observed during site visits. The results of Supplemental Phase IIb investigation are documented in the 2003 Draft Final Technical Team Memorandum 02-6 Phase IIb report (AMEC 2003b).

3.2.2 2005-2008 Multiple Increment Soil Sampling Program

From 2005-2008, a series of multiple increment sampling programs were implemented to characterize soils at six ranges (E, J, K, SE, SW, and T). The purpose of the multiple increment sampling program was to augment existing data for these sites and complete characterization of these sites to support range construction activities and the resumption of training activities under the EPA pilot test.

The scope of these field sampling efforts and analytical results for the multiple increment program are discussed in detail in Section 5 of this report.

3.2.3 2005 Tungsten Characterization Study

From July to December 2005, the USACE Cold Regions Research and Engineering Laboratory (CRREL) implemented an extensive field sampling and analysis program focused on tungsten distributions at selected Small Arms Ranges at MMR (USACE 2007). This investigation program involved sampling for tungsten in soil, pore water, and groundwater. Based upon review of range use data for tungsten ammunition, B, C, and I Ranges were selected for sampling.

At B, C, and I Ranges, surface soil samples were collected from the firing point, range floor, target area, trough, and berm areas of each range. Subsurface soil samples and lysimeter (pore) water samples were collected from the impact berm and trough locations at each range. Groundwater samples were also collected from selected existing monitoring wells. Soil samples were analyzed for tungsten using both portable/field x-ray fluorescence (XRF) techniques and off-site laboratory Inductively Coupled Plasma (ICP) atomic emission spectrometry (Method 6010A), and also ICP/Mass Spectroscopy (MS) techniques.

3.2.4 2006 Tungsten Berm Evaluation

Following the February 2006 suspension of the firing of tungsten ammunition at MMR, a comprehensive tungsten berm evaluation was implemented by the MAARNG to identify tungsten-impacted soils at the Small Arms Ranges (URS 2006). This investigation was implemented to determine whether response actions were warranted at any of the Small Arms Ranges.

The initial phase of this project involved an extensive screening level characterization of tungsten soil distributions at the 13 Small Arms Ranges at which tungsten ammunition had been used (B, C, D, E, G, I, IBC, J, K, KD, SE, SW, and T). Tungsten was also used at H Range, but the soil berm from that range had already been moved to KD Range (West) to make way for the thermal treatment of soils at H Range in 2004.

An XRF field analysis program was implemented to delineate tungsten concentrations in berm soils at each range. Results of the XRF readings indicated that at seven ranges (B, C, G, I, J, K, and T), maximum observed tungsten soil concentrations were greater than 150 mg/Kg. The 150 mg/Kg tungsten value was identified as the target cleanup goal for the removal project. At these ranges, it was determined that the tungsten in the soils was distributed in a manner that made excavation of the more highly contaminated soils feasible.

At four of the remaining six ranges (E, KD, SE, and SW), none of the pre-characterization samples were above 150 mg/Kg. At the remaining two ranges (D and IBC), one sample at each range contained a tungsten concentration greater than 150 mg/Kg. Based on these findings, no soil excavation was conducted at these six ranges.

Based upon the overall results of this investigation, a soil excavation program was implemented at seven ranges as discussed in Section 4. The Technical Memorandum summarizing this work effort is included in Appendix F of this report.

3.2.5 2007 Environmental Assessment of Lead

In 2007, CRREL (2007a) conducted a detailed evaluation of the mobility of lead at Small Arms Ranges at MMR. This investigation was conducted to evaluate whether past or future use of lead at the Small Arms Ranges had or could result in lead mobilization. Initial literature evaluations determined that lead mobilization in the environment tends to primarily occur through surface erosion and/or wind. However, at MMR the soils are highly permeable and surface water runoff and erosion is minimal. As such, evaluations focused on the potential for lead leaching through subsurface soils to groundwater.

Based upon detailed evaluations, the CRREL study concluded from multiple lines of evidence that lead had not contaminated groundwater at MMR. This conclusion was based on data evaluations that indicated that no lead plumes had been observed at MMR.

Associated geochemical considerations supported the groundwater data results. Geochemical observations of lead migration at MMR included the following:

- Soil conditions are not sufficiently acidic to readily dissolve metallic lead;
- High soil permeability, low chloride, and soil resistivity of surface soils are conditions not favorable for the rapid corrosion of lead;
- A high degree of lead adsorption based on site-specific soil profiles, unsaturated zone monitoring and aquifer studies; and
- Depth to groundwater of more than 90 feet at the Small Arms Ranges.

Additional MMR-specific evaluations of lead mobility included the following:

- Multiple soil profile samples collected prior to and post-berm maintenance from six Small Arms Ranges indicated little vertical migration of lead;
- Unsaturated zone modeling using multiple software codes (including SESOIL, Mixing Cell Model and GW Screen) predicted the vertical migration of lead would take greater than 100 years to reach groundwater (see also Rood and Hull 2007);
- Groundwater data collected from across MMR demonstrated low level lead detections at a few Small Arms Ranges, despite metallic lead being intermittently deposited on various range surface soil locations for more than 60 years; and
- Unpublished tracer studies conducted by the U.S. Geological Survey near MMR demonstrated that an aqueous form of lead was rapidly adsorbed to soil, which suggests that the same reactions will attenuate lead movement in the unsaturated zone (USGS 2006).

The CRREL evaluation also noted that literature information on the geochemistry of lead was consistent with both its predicted geochemical behavior at MMR and the reported field observations indicating the general absence of migration. The CRREL evaluation did, however, also note that “the lack of sufficient data to quantify the ability of Camp Edwards soils to immobilize lead, knowing the soil’s ability to immobilize lead is finite, and given its toxicity, range design and maintenance programs to limit lead exposure” were prudent.

3.2.6 2008 Lead Screening Program at Former B and Former D Ranges

In May 2008, an XRF field analysis program was initiated at the Former B and Former D Ranges to characterize residual soil lead levels. This sampling program was implemented to identify areas of the ranges with high concentrations of lead fragments and to support the remediation of lead containing soils at these ranges.

For the XRF screening efforts, both the Former B and Former D Ranges were divided into subareas to define lead distributions across the ranges. In addition, Former B Range was separated into north and south areas. In general, the ranges were separated into firing lines, range floors, target lines, backstop berms, behind berms, and hillside areas.

Field screening for lead was performed using portable XRF techniques (Innov-X field instrument). Both surface and subsurface soil lead concentrations were investigated. At surface locations indicating high lead levels, shallow subsurface samples were collected to develop depth profiles. At these locations, soil samples were sieved to visually characterize metal fragments in soil. Twenty-seven soil samples were submitted for off-site laboratory analysis for lead.

Results of the XRF field screening program indicated that several areas of the Former B Range contained soil lead levels in excess of 300 mg/Kg (the MassDEP S-1/GW-1 standard for lead). In general, lead levels for the Former D Range were somewhat lower than those for the Former B Range, although samples from several areas exceeded 300 mg/Kg.

Visual observations and the results from the screening program were used to determine areas of the Former B and Former D Ranges where excavation to reduce soil lead concentrations was warranted. As described in Section 4.1.2, this work supported a removal action of lead-impacted soil and bullet fragments from these ranges and from the M2, J and K Ranges.

3.2.7 2013 Multiple Increment Sampling and XRF Screening Program

The April 2013 Soil Investigation Program was implemented in order to fill data gaps that had been identified in the existing investigations of the Small Arms Ranges. This investigation focused on compiling additional data appropriate to assess the current levels of selected metals (typically including antimony, copper, lead and/or tungsten) of potential concern at some of the target berms; to characterize the levels of metals behind certain target berms; to establish the levels of explosives (including nitroglycerin) at the firing lines at inactive ranges; and, to collect data at some of the older ranges that had not been previously sampled. The data collected was also intended to support assessment of risks to the aquifer and the potential risk of direct exposure to soils contaminated by range use. The sampling results have been used in conjunction with other existing data to support the RI/FS and associated Risk Screening and ultimately the development of a Decision Document for Small Arms Ranges. A summary of the April 2013 sampling program is included in Table 3-2.

The April 2013 Soil Investigation program consisted of two principal sampling components as detailed in the Final Project Note (IAGWSP 2013a). The first component involved the collection of multiple increment samples at many individual Small Arms Ranges. Multiple increment samples were collected as needed to characterize contaminant concentrations at specific locations of concern on individual ranges. Individual sampling areas were constrained to 10,000 square feet or less and the minimum number of increments was not less than 30 per sample. In general, the number of increments (30, 50 or 100) was selected to ensure that one increment was collected for not more than every 100 square feet. The samples were collected at a depth of 0 to 3 inches bgs. Replicate samples were collected at approximately 25 percent of the multiple increment sample locations.

The entire sample volumes of multiple increment soil samples from the Small Arms Ranges were air dried at the laboratory, and then processed through a #10 sieve to remove any materials larger than 2mm in size. Samples were monitored to watch for and note the presence of any metal fragments in the samples that were removed from the sieve process. The sample was then ground in a puck mill to a fine powder. At that stage, the sample was spread evenly over a large tray, and aliquots for analysis were removed using Incremental Subsampling Methodology via the two-dimensional slab-cake technique. The resulting sample was then digested and analyzed for the required metals.

The overall conclusions of this multiple increment sampling effort included the following:

- Tungsten concentrations were below 160 mg/Kg (the proposed MassDEP soil standard) in all multiple increment range samples;
- Antimony concentrations were below 20 mg/Kg in most range samples;
- Lead concentrations were quite variable both between ranges and within the same range with concentrations ranging from <20 mg/Kg to >1,000 mg/Kg in a few samples; and
- Explosives were not detected in most of the samples that were analyzed although matrix interferences inhibited low-level nitroglycerin analyses in a few samples.

A range-by-range discussion of the multiple increment sampling and analytical results is included in Section 5.2.

XRF Screening Program

In addition to multiple increment sampling, a focused XRF field screening program (with confirmatory off-site laboratory analyses) was conducted for selected metals (antimony, copper, lead, tungsten, and chromium) at surface and subsurface soil locations at berm faces at four Ranges (B, C, G and KD). An Innov-X Alpha Model X-Ray Fluorescence (XRF) hand-held instrument was used to collect soil XRF readings. The field instrument was calibrated by the manufacturer (Olympus-Innov-X) prior to field use. Prior to sample analysis, three certified external soil standards and one blank standard were analyzed to confirm instrument accuracy for target analyte concentration measurements. The XRF was operated in a direct readout point and shoot mode. Multiple increment samples were analyzed in the site trailer.

All XRF readings were performed on composite multiple increment soil samples collected in transparent polyethylene Ziplock bags. Samples were inspected and hand-screened for rocks, roots, bullet fragments and debris prior to XRF screening. Large debris was removed and the bagged samples were shaken and mixed to homogenize the sample. The XRF detector was placed squarely against the sampling bag and XRF readings were collected. Three 60-second readings were recorded for each sample from different locations on the sample bag.

At the selected ranges, each berm face was divided horizontally into three horizons of approximately equal height: the top horizon above the bullet pockets, the second horizon at the bullet pocket zone and the third horizon at the trough area beneath the bullet pockets (Figure 2-1). Each of the three horizons was then partitioned into XRF surface soil sampling areas of approximately 2,000 square feet. Thirty-point multiple increment samples were then collected from 0 to 3-inch depths from each individual sampling area for XRF screening.

Based upon the XRF screening results for the surface soil samples at each range, soil borings were advanced to depths of up to 6 to 8 feet bgs and subsurface soil samples were collected from selected berm locations. At each of the four ranges noted above, soil borings were advanced at the three soil berm grids having the highest surface soil XRF tungsten screening results. Subsurface soil samples were collected across approximately one foot intervals and XRF screened for the selected metals. Approximately 10 percent of the XRF screened samples were submitted for confirmatory off-site analyses. Overall, XRF screening results were generally consistent with the results for multiple increment samples noted above. Antimony was essentially non-detect (<60-80 mg/Kg) in all samples with one exception. Lead and copper concentrations were quite variable, ranging from low mg/Kg levels to >1,000 mg/Kg in a few samples. Tungsten concentrations were below 160 mg/Kg in all samples. The XRF screening results for B, C, D and KD Ranges are presented in Tables 3-3A and 3-3B.

The off-site laboratory confirmation results of the field XRF screening berm and soil boring sample results for antimony, lead, tungsten and chromium (for B Range) are presented in Table 3-4. At each range, berm and boring samples with the highest XRF lead screening results were submitted for laboratory confirmation analysis by method SW6010 (SW6020 for tungsten).

Laboratory results generally confirmed the XRF screening results, although some variability was observed between the XRF screening results and off-site laboratory analytical results for certain samples. The XRF screening results for chromium in all B Range soil samples were non-detect at a detection limit of 65 mg/Kg; off-site laboratory analytical results for the “split” soil samples were also non-detect. The XRF screening results for antimony were all non-detect with a minimum detectable concentration of 69 mg/Kg. The off-site laboratory reporting limit for antimony (3 mg/Kg) was well below the limit of the XRF instrument. Low levels of antimony were reported in the “split” soil samples ranging from 1.2 to 7 mg/Kg. The tungsten results were generally comparable, with two exceptions. The XRF screening result for tungsten was non-detect (ND<9 mg/Kg) for the C Range berm sample (C15B) but was reported as 65.5 mg/Kg by the laboratory. The XRF screening result was non-detect (ND<8 mg/Kg) for the G Range boring sample (G6_SB1-2) but was reported as 18.3 mg/Kg by the laboratory. Lead results were detected by both methods in all soil berm and boring samples. The laboratory results for lead were generally higher than the XRF screening results for samples containing elevated lead concentrations. The discrepancies between the tungsten and lead results may be due to the fact that the multiple increment samples processed at the laboratory were dried, sieved and ground prior to digestion and analysis. In contrast, XRF readings were taken directly on collected multiple increment soil samples with no preliminary sample preparation.

As indicated above, field XRF screening and laboratory ICP analytical methods for metals involve fundamentally different sample preparation and analysis techniques. Portable XRF methods do not involve sample digestion and soil samples are typically not ground. Elemental detection and concentration determinations rely on XRF beam interactions with metal associated electrons in surface and near surface layers of soil or lead fragment particles. If individual soil (or small lead fragment) particles are not completely homogeneous, then metal concentrations in particle interiors may differ from those in surface layers. For example, the surfaces of small lead fragments may contain oxide coatings and/or soil related organic or inorganic material at different concentration ratios than within the interior of the particles. Under these conditions laboratory ICP methods that include particle grinding and digestion may report higher lead concentrations than those reported via XRF. This can result in differences in reported lead concentrations for XRF and ICP techniques. As indicated in Table 3-5, differences in reported metals concentrations between XRF screening and off-site analyses are generally much less than an order of magnitude.

May 2013 Supplemental Investigation

During the May 2013 Supplemental Investigation, supplemental visual inspections, metal detector sweeps and/or XRF screening were conducted at several additional ranges or areas of concern as a follow-up to the April 2013 investigation program. These investigations were conducted to further characterize certain ranges at which uncertainty existed concerning whether or not the ranges had undergone any significant past small arms use. The ranges undergoing metal detector evaluation included L Range (50s to 80s), L-1, L-2, L-3, L-4, Former M-3, Former M-4, Former N Range, downrange of GA/GB, Q Range, Skeet Range 2 and Succonsette Pond.

The Supplemental Investigations at these ranges initially consisted of a visual reconnaissance of the range to identify any features that might be associated with past small arms use. In conjunction with the visual investigations, metal detector sweeps were run across certain locations at the range. If the results of these evaluations suggested locations containing evidence or indications of possible past small arms use, a multiple increment sampling area was established and a sample was collected for both XRF screening and off-site laboratory analysis. If there was no evidence of past small arms use, a multiple increment sample was not collected.

Soil samples were collected at a number of ranges for both on-site field XRF screening and off-site laboratory multiple increment sample analyses. Field investigations were conducted in accordance with the Final Project Note – Additional Sampling to be Conducted in Support of Small Arms Ranges Supplemental Investigations (IAGWSP 2013b). Field screening for selected metals was performed using an Innov-X XRF field instrument. Details of the screening methodology were described above and presented in the Final Project Note for Small Arms Range sampling (IAGWSP 2013a). The results of the on-site XRF screening for antimony, copper and lead are summarized in Table 3-5. As indicated therein, triplicate XRF readings were conducted for each soil sample. Off-site laboratory analyses were also performed on the soil samples undergoing XRF screening. These off-site confirmatory results are presented in Table 3-6.

As is indicated in Table 3-5, XRF readings for antimony were generally low and all results were below the detection limit range of the instrument (57-67 mg/Kg). Copper concentrations were also generally low. With the exception of results for the Former N Range, all copper results were below the instrumental detection limit range (17-21 mg/Kg). Lead results were somewhat more variable and ranged from less than 30 mg/Kg at several ranges to over 1,000 mg/Kg at the Former N Range. With the exception of Former N Range, all lead XRF readings were below the MCP S1/GW1 standard of 300 mg/Kg. As indicated in Table 3-5, XRF readings were relatively consistent among the triplicate readings conducted for most samples. In addition, as indicated in Table 3-6, XRF screening results showed generally good agreement with off-site confirmatory samples, although some variability was observed in certain samples. The off-site samples confirmed the low levels of antimony and copper at most locations. As has been previously observed, off-site lead results, for samples having higher lead concentrations, tended to be slightly higher than the corresponding XRF screening results. This is likely due to the differences in the methods of sample preparation and analysis as previously discussed.

3.2.8 Laboratory Studies for Propellant-Related Compounds

To better characterize the potential leaching of propellant-related compounds, the USACE CRREL conducted a series of laboratory studies on the potential for dissolution and migration of DNT and nitroglycerin in soils (USACE 2009) from Small Arms Ranges at MMR. The objectives of these studies were to quantify the dissolution rates of DNT and nitroglycerin from propellant grains, determine the extent of sorption and desorption as DNT and nitroglycerin migrate through soil, and qualitatively evaluate the effects of biodegradation. The investigation program included bench-scale drip tests on propellant residues from four Small Arms Ranges, and batch and column tests utilizing soil from MMR Small Arms Ranges.

Dissolution Tests

In dissolution tests, fresh fired propellant residues were placed in four separate one centimeter (cm) diameter Buchner funnels fitted with a glass frit at the bottom. The residues that were evaluated included 39 mg of 9mm propellant residue, 18 mg of 7.62mm residue, 68 mg of 5.56mm residue, and 57 mg of 0.50 cal residues. Using a syringe pump, distilled water with a pH of 6 was dripped onto the residues at 0.5 milliliter (mL) per hour. Water flowed through each frit into 20-mL glass vials. The water volume and nitroglycerin concentration were measured daily from each vial.

On average, the fired propellants' grains used for the tests were 10 percent nitroglycerin and 90 percent cellulose. Approximately 5 percent of the nitroglycerin, or the amount located on the exposed surface of the grains, went into solution over approximately three months of this drip test. After three months, the rate of dissolution subsided to almost nothing, as the remaining nitroglycerin is encapsulated within the nitrocellulose fiber and cannot go into solution.

Sorption/Desorption Tests

A number of batch tests were conducted to evaluate sorption of nitroglycerin and DNT in solution to site soil, as well as to determine whether the sorption was reversible (i.e., would nitroglycerin and DNT subsequently desorb from the soil particles). Soil was collected from three Small Arms Ranges at MMR: E Range, J Range, and K Range. Aliquots of 14 grams of soil and 70 mL of deionized water, a one to five ratio, were placed in an orbital shaker. At the end of the shaking period, the soil and water were analyzed by Method 8330B high performance liquid chromatography to determine the nitroglycerin and DNT concentrations in each medium.

Numerous variables were evaluated in triplicate including time (five exposure periods); concentration (five solution concentrations); inter-site heterogeneity (three ranges); intra-site heterogeneity (two locations per range); depth; temperature; and pH. For the sorption experiments, the deionized water was spiked with a nitroglycerin and DNT solution. Experiments were also performed with site soil containing weathered propellant and site soil spiked with unfired and freshly-fired propellant residues. The majority of experiments included a biocide that was added to the deionized water to inhibit biological activity. Some experiments were run without the biocide to qualitatively evaluate the potential for biodegradation. For desorption tests, soil from the completed sorption tests was air-dried and reused with clean deionized water.

The batch experiments demonstrated that aqueous phase nitroglycerin and DNT will sorb to soil and that this process is reversible. Desorption does occur, albeit less readily than sorption (slightly retarded).

The batch tests also substantiated the dissolution tests. At the conclusion of the test runs containing unfired and freshly fired propellant, nitroglycerin was detected in the aqueous phase at concentrations equating to approximately 4 percent of the initial nitroglycerin mass in soil, provided biocide was used. If biocide was omitted, nitroglycerin was not detected in the aqueous phase. Furthermore, for test runs containing weathered propellant residue, nitroglycerin was not detected in the aqueous phase regardless of whether or not biocide was included.

The batch tests were followed by column experiments. Four tests were performed in duplicate for a total of eight column set-ups. Each glass column had a five cm inner diameter and was 61 cm long. A one cm permeable glass frit was at the column base with two cm of glass wool and three cm of 5mm glass beads placed on top of the frit to prevent sediment from clogging. A 20 cm layer of Small Arms Range soil was dry-packed and slightly tamped on top of the beads, and a 25 cm head of water was maintained on top of the soil surface. The columns were wrapped in foil to avoid potential impacts of photodegradation. Water flow was controlled with a peristaltic pump at a flow rate of 0.3 mL per minute. The four tests were:

- 1A, 1B: nitroglycerin and DNT solution with biocide run through clean soil;
- 2A, 2B: nitroglycerin and DNT solution without biocide run through clean soil;
- 3A, 3B: Clean water with biocide run through fresh fired 0.25 grams of a 50:50 mixture of 5.56mm- and 9mm-propellant residue at the soil surface; and
- 4A, 4B: Clean water without biocide run through fresh fired 0.25 grams of a 50:50 mixture of 5.56mm and 9mm-propellant residue at the soil surface.

In tests 1A and 1B, 90 percent of the applied nitroglycerin and DNT was recovered in the effluent, further demonstrating that the sorption process is reversible. For tests 2A and 2B, nitroglycerin or DNT were not detected in the effluent, as the microorganisms in the soil appear to have readily biodegraded these compounds. The influent nitroglycerin and DNT concentrations were 1 milligram per liter (mg/L) for 1,272 hours, or 111 pore volumes. The influent concentration was then increased to 10 mg/L for 484 hours (42 pore volumes) and 100 mg/L for 71 hours (6 pore volumes).

In tests 3A and 3B, sporadic low levels (less than 0.2 mg/L) of nitroglycerin were observed in the effluent. Soil samples from each two cm interval in Column 3B were collected and analyzed after 95 pore volumes of water passed through the column. A significant quantity of nitroglycerin remained in the 0 to 2 cm interval. These tests further verified that only the nitroglycerin exposed on the outside of the propellant grains was available to go into solution. In tests 4A and 4B, nitroglycerin or nitroglycerin daughter products were not observed in the effluent after 1,008 hours (88 pore volumes at 0.3 mL per minute) and 625 hours (109 pore volumes at 0.6 mL per minute) respectively, which again indicates that naturally occurring biodegradation was sufficient to eliminate any dissolved phase nitroglycerin and DNT.

Treatability Tests

A bench scale treatability study was proposed to evaluate the efficacy of using alkaline hydrolysis to chemically destroy 2,4-DNT encapsulated in nitrocellulose. This process was used successfully to treat soil at MMR contaminated with RDX, HMX, and TNT. However, it was unknown whether the nitrocellulose fibers could be broken down allowing the 2,4-DNT to be exposed and degraded. The tests were conducted by USACE Engineer Research Development Center in Vicksburg, Mississippi.

The test was intended to be a bench scale container or mesocosm study. The propellant selected for the study was M1 artillery propellant, which is approximately 90 percent nitrocellulose and 6 to 8 percent DNT, with the remaining percentages being binders and plasticizers. The propellant is manufactured using organic solvents, extruded in a tubular form, rinsed in water to remove solvent residue and dried. The propellant is then coated with a thin layer of graphite so that the individual grains do not stick together and flow easily into containers.

After inspecting the M1 propellant, it was determined that it was not appropriate for the mesocosm study because of the particle size and durability of the propellant grains. Attempts were made to crush the particles with a mortar and pestle. The crushed propellant flattened the tube into loosely attached fibers. Experiments were then conducted to reduce the size of the grains by placing the propellant in a ceramic ball grinding roller mill along with clean sand and soil obtained from MMR. The mixtures were ground for up to seven days. At the completion of the experiments, the ceramic balls and propellant were sieved out of the sand and soil. Very little of the propellant passed through the sieve with the sand or soil.

Experiments were then conducted on crushed and uncrushed propellant samples using caustic (pH of 12.9) and acidic (pH of 2) solutions. The extremely high and low pH may have broken down some 2,4-DNT that resided on the surface of the unweathered propellant grain; however, most of the DNT in the study remained untreated.

The results indicate that the 2,4-DNT encapsulated in nitrocellulose is generally unavailable to hydrolysis liquids under either acid or alkaline conditions. In addition, the soil attrition tests did not reduce the propellant size or shape to more readily free the DNT from the propellant. Therefore, it appears that alkaline hydrolysis would not be an effective method to remediate 2,4-DNT contaminated soil from the Small Arms Ranges. Based on the results of the initial tests, further work on the bench test study was not appropriate. These treatability tests confirmed the earlier dissolution tests demonstrating that even under extreme pH conditions, the DNT is not released from the nitrocellulose.

4.0 RESPONSE ACTION AND RANGE MAINTENANCE ACTIVITIES

4.1 Response Actions

4.1.1 1998 Berm Maintenance Program

In 1998, prior to commencement of soil or groundwater investigations, a program was undertaken to remove and recycle lead bullets from the Small Arms Ranges and to chemically fix leachable lead remaining in the soil. This Berm Maintenance Program was implemented at 16 Small Arms Ranges [A, B, C, D, E, G, H, I, J, K, KD, N, O, P, SE, and SW] (Figure 4-1). At each range, soils containing leachable lead levels greater than 5.0 mg/L, as determined by Toxicity Characteristic Leaching Procedure (TCLP), were excavated and treated.

During the initial phase of the Berm Maintenance Program, approximately 1,125 pre-excavation soil samples were collected to characterize total lead and leachable lead in the berms. Approximately 821 samples were analyzed on-site with the remainder submitted to an off-site laboratory. In addition, 160 soil samples were collected to characterize total copper, total iron, total nickel, and total antimony concentrations present in berm soils. Results indicated the highest leachable lead levels were generally within the first 2 feet of soil within the berm faces.

Following characterization of lead distribution in the berm at each range, approximately 17,788 cubic yards of soil were excavated from the berm faces and transported to a central processing area south of Camp Edwards Range Control. Excavated soils were sifted to remove recyclable lead projectiles and then treated using the MAECTITE process to chemically fix the remaining lead in the soils. The process involves immobilizing leachable lead by chemically bonding the leachable lead fraction.

Following ex-situ treatment, random grab samples were collected for approximately every 50 tons of processed soil and tested to confirm leachable lead levels of less than 5.0 mg/L. Treated soils were initially used to reconstruct the berms on B and C Ranges and subsequently other Small Arms Ranges. In-situ soil treatment using the MAECTITE process was subsequently implemented at berms where no bullet pockets were observed but post-excavation soil sampling revealed residual lead concentrations exceeding the cleanup criterion.

The chemical fixation process reduced TCLP leachable lead concentrations in 27,952 tons of soil below project requirements. Leachable lead concentrations in soil remaining on the ranges were reduced to below the EPA’s project-specific requirement that soils on the ranges have leachable lead of less than 5 mg/L based on TCLP testing.

Approximately 56 tons of lead bullets were recovered and recycled under this project.

4.1.1.1 MAECTITE Process

As indicated above, the MAECTITE process utilized in the 1998 Berm Maintenance Program involves the chemical fixation of lead. The process uses a proprietary liquid reagent (containing reactive phosphates and sulfates) that readily permeates through soil and rapidly reacts with leachable lead. This chemical bonding process results in the formation of microscopic hard and geochemically stable synthetic mineral crystals in the soil matrix. The crystalline morphology of the processed material includes metal-substituted hydroxyapatite [$Ca_5(PO_4)_3(OH)$] and mixedapatite-barite minerals incorporating heavy metals into geologically stable forms possessing reduced susceptibility to precipitation induced leaching. With respect to lead, the primary mineral phases are lead phosphate related.

During the 1998 Berm Maintenance Program, excavated soil was placed in a central stockpile and fed into an ex-situ processing system. Material was pushed by bulldozer and handled by a tracked excavator, which loaded material onto a bar/screen shredder where oversized material was removed. Material passing a 6-inch screen was conveyed to a screening plant consisting of a 2-inch screen followed by a #4 screen (0.187-inch nominal diameter). Material passing through the #4 screen was conveyed by belt to a pug mill mixer. MAECTITE chemicals were metered, added and mixed into the soil. Soil was then discharged and accumulated in 500-ton stockpiles. Based upon the results of 56 confirmatory samples, all post processed material stockpiles attained the performance criteria of <5.0 mg/L TCLP lead. Ninety percent of the piles achieved <0.5 mg/L TCLP lead.

Recently, as part of the April 2013 range investigations, SPLP leaching tests were conducted on soil samples from three ranges to assess the long-term stability of lead in MAECTITE processed soils. The results of these leaching tests are discussed in Section 5.1.2.

4.1.1.2 Lead Phosphate Precipitation Research

Over the last several years, research has been conducted to further examine the use of lead phosphate formation [including pyromorphite ($PbO_5(PO_4)3X^-$ where $X=Cl^-$, OH^-or F^-)] as a treatment technology to immobilize lead in surface soils at firing ranges. Due to its relatively low solubility, pyromorphite formation offers an attractive chemical means of precipitating and mineralizing lead in surface soils, reducing aqueous phase lead concentrations and inhibiting migration. Recent research has examined some of the chemical factors affecting the formation of pyromorphite in soils, as well as factors potentially affecting the longer-term stability of this and related mineral phases.

Chrysochoou et al. (2007) conducted a detailed review of some of the chemical processes potentially affecting pyromorphite precipitation and mineral formation in natural soils. These authors indicated that multiple chemical factors could potentially influence the rate and extent of pyromorphite formation. These included system pH, Eh, lead speciation in soils, particle size of lead materials, phosphate speciation, solution chemistry (including calcium) and the availability of water. These researchers noted that reactions involving pyromorphite formation in soils can be relatively pH sensitive, since dissolution of existing lead species is typically an initial step in the precipitation process. Variations in system pH and Eh may potentially influence both the kinetics of the pyromorphite formation process and the ultimate chemical end products based upon thermodynamic stability.

During the original ex-situ and in-situ lead treatment using the proprietary MAECTITE process at the Small Arms Ranges, system chemical composition (including pH and Eh) would have been controlled to optimize the formation of pyromorphite. Although the soils at the Small Arms Ranges at MMR are generally similar, there are some differences in the soil chemical characteristics at individual ranges (including soil pH and Eh). Therefore, the solution chemistry factors affecting MAECTITE formation might have varied somewhat depending upon the individual range soil, possibly influencing the final reaction products. This would be expected to be of potentially greater significance during in-situ treatment as compared to ex-situ treatment because in ex-situ treatment the soil would be homogenized during the treatment process. Also, during the ex-situ process, chemical reaction conditions were likely to have been more tightly controlled.

Chrysochoou et al. (2007) also noted that lead speciation in firing range soils can vary significantly and may include metallic Pb fragments, carbonates (including cerussite $PbCO_3$), anglesite ($PbSO_4$) and litharge (PbO). Lead may also be sorbed on iron and aluminum oxyhydroxides and on soil organic matter. In addition, the nature of the lead metal fragments at individual ranges is dependent upon several factors, including the types of bullets historically used at the range (pistol, rifle, machine gun etc.) and their extent of fragmentation during firing. Variations in the chemical form of lead in range soils, including the extent of metal fragments present and their size, could potentially influence pyromorphite formation reactions and their kinetics and/or the reaction products formed during treatment. Again, these factors would likely have had greater influence on in-situ MAECTITE mineral formation as compared to ex-situ treatment.

Recent research has also considered the longer-term stability and potential effectiveness of lead phosphate minerals (such as pyromorphite) in controlling solution lead concentrations following initial mineral formation. Martinez et al. (2004) studied the longer-term solubility of lead orthophosphate mineral suspensions [B-$Pb_9(PO_4)_6$ and $PbHPO_4$] after aging for three years. These researchers noted that lead phosphate mineralization reactions can be kinetically slow and may require months to years to complete. The researchers compared experimentally measured lead concentrations (Pb^{+2} activities) to lead activities calculated based upon equilibrium solubility product (K_{sp}) values from the scientific literature. Overall results indicated that experimentally measured aqueous phase Pb^{+2} activities could be as much as 1-2 orders of magnitude higher than those predicted based upon theoretical (literature) K_{sp} values. It was indicated that the experimentally observed increases in aqueous phase lead solubility might result, in part, from several factors including slow mineralization reaction kinetics (equilibrium not attained), variations in the chemical compositions of lead phosphate particle surfaces versus the crystal particle interiors, and variations in the size and degree of crystallinity of the mineral phases. It was noted that the formation of smaller particle size minerals could favor increased lead solubilization over time, due to higher particle surface area to mass ratios. It was also suggested that depending upon solution chemistry, metal ion substitutions (such as zinc) in lead phosphate mineral crystal structures might tend to reduce the degree of mineral crystallinity, potentially affecting longer-term stability and possibly increasing lead solubility.

In associated experiments, Martinez et al. (2004) examined the potential influence of soluble organic ligands on mineral stability as evidenced by solution lead activities. Experimental results indicated that lead dissolution from the B-$Pb_9(PO_4)_6$ mineral at neutral pH levels (pH-7.2), was enhanced by the presence of humic acids. It was speculated that in pH dependent reactions, humic acid ligands may be capable of chelating mineral phase surface lead, thus increasing aqueous phase concentrations. These effects were predicted to be significantly more pronounced at neutral or alkaline soil pH conditions than under acidic conditions. These results suggest that under appropriate soil chemical conditions, certain types naturally occurring organic matter in soils may tend to solubilize some precipitated lead, increasing aqueous phase concentrations to levels greater than those predicted by lead phosphate mineral K_{sp} values.

In summary, recent research results acknowledge that lead immobilization through phosphate mineral formation (such as in the MAECTITE process) is expected to be an effective means of reducing aqueous phase lead concentrations and reducing the potential for subsurface lead migration. However, this research also indicates that the chemical processes potentially affecting lead mineral formation and subsequent stability in surface soils are likely to be relatively complex. As noted above, factors including solution chemistry, phosphate concentration, lead speciation and particle size and the presence of inorganic ions and organic ligands may influence the kinetics of lead formation reactions, the specific chemical composition of the lead mineral phases and the longer-term solution aqueous phase lead concentrations related to these mineral phases.

Overall, the use of the MAECTITE treatment process has been and remains an effective means for minimizing lead migration at the Small Arms Ranges. The research discussed above suggests that the formation of pyromorphite and/or related lead phosphate mineral species during the MAECTITE treatment process at the Small Arms Ranges might have been influenced somewhat by several factors, including the treatment conditions (in-situ vs ex-situ), range-specific soil chemical conditions and the lead speciation at a given range. Subsequent lead mineral weathering (if any) may also be influenced by range-specific soil chemical conditions, including the presence of other inorganic ions and/or organic (humic acid) ligands. Detailed range-specific soil characterizations of the pyromorphite/lead mineral phases produced during the MAECTITE process (using x-ray diffraction-XRD, scanning electron microscopy/x-ray spectroscopy, extended x-ray absorption fine structure-EXAFS, etc.) are not available. In the absence of this type of data, it is difficult to accurately assess the lead mineral phases originally formed and currently present in surface soils at individual ranges. As such, some uncertainty exists with respect to accurately predicting the long-term stability (in years) of the residual MAECTITE reaction products. However, the continued application of Best Management Practices at the ranges should minimize the possibility of any significant lead migration.

4.1.2 2009 Lead Removal Program

In 2009, surface soil removal actions were performed at several Small Arms Ranges (Former B, Former D, Former M-2 Range, J Range, and K Range) to remove lead projectiles and elevated levels of lead in soil detected during previous range investigations. Excavation was focused on bullet fall-out areas and where soils had lead concentrations in excess of 300 mg/Kg. It was determined that soil excavation would be conducted at four areas at Former D Range, six areas at Former B Range, the berm face at Former M-2 Range, and the backsides of the berms at J Range and K Range.

Following site preparation surface soils were excavated to prescribed depths based upon previous screening results. Excavated material from the ranges was stockpiled at Former D Range for subsequent mechanical screening. Upon completion of excavation at each area, excavation footprints were screened using XRF to determine the remaining lead concentrations. If XRF screening results across an area were less than 300 mg/Kg, then confirmatory multiple increment samples were collected for off-site lead analysis.

Initial excavation was completed in October 2009 from six areas identified within the Former B Range. One 50-point post-excavation multiple increment sample was collected from each of the six excavation areas. Results from these samples indicated that lead levels in the remaining soil were below 300 mg/Kg for all areas of excavation with the exception of area B-6, which had a soil lead level of 1,440 mg/Kg. Additional lifts of soil were excavated from area B-6 in September 2010, November 2010, and March 2011. The lead results for the fourth round of post-excavation samples were below 300 mg/Kg. The excavation areas at Former B Range are presented in Figure 4-3. Overall, approximately 605 cubic yards of soil were excavated from this range.

The Former D Range was divided into four areas for the initial XRF screening: a firing line, a short (~ 20 meters) range floor, a backstop berm and a large hillside area. These results were used to delineate the following areas of excavation: D-1 (divided further into D-1A, D-1W, and D-1E), D-2, D-3 (further divided into D-3A, D-3B, D-3C, and D-3D), and D-4 (consisting of D-4N and D-4S). These areas contained all of the high concentrations of lead identified in the initial XRF survey.

Initial excavation was completed in October 2009 from these areas identified within the Former D Range. Each area was initially excavated down to 21 inches. Confirmatory 100-point post-excavation multiple increment samples were collected from each of the subareas D-1A, D-1W, and D-1E and analyzed for lead. Sample results indicated that lead levels in the remaining soil were below 300 mg/Kg for subarea D-1E, but were above 300 mg/Kg in subareas D-1A and D-1W. Therefore, it was determined that further excavation was necessary in portions of Area D-1. Confirmatory 100-point post-excavation multiple increment samples were collected in Area D-2, D-3A, D-3B, D-3C, D-3D, D-4N and D-4S). Results from these samples indicated that lead levels in the remaining soil were below 300 mg/Kg for all these areas and it was determined that no further excavation was necessary. The excavation areas at Former D Range are presented in Figure 4-4.

Area D-1W was separated into two sampling areas (D-1WA and D-1WB) and D-1A was divided into three sampling areas (D1-AA, D1 AB, and D1-AC). In September 2010, 50-point multiple increment sample was collected in each of these subareas. Sample results indicated that sampling areas D1-AA, D1-AB, and D1-AC did not have lead levels in exceedance of 300 mg/Kg, but sampling areas D1-WA and D1-WB did. Therefore, an additional 6-inch layer of soil was excavated from these two sampling areas and soil was removed to a depth of 12 inches near well MW-174 and centered on the previous high lead concentration result identified in the Phase IIB sampling in 2002. Confirmatory 30-point multiple increment samples collected in September 2010 indicated that lead levels were still in exceedance of the 300 mg/Kg threshold concentration. In response to the sample results, an additional 6-inch lift was removed from the MW-174 footprint, for a total excavation depth of 18 inches and a volume of approximately 50 cubic yards of soil removed from this area. One confirmatory multiple increment sample was collected in November 2010 from the MW-174 area.

Results from the confirmatory samples at D1-WA, D1-WB, and MW-174 indicated that existing lead levels were below 300 mg/Kg, and that no further excavation is required at Former D Range.

A total of approximately 4,099 cubic yards were removed from Former D Range.

Former M2 Range was built in the 1940s and has not been utilized for training since the 1950s. There is a backstop berm approximately 10 to 12 feet high and 200 feet long on this range. Excavation activities began at Former M-2 Range in November 2009. Excavation boundaries were confirmed using hand-held GPS prior to excavation. Twelve inches of lead-impacted soil was removed from these areas and an XRF survey was performed. Several areas exceeding the project threshold of 300 mg/Kg were identified. Based on the survey results, an additional 24 inches of soil was excavated. A total of 36 inches, approximately 329 cubic yards, of soil was excavated and the material was trucked to Former D Range and stockpiled in anticipation of the soil screening. One 50-point multiple increment sample was collected and was analyzed for total metals. Results from this sample indicated that lead concentrations were below 300 mg/Kg.

In 2009, additional soil excavation was conducted as part of a lead removal action at J Range. Approximately 6 inches of soil was removed from behind the target berm and transported to the Former D Range for screening and preparation for on-site reuse and recycling. A similar lead removal action was also performed at K Range.

Upon completion of excavation activities, stockpiled material was mechanically screened to four size fractions using a deck screener and a rotary trammel. Material sizes separated during screening operations were four inches or more, one inch to four inches, one-half inch to one inch, and one-half inch or less. Sorted materials were assessed for further processing for reuse on the range. The soil fraction less than one inch was further separated to a size of 3/16 inch or less for this purpose. The 3/16 inch to one inch fraction was processed using a pneumatic separation unit, which uses a stream of air to separate lead from soil by specific gravity. Bullets collected during the pneumatic separation process were drummed and stored on-site pending final disposition. Oversized rock fragments were spread within the footprint of the Former D Range. Approximately 15 tons of lead bullets were recovered for recycling using the pneumatic separation process.

4.2 Range Maintenance Activities

4.2.1 2006 Berm Maintenance – Tungsten Removal

In 2006, a Berm Maintenance Project was undertaken to address concerns related to the use of tungsten-containing bullets at certain Small Arms Ranges at MMR. Following an initial range evaluation and field screening program (discussed in Section 3.2.4), soil excavation and removal actions were implemented at seven ranges (B, C, G, I, J, K, and T) (Figure 4-2). Initial field XRF evaluations indicated that soil tungsten levels at one or more locations on the berms at these ranges were in excess of the 150 mg/Kg threshold level established for this project. The Technical Memorandum (URS 2006) summarizing this work effort is included in Appendix F of this report.

A total of approximately 4,615 cubic yards of soil was excavated from the seven ranges identified above. In general, individual berms were excavated to depths of up to 2.0 feet across the toes of the berms, 3.0 feet across the middle of the berms, and 0.5 feet across the backs of the berms. During the soil excavation process, all soil excavated from B, C, and T Ranges was consolidated in the northern half of the range floor of C Range. All of the soil excavated from G, I, J, and K Ranges was consolidated on the range floor of the KD Range (West).

4.2.2 2007/2008 J, K and T Range Berm Maintenance – Nitroglycerin Removal

In 2007, a soil excavation action was implemented at the firing line at T Range (Figure 4-2). Soils containing elevated nitroglycerin levels were excavated from Area 1 East, Area 1 Center, and Area 1 West (Figure 5-37B). Post-excavation sampling confirmed low soil nitroglycerin levels (less than 5.0 mg/Kg) in all excavated areas.

In September 2008, soil removal actions were conducted at the J and K Ranges. These removal actions are described in detail in the Project Note dated September 24, 2008. At J Range, soil was excavated to depths of up to one foot. Nitroglycerin was not detected in any of the post-excavation multiple increment confirmatory soil samples. At K Range, soil was excavated to depths of up to one foot. Following excavation, post-excavation soil samples indicated residual nitroglycerin in some of the grids. J, K, and T ranges were rebuilt with new soil to prepare for use under the EPA pilot test of the STAPP™ bullet trap systems. The excavated soil remains stockpiled on K Range. Since studies demonstrate that nitroglycerine is not a threat to groundwater, the soil is available to be used for Range Maintenance activities.

5.0 NATURE AND EXTENT OF CONTAMINATION

This section presents an overview of the nature and extent of groundwater and soil contamination at Small Arms Ranges, including discussion of recent groundwater results. This section also presents a detailed discussion of soil sampling at the ranges, including results of recent multiple increment sampling. The locations of the ranges are presented in Figure 1-1. Analytical results for groundwater and soil are presented in Appendix A.

5.1 Groundwater

This section summarizes the results of long-term groundwater monitoring at Small Arms Ranges. These investigations were conducted to determine whether any of the chemical constituents detected in soils at Small Arms Ranges might be adversely impacting groundwater.

As part of the Small Arms Range investigation, data from 54 monitoring wells were evaluated to determine whether any chemical constituents at the Small Arms Ranges might be impacting groundwater (Figure 5-1). These wells were selected based on their proximity to the various Small Arms Ranges, their well screen depth, groundwater flow direction, and the current understanding of water chemistry in these areas. The 54 selected wells were each associated with one or more of the ranges. The wells selected were: MW-471S and MW-472S (J Range); MW-473S and MW-474S (K Range); MW-468S (E Range); MW-465S and MW 466S (SW Range); MW-55S (SE/SW Ranges), MW-467S and MW-489S (T Range); MW-23S (A Range); MW-124M3, MW-455S, MW-490S, and MW-72S, and the newly installed wells MW-537M1, MW-538M1, and MW-539M1 (B Range); MW-123S (B Range and C Range); MW-103S, MW-456S and MW-491S (C Range); MW-102S (D Range); MW-34M3, MW-36S, and MW-470S (G Range); 03MW0006, 03MW0007A, 03MW0014A, 03MW0020, 03MW0025A 03MW0709, and 03MW0710 (GA/GB Range); MW-60S and MW-109S (KD Range [East]); MW 492S (O Range); DP-459 and MW-215 (P Range); MW-475S and MW-476S and XXLRWS8-2 (Former B Range); MW-219M4 (Former C Range); MW-174S and MW-282M2 (Former D Range); MW-56S (Former M-1 Range); XXLRWS6-1 and MW-264M2 (Former M-2 Range); MW-116S, MW-121S, and MW-154S (N Range); MW-63S (L Range 1950s to 1980s); MW-67S (L-2 Range); and MW-344S (L-3 Range); and LRM0003 (L-4 Range).

Groundwater data collected between May 1999 and December 2012 were included in this evaluation. Samples were analyzed for explosives, perchlorate, semivolatiles (SVOCs), pesticides, herbicides, PCBs, volatiles, metals and inorganics. Select wells were also analyzed for tungsten. Maximum contaminant concentrations are summarized in Table 5-1 and overall results are evaluated below by analyte and further discussed in the Risk Screening (Section 7). Analyte detection frequencies are presented in Table 5-1.

Explosives and Perchlorate

Explosives data (Method 8330) were collected for samples from 48 of the 53 monitoring wells. There was a single detection of RDX (0.37 µg/L) in MW-34M3 in November 2003. RDX was not detected in the 13 groundwater monitoring events conducted prior to this date or the 11 events conducted subsequently. Explosives were not detected in any other sample in the data set. Perchlorate data (Method E314.0 or Method SW6850) was collected in samples from 22 of the 53 monitoring wells. Perchlorate was consistently detected above the reporting limit in samples from only one monitoring well (MW-344S). The reporting limit for perchlorate detections by Method E314 is 2.0 µg/L for samples collected prior to 2009. The reporting limit for Method SW6850 is 0.2 µg/L for samples collected after 2009. Perchlorate detections in this well have ranged from 0.31 µg/L to 2.2 µg/L. Perchlorate detections in this well have been evaluated as part of the Northwest Corner investigation and are believed to be unrelated to the use of the L-3 Small Arms Range that is proximate to this well location. The perchlorate detection may be related to non-small arms training activities in the Northwest Corner, including use of illumination signals, smoke grenades and simulators. Perchlorate has been sporadically detected in MW-116S, which is located near N Range. A few trace detections of perchlorate were also reported below the reporting limit in MW-282M2, MW-34M3 and MW-67S. These wells are located near the Former D Range, adjacent to G Range and cross gradient to L-2 Range, respectively. Perchlorate was detected once in MW-215S, which is located near P Range.

SVOCs, Pesticides, Herbicides, and PCBs

SVOC (Method 8270) data were collected from 38 of the 53 monitoring wells. Twelve SVOCs were detected at least once in groundwater. These include 2-chlorophenol, 4-methylphenol, benzoic acid, benzyl alcohol, dibenzofuran, hexadecanoic acid, naphthalene, phenol and four phthalate compounds (i.e., bis(2-ethylhexyl)phthalate, diethyl phthalate, di-n-butyl phthalate, and di-n-octyl phthalate). Bis(2-ethylhexylphthalate) and di-n-butyl phthalate were the most frequently detected SVOCs. Bis(2-ethylhexylphthalate) has been detected in nine wells at a maximum concentration of 24 µg/L (MW-23S). Di-n-butyl phthalate has been detected at trace levels in five wells at a maximum concentration of 0.55 µg/L (MW-264M2). Of the detected SVOCs, several (2-chlorophenol, 4-methylphenol, benzoic acid, benzyl alcohol, dibenzofuran, and phenol) were observed only in MW-264M2 on a few occasions. MW-264M2 is located near the Former M-2 Range.

Pesticides, herbicides and PCBs were analyzed in samples from 24 monitoring wells. No pesticides were reported in any of the groundwater samples; however, five herbicides (i.e., 2,4,5-trichlorophenoxyacetic acid (2,4,5-T) [MW-60S and MW-67S], bentazon [MW-63S], chloramben [MW-63S, MW-67S, MW-72S, and MW-109S], dichloroprop [MW-63S] and MCPP [XXLRWS8-2]) were reported. 2,4,5-T was detected in a single sample from MW-60S in 1999 at an estimated concentration of 0.12 µg/L and in a single sample from MW-67S in 1999 at an estimated concentration of 0.13 µg/L. Bentazon was presumptively detected in a single sample from MW-63S in 1999 at an estimated concentration of 1.5 µg/L. Chloramben was detected in four samples from four wells (MW-63S, MW-67S, MW-72S, and MW-109S) between 1999 and 2001 at a maximum estimated concentration of 0.4 µg/L. Dicholoprop was detected in a single sample from MW-63S in 1999 at a trace concentration of 1.2 µg/L. MCPP was reportedly detected in a single sample from XXLRWS8-2 at an estimated concentration of 230 µg/L. No herbicides have been detected since then in subsequent sampling rounds. No Aroclors (PCB mixtures) were reported in any samples.

Volatile Organics (VOCs)

VOCs (Method 8260) were analyzed in samples from 27 monitoring wells between 1997 and 2012. Thirteen VOCs were detected: 1,2,4-trichlorobenzene, 1,4-dichlorobenzene, acetone, carbon disulfide, chloroform, chloromethane, cis-1,3-dichloropropene, ethylbenzene, methyl ethyl ketone, styrene, PCE, toluene, and TCE. In 2001, 1,2,4-trichlorobenzene was reported in one sample at a trace concentration of 0.3 µg/L in well MW-67S. With the exception of chloroform, chloromethane, and TCE, these VOCs have only been detected in one or two samples from a few monitoring wells in 1999 and/or 2003. In April 1999, PCE was detected in three different wells located near GA/GB Range (03MW0020, 03MW0014A, 03MW0007A). These wells are located near the BOMARC Chemical Spill 10. TCE was detected at this same time in these same three wells and also in LRMW0003 (which is located near L-4 Range). TCE was frequently detected in LRMW0003 from 1999 up through 2004 (concentrations range from non-detect to 2 µg/L). The most recent two rounds of VOC sampling at this well were non-detect for all VOCs except chloroform. Notably in 2003, 1,4-dichlorobenzene, acetone, carbon disulfide, ethylbenzene, methyl ethyl ketone, styrene, and toluene were detected in MW-264M2. This well was installed as part of the J-3 Range investigation and is located near the Former M-2 Range and Fuel Spill 12. In 2003, the Fuel Spill 12 treatment plant was constructed to remediate the FS12 plume. No VOCs were detected in MW-264M2 in the December 2012 sampling event. Also in 2003, cis-1,3-dichloropropene was reported in one sample from LRM0003 at a trace concentration of 0.5 µg/L. With the exception of chloroform, no VOCs have been detected since 2005. Chloroform was detected in 19 of the 27 monitoring wells that have been analyzed for VOCs and its degradation product (chloromethane) was detected in three monitoring wells. Chloroform (and chloromethane) has been determined to be ubiquitous in groundwater on Cape Cod (Earth Tech 2000).

Metals and Inorganics

Metals and/or inorganics (Methods 6010 and 6020) were analyzed in samples from 46 of the monitoring wells. Twenty-nine metals and/or inorganics were detected in one or more monitoring wells. The frequencies of detection of individual metals in groundwater vary widely. A number of metals including antimony, arsenic, beryllium, cadmium, cobalt, lead, mercury, selenium, silver, thallium and vanadium were detected in less than 10 percent of the samples that were analyzed. Many of these, including beryllium, cobalt, mercury, silver, thallium and vanadium, were detected in less than five samples. The maximum detected concentrations of individual metals are reported from a number of different monitoring wells and are not localized at any one range. The maximum detected concentrations of copper (103 µg/L) and lead (7.7 µg/L) were observed at wells MW-67S and MW-470S, respectively. Overall, most of the metals detections were at low levels (<10 µg/L) and likely reflected the naturally occurring presence of these metals in groundwater or in the sediments that sometimes get entrained in groundwater samples.

Tungsten

There is no USEPA formally approved method for analyzing tungsten in groundwater. As such, early (2006) groundwater analyses for tungsten at MMR were prone to variability and analytical uncertainty. This complicated efforts to evaluate tungsten levels in groundwater. During this time frame, reported groundwater monitoring well tungsten results for Small Arms Ranges were variable, generally ranging from 0.2 to ~22 µg/L. However, in conjunction with a research evaluation of tungsten at MMR conducted in 2006, CRREL reported a groundwater tungsten concentration of 560 µg/L in a May 2006 sample collected from well MW-72S at B Range.

Following the May 2006 sampling event, berm soils at B Range were excavated to reduce tungsten levels in conjunction with the 2006 Berm Maintenance Program. Subsequent tungsten sample results for MW-72S were much lower than the pre-excavation result. It was suggested that the elevated tungsten result at MW-72S may have been due to a transient pulse of tungsten moving downward through the vadose zone.

In an effort to improve the reliability of groundwater tungsten data at low concentrations, an analytical Method Development Work Group for the analysis of tungsten in groundwater was established in 2006 by the IAGWSP, USACE, EPA and MassDEP. The main goal of this work group was to develop a valid and defensible SW-846 Performance-Based modified-Method 6020 for the analysis of tungsten in groundwater in MMR site-specific matrices. The laboratory chemists involved evaluated tungsten groundwater results in order to solve multiple complex sampling and analytical method-related issues. Many of the initial results of tungsten analyses in groundwater were later determined to be false positives due to not using nitric acid preservation or acidification prior to analysis. ICP/MS instrument carryover and memory effects were also observed initially, but were overcome by adjusting the instrument parameters and rinse times, as well as performing the nitric acid preservation/acidification procedures. The tungsten analytical method development studies included two performance evaluation samples, numerous QA-split sample comparisons between up to four labs, for both total and dissolved tungsten, and preserved and unpreserved tungsten sample collection methods. The final conclusion reported from the tungsten work group was that a valid and defensible modified-Method 6020 was developed for MMR site-specific groundwater matrices. The Method 6020 ICP/MS developed by the four participating laboratories had slightly different standard operating procedures, which yielded comparable results for the majority of the last several rounds of QA-split samples analyzed.

Results of tungsten analyses of groundwater since the completion of the study indicate that false positives have apparently been eliminated. Most of the wells that were suspected of having false positives prior to 2007 have not had detections since the method was modified. Tungsten analytical results for groundwater samples collected prior to mid-2007 should not be used for decision making purposes.

Tungsten was detected in 31 of 200 unfiltered samples and 25 of 64 filtered samples in the groundwater data set. The maximum detected concentration of tungsten since the improvement of the method in 2007 (14.3 µg/L total and 10.4 µg/L field filtered) was detected in well MW-538M1 at B Range. In fact all post-2007 positive detections of tungsten have been at B Range wells with one exception (a single detection in March 2011 at MW-491S, which is located near C Range). Of the six wells located on or near B Range that have been analyzed for tungsten since 2007, tungsten has been detected in three wells: MW-537M1, MW-538M1, and MW-72S. Of the three sampling events at MW-537M1, tungsten was detected once at an estimated concentration of 0.5 µg/L. Of the two sampling events at MW-538M1, tungsten was detected on both occasions at a concentration of 14.3 µg/L in April 2010 and a trace concentration of 0.66 µg/L in March 2012. Tungsten was detected in both total and field filtered samples from MW-72S collected during all seven sampling events since 2007. Reported levels were fairly consistent with little difference between the total and field filtered results. Total tungsten results since 2008 ranged from non-detect µg/L (March 2011) to 2.8 µg/L (December 2009). A field filtered sample collected in March 2010 had tungsten detected at 1.5 µg/L. The reporting limit for tungsten by Method 6020 is 2 µg/L.

5.1.1 J, K and T Range OMMP Pore Water Sampling

As discussed in Section 3.1.4, an extensive soil pore water (lysimeter) sampling program was implemented under the OMMP program from 2010 to 2012 at the J, K and T Ranges. Pore water samples (both filtered and unfiltered) were analyzed for selected metals (antimony, copper and lead) using Methods 6010 and/or 6020. Samples were collected in October 2010, May 2011, October 2011, and September 2012. Additional samples were analyzed for antimony in November 2012. Details of the sampling efforts are contained in the individual semi-annual and annual OMMP Sampling and Analysis Reports.

In May 2011, the highest lead concentration in pore water analyzed to date was 9 µg/L in lysimeter LYJRNG003 on J Range. However, no lead was detected in this same lysimeter in October 2011. A low concentration of lead [filtered sample – 0.09 µg/L; unfiltered 0.24 µg/L] just above the detection limit was detected in September 2012. Antimony concentrations were also generally less than 6 µg/L over the course of the program but did show some variability. However, during the September 2012 sampling round, antimony concentrations for a few samples from J and K Ranges did exceed 6 µg/L. The highest concentration (11.4 µg/L) was observed in a sample from J Range (lysimeter LYRNG003). A somewhat lower antimony concentration (7.1 µg/L) was observed in K Range lysimeters LYKRNG003 and LYKRNG004. Supplemental lysimeter sampling for antimony in November 2012 continued to show slightly elevated levels. Copper concentrations in most lysimeter samples were generally low (<20 µg/L) and in many cases less than 10 µg/L.

5.1.2 May 2013 Supplemental Investigation Pore Water Results

Results for the May 2013 sampling of lysimeters at B and G Ranges are presented in Table 5-2. As is indicated, the antimony concentrations for the B Range and G Range samples were 18.5 µg/L and 61.6 µg/L, respectively. Chromium was not detected in samples from either range. The lead concentrations at B Range and G Range were 1.5 µg/L and 9.7 µg/L, respectively. The tungsten concentration for the B Range sample (844 µg/L) was higher than that reported at G Range (32 µg/L). As indicated in Table 5-2, the B Range tungsten concentration was very similar to values reported for samples collected from this lysimeter in 2012.

5.1.3 Synthetic Precipitation Leaching Procedure (SPLP) Investigation

As discussed in Section 3.2.7, during the April 2013 investigation program, SPLP testing for lead was conducted on selected soil samples collected from B, C and G Ranges to assess the long-term effectiveness of the MAECTITE lead fixation process. The samples were collected from specific locations at the target berm faces at each of these ranges based on the results of initial surface soil XRF screening. Samples were analyzed for SPLP aqueous phase leachate lead concentrations as well as total lead concentrations in the original solid phase soil samples.

The results of the SPLP analyses are summarized in Table 5-3. Included are the initial XRF lead screening results, the off-site laboratory soil lead concentrations, and the SPLP aqueous phase lead concentrations. Total solid phase phosphorus concentrations are also included. As indicated in Table 5-3, the solid phase lead concentrations for the samples from the three ranges are generally similar and range from 360 mg/Kg (B Range) to 450 mg/Kg (C Range). However, the SPLP aqueous phase leachate lead concentrations vary widely and range from 42.8 µg/L for C Range to 2,020 µg/L for G Range. The reason for the large variation in leachate lead concentrations is uncertain. As indicated in Table 5-3, the solid phase phosphorus concentrations in the samples are generally similar and range from 1,000 mg/Kg in the G Range sample to 1,370 mg/Kg in the sample from B Range.

A review of data compiled in the Completion of Work Report [Ogden 1999] for the MAECTITE remediation process at MMR indicates that G Range contained the highest measured pre-excavation soil lead concentration (12,200 mg/Kg) while B Range contained the second highest (11,546 mg/Kg). The pre-excavation lead concentration at C Range was significantly lower (1,339 mg/Kg). In addition, further review of the pre-excavation results indicates that a significantly higher percentage of the pre-excavation soil samples from the primary berm face at G Range had high soil lead concentrations (>1,000 mg/Kg) as compared to results for C Range. Similar results were also observed for pre-excavation lead concentrations in the toe of the primary berm at G Range. It is uncertain whether potentially higher soil lead concentrations at multiple locations at G Range could have affected the stoichiometry of mineral phase formation during the MAECTITE process itself.

Further review of the information compiled in the Completion of Work Report does indicate some apparent late-stage differences in operations at B, C and G Ranges. At all three ranges supplemental in-situ MAECTITE treatment was performed since some soil leachates at each range still exceeded the 5.0 mg/L TCLP treatment criteria following the initial ex-situ treatment. The Completion of Work Report also indicates that the berms at B and C Ranges were subsequently re-constructed using only ex-situ treated soils from a stockpile whose soils had been confirmed to be below the 5.0 mg/L TCLP criteria. Therefore, there may have been a greater degree of MAECTITE related berm re-construction at B and C Ranges than at G Range.

Overall, these results suggest that over the long-term, some limited surface soil leaching of lead may occur from the lead phosphorus produced from the MAECTITE process. However, the general absence of lead in groundwater at the Small Arms Ranges indicates that any lead that is leached from MAECTITE in surface soils is likely to be rapidly adsorbed by underlying subsurface soils.

5.1.4 Range Specific Groundwater Data

This section summarizes groundwater monitoring results for the Small Arms Ranges on a range by range basis. The overall data associated with this discussion is presented in Table 5-4. Water table groundwater monitoring wells located within large or high use range boundaries or immediately downgradient of individual ranges are identified. Well screen intervals are also identified in the text and/or Table 5-4 along with the depth to groundwater and the time the depth to groundwater was measured. The depths to groundwater have been included to show which wells are water table wells and which wells are screened below the water table.

The maximum detected concentrations of the principal contaminants of concern at the Small Arms Ranges [select metals (antimony, copper, lead and tungsten), explosives (RDX and nitroglycerin) and perchlorate] are presented for each range. The presentation of maximum values for these contaminants is intended to conservatively reflect range groundwater conditions. Data for two representative propellant constituents (2,4-dinitrotoluene and n-nitrosodiphenylamine) are also included in Table 5-4. However, there were no detections for these compounds for any of the wells listed in Table 5-4. A compilation of all groundwater data for individual wells is presented in Appendix A.

It should be noted that not all monitoring wells for individual small arms ranges are included in the following discussion. A number of monitoring wells at individual ranges were installed for reasons other than to assess contaminant migration from the overlying small arms range. In many cases, these wells are screened at deeper groundwater depths to intercept plumes from other ranges. As such, data from these wells is not appropriate to assess small arms use. The following discussion focuses on results for water table wells that should most appropriately reflect any contaminant migration from overlying small arms ranges.

As indicated below, for certain ranges there are no monitoring wells within the boundaries or immediately downgradient of the range. In many cases, these are ranges that are immediately adjacent to ranges that do have one or more monitoring wells located within their boundaries. Therefore, in these cases, groundwater quality data for locations in relatively close proximity to the range does exist. For other ranges that do not have monitoring wells, the historical small arms usage at the range in question was often very similar or less than another range for which monitoring data does exist.

The chemical quality of water beneath MMR is consistent from range to range. The rapid rate of aquifer recharge, short ground-water flow paths, chemically inert character of the quartz and feldspar sand that comprise the aquifer (Olcott 1995), and the unconfined conditions all contribute to minimal mineralization of the ground water and similar leaching characteristics.

Overall, as indicated by Table 5-4, an extensive suite of monitoring wells exists with which to evaluate the Small Arms Ranges.

5.1.4.1 A Range

There are no monitoring wells located within the boundaries of the A Range (Figure 5-3A). However, well MW-23S is located immediately across Burgoyne Road. This well is slightly cross-gradient to the firing line and downgradient of the range floor and target berm. This water table well is screened at 122.5 feet to 132.5 feet bgs. As indicated in Table 5-4, the maximum concentrations of copper (5.2 µg/L) and lead (4.2 µg/L) were both from unfiltered samples. Copper and lead have not been detected in filtered (dissolved phase) groundwater samples. Antimony has also not been detected in this well. Tungsten bullets were not used at A Range and groundwater analyses for tungsten have not been conducted. RDX and nitroglycerin have not been detected in any samples from this well. Perchlorate was not a target analyte at this range.

5.1.4.2 B Range

There are several monitoring wells located within the boundaries of the B Range (Figure 5-4A). Water table well MW-72S is located immediately downgradient of the central berm area. Wells MW-537S, MW-538S and MW-539S are also located within the same area. MW-490S is located downgradient of the northern portion of the berm. MW-455S and MW-124M3 are located further downgradient in the vicinity of Burgoyne Road. Screen intervals for these wells are presented in Table 5-4. As indicated in Table 5-4, the maximum concentration of antimony (10.8 µg/L) was reported in a filtered sample from MW-538M1. Antimony was not detected in other wells. The maximum detected concentration of copper was reported for an unfiltered sample from MW-539M1. The maximum reported lead (23.8 µg/L – unfiltered) and tungsten (14.3 µg/L – unfiltered) concentrations were also reported from MW-538M1. [It should be noted that prior to the development of an appropriate analytical method for tungsten, a concentration of 560 µg/L was reported for a groundwater sample collected from MW-72S in 2006.] RDX, nitroglycerin and perchlorate have not been detected in any wells at B Range at which they were analyzed.

5.1.4.3 Former B Range

There are two monitoring wells located within the boundaries of the Former B Range (Figure 5-5A). Screen intervals for these wells (MW-475S and MW-476S) are presented in Table 5-4. As indicated in Table 5-4, the maximum detected concentration of copper (4.9 µg/L) was detected in a filtered sample collected from MW-476S. No other metals (antimony, lead and tungsten) have been detected in either well. RDX and/or nitroglycerin have not been detected in any water table wells at Former B Range. Perchlorate was not a target analyte for the Former B Range.

5.1.4.4 C Range

There are two monitoring wells located within the boundaries of the C Range and two outside the range boundaries (Figure 5-6A). MW-456S and MW-491S are located downgradient of the central berm area. MW-103S and MW-123S are located further downgradient in the vicinity of Burgoyne Road. Screen intervals for these wells are presented in Table 5-4. As indicated in Table 5-4, the maximum concentration of antimony (3.1 µg/L) was reported in a filtered sample from MW-103S. Antimony was not detected in other wells. The maximum detected concentration of tungsten (0.9 µg/L) was reported for an unfiltered sample from MW-491S. Copper and lead have not been detected in C Range wells. RDX and/or nitroglycerin have not been detected in any wells at C Range. Perchlorate was not a target analyte for the C Range.

5.1.4.5 Former C Range

There are no monitoring wells located within the boundaries of the Former C Range (Figure 5-7A). However, well MW-219M4 is located to the south of the range along Frank Perkins Road. This well is screened at 225 feet to 235 feet bgs. RDX, nitroglycerin or perchlorate have not been detected in any samples from this well and no samples were submitted for target analyte metals (antimony, copper, lead and tungsten) analyses.

5.1.4.6 D Range

There are no monitoring wells located within the boundaries of the D Range (Figure 5-8A). However, well MW-102S is located downgradient to the south of the range across Burgoyne Road. Given its location this well would likely only intercept groundwater flowing from the portion of D Range behind the berm. This well may also intercept groundwater from E Range. This water table well is screened at 145 feet to 155 feet bgs. As indicated in Table 5-4, the maximum concentration of antimony (6.7 µg/L - total) was reported in an unfiltered sample collected from this well. Antimony was the only target analyte analyzed from this well. Copper, lead and tungsten were not target analytes for this range. RDX, nitroglycerin or perchlorate have not been detected in any samples from this well.

5.1.4.7 Former D Range

There are two monitoring wells located within the boundaries of the Former D Range (Figure 5-9A). Screen intervals for these wells (MW-174S and MW-282M2) are presented in Table 5-4. As indicated in Table 5-4, the maximum concentrations of copper (3.6 µg/), lead (7.3 µg/) and tungsten (0.32 µg/) were reported in an unfiltered sample collected from MW-174S. RDX, nitroglycerin or perchlorate have not been detected in any samples from this well. Perchlorate was reported at an estimated level of 0.043 µg/L in a sample collected from MW-282M2. It is believed that this detection is associated with the Western Boundary operable unit. It should be noted that this is not a water table well but is screened within 20 feet of the water table. RDX and/or nitroglycerin have not been detected in any samples from this well and no samples were submitted for target analyte metals (antimony, copper, lead and tungsten) analyses.

5.1.4.8 E Range

There is one monitoring well located within the boundaries of the E Range (Figure 5-10A). This water table well (MW-468S) is screened at 170 feet to 180 feet bgs. As indicated in Table 5-4, the maximum reported concentration of copper (6.3 µg/L) was from an unfiltered sample and the maximum concentration of tungsten (0.39 µg/L) was from a filtered sample. Antimony and lead were not detected in samples from this well. RDX and nitroglycerin also have not been detected in any samples from this well. Perchlorate was not a target analyte for the E Range.

5.1.4.9 E-1 and E-2 Ranges

There are two monitoring wells at E-2 Range (Figure 5-11) and no monitoring wells at E-1 Range. These ranges have not been evaluated as part of this Small Arms Range Report.

5.1.4.10 G Range

There are three monitoring wells located within the boundaries of the G Range (Figure 5-12A). Screen intervals for these wells (MW-34M3, MW-36S and MW-470S) are presented in Table 5-4. As indicated in Table 5-4, the maximum detected concentration of copper (4.3 µg/L) was reported for an unfiltered sample collected from MW-36S. The maximum reported lead (7.7 µg/L – unfiltered) and tungsten (0.81 µg/L – filtered) concentrations were reported in samples collected from MW-470S. Antimony and lead have not been detected in these wells. RDX and perchlorate were detected in samples collected from MW-34M3 at 0.37 µg/l and 1.12 µg/L, respectively. This well is not a water table well and these detections are attributed to Demo 1. RDX, nitroglycerin and /or perchlorate have not been detected in any other wells at G Range.

5.1.4.11 GA/GB Range

There are several monitoring wells located within the boundaries or immediately upgradient of the GA/GB Range (Figure 5-13A). Screen intervals for these wells (03MW0006, 03MW0014A, 03MW0020, 03MW0709 and 03MW0710) are presented in Table 5-4. As indicated in Table 5-4, the maximum concentration of antimony (2.9 µg/L) was reported in an unfiltered sample from 03MW0006. Copper and lead have not been detected in unfiltered samples collected from GA/GB range wells. Tungsten was not a target analyte at this range. RDX and/or nitroglycerin have not been detected in samples collected from these wells. Perchlorate was not a target analyte for the GA/GB Range.

5.1.4.12 H Range

There are no water table monitoring wells within the boundaries of H Range or immediately downgradient of this range (Figure 5-14A). As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. There is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.13 I Range

There are no water table monitoring wells within the boundaries of I Range or immediately downgradient of this range (Figure 5-15A). As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. There is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.14 J Range

Two water table wells are located within the boundaries of J Range (Figure 5-16A). MW-471S is located in the west-central portion of the range in the range floor area. MW-472S is located in the southern portion of the range proximate to the firing line areas. Well screen intervals are identified in Table 5-4. As indicated in Table 5-4, copper has been detected in both wells. The maximum concentrations of copper were 7.3 µg/L and 1.9 µg/L for filtered samples from MW-471S and MW-472S, respectively. Antimony and lead have not been reported in samples from either well. Tungsten was reported at a maximum concentration of 0.3 µg/L, in a filtered sample from MW-471S. RDX and nitroglycerin have not been detected in either well. Perchlorate was not a target analyte for the J Range.

5.1.4.15 K Range

One water table well (MW-473) is located within the range boundaries immediately downgradient of the berm area (Figure 5-17A). A second well (MW-474) is located just outside the southwest corner of the range area immediately downgradient of the firing line area. Well screen intervals are identified in Table 5-4. As indicated in Table 5-4, copper has been detected at maximum concentrations of 8.3 µg/L (filtered sample) and 1.7 µg/L (filtered sample) in MW-473S and MW-474S, respectively. Lead has been detected in unfiltered samples at maximum concentrations of 0.18 µg/L and 0.042 µg/L, in MW-473 and MW-474, respectively. Antimony and tungsten have not been detected in either well. RDX and nitroglycerin have not been detected in either well. Perchlorate was not a target analyte for the K Range.

5.1.4.16 KD Range East

There are no monitoring wells within the boundaries of KD Range East. However, two monitoring wells are located immediately downgradient of the range (Figure 5-18A). MW-109S is located immediately downgradient of the firing line area at the south end of the range. MW-60 is located beyond and cross-gradient to the north end of the range. Well screen intervals are identified in Table 5-4. As indicated in Table 5-4, copper has been detected at a maximum concentration of 3 µg/L in an unfiltered sample from MW-190S and at a lower maximum concentration (2.2 µg/L) in MW-60. Lead has been detected in an unfiltered sample from MW-190S at a maximum concentration of 0.96 µg/L. Antimony has not been reported in either well. Tungsten has not been detected MW-109S. It has not been analyzed for in MW-60S RDX, nitroglycerin and perchlorate have also not been detected in either well.

5.1.4.17 Former K Range

There are monitoring wells located within the boundaries of Former K Range (Figure 5-19). However, this range is being evaluated under the MMRP program and is not included in this report.

5.1.4.18 L Range (40s and 50s)/L-1 Range

There are no monitoring wells located within the boundaries of L Range (50s to 80s) or immediately downgradient of the range (Figure 5-20A). Well WS-1 is located to the east of the eastern end of the range but is cross-gradient to the range. However, this range is within the immediate zone of contribution for WS-1 which pumps significant quantities of water. This water is tested regularly to meet MassDEP water supply requirements and is shown to meet drinking water standards.

5.1.4.19 L Range (50s to 80s)

There are no monitoring wells located within the boundaries of L/L-1 Range or immediately downgradient of the range (Figure 5-20C). MW-340 is located a significant distance downgradient of the range. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. There is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.20 L-2 Range

There are no wells within the boundaries of L-2 Range (Figure 5-21A). Water table well MW-67S is located immediately downgradient of the southern portion of the L-2 Range. This well is screened from 161 feet to 171 feet bgs. Copper was reported in an unfiltered sample, at a maximum concentration of 103 µg/L (Table 5-4). Antimony, lead and tungsten have not been reported in samples from this well. RDX and nitroglycerin have not been observed at this well. Perchlorate was detected at a trace level of 0.04 µg/L in one sample. The perchlorate detection appears likely to be associated with past training activities in the Northwest Corner rather than small arms use at L-2 Range.

5.1.4.21 L-3 Range

There are no monitoring wells within the boundaries of the L-3 Range (Figure 5-22A). Water table well MW-344S is located to the north of the range, downgradient and partially cross-gradient to the southeastern portion of the range. This well is screened from 115.5 feet to 125.5 feet bgs. Antimony, copper, lead and tungsten were not target analytes at the L-3 Range.

RDX and nitroglycerin have not been detected in this well. Perchlorate was reported at a maximum concentration of 2.2 µg/L. L-3 Range is close to Canal View Road and the perchlorate detection was likely related to past off-base fireworks or training activities in the Northwest Corner rather than small arms use.

5.1.4.22 L-4 Range

There are no monitoring wells within the boundaries of the L-4 Range (Figure 5-23A). Well LRWS3-1 (LRMW0003) is located approximately 500 feet downgradient to the north of the range. This well is screened from 95 feet to 105 feet bgs. Copper has been detected at a maximum concentration of 1.3 µg/L in an unfiltered sample (Table 5-4). Antimony and lead have not been detected in samples from this well. Tungsten was not a target analyte at this range. RDX, nitroglycerin and perchlorate have not been detected in samples from this well.

5.1.4.23 Former M-1 Range

There are no monitoring wells within the boundaries of the Former M-1 Range (Figure 5-24A). Well MW-56S is located immediately downgradient of the southern end of the range. MW-LRWS6-1 is located across Greenway Road by-pass to the west of the range and somewhat cross-gradient to groundwater flow. As indicated in Table 5-4, antimony, copper and lead have not been detected in samples from these wells. Tungsten was not a target analyte for the M-1 Range. RDX and nitroglycerin have not been detected in samples from these wells. Perchlorate has only been analyzed in MW-56S but has not been detected.

5.1.4.24 Former M-2 Range

There is one monitoring well (MW-264M2) located within the boundaries of the Former M-2 Range (Figure 5-25A). This well is located downgradient of the south-central portion of the range and is screened from 136 feet to 146 feet bgs. Antimony, copper, lead and tungsten were not target analytes for groundwater at the Former M-2 Range. RDX, nitroglycerin and perchlorate have not been detected in samples from MW-264M2.

5.1.4.25 Former M-3 Range

There is one monitoring well located within the boundaries of Former M-3 Range (Figure 5-26A). Well MW-294 is located in the western portion of the range. Due to the proximity of this well to the J-3 Groundwater Treatment Plant and the extensive past excavation of this range, this well is not considered to be representative of groundwater conditions beneath a small arms range as any potential impact at this range has been masked by plumes from the J-3 Range.

5.1.4.26 Former M-4 Range

There are no monitoring wells within the boundaries of Former M-4 Range (Figure 5-27A). As stated in Section 5.1.4, the chemical and leaching characteristics of the groundwater in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.27 N Range

There are two water table monitoring wells (MW-116S and MW-154S) located within the boundaries of N Range (5-28A). MW-121S is located upgradient of the southwestern portion of the range. Screen intervals for these wells are presented in Table 5-4. Copper has been detected in unfiltered samples from the wells at N Range. The maximum concentration (5.8 µg/L) was reported for an unfiltered sample from MW-116S. Antimony and lead have not been detected in samples from N Range wells. Tungsten was not a target analyte for N Range. RDX and nitroglycerin have not been detected in N Range wells. Perchlorate was detected at a maximum concentration of 0.64 µg/L in a sample from MW-116S.

5.1.4.28 Former N Range

There are no monitoring wells within the boundaries of Former N Range (Figure 5-29). There is one monitoring well downgradient of this range (MW-55S) across Gibbs Road that has been evaluated as part of the SE/SW Ranges and represents groundwater coming from these areas (Figure 5-34A). No small arms range metals were detected above action levels in well MW-55S. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. There is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.29 O Range

There is one water table monitoring well (MW-492S) located within the boundaries of O Range (Figure 5-30A). This well is screened from 79.5 feet to 89.5 feet. Copper has been detected at a maximum concentration of 1.8 µg/L in an unfiltered sample. Lead has been detected at a maximum concentration of 0.4 µg/L, also in an unfiltered sample. Antimony and tungsten have not been detected at MW-492S. RDX, nitroglycerin and perchlorate were not target analytes at O Range. It should be noted that well MW-310 shown on Figure 5-30A is not a water table well and is screened approximately 100 feet below the water table.

5.1.4.30 P Range

There are two monitoring wells (MW-215S and DP-459) within or immediately outside the boundaries of P Range (Figure 5-31A). Well screen intervals are presented in Table 5-4. Antimony, copper and lead have been analyzed for in MW-215S but have not been detected. Tungsten was not a target analyte for P Range. RDX, nitroglycerin and perchlorate have not been detected in DP-459. Perchlorate has been detected at a maximum concentration of 1.4 µg/L in MW215S.

5.1.4.31 Q Range

There are no monitoring wells within the boundaries of Q Range (Figure 5-32A) or downgradient of the Range. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.32 Former R Range

There are no monitoring wells within the boundaries of Former R Range (Figure 5-33A) or downgradient of the Range. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.33 SE/SW Ranges

One water table monitoring well (MW-465S) is located within the boundaries of the SE/SW Ranges (Figure 5-34A). MW-466S is located immediately downgradient of the northern end of SW Range. MW-55S is located across Gibbs Road and downgradient of SE Range. Well screen intervals are presented in Table 5-4. Copper has been detected in unfiltered samples from all three wells. Copper has been detected at a maximum concentration of 3.2 µg/L in an unfiltered sample from MW-465S. Antimony and lead have not been detected in any of the three wells. Tungsten has been detected at a maximum concentration of 1.3 µg/L in a filtered sample from MW-465S. RDX, nitroglycerin and perchlorate have not been detected in any samples from these wells.

5.1.4.34 Skeet Range 1

There are several monitoring wells within the boundaries of Skeet Range 1 (Figure 5-35A). These wells were installed as part of the AFCEE program and do not represent water quality at the water table for this range. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.35 Skeet Range 2

There are no monitoring wells within the boundaries of Skeet Range 2 (Figure 5-36A) or downgradient of the Range. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.36 Succonsette Pond

There are no monitoring wells within the boundaries of Succonsette Pond (Figure 5-37A) or downgradient of the Pond. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.1.4.37 T Range

Two water table monitoring wells (MW-467S and MW-489S) are located within the boundaries of T Range (Figure 5-38A). MW-467S is located in the north central portion of the range immediately downgradient of the center of the range. MW-489S is located further upgradient along the southwestern edge of the range. Well screen intervals are presented in Table 5-4.

Copper has been detected in both wells, with a maximum concentration of 3.6 µg/L in an unfiltered sample from MW-489S. Lead has been detected at a maximum concentration of 7.1 µg/L in an unfiltered sample from MW-467S. Lead has not been detected in filtered samples from this well. Lead has also not been detected at MW 489S. Antimony has not been detected in samples from either well. Tungsten has been detected at a maximum concentration of 0.7 µg/L in an unfiltered sample from MW467S. RDX and nitroglycerin have not been detected in samples from MW-467S. Perchlorate was not a target analyte for this range.

5.1.4.38 500-Yard Rifle Range

There are no monitoring wells within the boundaries of the possible 500-Yard Rifle Range location on Jefferson Road (Figure 5-39A). There are several monitoring wells located in the vicinity of the possible location along Wood Road (Figure 5-39B). However, these wells were not installed to assess possible small arms use. As stated in Section 5.1.4, the chemical and leaching characteristics of the ground water in this aquifer is relatively uniform. Soil results were below action levels and there is nothing unique about this range to indicate a greater threat to groundwater than other ranges where range-specific groundwater monitoring was conducted.

5.2 Soil

This section summarizes the results of the extensive soil sampling programs conducted at the Small Arms Ranges on a range-by-range basis. Most of the earlier (pre-2005) results are associated with the 2002 Supplemental Phase IIb Investigation sampling program as summarized in the Final IAGWSP Technical Team Memorandum 02-2 (AMEC 2003a). However, for some ranges additional soil sampling programs were implemented either prior to or following the 2002 Supplemental Phase IIb investigations. As is indicated in Figure 5-2, extensive soil sampling has been conducted at the large majority of the individual Small Arms Ranges. At some ranges, in excess of 100 soil samples have been collected and analyzed. The majority of the historical (pre-2006) soil samples that have been collected at the Small Arms Ranges were discrete or 5-point or 9-point composite samples. Since 2006 multiple increment sampling methods have been used for most samples.

Extensive multi-phase sampling and subsequent operational monitoring programs have been implemented at J, K, and T Ranges between 2006-2012. Also as discussed in Section 3.2.7, an extensive multiple increment sampling program was implemented at multiple small arm ranges in April 2013. In addition, in May 2013 a Supplemental Investigation program was implemented at several ranges to augment the April 2013 sampling effort.

Analytical results from EDMS for the small arms ranges for which data is available are compiled in Appendix A. Analytical results for the April 2013 sampling program are summarized in Table 5-5. A risk screening evaluation of the range soil data discussed in the following section is presented in Section 7.2. Background soil data for the Small Arms Ranges is presented in Appendix B. Analytical results for the May 2013 supplemental sampling program are summarized in Table 5-6.

5.2.1 Ranges

This section summarizes the results of soil sampling programs on a range-by-range basis.

Figures depicting representative range surface soil sampling results have been included to support range discussions. It should be noted that most figures associated with individual ranges contain representative analytical results for surface soil metals and explosives detections only. Semivolatile organic detections have not been included on most figures, but are discussed below. Also, some historical figures do not include all sampling data due to space limitations. At locations where multiple samples have been collected, the highest surface soil concentrations are reported.

5.2.1.1 A Range

A Range is an inactive operational .50 cal machine gun training range located at the intersection of Burgoyne and Wood Roads. It was constructed in the mid-1970s and has been used since that time for M2 (.50 cal) machine gun training. Range use records show that both .50 cal ball and plastic rounds have been fired at this range (USACE 1999). Two fixed firing points (marked by two permanent iron pipe H-frames) and a concrete pad, sized to accommodate two vehicle-mounted guns, are present on the western end of the range just off Burgoyne Road. Two wooden target frames are located on the southern side of Wood Road east of the firing points. A natural embankment, located at the extreme eastern end of the range, serves as a range backstop. The backstop was treated during the 1998 Berm Maintenance Program (Ogden 1999). Numerous plastic .50 cal projectiles were present at the surface in an open area located between the backstop and target frames.

A Range Investigations

During the Supplemental Phase IIb investigations, soil samples were collected at the firing points to determine whether residual propellant compounds existed in the soil on this range. Three 5-point soil sampling grids (157A, 157B, and 157C) were established just downrange of the firing points (Figure 5-3A). Grid 157A was aligned with the center of the concrete pad where vehicle-mounted guns were positioned during training. The remaining two grids (157B and 157C) were positioned immediately downrange of the two fixed firing points. The center points for each grid were positioned approximately 10 feet downrange of the presumed firing line as defined by the eastern edge of the concrete pad and two H-frames.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Four propellant-related SVOCs (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine and n,n’-diethylcarbanilide) were detected in one or more of the 19 samples that were collected at A Range. N,n’-diethylcarbanilide was the most frequently detected propellant-related SVOC and was reported in 12 samples. The maximum detected concentration for this compound (1.9 mg/Kg) was reported for a discrete surface sample for grid 157B. Di-n-butyl phthalate was the next most frequently detected compound (11 samples), with a maximum reported concentration of 0.64 mg/Kg. Bis(2-ethylhexyl)phthalate was detected in eight samples at a maximum concentration of 10 mg/Kg. Five metals (antimony, barium, copper, lead and zinc) were reported at concentrations above background in one or more samples (Figure 5-3A). The maximum reported concentration of lead was 29.3 mg/Kg.

2012 Investigation

In 2012, the IAGWSP conducted an evaluation of the range use history and sampling results at A Range to evaluate whether there was a concern with using the range for an Army Guard training exercise. As described above, low levels of SVOCs and metals were detected in the Supplemental Phase IIb investigation. In reviewing the range use, it was noted that tracer rounds have been used at the range. A question arose as to whether or not these rounds contained perchlorate. Upon further review of the munitions composition data, it was determined that the rounds used did not contain perchlorate. No further sampling was needed and the training exercise proceeded as planned.

2013 Soil Investigation

In April 2013, a site visual investigation and multiple increment soil sampling was conducted at A Range. During the visual investigation, it was noted that numerous .50 cal ball rounds were observed on the embankment/backstop. One 100-point multiple increment sample (AR01A) was collected from an approximately 10,000 square foot area across the face of the target berm. An additional 100-point multiple increment sample (AR02A) was collected from an approximately 10,000 square foot area behind the berm. The sampling areas are identified in Figure 5-3B. Both samples were analyzed for selected metals [antimony, lead and copper]. Results (Table 5-5) indicated that antimony (0.34 mg/Kg), copper (11.5 mg/Kg) and lead (15.6 mg/Kg) concentrations in the Target Berm sample were generally similar to the respective antimony (0.67 mg/Kg), copper (18 mg/Kg) and lead (16.6 mg/Kg) levels in the behind the berm sample. Antimony and lead levels were well below their MassDEP S1/GW-1 standards (20 mg/Kg and 300 mg/Kg, respectively).

5.2.1.2 B Range

B Range is an inactive operational 25-meter rifle and pistol range located on Burgoyne Road just south of Wood Road. It was constructed in 1991 for M16 rifle and pistol training. Ammunition authorized for this range includes 5.56mm ball and tracer rounds (M16 rifles) and .45 cal and 9mm ball rounds (pistols). The range currently supports 55 firing points. The firing points are evenly-spaced at 11-foot intervals along the 615-foot long firing line. The target line is positioned 82 feet (25 meters) from the firing line. Numerous plastic 5.56mm projectiles were present in the backstop berm, which is located approximately 5 feet beyond the wooden target frames. This backstop was treated during the 1998 Berm Maintenance Program and soil removal was conducted under the 2006 Berm Maintenance – Tungsten Removal Project discussed in Section 4. Stressed vegetation at the firing line and erosional features in the backstop berm suggest that the central firing points were the most frequently used during training activities at this range.

<u>B Range Investigations</u>

During the Supplemental Phase IIb investigations, five 5-point soil grids were sampled at the firing line to determine whether residual propellant compounds existed in soil there

(Figure 5-4A). Grid 154C was positioned near the center of the range, opposite the firing point presumed to be most frequently used, just downrange of the firing line. Two of the four remaining grids (154A and 154E) were positioned downrange of firing points located near the northern and southern limits of the range and just downrange of the firing line. The remaining two grids (154B and 154D) were positioned between the central and end grids at firing points where recent range use was evident. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

During the Supplemental Phase IIb investigation, five propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT and n,n' diethylcarbanilide) were detected among the 30 samples analyzed from B Range. Di-n-butyl phthalate was the most frequently detected compound (18 samples) with a maximum detected concentration of 0.3 mg/Kg reported in a discrete sample from grid 154D. N-nitrosodiphenylamine was detected in 16 samples with a maximum reported concentration of 0.68 mg/Kg at grid 154C. Nitroglycerin was detected as a tentatively identified compound at grid 154E at a low concentration of 0.11 mg/Kg. A few polycyclic aromatic hydrocarbons (PAHs) were detected at trace levels below the reporting limit. Fifteen metals were detected at concentrations above their respective MMR background concentrations. The maximum reported lead concentration was 23.4 mg/Kg. Tungsten was not analyzed during the Phase IIb investigation.

2006 Removal Action

In 2006, a soil removal action was implemented at B Range as part of the Berm Maintenance Project for tungsten (as discussed in Section 4.2). The objective of this removal action was to excavate tungsten-contaminated soils to reduce overall soil tungsten concentrations at the berm. Extensive field XRF screening investigations were conducted to characterize soil tungsten concentrations prior to the excavations. At B Range, focused excavations were conducted along the back and crest of the berm to a depth of approximately 0.5 feet. Middle and toe areas of the berm were excavated to depths of up to approximately 3 feet and 2 feet, respectively. Post-excavation field XRF screening and off-site laboratory soil analyses were conducted to confirm the effectiveness of the removal efforts. The Technical Memorandum (URS 2006) summarizing this work effort is included in Appendix F of this report.

As a consequence of the removal action, the maximum reported residual concentration of tungsten was 159 mg/Kg from sample SBR11-2A (location SBR01). Although not included in the lead removal actions, the maximum detected residual concentration of lead was 1,430 mg/Kg from sample SBR20-1A (location SBR02) and the average residual lead concentration was 50 mg/Kg.

2010 Soil Investigation

In February 2010, subsurface soil samples were collected from soil borings at wells MW-538 and MW-539. The boring at MW-538 was located within the former footprint of the soil berm while boring MW-539 was intended to assess background concentrations in deep soil. Samples were submitted for analysis of select metals and tungsten. The select metals list includes aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, phosphorous and zinc.

Results from soil boring MW-538 indicated tungsten in surface soil with a maximum reported concentration of 40 mg/Kg. The maximum reported tungsten concentration was 82 mg/Kg at a depth of 4 to 6 feet bgs. Tungsten concentrations were <1.0 mg/Kg in samples below 6 feet bgs.

In May 2010, XRF screening was performed on the face of the remaining berm to determine residual tungsten levels. The area of XRF screening, which including 124 individual readings, was centered on the middle of the berm near MW-72S and extended out 100 feet to the north and south. The results of the XRF screening were consistent with the post-excavation soil sample results. The highest XRF reading was 211 mg/Kg in the northern portion of the berm. Two other readings were at or above 100 mg/Kg.

The soil berms were sampled at six locations (SBR1 through SBR6) within the area screened using the XRF. Soil berm sample SBR1 was installed at the location with the highest XRF reading. The remaining five sample locations were placed in former bullet pockets that were removed during 2006 removal action. All six borings were advanced to approximately 4 feet bgs. The maximum detected tungsten concentration was 159 mg/Kg (boring SBR-1, 1 to 2 feet). Lead concentrations in some samples exceeded 300 mg/Kg with a maximum concentration of 1,430 mg/Kg and average residual lead concentration of 50 mg/Kg.

2011 Lysimeter Investigation

A pan lysimeter was installed at the middle of the B Range berm in October 2011 (LYBR001). This is the portion of the berm that historically had the highest use. The lysimeter was installed approximately 10 to 15 feet from the base of the backstop berm to evaluate the potential migration of tungsten in pore water that may infiltrate from the base of the berm.

The lysimeter was initially sampled in January 2012. Unfiltered and field filtered pore-water samples were collected and submitted for laboratory analysis (TestAmerica) for total and dissolved tungsten. Samples were also analyzed for total and dissolved aluminum, antimony, arsenic, barium, cadmium, chromium, copper, iron, lead, nickel, phosphorus, zinc and pH. As a key element of this investigation, pore-water samples were also submitted to the USACE ERDC laboratory for aqueous tungsten speciation analysis, specifically for both total tungsten and tungstate ion.

Results from both laboratories agreed closely and confirmed the presence of elevated pore-water tungsten concentrations. The Test America results for tungsten were 452 µg/L (field filtered) and 461 µg/L (total). The tungsten results measured by ERDC ranged from 464 to 495 µg/L. The results of the tungsten speciation analyses run by ERDC indicated that the majority of the total aqueous phase tungsten was present as tungstate. ERDC indicated that as much as 95 percent of the tungsten was present as the tungstate ion. The measured pH of the water in the lysimeter was 6.68 and was compatible with the presence of tungstate as a predominant tungsten species.

In a follow up sampling round, an unfiltered sample and a field duplicate sample were collected from the pan lysimeter in June 2012 and submitted for analysis of total tungsten. The total tungsten concentrations for these samples were 844 and 877 µg/L, respectively. The reason for the increase in aqueous phase tungsten is uncertain. As indicated in Section 5.1.2, this lysimeter was again sampled for tungsten in June 2013. A tungsten concentration of 844 µg/L was reported. This concentration is very similar to the 2012 results.

2011 Soil Boring Investigation

In February 2011, a total of 48 subsurface boring samples were collected from four locations (SBR-2 through SBR-5) within the footprint of the former berm. Samples were collected at two-foot intervals to a depth of approximately 24 feet bgs at each boring location. Samples were analyzed for select metals and tungsten.

Results for the February 2011 investigation indicated the highest tungsten level was 200 mg/Kg detected in a sample from boring SBR-3 (depth 6 to 8 feet bgs). The highest tungsten levels were observed at 5 to 10 feet bgs and quickly attenuated below these depths. Lead concentrations were generally low. The highest concentration detected was 35 mg/Kg.

2013 Soil Investigation

In April 2013, both multiple increment soil sampling and XRF screening was conducted at B Range. One hundred-point multiple increment samples (BR01A, BR02A and BR03A) were collected from three approximately 200 feet by 40 feet sampling areas from behind the berm locations. Two replicate samples (BBR02B and BR02C) were collected from sampling area BR02. The multiple increment samples were submitted to the off-site laboratory for selected metals [antimony, copper, lead, chromium and tungsten] analysis by method SW6020. Results (Table 5-5) for lead were elevated and ranged from 464 mg/Kg to 826 mg/Kg. Antimony results for the samples ranged from 3.0 to 8.2 mg/Kg. Copper results were variable and ranged from 35 mg/Kg to 2970 mg/Kg. Tungsten results were also variable and ranged from 9.9 mg/Kg to 133 mg/Kg. Sampling locations and analytical results for the behind the berm samples are presented in Figure 5-4B.

In addition to multiple increment sampling, XRF screening was conducted for selected metals at the B Range berm for both surface and subsurface soil samples. Following the methodology summarized in Section 3.2.7, the B Range berm surface was divided into nine sampling areas of approximately 2,000 square feet. The sampling areas (identified as areas 1 through 9) are indicated in Figure 5-4B. Each sample was screened by XRF for antimony, chromium, lead and tungsten. Individual XRF screening results (Tables 3-3A) for surface soil samples for lead ranged from 52 mg/Kg (sample B2A) to 414 mg/Kg (B9C). Individual results for tungsten ranged from non-detect (B1A) to 25 mg/Kg (B5B). All results for antimony and chromium were non-detect with the exception of a single chromium detection (81 mg/Kg) in sample B5A. However, this detection was not confirmed in the two other XRF readings of this sample.

Soil boring samples were collected from three berm sampling areas, which were selected based on XRF screening results from surface soil samples, as defined in Section 3.2.7. Each sample was screened by XRF for antimony, chromium, lead and tungsten. Individual XRF screening results (Table 3-3B) for subsurface soil samples for lead ranged from non-detect (sample B4) to 175 mg/Kg in (B6 1-2’ bgs). Individual XRF screening results for tungsten ranged from non-detect (B4) to 29 mg/Kg (B6 3-4’ bgs). XRF screening results for antimony and chromium were non-detect in all subsurface samples.

5.2.1.3 Former B Range

Former B Range is a non-operational small arms range located on the northern side of Monument Beach Road in Training Area B-8. The range, originally referred to as the Monument Beach Road 1000-inch range and the 1000-inch Machine Gun “A” Range, was constructed sometime between 1935 and 1941 for use as a machine gun and pistol training range. It continued to be used in this manner until sometime in the 1950s. The existing, natural hillside used as a backstop at this range was reworked sometime after 1941 to increase the size of the range. A dividing earthen berm was constructed to separate the range into two portions so that training activities on either side could be performed independently. Machine gun targets were positioned at the base and on the slope of the hillside. Pistol targets were located at 15 and 25 yards from the firing line. Documented ordnance use during the first 15 years of use includes .30, .38, .45, and .50 cal ball rounds.

Between 1955 and 1967, Former B Range was used exclusively as a pistol range and was configured with 30 firing points at both 15 and 25 yards from targets. Records indicate .38 and .45 cal rounds were fired during this time period. In 1967, the range was converted to a 1,000-inch rifle range with 25 to 27 firing points along the firing line. Former B Range was used in this manner until the early 1980s, when it was converted to a mortar firing position (Old MP-2). Reported ammunition use during this period includes .30 cal, 5.56mm, and 7.62mm rounds.

Physical evidence of the Former B Range firing line has been obscured by a currently-operating composting area. A hillside and earthen berm described in historical documents remain visible and are located to the east beyond the compost stockpiles. The presence of small arms projectiles discovered in the hillside and pockmarked boulders is consistent with historical records. Soil removal at Former B Range was included in the 2009 and 2010 lead removal actions.

Former B Range Investigations

The Former B Range was investigated as Old MP-2 as part of the Gun and Mortar Position Investigation (Tetra Tech 2011). Eighteen soil grids (73A through 73R) were located at this range (Figure 5-5A). Several of these grids, including 73E, 73I, 73L, 73N, 73P, and 73R, were located at the base of the backstop hillside. Under the Phase IIb investigation (conducted in 2000), 10 soil grab locations (140A through 140J) were sampled at the Former B Range backstop midway up the hillside where physical evidence of bullet fragments was observed. Discrete soil samples were collected from two depths (0 to 0.5 feet bgs and 1.5 to 2.0 feet bgs) at each location and submitted for target analyte metals and TCLP lead analyses.

Based on previous findings under both the Gun and Mortar Position and Phase IIb investigations, Supplemental Phase IIb sampling was conducted in 2001 in the vicinity of sampling locations where the highest lead concentrations were previously reported (i.e., grids 73E, 73I, and 73N) to characterize the lateral and vertical extent of contamination there.

Discrete soil samples were collected from 12 additional locations (140K through 140V), four around each of the aforementioned grids, each spaced 25 feet more or less from the original center grid node. Samples were obtained from the surface (0 to 6 inches bgs) and shallow subsurface (18 to 24 inches bgs) and submitted for analysis of total metals.

The maximum reported total lead concentration for the initial Phase IIb samples was 64.5 mg/Kg at location 140I. Under the Phase IIb supplemental investigation, 11 metals were detected at levels above their respective MMR background levels in one or more of the 12 samples that were analyzed. Lead was detected in all 12 samples with a maximum reported concentration of 2,810 mg/Kg at location 140S.

2008/2009 Removal Action

As a result of the Phase IIb supplemental results, a response action to remove soils with concentrations of lead greater than 300 mg/Kg was initially implemented at the Former B Range. In 2008, a field XRF investigation program was undertaken at Former B Range to further characterize lead distribution in surface and near surface soils. Range soils containing greater than 300 mg/Kg of lead were delineated to support soil removal actions. In May-July 2008, 12 soil samples were submitted for off-site laboratory analyses in support of the XRF field program.

Based on the results of the 2008 XRF field screening investigation, a removal action to reduce soil lead concentrations was implemented in 2009. Under this removal action, soils containing greater than 300 mg/Kg lead were excavated and stockpiled. Stockpiled material was mechanically screened. Post-excavation soil samples were collected and analyzed from the excavated areas to evaluate the excavation effectiveness. This excavation program is discussed in additional detail in Section 4 and summarized in Figure 4-3.

As a consequence of the removal actions, the maximum concentration of lead detected in post-excavation confirmatory samples was 202 mg/Kg. However, additional confirmatory multiple increment samples will be collected to confirm that the removal action is complete.

2013 Soil Investigation

In April 2013, additional sampling was conducted at Former B Range. Two 100-point multiple increment samples (FMRB01A and FMRB02A) were collected from each of the two former firing line locations. The sampling locations are identified in Figure 5-5B. The multiple increment samples were analyzed for explosives including nitroglycerin. All explosives results including nitroglycerin were non-detect in both samples (Table 5-5).

5.2.1.4 C Range

C Range is an inactive operational rifle and pistol range located on Burgoyne Road just south of B Range. The range is nearly identical in construction to the B Range and was built sometime between 1986 and 1989. Ammunition authorized for this range includes 5.56mm ball rounds (M16 rifle) and all caliber pistol rounds.

The range is comprised of 55 evenly-spaced firing points along a 615-foot-long firing line. Like the B Range, targets are positioned 82 feet (25 meters) downrange. An earthen backstop berm is present behind target frames on the southern half of the range; the northern half of the range (firing points 1 through 29) has no backstop. Numerous plastic 5.56mm rounds are present on the surface of the backstop. The most frequently used firing points appear to be concentrated in the center of the range. The existing backstop berm was treated during the 1998 Berm Maintenance Program and soil removal at the range was performed under the 2006 Berm Maintenance – Tungsten Removal Project.

C Range Investigations

During Supplemental Phase IIb investigations, five 5-point soil grids were established at the firing line to determine whether residual propellant compounds exist in soil there (Figure 5-6A). Consistent with the B Range, one grid (155C) was positioned near the center of the range, opposite the firing point presumed to be most frequently used. Two of the four remaining grids (155A and 155E) were located near the northern and southern limits of the range and just downrange of the nearest firing point. The remaining two grids (155B and 155D) were located between the central and end grids at firing points where evidence of recent use was observed. The center nodes for each of the five grids were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Five propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT and n,n'-diethylcarbanilide) were detected among the 19 samples collected from C Range. The highest concentration of each of these compounds was reported in a sample from grid 155C. The maximum detected concentration of di-n-butyl phthalate was 0.24 mg/Kg. N-nitrosodiphenylamine and di-n-butyl phthalate were the most frequently detected propellant-related compounds and were detected in eight of 19 samples. Nitroglycerin was reported as a tentatively identified compound in one sample at a concentration of 0.24 mg/Kg. Ten metals were reported in one or more samples at concentrations above their respective MMR background levels. The maximum reported concentration of lead was 20.3 mg/Kg. During sampling conducted in 2006, a higher level of lead (383 mg/Kg) was reported in sample SSCRSW01.

2006 Removal Action

In 2006, a soil removal action was implemented at C Range as part of the Berm Maintenance Project (as discussed in Section 4.2). The objective of this removal action was to excavate tungsten contaminated soils to reduce overall soil tungsten concentrations at the berm. Preliminary field XRF evaluations were conducted to characterize soil tungsten concentrations. At C Range, focused excavations were conducted along the back and crest of the berm to a depth of approximately 0.5 feet. Middle and toe areas of the berm were excavated to depths of up to approximately 3 feet and 2 feet, respectively. Post-excavation field XRF screening and off-site laboratory soil analyses were conducted to confirm the effectiveness of the removal efforts.

As a consequence of the removal action, the maximum detected residual concentration of tungsten was 50.5 mg/Kg (sample SSCRSW01_PE). The maximum residual detected concentration of lead was 383 mg/Kg (sample SSCRSW01_PE) and the average residual lead concentration 31 mg/Kg.

2013 Soil Investigation

In April 2013, both multiple increment sampling and XRF screening was conducted at C Range. Four 100-point multiple increment samples (CR01A, CR02A, CR03A and CR04A) were collected from behind the berm locations. Three of the sampling areas were immediately behind the berm and each extended approximately 140 feet along the berm and 40 feet away from the berm. The fourth sampling area was approximately 100 feet by 100 feet and extended behind the two northernmost behind the berm samples. The multiple increment samples were submitted to the off-site laboratory for selected metals [antimony, copper, lead and tungsten] analysis by method SW6020. Results (Table 5-5) for lead ranged from 103 mg/Kg to 749 mg/Kg. Antimony results for the samples ranged from 0.86 to 9.1 mg/Kg. Copper results ranged from 14 mg/Kg to 104 mg/Kg. Tungsten results were variable and ranged from 7.9 mg/Kg to 42 mg/Kg. Sampling locations and analytical results for the behind the berm samples are presented in Figure 5-6B.

In addition to multiple increment sampling, XRF screening was conducted for selected metals at the C Range berm for both surface and subsurface soil samples. Following the methodology summarized in Section 3.2.7, the C Range berm surface was divided into 15 sampling areas of approximately 2,000 square feet. The sampling areas (identified as 1 through 15) are indicated in Figure 5-6B. Each sample was screened by XRF for antimony, lead and tungsten. Individual XRF screening results (Tables 3-3A) for surface soil samples for lead ranged from 22 mg/Kg (sample C1A) to 3,252 mg/Kg (C15B). However, the other two XRF readings of sample C15B were much lower (384 mg/Kg and 404 mg/Kg) and did not confirm the initial reading. Individual XRF screening results for tungsten ranged from non-detect to 73 mg/Kg (C5A). Again, the two other XRF readings for sample C5A were significantly lower than 73 mg/Kg. All XRF screening results for antimony were non-detect.

Soil boring samples were collected from three berm sampling areas, which were selected based on XRF screening results from surface soil samples, as defined in Section 3.2.7. Each sample was screened by XRF for antimony, lead and tungsten. Individual XRF screening results (Table 3-3B) for subsurface soil samples for lead ranged from non-detect (sample C5 5-6' bgs) to 608 mg/Kg in (C10 1-2' bgs). XRF screening results for antimony and tungsten were non-detect in all subsurface samples.

5.2.1.5 Former C Range

Former C Range is a non-operational small arms range located on the northern side of Frank Perkins Road on the western side of Training Area B-7 southeast of Former B Range. The range, originally referred to as Machine Gun “B” Range, was constructed sometime between 1935 and 1941, and used until the 1950s for machine gun training. Reported ammunition use at this range between the 1940s and 1950s includes .30 and .50 cal ball and tracers rounds.

Between the 1950s and early 1960s, Former C Range was converted to a 1000-inch machine gun range. During this time period, .50 cal ball rounds were fired from 20 separate firing points. In the early 1960s, the range was again converted to a 1000-inch rifle range and was configured with 40 firing points. Ammunition fired during this period included .30 cal, 5.56mm, and 7.62mm ball rounds. It continued to be used in this manner until the early 1980s at which time 15 additional firing points were added to the firing line. Training activities ceased at Former C Range sometime between 1986 and 1989.

Based on topography and historical aerial photographs, it appears that weapons were fired from a southwestern firing line somewhere near the current parking area towards a bowl-shaped, natural embankment located in the northeastern portion of the range. Numerous bullet fragments consisting mostly of 7.62mm (or possibly .30 cal) and .50 cal have been discovered at the top of this embankment. Boulders in the face at the top of this slope also exhibit significant pockmarking similar to that discovered at Former B Range and presumed to be the result of past bullet impacts. Few projectile fragments have been found on the middle and lower portions of the embankment suggesting targets were positioned at the top of the slope.

Former C Range Investigations

Eighteen locations (136A through 136R) were sampled at Former C Range during initial Phase IIb sampling (Figure 5-7A). Two discrete grab sample locations (136A and 136B) were positioned on a small hill within the downrange target area. Ten additional grab sample locations (136D through 136M) were positioned in various downrange sites along the range backstop in cleared areas or where evidence of bullet fragments and pitted rock faces were observed. Two soil grids (136C and 136N) were positioned down slope of the firing line, and the remaining four sampling sites (grids 136O through 136R) were situated along the firing line. Lead was detected at concentrations above background in samples collected from the target areas.

During subsequent Phase IIb investigations, additional sampling was conducted in the vicinity of locations where lead concentrations were highest (i.e., grids 136B, 136H, 136J, and 136L) to further characterize the lateral and vertical extent of contamination there. Discrete soil samples were collected from four locations strategically positioned around each of the aforementioned grids. Because grid locations 136J and 136L were in such close proximity, they were treated as a single sampling site. The 12 sampling locations were spaced 25 feet more or less from the original center grid node. Samples were obtained from 0 to 6 inches bgs and 18 to 24 inches bgs and submitted for analysis of total metals.

During initial Phase IIb investigations, the highest lead concentrations were found in samples collected from locations 136B (573 mg/Kg), 136H (424 mg/Kg), 136J (1,560 mg/Kg) and 136L (825 mg/Kg). During the Supplemental Phase IIb investigation, three metals (copper, lead and antimony) were detected above their respective MMR background levels in one or more of the 12 samples that were collected at the Former C Range at locations 136S through 136AD. Similar distributions of metals were observed in the 12 subsurface samples collected at the Former C Range. The maximum detected concentrations of lead (1,560 mg/Kg) and copper (140 mg/Kg) were detected in surface samples from the 136J and 136AC sites, respectively.

2013 Soil Investigation

In April 2013, additional sampling was conducted at Former C Range. A 100-point multiple increment sample (FMRC01A) was collected from the former firing line area. In addition, two replicate samples (FMRC01B and FMRC01C) were also collected at this location. The sampling locations are identified in Figure 5-7B. The multiple increment samples were analyzed for explosives including nitroglycerin. All explosives results including nitroglycerin were non-detect in the samples (Table 5-5).

5.2.1.6 D Range

D Range is an inactive operational M60 machine gun training range located just south of C Range on Burgoyne Road. The range was established sometime between 1986 and 1989 as a machine gun zeroing range designed to accommodate 7.62mm ball rounds. The range has eight firing points positioned along an 83-foot long firing line. Target frames were located 33 feet (10 meters) downrange of the firing line, and the backstop, which was treated during the 1998 Berm Maintenance Project, appears to have been constructed out of the natural hillside just beyond the target frames.

D Range Investigations

During Phase IIb investigations, two 5-point grids were established, one positioned just downrange of the central firing point and the other located at the southern end of the range (Figure 5-8A). The center nodes of these grids were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval, and samples were submitted for analysis of SVOCs and TAL metals.

Five propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT and n,n'-diethylcarbanilide) were detected among the 12 samples analyzed from D Range. The maximum concentrations of all five compounds were reported in the discrete surface sample from grid 158A. N-nitrosodiphenylamine and di-n-butyl phthalate were the most frequently detected propellant-related compounds and were detected in seven samples, at maximum detected concentrations of 0.75 mg/Kg and 1.1 mg/Kg, respectively. Bis(2-ethylhexyl)phthalate was also detected in six samples at a maximum reported concentration of 0.22 mg/Kg. Eleven metals were reported in one or more samples at concentrations exceeding their respective MMR background levels. The maximum concentration for lead (1,030 mg/Kg) was reported in a sample from grid 158A.

2013 Soil Investigation

In April 2013, additional sampling was conducted at D Range. One 30-point multiple increment sample (DR01A) was collected from a behind the berm location. The sampling area extended along the length of the berm (about 80 feet) and approximately 40 feet behind the berm. The sampling location is identified in Figure 5-8B. The multiple increment sample was analyzed for selected metals [antimony, copper, lead and tungsten]. The result (Table 5-5) for lead (1,840 mg/Kg) was elevated and exceeded the MassDEP S-1/GW-1 standard. The result for antimony (12.1 mg/Kg) was below the MassDEP S-1/GW-1 standard. Copper and tungsten were detected at concentrations of 31.8 mg/Kg and 0.25 mg/Kg, respectively.

5.2.1.7 Former D Range

The Former D Range is a non-operational small arms range located on the northern side of Frank Perkins Road at Pine Hill just northwest of the MMR Range Control building. The range, also referred to in the past as the Anti-Aircraft Miniature Range, was originally constructed sometime between 1935 and 1941 for use as an anti-aircraft miniature rifle range. It continued to be used this way until the 1950s. Ammunition used during this time period was limited to .22 cal ball rounds.

As with Former C Range, the range was converted in the 1950s to a 1,000-inch machine gun range. During this time period, the range was configured with 20 firing points from which .50 cal ball rounds were fired. Former D Range continued to be used as a machine gun range until the early 1960s. Between the early 1960s and late 1980s, the range was converted to a rifle range. Ammunition fired from the 44 firing points included .30 cal and 7.62mm ball rounds.

The clearing located at the southern end of this range was most recently used as a pistol range. An earthen berm constructed a short distance from the parking area served as a backstop to this range. There are several cleared areas located downrange of the original firing line that are arranged in a semicircular arc leading from one end of the former firing line, downrange, and back to the other. The terrain surrounding these clearings consists of a scrub pine forested area. Several of the clearings are located on the southwestern slopes of small topographic rises within the downrange area. Numerous .30 cal bullet fragments, consistent with past range use, are present on the ground surface within several of these clearings. Soil at Former D Range was included in the 2009 lead removal action.

Former D Range Investigations

During an early Phase IIb investigation, eight locations (135A through 135H) were sampled in sites downrange along the presumed backstop of Former D Range (Figure 5-9A). Sampling locations were selected based both on historical aerial photographic evidence and the presence of projectile fragments observed during the field inspection. Five soil grids (135I through 135M) were also sampled along the former firing line. Elevated lead concentrations were detected in most surface samples collected from the target area (i.e., 135C through 135H) with concentrations ranging up to 10,100 mg/Kg.

Based on these findings, Supplemental Phase IIb sampling was conducted throughout the target area where elevated lead concentrations were detected to further characterize the lateral and vertical extent of contamination. Fifteen discrete soil sampling locations (135N through 135AB) were positioned between the existing sampling locations and uprange and downrange of the presumed backstop. Samples were obtained from 0 to 6 inches bgs and 18 to 24 inches bgs and submitted for analysis of total metals.

During the Supplemental Phase IIb investigation, four metals (copper, lead, antimony and iron) were detected above their respective MMR background levels in one or more of the 15 surface samples at the Former D Range at locations 135N through 135AB. Metals distributions in the 15 subsurface samples that were collected were generally similar to those observed in the surface samples although iron was not reported above background. The maximum detected concentrations of lead (3,090 mg/Kg) and copper (252 mg/Kg) were both reported in the surface sample collected from location 135X. The maximum observed lead and copper concentrations in the subsurface samples were significantly lower.

2008/2009 Removal Action

In 2008, a field XRF investigation was undertaken at Former D Range to further characterize lead concentrations in surface and near surface soils. Range soils containing greater than 300 mg/Kg of lead were delineated to support soil removal actions. This excavation program is further discussed in Section 4 and summarized in Figure 4-4.

Based on the results of the 2008 XRF field investigation, lead was removed from site soils as part of the 2009 Lead Removal Program. Under this removal action (discussed in Section 4) soils containing greater than 300 mg/Kg lead were excavated and stockpiled. Stockpiled material was mechanically screened. In October 2009, ten 100-point post-excavation samples were collected to delineate lead concentrations.

As a consequence of the removal actions, the maximum concentration of lead detected in post-excavation confirmatory samples was below 300 mg/Kg (Figure 5-9A). However, additional multiple increment samples will be collected to confirm that the removal action is complete.

2013 Soil Investigation

In April 2013, additional sampling was conducted at Former D Range. The former soil stockpiling area was divided into four sampling areas. A 100-point multiple increment sample (FMRD01A-FMRD04A) was collected from each of the four sampling areas. Two replicate samples (FMRD03B and FMRD03C) were collected at sampling area FMR03. The sampling locations are identified in Figure 5-9B. The multiple increment samples were analyzed for lead and explosives including nitroglycerin. Results for lead ranged from 91.6 mg/Kg to 199 mg/Kg in the original samples. The results for field replicates FMRD03B (199 mg/Kg) and FMRD03C (179 mg/Kg) were similar to the original sample FMRD03A (199 mg/Kg). All explosives results including nitroglycerin were non-detect in all samples (Table 5-5) at estimated levels

5.2.1.8 E Range

E Range is an inactive operational pistol range located on the eastern side of Burgoyne Road south of D Range. The range was established at its current location in the mid-1980s. The 15 firing points of this range were designed to accommodate all calibers of pistol ammunition to include .45 cal, .40 cal, .38 cal, .30 cal, 9mm lead and frangible and 12 gauge shotgun. The range contains five rows of mechanical pop-up targets positioned downrange of a 416-foot long firing line. The targets are arranged in rows at distances varying from 29 to 97 feet downrange of the firing line. In 2006, there was significant reworking of E Range and associated range soil as part of a range/target upgrade. The backstop berm, which appears to be part of the natural hillside, is approximately 40 feet beyond the last row of targets. The backstop and target mounds, which were treated during the 1998 Lead Removal Program, contained both 9mm and .40 cal projectiles.

E Range Investigations

Phase IIb Sampling

During the Supplemental Phase IIb investigation, five 5-point soil grids were established at the firing line of this range to determine whether residual propellant compounds exist in soil there (Figure 5-10A). Grid 159C was positioned near the center of the range, opposite the firing point presumed to be most frequently used, just downrange of the firing line. Two of the four remaining grids (159A and 159E) were located near the northern and southern limits of the range downrange of firing points 1 and 15. The remaining two grids (159B and 159D) were positioned between the central and end grids. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers. The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Samples were submitted for analysis of SVOCs and TAL metals.

Propellant-related SVOCs were detected among 32 soil samples collected from E Range. These included di-n-butyl phthalate in 24 samples, n,n'-diethylcarbanilide in 18 samples and n-nitrosodiphenylamine in 15 samples. The maximum observed concentrations for these three compounds were 0.28 mg/Kg, 0.56 mg/Kg and 0.39 mg/Kg, respectively. 2-Nitrodiphenylamine was also detected in eight samples at a maximum concentration of 140 µg/Kg. Fifteen metals were reported in one or more samples at concentrations above background levels. The maximum concentration of lead (261 mg/Kg) was reported in a surface composite from grid 159E.

Multiple Increment Sampling

During 2006, soil multiple increment sampling was conducted at E Range. E Range was conceptually divided into five investigation areas based upon known past use of the range and the conditions at the time of sampling (Figure 5-10B). The five investigation areas were as follows:

- Area 1 – the area from the firing points to the nearest pop-up targets
- Area 2 – the area within the pop-up targets
- Area 3 – the remainder of the range floor between the targets and the embankment at the back of the range
- Area 4 – the embankment at the back of the range
- Area 5 – two onsite soil piles

These five areas were further subdivided into a total of twelve subareas. Fifty- and/or 100-point multiple increment samples were collected from each area with the exception of the soil piles from which only 4-point composites were collected. A subsurface (9 to 12 inches bgs) multiple increment soil sample was also collected from Area 1/Center. Replicate samples were collected from Area 1/Center, Area 2/Center, and Area 3/Center.

A systematic random sampling approach was used to collect multiple increment samples. As discussed in CRREL Report TR-07-01, the sampler begins at a point on the edge of the area to be characterized and collects an increment of surface soil after a number of steps, while walking back and forth in a systematic manner across the area of interest. Samples from Area 1 were analyzed for explosives, SVOCs, and a suite of five metals (antimony, arsenic, copper, lead, and tungsten). Area 2/Center was analyzed for explosives and five metals. All other sampling areas were analyzed for the suite of five metals.

Nitroglycerin was the predominant propellant-related compound detected at E Range. The highest concentrations of nitroglycerin were detected in surface soil samples (0 to 3 inches bgs) from Area 1/Center located in the center of the firing line. The maximum reported concentration was an estimated 9.3 mg/Kg. The replicate result for this sample was 3.7 mg/Kg. Nitroglycerin was not detected in the subsurface soil sample (9 to 12 inches bgs) collected from Area 1/Center. Nitroglycerin concentrations on the northern portion of the firing line (Area 1 North) were less than half of those in the center of the firing line and were not detected at all in the southern portion of the firing line (Area 1 South).

Several propellant-related SVOCs (including 2-nitrodiphenylamine, n-nitrosodiphenylamine, di-n-butyl phthalate, and n,n’-diethylcarbanilide) were observed in soil samples from certain firing line, range floor, and behind berm areas of the range. Concentrations of these four propellant-related compounds were generally low with the maximum observed estimated concentrations of these compounds, in all cases, being 0.2 mg/Kg.

Results for metals were somewhat variable across the E Range. Most of the five metals that were analyzed were detected in most surface soil samples. Antimony was reported in a number of surface soil samples with the maximum concentration (3.8 mg/Kg) observed in Area 4/South. Arsenic was detected in all surface soil samples with the concentrations in all samples being less than 3.3 mg/Kg. Copper was detected in all surface soil samples with the maximum concentration (47.4 mg/Kg) observed in the sample from Area 4/North. Lead was detected with the maximum observed concentration (555 mg/Kg) reported for the Area 4/South. Lower lead levels (less than 300 mg/Kg) were reported for all other samples including all firing line and range floor samples. Tungsten was detected in all samples in which it was analyzed at a maximum concentration of 5.1 mg/Kg.

5.2.1.9 E-1 Range

The original E Range (E-1) is non-operational and was constructed in 1941, and at that time, access to the range was gained via a road extending north from Pocasset-Forestdale Road. The range was designed and used as an anti-tank training range until the late 1950s or early 1960s. Records indicate that 2.36-inch and 3.5-inch rockets, 37mm and 75mm practice artillery rounds, and .30 cal ball ammunition were fired at the E-1 Range. No information on training activities at the E-1 Range after the early 1960s have been discovered. Some investigations of the E-1 Range were conducted in 2000 and 2001 as part of the Phase IIb work.

Given the historical use of rockets and artillery rounds and minimal documentation of small arms ammunition use, this range will not be evaluated as part of this report. Further assessment of the range will be conducted as part of the Training Areas investigations.

5.2.1.10 E-2 Range

The E-2 Range is non-operational and was established in 1965 as a squad/platoon attack course in the area of the current Demolition Area 1 (Figure 5-11). The description of the range changed to a close combat course and rifle squad in attack course over the next five years, but its use remained essentially the same. Available documentation does not describe the layout of the range; only that .30 cal ball ammunition were used there. It is assumed the direction of fire would have been northerly towards the impact area. Use of the E-2 Range at this location ended in 1970.

This range was investigated as part of Demolition Area 1 and was not evaluated as part of this report.

5.2.1.11 G Range

G Range is an inactive operational rifle and machine gun training range located on Pocasset-Forestdale Road. The range, which was constructed in the late 1980s, is designed for M16 rifle and M60 machine gun training. Ammunition authorized for use at this range includes 5.56mm and 7.62mm ball rounds.

There are 27 firing points positioned along the range's 185-foot long firing line. The distance from firing line to target frames measured 85 feet (approximately 25 meters). An earthen backstop berm, which extends the full length of the range, was situated 23 feet downrange of the target frames. Plastic 5.56mm projectiles exist on the uprange face of the berm. Further downrange, in a cleared area beyond the backstop berm, metallic small arms projectiles and projectile fragments have also been discovered. Bare spots at the firing line and erosion in the face of the backstop at the firing line suggested the centrally located firing points were most frequently used. The backstop was treated during the 1998 Berm Maintenance Program and soil removal for G Range was included in the 2006 Tungsten Removal Project.

G Range Investigations

In October 2000 during initial Phase IIb investigations, soil samples were collected from a central location along the firing line of this range immediately after a live-fire training exercise to evaluate possible impacts to soil from the airborne deposition of propellant-related compounds Sample locations are indicated on Figure 5-12A.

In subsequent Supplemental Phase IIb investigations, two 5-point soil grids were established at either end of the firing line to determine whether residual propellant compounds exist in soil there. The grids (128C and 128D) were positioned near the eastern and western limits of the range more or less equidistant from the existing, collocated grids 128A and 128B located in the center of the range. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

Grids 128C and 128D were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Three soil sampling locations (128E, 128F, and 128G) were also established within the clearing located beyond the backstop berm where the metallic small arms projectiles were observed. Using a sampling approach consistent with that used during earlier investigations of Former B, C, and D Ranges, discrete soil samples were obtained from 0 to 6 inches bgs and 18 to 24 inches bgs at these locations and submitted for analysis of TAL metals.

Six propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT, 2,6-dinitrotoluene (2,6-DNT) and n,n'-diethylcarbanilide) were detected in one or more of the 24 samples analyzed from G Range. 2,4-DNT was detected in 17 of the 24 samples for which it was analyzed, with a maximum detected concentration of 3.4 mg/Kg in a surface sample from grid 128A. Other SVOCs detected at the firing line included low levels (comparable to MMR background) of 10 PAH compounds. Six metals were reported in one or more samples at concentrations exceeding their respective MMR background levels. The maximum detected concentration of lead (5,170 mg/Kg) was reported in a discrete surface sample from grid 128E. Tungsten was not analyzed during the Phase IIb investigation.

2006 Removal Action

In 2006, a soil removal action was implemented at G Range as part of a Berm Maintenance Project (as discussed in Section 4.2). The objective of this removal action was reduce overall soil tungsten concentrations at the berm. Preliminary field XRF screening investigations were conducted to characterize soil tungsten concentrations. Berm areas were excavated to depths ranging from 0.5 feet to 3.0 feet. Post excavation field XRF screening and off-site laboratory soil analyses were conducted to confirm the effectiveness of the removal efforts.

As a consequence of the removal action, the maximum detected residual concentration of tungsten was 84.5 mg/Kg (sample SSGRS01_PE). The maximum residual concentration of lead was 566 mg/Kg (sample SSGRS01_PE) and the average residual lead concentration 108 mg/Kg.

2013 Soil Investigation

In April 2013, both multiple increment sampling and XRF screening was conducted at G Range. One 100-point multiple increment sample (GR01A) was collected from a behind the berm location. The sampling area extended along the length of the berm (about 160 feet) and approximately 40 feet behind the berm. The multiple increment sample was submitted to the off-site laboratory for selected metals [antimony, copper, lead and tungsten] analysis by method SW6020. The result (Table 5-5) for lead (3,850 mg/Kg) was elevated and exceeded the MassDEP S-1/GW-1 standard and the MassDEP UCL of 3,000 mg/Kg. The result for antimony (25.4 mg/Kg) also exceeded its S-1/GW-1 standard. Copper (207 mg/Kg) and tungsten (33 mg/Kg) concentrations were also higher than those at the majority of Small Arms Ranges. The sampling location and analytical result for the behind the berm sample is presented in Figure 5-12B.

In addition to multiple increment sampling, XRF screening was conducted for selected metals at the G Range berm on both surface and subsurface soil samples. Following the methodology summarized in Section 3.2.7, the G Range berm surface was divided into six sampling areas of approximately 2,000 square feet. The sampling areas (identified as 1 through 6) are indicated in Figure 5-12B. Each sample was screened by XRF for antimony, lead and tungsten. Individual XRF screening results (Tables 3-3A) for surface soil samples for lead ranged from 260 mg/Kg (sample G3A) to 926 mg/Kg (G2C). The majority of the lead XRF surface soil screening results exceeded 300 mg/Kg. Individual XRF screening results for tungsten ranged from non-detect to 31 mg/Kg (G3A). All XRF screening results for antimony were non-detect.

Soil boring samples were collected from three berm sampling areas, which were selected based on XRF screening results from surface soil samples, as defined in Section 3.2.7. Each sample was screened by XRF for antimony, lead and tungsten. Individual XRF screening results (Table 3-3B) for subsurface soil samples for lead ranged from 15 mg/Kg (sample G2 1-2' bgs) to 515 mg/Kg in (G6 3-4' bgs). XRF screening results for antimony and tungsten were non-detect in all subsurface samples.

5.2.1.12 GA/GB Ranges

The GA/GB Ranges are non-operational ranges that were constructed sometime between 1935 and 1941 north of Dolan Road. Subsequent modifications were made in the early 1940s, expanding the existing 20 targets to 150 targets at the 200-yard GA Range, and 70 targets at the 300-yard GB Range. Wooden timbers (railroad ties) were used in the construction of east-west trending butt wall backstops for both the GA/GB Ranges. Construction specifications for these backstops indicate that the walls were fortified with crib walls built of railroad ties and backfilled with earth. Targets were manually raised and lowered in front of the butt wall. An earthen parapet was constructed uprange of the target areas to protect target operators from rifle fire. The remnants of these features for GA Range were noted in the field during reconnaissance in 2002. Construction of the former MMR UTES facility has eliminated evidence of these features in the former GB Range.

The target areas were accessed by three north-south trending tunnels that traversed the length of the 200-yard GA Range and a downrange portion of GB Range. Some tunnel entrances and collapse features in the tunnel ceilings are observable at the surface in GA Range.

Firing lines consisted of 20-foot-wide raised east-west trending embankments that sloped backward (uprange) from a height of approximately 2 feet above the surrounding terrain to form a gentle ramp from which trainees would fire rifles. These ramps were constructed of materials excavated from the target area during butt wall construction. Two separate firing lines, one at 100 yards and another at 200 yards, were constructed at GA Range. GB Range had a third firing line at 300 yards. Based on historical records, expected ammunition use was limited to .30 cal ball rounds. Use of GA/GB Ranges ended in the 1950s.

<u>GA/GB Range Investigations</u>

As part of the Phase I / Phase IIb investigations, sampling and analyses were conducted at the GA/GB Ranges (Figure 5-13A). Soil samples were collected at the soil berm, a drainage ditch, a coal ash deposit, and firing line locations. At all locations, soil samples were collected from two depth intervals (0 to 6 inches bgs and 18 to 24 inches bgs).

At the soil berm, samples were collected at three selected locations along the top of the berm (143A, 143B and 143C) where small caliber projectile fragments had been identified. Samples were analyzed for SVOCs, metals, and TCLP lead. At the drainage ditch adjacent to the soil berm, discrete samples were collected from eight locations and analyzed for the full suite of Phase I parameters. Along the east-west trending firing line, samples were collected at four locations where coal ash and slag had been previously observed. Samples were analyzed for the full suite of Phase I parameters. In addition, 10 sampling grids (5-point grids measuring 22 feet by 22 feet) were positioned along the firing lines of both ranges. At each grid, one composite sample and one discrete sample (from the center of each grid) were collected and submitted for SVOCs, pesticides, herbicides, and TAL metals analyses.

SVOCs were not detected in any samples from the GA/GB berm area. Four metals (antimony, copper, lead and manganese) were reported above background in one or more of the three samples that were collected from the berm area surface samples. Lead was reported at a maximum concentration of 128 mg/Kg at location 143E. Antimony, copper and lead were also detected above background in subsurface berm samples.

Two propellant-related compounds (2,4-DNT and n-nitrosodiphenylamine) were detected in surface soil samples collected from the GA/GB firing lines. Several additional SVOC compounds including six PAH compounds and benzoic acid were also reported in the firing line samples. Two metals (lead and molybdenum) were detected at concentrations above their respective background levels.

A number of SVOCs, including bis-2-ethylhexylphthalate, benzyl butyl phthalate and several PAHs (benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, and pyrene), were reported above background. A number of metals, including aluminum, antimony, arsenic, beryllium, cadmium, chromium, iron, lead, manganese, molybdenum, and vanadium, were also detected above background in one or more samples. The maximum reported lead concentration was 128 mg/Kg. Several pesticides were detected although none exceeded background levels.

One SVOC, naphthalene, was detected in four surface samples at a maximum concentration of 100 µg/Kg. Several metals including arsenic, barium, beryllium, boron, calcium and sodium were reported at concentrations exceeding background in one or more samples.

2013 Soil Investigation

In April 2013, additional sampling was conducted at GA/GB Range. A 100-point multiple increment sample was collected from each of the two firing lines on GA and GB Ranges (four samples - GAR01-GAR04). Each sampling area measured approximately 500 feet by 20 feet. The sampling locations are identified in Figure 5-13B. The multiple increment samples were analyzed for explosives including nitroglycerin. Explosives results were non-detect in all samples (Table 5-5).

Downrange of GA/GB Ranges

The downrange area considered in the Supplemental Investigation is located west of the UTES facility and north of GA Range. As part of the field investigation, a visual site inspection and three metal detector sweeps were conducted across the downrange area. Scattered detections of metal were found throughout the areas traversed during the metal detector sweeps with no particular pattern or areas of high accumulation of metals (Figure 5-13C).

Visual inspections included emphasis on the north end of the downrange area to inspect a location where bullets had previously been identified in the root ball of a fallen pine tree. Approximately twelve .30 cal bullets were found in an area that measures approximately one square foot just south of Pocasset-Forestdale Road. A brief inspection of two or three overturned trees in the immediate area indicated additional .30 cal projectiles.

Based upon site inspection and review, a 100-point multiple increment sample (SSGARNGO5) was collected from a 100 by 100-foot area downrange of GA/GB Ranges, where old photos indicate stressed vegetation. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (0.9 mg/Kg) and lead (94.1 mg/Kg) were below their respective MassDEP S-1/GW-1 standards (antimony - 20 mg/Kg; lead - 300 mg/Kg). Copper was detected at a concentration of 14.6 mg/Kg. There is no S-1/GW-1 standard for copper.

A second 100-point multiple increment sample (SSGARNGO6) was collected from a 100 by 100-foot location at the north end of the downrange area, just south of Pocasset-Forestdale Road. The sample area was centered on the tree described above where several bullets were found. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (0.4 mg/Kg) and lead (34.1 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 12.1 mg/Kg.

5.2.1.13 H Range

H Range is an inactive operational rifle and machine gun training range located off Pocasset-Forestdale Road on the eastern side of the access road to Demolition Area 1. The range, which is similar in design to G Range was constructed at its present location sometime in the late 1980s at more or less the same time G Range was built. It was most recently used for M16 rifle and M60 machine gun training.

The H Range firing line was nearly identical in construction to G Range (i.e., 27 firing points along a 185-foot long firing line with targets positioned 25 meters downrange). The backstop berm, which was treated during the 1998 Berm Maintenance Program, was somewhat further downrange than the one at G Range, measuring 33 feet from the target frames. However, widespread soil removal occurred at H Range during construction of the thermal treatment unit. The berm was removed and the rest of the surface soil was graded and leveled. Subsequently, much of the area was covered by a concrete pad, which still remains.

H Range Investigations

During Phase IIb investigations, three 5-point soil grids were established at the firing line to determine whether residual propellant compounds exist in soil there (Figure 5-14A). One grid (160B) was positioned near the center of the range, opposite the firing point presumed to be most frequently used. The two remaining grids (160A and 160C) were positioned downrange of firing points located near the eastern and western limits of the range. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Five propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT, and n,n'-diethylcarbanilide) were detected in one or more of the 18 samples analyzed from H Range. Di-n-butyl phthalate was the most frequently detected propellant-related SVOC and was detected in 17 samples with the maximum concentration (1.7 mg/Kg) reported in a discrete surface sample from grid 160B. Both 2,4-DNT and 2-nitrodiphenylamine were detected in 16 samples, each with a maximum concentration of 1.1 mg/Kg. Seven PAHs were also detected at trace concentrations below their MMR background levels. Thirteen metals were detected in one or more samples at concentrations exceeding their respective MMR background levels. The maximum concentration for lead (2,600 mg/Kg) was observed in a subsurface sample from grid 160B (location shown on Figure 5-14A). The average concentration of lead was 820 mg/Kg.

Thermal Treatment Unit

In 2004, the thermal treatment unit for processing contaminated soils was established at H Range. In conjunction with operational set-up, a concrete pad was constructed over much of the range.

2013 Soil Investigation

In April 2013, additional sampling was conducted at H Range. A 100-point multiple increment sample (HR01A) was collected from the area behind the former berm. Two replicate samples (HR01B and HR01C) were also collected at this location. The sampling area extended along the length of the former firing line (approximately 160 feet) and to a depth of approximately 40 feet behind where the berm was formerly located. The sampling location is identified in Figure 5-14B. The multiple increment samples were analyzed for selected metals (antimony, copper lead and tungsten). Results (Table 5-5) for lead in the original and two replicate samples ranged from 193 mg/Kg to 262 mg/Kg. Antimony concentrations ranged from 2.0 mg/Kg to 2.4 mg/Kg. Copper concentrations ranged from 20.2 mg/Kg to 24.8 mg/Kg. Tungsten concentrations ranged from 1.3 mg/Kg to 2.1 mg/Kg.

5.2.1.14 I Range

I Range is an active operational 25-meter rifle range located on Pocasset-Forestdale Road east of the H Range. It was constructed concurrently with G and H Ranges at what was originally the F Range. Between 1960 and the late 1980s, F Range functioned as a rifle range and tank-mounted coaxial machine gun range. Ammunition used at that time included .30 cal, 5.56mm, and 7.62mm ball rounds. At the tank machine gun qualification range, there were 10 firing points from which a moving target was fired upon. Between the late 1980s and 1991 the range continued to be used for tank-mounted machine gun training under the I Range designation. Thereafter, range use reverted to rifle, shotgun and pistol training using various types of ammunition.

The current range layout is nearly identical to G and H Ranges: 27 firing points along a 185-foot long firing line with target frames positioned 83 feet (25 meters) from the firing line. The first of two backstop berms is located at approximately 15 feet downrange of the target frames. Both berms were treated during the 1998 Berm Maintenance Program. The remnants of the Former F

Range moving target mechanism (i.e., narrow-gauge steel rails) are located between the two berms. Soil removal at I Range was also included in the 2006 Tungsten Removal Project.

I Range Investigations

In October 2000, as part of the Phase IIb investigations, soil samples were collected from a central location (129A and 129B) along the firing line of this range immediately after a live-fire training exercise to evaluate possible impacts to soil from the airborne deposition of propellant-related compounds.

In subsequent Supplemental Phase IIb investigations conducted in 2002, two 5-point soil grids (129C and 129D) were established at the firing line to determine whether residual propellant compounds exist in soil there (Figure 5-15A). The grids were positioned downrange of firing points located near the eastern and western limits of the range. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers. The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of the MMR target compound list of 78 SVOCs and 25 TAL metals.

Three sampling locations (129E, 129F, and 129G) were also established within a clearing located beyond the northernmost berm where numerous small arms projectile fragments were observed to measure the concentrations of residual metals present in soils there. Using the approach consistent with that used at the Former B, C, and D small arms range backstops in earlier Phase IIb investigations, discrete soil samples were obtained from two depth intervals (0 to 6 inches bgs and 18 to 24 inches bgs) at these locations. The samples were submitted for TAL metals analysis.

Five propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT and n,n'-diethylcarbanilide) were detected in one or more of the total of 25 samples analyzed from I Range. N-nitrosodiphenylamine was the most frequently detected propellant-related compound (20 samples) and was detected at a maximum concentration of 0.48 mg/Kg in a discrete surface sample from grid 129D. 2,4-DNT was detected at a maximum concentration of 0.057 mg/Kg in a sample from grid 129A. Low levels of a few other SVOCs including fluoranthene and bis(2-ethylhexyl)phthalate were detected in certain samples. Two metals (copper and lead) were detected in one or more samples at concentrations above their respective MMR background levels. The maximum lead concentration reported during the October 2000 sampling event was 585 mg/Kg (129A), while the maximum concentration reported in 2002 was 35.3 mg/Kg.

2006 Removal Action

In 2006, a soil removal action was implemented at I Range as part of a Berm Maintenance Project (as discussed in Section 4.2). The objective of this removal action was to excavate tungsten-contaminated soils to reduce overall soil tungsten concentrations at the berm. Preliminary field XRF evaluations were conducted to characterize soil tungsten concentrations prior to the excavation. At I Range, focused excavations were conducted along the back and crest of the berm to a depth of approximately 0.5 feet. Middle and toe areas of the berm were excavated to depths of up to approximately 3 feet and 2 feet, respectively. Post excavation field XRF screening and off-site laboratory soil analyses were conducted to confirm the effectiveness of the removal efforts.

As a consequence of the removal action, the maximum residual concentration of tungsten was 2.5 mg/Kg (sample SSIRNG01). The maximum residual concentration of lead was 585 mg/Kg (sample SS129A) and the average was 54 mg/Kg.

2012 Soil Sampling

In May 2012, soil sampling was conducted at the I Range to characterize tungsten and lead contamination at the two range target berms. The sampling effort focused on the target berms and the trough between the berms. Thirty-point composite surface soil samples were collected from 0 to 3 inches bgs at 18 sampling girds, each between 800 and 1,000 square feet in size. Hand auger soil borings were advanced at the center of nine of the sampling grids and soil samples were collected at 1 to 2, 3 to 4, and 5 to 6 feet bgs or refusal.

All samples were screened for tungsten and lead in the field by XRF. XRF lead and tungsten screening results were compared to the established range action levels of 3,000 mg/Kg for lead and 35 mg/Kg for tungsten. Based on this comparison, Grid 1 located at the western edge of the front berm was subdivided into six sub-grids and additional soil boring samples were collected and analyzed for tungsten to delineate soil excavation areas. Approximately 20 cubic yards of soil were excavated from this grid and a 30-point post excavation sample was then collected. The results for lead and tungsten from the post-excavation sample were below the range action levels.

2013 Soil Investigation

In April 2013, additional sampling was conducted at I Range. One 100-point multiple increment sample (IR01A) was collected from a behind the berm location. The sampling area extended along the length of the berm (about 250 feet) and approximately 40 feet behind the berm. Two field replicates (IR01B and IR01C) were also collected from this location. The sampling location is identified in Figure 5-15B. The multiple increment samples were analyzed for selected metals [antimony, copper, lead and tungsten]. The maximum reported concentrations (Table 5-5) for antimony (2.2 mg/Kg) and lead (230 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper and tungsten were detected at maximum concentrations of 20.5 mg/Kg and 2.5 mg/Kg, respectively. Results for the replicate samples were generally consistent with the results of the original sample.

Post-Reconstruction Pore-Water Investigations

I Range has been used only for copper bullets since it was reconstructed in 2012. Reconstruction included limited soil excavation and removal to reduce lead and tungsten concentrations on the berm. Then, additional soil was placed on the berm face. Pore water sampling has been conducted on the range as per the range standard operating procedure. Elevated concentrations of antimony, copper and lead (10.1 µg/L, 1,020 µg/L, and 25.1 µg/L, respectively) were detected in a pore water lysimeter at the base of the berm during operational sampling in Summer 2013. These concentrations are significantly higher than the antimony, copper, and lead detected in previous sampling rounds (7.1 µg/L, 178 µg/L, and 2.1 µg/L, respectively). The increase of metals concentrations is an indication that sediment may be a factor in these unfiltered samples. Bullets containing lead and antimony have not been fired into the I Range berm since re-construction so contributions of these metals from on-going training are negligible. The lysimeter will be sampled again in 2014 and the results will be compared to the previous results.

5.2.1.15 J Range

The J Range is an active operational pistol range located immediately west of the K Range on Pocasset-Forestdale Road. It was established in the late 1980s at the site of the former Air Force A pistol range. Records indicate that it continued to be used as a pistol range after the name change, and a variety of types of ammunition have been authorized for use at the J Range (USACE 1999, 2001). Ammunition used at J Range has included 9mm, .38 cal, .40 cal, and .45 cal pistol ammunition, .30 cal revolver, 5.56mm rifle, and 12 gauge shotgun ammunition. Sixteen firing points are positioned along the 104-foot-long east-west trending firing line. Target frames are located approximately 83 feet (25 meters) north of the firing line. The backstop berm, which was treated during the 1998 Berm Maintenance Program, is positioned approximately 53 feet beyond the target frames. Soil removal at the J Range was also conducted under the 2006 Tungsten Removal Project, the 2008 Range Floor and Berm Face Removal Project, and the 2009 lead removal action.

J Range Investigations

Phase IIb Sampling

During Phase IIb investigations, in 2000, three 5-point soil grids (161A, 161B, and 161C) were established at the firing line to determine whether residual propellant compounds exist in the soil there (Figure 5-16A). The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and metals. In addition, three locations were established within the clearing located beyond the backstop berm (161D, 161E, and 161F) where numerous small arms projectile fragments were observed. Discrete soil samples were obtained from 0 to 6 inches bgs and 18 to 24 inches bgs at these locations and submitted for SVOC and metals analysis.

Five propellant-related SVOCs were detected among the 18 soil samples collected from the J Range firing line including, n,n’-diethylcarbanilide, 2-nitrodiphenylamine, n-nitrosodiphenylamine, 2,4-DNT and di-n-butyl phthalate. N,n’-diethylcarbanilide was detected at a maximum concentration of 1 mg/Kg. The maximum concentrations of n-nitrosodiphenylamine (0.59 mg/Kg) and 2,4-DNT (0.25 mg/Kg) were detected in surface samples from grids 161B and 161A, respectively. Nine other SVOCs including eight PAHs were detected in firing line samples although none exceeded background concentrations. Thirteen metals were detected in one or more of 25 samples at concentrations above their MMR background levels. The maximum concentration of lead (400 mg/Kg) was detected in a sample from grid 161D.

2006 Removal Actions

In 2006, a berm maintenance action was implemented at the J Range to reduce the berm tungsten concentrations. Initially, pre-excavation XRF screening was conducted to identify soil berm areas with tungsten concentrations exceeding 150 mg/Kg. At J Range, focused excavations were conducted along the back and crest of the berm to a depth of approximately 0.5 feet. Middle and toe areas of the berm were excavated to depths of up to approximately 3 feet and 2 feet, respectively. Post-excavation XRF screening results indicated the maximum residual soil berm tungsten concentration to be 146 mg/Kg, below the 150 mg/Kg cleanup level.

Multiple Increment Sampling

Multiple increment sampling was performed at the J Range during September-October 2007 to complete characterization of the range prior to reopening the range to small arms training. A supplemental sampling effort was performed in December 2007 to better refine the areas of concern identified within the range floor during the September 2007 sampling effort.

During the September 2007 multiple increment sampling program, the J Range was divided into four areas (Figures 5-16B and 5-16C). All multiple increment samples were either 50- or 100-point composites in accordance with the Project Note (IAGWSP 2007). Subsurface soil samples were 30-point composites. Replicate (triplicate) samples were collected from multiple locations including firing line, range floor, and berm face areas. Firing line and range floor samples were analyzed for explosives, SVOCs, perchlorate, metals, and total organic carbon. Berm face and behind berm samples were analyzed for metals. A suite of six metals (arsenic, antimony, chromium, copper, lead, and tungsten) was analyzed at the range.

During the December 2007 sampling effort, the range floor was divided into four sub areas and multiple increment samples were collected from each. Two additional sampling areas were established in an area to the immediate south of the original firing line. All surface soil multiple increment samples were either 50- or 100-point composites. Multiple increment samples were analyzed for explosives and metals during the December 2007 program.

Nitroglycerin was the predominant propellant-related compound detected at J Range. It was detected in surface soil samples from both firing line and range floor samples. During the September 2007 sampling program, the highest nitroglycerin concentrations were observed in multiple increment samples from the firing line with concentrations ranging from 31 mg/Kg to 42 mg/Kg. Nitroglycerin was not detected in the firing line (9 to 12 inches bgs) subsurface sample. 2,4-DNT was also detected in multiple J Range firing line soils but not in range floor samples. 2,4-DNT concentrations in firing line samples ranged from 0.069 mg/Kg to 0.19 mg/Kg.

Consistent with the September 2007 results, nitroglycerin was the principal propellant-related compound reported during the December sampling round. Nitroglycerin was observed in samples from both the Firing Line 2 and Firing Line 3 sampling areas. The maximum concentration (73 mg/Kg) was observed in a replicate sample from the Firing Line 2 area. However, the two other replicate concentrations were both 12 mg/Kg. Nitroglycerin was also detected in range floor surface soil samples at concentrations up to 49 mg/Kg (Range Floor 2).

Nitroglycerin was not detected in the subsurface soil sample (9 to 12 inches bgs) from Range Floor 1.

Several other propellant-related SVOCs (including 2-nitrodiphenylamine, n-nitrosodiphenylamine, di-n-butyl phthalate, and n,n'-diethylcarbanilide) were observed in soil samples from firing line and range floor samples during the September 2007 sampling program. Concentrations of these four propellant-related compounds were generally low with the maximum observed concentrations of these compounds, in all cases, being less than 1.0 mg/Kg. N-nitrosodiphenylamine and n,n'-diethylcarbanilide were also detected at low levels during the December sampling event.

Low levels of a variety of PAHs were detected in surface and subsurface soil samples from the firing line, range floor, and behind berm sample areas of the J Range during the September 2007 sampling program. For the observed PAHs (including pyrene, fluorene, benzo(a)pyrene, benzo(a,h)anthracene, etc.) the maximum concentrations at J Range were in all cases less than 0.4 mg/Kg.

Results for metals during the September and December 2007 sampling programs were variable across the J Range (Figure 5-16C). Most of the six metals that were analyzed were detected in most range surface soil samples. During September 2007, arsenic was detected in all surface soil samples with the highest concentration of 14.7 mg/Kg observed in a firing line sample. All results for arsenic were comparable to background. Antimony was reported in a number of surface soil samples with the maximum concentration (79.5 mg/Kg) observed at the firing line. The maximum chromium detection reported was 12.6 mg/Kg. Copper concentrations in surface soils ranged up to 636 mg/Kg. Lead was detected at J Range with the maximum observed concentration (9,010 mg/Kg) reported for a firing line sample. Elevated lead levels (greater than 300 mg/Kg) were also observed in several range floor samples. The maximum observed tungsten concentration (34 mg/Kg) was reported in a berm face sample.

December 2007 maximum reported concentrations for antimony (35.2 mg/Kg), arsenic (18 mg/Kg) and chromium (16.7 mg/Kg) were generally similar to the levels observed in the September 2007 sampling event. However, the maximum observed concentrations of copper (50.9 mg/Kg) and lead (2,100 mg/Kg) were distinctly lower than the levels reported for September.

The reasons for the variability in the nitroglycerin and metals triplicate sample results in Figures 5-16B and 5-16C are uncertain, but similar data variability has been seen in other multiple increment triplicate samples collected at MMR. With respect to the metals including lead, the variability may reflect the presence or absence of small bullet/lead fragments in certain soil subsamples but not others. Concentrations of nitroglycerin have been observed to be rather heterogeneous at certain range sampling locations. Nitroglycerin is likely encased/absorbed in nitrocellulose. The nitrocellulose may be heterogeneously distributed in soil, not uniformly adsorbed to all soil particles.

2008 Berm Maintenance – Nitroglycerin Removal

In September 2008, a soil removal action was conducted to reduce surface soil nitroglycerin concentrations (as discussed in Section 4.2). Soil removal was conducted in accordance with the Project Note entitled "Juliet and Kilo Range Soil Sampling and Soil Removal of Range Floor and Juliet Range Berm Face" (IAGWSP 2008). Sampling areas including Range Floor 1, Range Floor 2, Range Floor 3, Firing Line 1, Firing Line 2, and Firing Line 3 were excavated to a depth of one foot. Post-excavation soil multiple increment samples were collected to confirm the effectiveness of the removal action. Nitroglycerin was not detected in the post-excavation samples. During the 2008 and 2009 soil removal efforts at J Range (discussed below), a combined total of approximately 900 cubic yards of soil were excavated. This soil was transported and stockpiled on K Range.

2009 Removal Action

In 2009, additional soil excavation was conducted as part of a lead removal action at J Range. Approximately six inches of soil was removed from behind the target berm and transported to the Former D Range for screening and preparation for on-site reuse and recycling.

As a consequence of these removal actions, the maximum residual concentration of nitroglycerin was 4.6 mg/Kg (sample JR10003GB), and the maximum residual concentration of lead was 192 mg/Kg (sample SSJRNG003).

2010 Operation and Maintenance Sampling

As part of the 2010 operation and maintenance monitoring program at the J Range, multiple increment samples were collected from six equal-sized grids identified as JR-1 through JR-6. Each of these multiple increment samples consisted of soil from 100-point composites, at a depth of 0 to 3 inches bgs. Multiple increment samples were collected from the grid areas, homogenized, and divided for analysis via two separate preparation/grinding protocols. A ground sample was analyzed for lead, copper, zinc, antimony, tungsten, and nitroglycerin. The unground sample was analyzed for lead, copper, zinc, antimony, and tungsten. Replicate samples were collected from grids JR-1, JR-3, and JR-5.

Results for the 2010 operation and maintenance sampling program indicated the presence of low levels of nitroglycerin in several samples. The maximum reported concentration of nitroglycerin was 4.61 mg/Kg. Concentrations of antimony, copper and zinc were relatively low and were generally comparable to background in most samples. Copper and antimony concentrations were below 20 mg/Kg in all samples. Lead concentrations were variable with the maximum detected concentration being 159 mg/Kg. However, most results were below 50 mg/Kg. Tungsten concentrations were largely non-detect with the maximum detected concentration being 0.32 mg/Kg.

2011 Operations and Maintenance Sampling

In accordance with established range-specific Best Management Practices and Operations, Maintenance, and Monitoring Plans, soil sampling was again conducted at the J Range during 2011. Multiple increment surface soil samples were collected from six equal-sized grid locations on the range. One hundred-point multiple increment samples were collected from each grid with replicates collected at three of the grid locations. Samples were analyzed for nitroglycerin and selected metals (antimony, copper, lead, zinc and tungsten). The maximum nitroglycerin concentration was 11.9 mg/Kg. The maximum lead concentration was 192 mg/Kg. Tungsten was not detected in any samples.

2012 Operations and Maintenance Sampling

In accordance with established range-specific Best Management Practices and Operations, Maintenance, and Monitoring Plans, soil sampling was again conducted at the J Range during 2012. Multiple increment surface soil samples were collected from six equal-sized grid locations on the range. One hundred point multiple increment samples were collected from each grid with replicate samples collected at one of the grid locations. Samples were analyzed for selected metals (antimony, copper and lead). The maximum copper concentration was 17.6 mg/Kg and the maximum lead concentration was 43.3 mg/Kg.

5.2.1.16 K Range

The K Range is an active operational rifle and pistol range located immediately east of the J Range on Pocasset-Forestdale Road. It was established at the same time as the J Range in the late 1980s at the site of the former Air Force B pistol range. The remnants of the former Air Force B pistol range are located at the edge of the parking area on the extreme southern end of the open area. Records indicate that the range continued to be used as a pistol range after the name change, and a variety of types of ammunition have been authorized for use at the K Range (USACE 1999, 2001). Ammunition used at K Range has included 9mm, .38 cal, .40 cal, and .45 cal pistol ammunition, .30 cal revolver, 5.56mm rifle, and 12 gauge shotgun ammunition. Twenty-six firing points are positioned along the 191-foot-long east-west trending firing line (Firing Line 2). Target frames are located approximately 80 feet (25 meters) north of the firing line. The backstop berm, which was treated during the 1998 Berm Maintenance Program, is positioned approximately 142 feet beyond the target frames. Soil removal at K Range was included in the 2006 Berm Maintenance – Tungsten Removal Project, the 2008 Range Floor Removal Project, and the 2009 lead removal project.

K Range Investigations

Phase IIb Sampling

During Phase IIb investigations, three 5-point soil grids (156A, 156B, and 156C) were established at the K Range firing line to determine whether residual propellant compounds exist in soil there (Figure 5-17A). One grid (156B) was positioned near the center of the range, opposite the firing point presumed to be most frequently used. The two remaining grids were positioned downrange of firing points located near the eastern and western ends of the range. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

An additional set of sample grids (156D, 156E, and 156F) were located at the former Air Force B Range firing line. As with the previous K Range locations, one grid (156E) was positioned near the center of the range just downrange of the firing line. The two remaining grids were positioned downrange of firing points located near the eastern and western limits of the range as were the others at the current firing line. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective land markers.

Each firing line grid was sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Several propellant-related SVOCs were detected in the 36 soil samples collected at K Range. The most frequently detected propellant-related compounds included di-n-butyl phthalate, n-nitrosodiphenylamine, 2,4-DNT, and 2-nitrodiphenylamine. All were detected in 18 or more of 36 samples. Maximum detected concentrations of these compounds were 1.8 mg/Kg, 2.3 mg/Kg, 1.7 mg/Kg and 1.7 mg/Kg, respectively. Several other SVOCs, including low levels of 10 PAHs, were detected. Nineteen metals were also detected in one or more of the 36 samples that were analyzed. The maximum concentration of lead (52.8 mg/Kg) was reported in a surface sample from grid 156B.

2006 Berm Maintenance – Tungsten Removal

In 2006, a berm maintenance action was implemented at the K Range to reduce the berm tungsten concentrations. Initially, pre-excavation XRF screening was conducted to identify soil berm areas with tungsten concentrations exceeding 150 mg/Kg. At K Range, focused excavations were conducted along the back and crest of the berm to a depth of approximately 0.5 feet. Middle and toe areas of the berm were excavated to depths of up to approximately 3 feet and 2 feet, respectively. Post-excavation XRF screening results indicated the maximum residual soil berm tungsten concentration to be 141 mg/Kg, below the 150 mg/Kg cleanup level.

2008 Multiple Increment Sampling

During 2008, multiple increment soil sampling was conducted at K Range to support MAARNG range construction plans. Multiple increment samples were collected from firing line, range floor, behind target, and behind berm areas (Figure 5-17B).

Multiple increment sampling was performed at the K Range in January 2008 in accordance with the Project Note (IAGWSP 2008) and is briefly summarized as follows. Multiple increment samples were collected from 12 sampling areas established to encompass the entire range. Two sampling areas were established at the firing lines at K Range (one sampling area at each of the two firing lines at the range). Six sampling areas were established across various elements of the range floor. In addition, two sampling areas were established behind the target array, one at the berm face and one behind the berm.

All surface soil multiple increment samples were either 50-, 100- or 200-point composites. Subsurface soil samples were 30-point composites. Replicate samples were collected from multiple locations, including firing line and behind target sampling areas.

Nitroglycerin was the predominant propellant-related compound detected at K Range. It was detected in surface soil samples from the firing lines, the majority of the range floor samples, and the behind target areas. The highest nitroglycerin concentrations were observed in multiple increment surface samples from the firing lines with concentrations generally ranging from 31 mg/Kg to 70 mg/Kg. The highest nitroglycerin concentration was observed in a replicate sample from Firing Line 1. However, nitroglycerin was detected at only a low concentration (3.2 mg/Kg) in the subsurface sample (6 to 9 inches bgs) from Firing Line 1 and was not detected in the subsurface sample from Firing Line 2. Nitroglycerin was detected at lower concentrations in certain range floor (2.8 mg/Kg to 23 mg/Kg) and behind target samples (2.6 mg/Kg to 3 mg/Kg).

2,4-DNT was also confirmed in multiple K Range samples. 2,4-DNT concentrations in firing line samples were generally higher than those observed for the range floor. Firing line 2,4-DNT concentrations ranged from 0.13 mg/Kg to 1.7 mg/Kg. (Based on these results, a surface soil excavation was implemented in September 2008 [discussed in Section 4.2].)

Several propellant-related SVOCs (including 2-nitrodiphenylamine, n-nitrosodiphenylamine, di-n-butyl phthalate, and n,n'-diethylcarbanilide) were also observed in soil samples from certain firing line, range floor, and behind berm areas of the range. Concentrations of these four propellant-related compounds were generally low with the maximum observed concentrations of these compounds, in all cases, being less than 1.3 mg/Kg. Low levels of a variety of semivolatiles (primarily PAHs) were detected in surface and subsurface soil samples from the firing line, range floor, and behind berm areas of the K Range. For the observed PAHs (including pyrene, fluorine, benzo(a)pyrene, benzo(a,h)anthracene, etc.), the maximum observed concentrations at K Range were in all cases less than 0.4 mg/Kg.

Results for metals were variable across the K Range (Figure 5-17C). Most of the six metals that were analyzed were detected in most range surface soil samples. Arsenic was detected in all surface soil samples with the highest concentration 4.9 mg/Kg observed in a behind target sample. Antimony was reported in a number of surface soil samples with the maximum concentration (5.7 mg/Kg) observed in a behind-target sample. Chromium concentrations (unground) in surface soil samples ranged up to a maximum of 73.3 mg/Kg. Copper concentrations in surface soils (unground) ranged up to 61 mg/Kg. Lead was detected in a number of samples at K Range with the maximum observed concentration 955 mg/Kg, but the unground sample result for this behind target sample was 754 mg/Kg. Elevated lead levels (greater than 300 mg/Kg) were also observed in some berm face and behind berm samples. Lower lead levels (less than 200 mg/Kg) were reported for firing line and range floor samples.

2008 Berm Maintenance – Nitroglycerin

In 2008, a soil removal action was implemented at the K Range to reduce surface soil nitroglycerin concentrations (see also Section 4). Soil removal was conducted in accordance with the Project Note entitled "Juliet and Kilo Range Soil Sampling and Soil Removal of Range Floor and Juliet Range Berm Face" (IAGWSP 2008). Range areas including Firing Line 1 and Range Floor 4 were excavated to depths of one foot and six inches, respectively. In addition, portions of the Range Floor 5 and Range Floor 6 areas were modified to remove nitroglycerin in conjunction with the construction of the STAPP™ bullet catcher system for the site. During the 2008 and 2009 (discussed below) soil removal efforts at K Range, a combined total of approximately 300 cubic yards of soil were excavated. The soil is stockpiled behind the berm at K Range. Since studies demonstrate that nitroglycerin is not a threat to groundwater the soil is available to be used for range maintenance activities.

2009 Removal Action

In 2009, additional soil excavation was conducted as part of a lead removal action at K Range. As a consequence of these removal actions, the maximum residual concentration of tungsten is

47.2 mg/Kg (sample SSKRBF0003-C-01U), the maximum residual concentration of nitroglycerin was 46 mg/Kg (sample SSKRFL20003-C-04), and the maximum residual concentration of lead was 955 mg/Kg (sample SSKRBT20003-C-01), and the average residual lead concentration was 205 mg/Kg.

2010 Operation and Maintenance Sampling

As part of the 2010 operation and maintenance monitoring program, multiple increment samples were collected from six equal-sized grids identified as KR-1 through KR-6. These multiple increment samples consisted of soil from 100-point composites, at a depth of 0 to 3 inches bgs. Multiple increment samples were collected from the grid areas, homogenized, and divided for analysis. The laboratory ground sample was analyzed for lead, copper, zinc, antimony, tungsten, and nitroglycerin. The unground sample was analyzed for lead, copper, zinc, antimony, and tungsten. Two additional replicate samples were collected from grids KR-1, KR-3, and KR-5.

Results for the 2010 operation and maintenance sampling program indicated the presence of low levels of nitroglycerin in some samples. The maximum reported concentration of nitroglycerin was 5.29 mg/Kg. Concentrations of antimony, copper and zinc were relatively low and comparable to background in most samples. Antimony was not detected. Concentrations of copper were below 20 mg/Kg in all samples. Lead concentrations were relatively low. The maximum reported concentration was 31 mg/Kg. Tungsten was not detected in most samples and the maximum concentration (0.19 mg/Kg) was close to the analytical detection limit.

2011 Operations and Maintenance Sampling

In accordance with established range-specific Best Management Practices and Operations, Maintenance, and Monitoring Plans, soil sampling was again conducted at the K Range during 2011. Multiple increment surface soil samples were collected from six equal-sized grid locations on the range. One hundred-point multiple increment samples were collected from each grid with replicates collected at three of the grid locations. Samples were analyzed for nitroglycerin and selected metals (antimony, copper, lead, zinc and tungsten). The maximum nitroglycerin concentration was 22.4 mg/Kg. The maximum lead concentration was 35.5 mg/Kg. Tungsten was not detected in any samples.

5.2.1.17 KD Range (East)

KD Range is an active operational range located on Pocasset-Forestdale Road east of the K Range. This range, originally known as the CTR-1 and CTR-2 Aerial Gunnery Range, was constructed in the mid-1970s. It received its KD (known distance) designation in the mid-to late-1980s and was used for rifle, grenade launcher, and missile training exercises. KD Range consists of two separate parallel ranges: KD Range (East) and KD Range (West). KD Range (West) was used for a variety of types of ordnance, including TOW missiles and 90mm recoilless rifle HEAT rounds, and is not evaluated in this report. KD Range (West) is being evaluated under the Training Areas Operable Unit.

A 600-meter known distance rifle range is situated on KD Range (East). The range consists of six mounded firing lines, each having 20 firing points, positioned at various distances from a raised target line. Five firing lines are spaced at regular 100-yard intervals from the target line (i.e., positioned 100 through 500 yards from the targets). The sixth firing line berm was situated between the 300 and 400 yard firing lines at 100 meters from the targets. Known ordnance use at this range includes 5.56mm and 7.62mm ball and tracer rounds. Shell casings (5.56mm) are present on most of the raised firing lines. Target frames are positioned at the top of a 12-foot high earthen berm located at the end of the range. The face of this target berm was treated during the 1998 Berm Maintenance Program.

Several abandoned Coast Guard boat hulls were discovered during the inspection of a vegetated area located downrange of the target berm. Other items found with the boat hulls included several empty 55-gallon steel drums, a junked diesel generator, scrap metal, and a cluster of expended teargas grenades. The larger items discovered (i.e., boat hulls, generator, and drums) are thought to have been intended for use as future targets for the Camp Edwards Impact Area.

KD Range (East) Investigations

During Phase IIb investigations, samples were collected from three of the six firing lines (Figure 5-18A). Three 5-point soil grids were established at each of three selected firing lines (100-, 300-, and 500-yard mounds) to determine whether residual propellant compounds exist in soil there. Three grids (162B, 162E, and 162H) were positioned near the center of the range on the downrange face of the three selected firing lines. The remaining grids (162A, 162C, 162D, 162F, 162G, and 162I) were positioned in the same relative position near the eastern and western limits of the range. The center nodes for each of the nine grids were positioned approximately 10 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

In addition, one soil grid (162K) was located among the empty 55-gallon drums. Samples were collected from the same depth intervals as at the firing lines and analyzed for the full suite of Phase I parameters (i.e., explosives, SVOCs, metals, VOCs, pesticides, PCBs, and herbicides). A single discrete sampling point (162J) was also located at a cluster of expended chloroacetophenone (CN) teargas grenades. Discrete soil samples were again obtained from the same depth intervals, and analyzed for SVOCs to detect the presence of CN or its degradation products, which will appear among the tentatively identified compounds if present at detectable concentrations.

Eight propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT, n,n'-diethylcarbanilide, di-n-octyl phthalate, dimethyl phthalate, and diethyl phthalate) were detected in one or more of the 68 samples analyzed from KD East Range. The two most frequently detected compounds were di-n-butyl phthalate (18 samples) and n-nitrosodiphenylamine (14 samples). Maximum reported concentrations for these two compounds were 0.31 mg/Kg and 0.3 mg/Kg, respectively. 2,4-DNT was detected in four samples at a maximum concentration of 0.2 mg/Kg. Di-n-octyl phthalate, dimethyl phthalate and diethyl phthalate were all detected in two or fewer samples. Several additional SVOCs including nine PAHs were detected in one or more samples. Seventeen metals were detected in one or more samples at concentrations above their respective MMR background levels. The maximum detected concentration of lead (147 mg/Kg) was reported for the discrete surface sample from grid 162K.

2013 Soil Investigation

In April 2013, both multiple increment sampling and XRF screening analyses were conducted at KD Range (East). One 100-point multiple increment sample (KDR01A) was collected from a behind the berm location. The sampling area extended along the length of the berm (about 200 feet) and approximately 40 feet behind the berm. Two field replicates (KDR01B and KDR01C) were also collected from this location. The multiple increment samples were submitted to the off-site laboratory for selected metals [antimony, copper, lead and tungsten] analysis by method SW6020. The maximum concentrations (Table 5-5) for antimony (1.6 mg/Kg), copper (13.4 mg/Kg), lead (49.5 mg/Kg) and tungsten (1.1 mg/Kg) were relatively low and comparable to or below most other Small Arms Ranges. Results for the replicate samples were generally consistent with the results of the original sample. The sampling location and analytical results for the behind the berm sample is presented in Figure 5-18B.

In addition to multiple increment sampling, XRF screening was conducted for selected metals at the KD Range berm on both surface and subsurface soil samples. Following the methodology summarized in Section 3.2.7, the KD Range berm surface was divided into three sampling areas of approximately 2,000 square feet. The sampling areas (identified as 1 through 3) are indicated in Figure 5-18B. Each sample was screened by XRF for antimony, lead and tungsten. Individual XRF screening results (Table 3-3A for surface soil samples for lead ranged from 62 mg/Kg (sample KD2A) to 110 mg/Kg (KD1A). All lead XRF surface soil screening results were well below 300 mg/Kg. Individual XRF screening results for tungsten ranged from non-detect to 21 mg/Kg (KD1A). All XRF screening results for antimony were non-detect.

Soil boring samples were collected from three berm sampling areas, which were selected based on XRF screening results from surface soil samples, as defined in Section 3.2.7. Each sample was screened by XRF for antimony, lead and tungsten. Individual XRF screening results (Table 3-3B) for subsurface soil samples for lead ranged from 9 mg/Kg (KD3A 3-4’ bgs) to 148 mg/Kg (KD2 1-2’ bgs). XRF screening results for antimony and tungsten were non-detect in all subsurface samples.

5.2.1.18 Former K Range (1941-1950s)

The original K Range is a non-operational range that was constructed as a moving target rifle range in 1941 off Greenway Road just north of Wood Road, in the area now known as the USCG Communications Station (Figure 5-19). The range had two firing lines, a 200-yard firing line 915 feet long and a 300-yard firing line 1,360 feet long. The firing lines ran parallel to Greenway Road, with the 300-yard firing line located just west of Greenway Road. Both lines fired at a target butt made of railroad ties and earth. Silhouette targets were carried on sticks by soldiers behind the target butt to simulate moving targets. Expected ordnance use on K Range is limited to .30 cal ball rounds. Direction of rifle fire was to the northwest. No impact berm was present, but poorly fired rounds could have impacted on the target butt wall. K Range was used as a moving target rifle range until the 1950s.

During the Phase IIb range inspection, no evidence of small arms usage was identified. Thus, field sampling investigation was not conducted at Former K Range as part of the Phase IIb Small Arms Range Program. This range will be investigated under the Military Munitions Response Program managed by the Air Force Civil Engineering Center.

5.2.1.19 L Range (1941-1950s)/L-1 Range

The first L Range is a non-operational range that was constructed in 1941 and was known as the Musketry Range Number 2 (Figure 5-20A). It was located along Greenway Road running from the northern end of the USCG Communications Station almost to Gibbs Road. L Range was very similar to the other musketry range used during this time. The primary difference was that troops would combine fire and movement on L Range to defeat the enemy as simulated by randomly appearing silhouettes. It is believed that the musketry range was used into the 1950s and that only .30 cal ball rounds were used. The direction of rifle fire would have been westerly and no berm would have been present on the range.

L-1 Range is a non-operational range that is believed to have been similar in purpose to L-2, L-3, and L-4 Ranges (see below). It was constructed within the footprint of the L Range. The L and L-1 Ranges were not investigated during the Phase IIb investigation.

L-1 Range

L-1 Range was investigated during the May 2013 Supplemental Investigation. As noted above, this range was located along Greenway Road within the footprint of the original L Range (40s-50s). Initial site visits had identified two man-made features of interest on this range. The first was a wood-reinforced pit that may have been either a fighting position or an objective used for troop infiltration training on the range. The other was a 2 to 3-foot deep trench dug into the ground several hundred yards to the west of the pit. A metal detector sweep was conducted around the wood-reinforced pit at the top of the hill. This sweep resulted in several detections of metal in the area (Figure 5-20B). A sweep conducted while walking from the dugout westward to the trench had no metal detections. Very little was detected at the trench. The most prominent detection was far too big to be a bullet and was probably a piece of wire or cable about 3 feet long. An empty ammunition clip was found, but there were no signs of any accumulations of bullets. The empty clip suggests that this feature was more likely used as a firing position than a target. Based upon the lack of detections during the metal detector sweeps, no sampling was conducted at the trench area.

Based upon the visual inspection and metal detector results, multiple increment sampling was conducted in an area that included the wood-reinforced dugout and the surrounding area where the greatest concentration of ring-offs from the metal detector occurred. A 30-point multiple increment sample (SSFMRL101) was collected from an approximately 40 by 40-foot area. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (0.9 mg/Kg) and lead (60.2 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 15.4 mg/Kg.

5.2.1.20 L Range (1950s-Late 1980s)

In the 1950s, L Range moved to a location south of Gibbs Road (Figure 5-20C). From the 1950s until the late 1980s, L Range changed names several different times, but its use remained essentially the same. During that time period, it was known as a combat firing range, close combat course, squad in attack course, and squad/platoon attack course. These types of ranges/courses are generally live fire courses where small sized units attack and maneuver through various types of stationary targets. Known ordnance use during this era includes .30 cal, 5.56mm, and 7.62mm ball and tracer rounds. Direction of fire was southwest and no impact berm was present on the range. The designation of L Range for this location was used until the late 1980s. During the Phase IIb range inspection, no evidence of small arms usage was identified and field sampling investigations were not conducted at this L Range location.

During the May 2013 Supplemental Investigation, a visual investigation and metal detector sweep were performed at this site. The metal detector sweep was made from east to west and then back again, a couple of hundred yards further north (Figure 5-20C). No significant metal debris was detected and there was no visual evidence of past use of the area as a range. Although it is likely a drainage structure associated with Gibbs Road, the U-shaped earthen berm on the north edge of the area was the only man-made feature on the site. As such, a metal detector sweep was completed on the berm. No metal was detected. There were no visual or metal detector indications that this area was ever a small arms range. Because no metal was detected and no features indicative of use of the area as a small arms range were observed, no multiple increment sampling or off-site laboratory analysis was conducted.

5.2.1.21 L-2, L-3, and L-4 Ranges

A series of four L Ranges existed primarily in the 1940s. Although they are not mentioned in any construction reports, they are shown on historical maps from the 1940s. As noted above, L-1 Range was located within the boundaries of L Range at that time. L-2 Range was located west of Gibbs Road in the current Training Area B-11 (Figure 5-21A). L-3 Range was also located in the current Training Area B-11 north of Cat Road and west of Jefferson Road (Figure 5-22A). Lastly, L-4 Range existed in the current Training Area C-16 on the east side of Barlow Road (Figure 5-23A). All four ranges are currently non-operational.

A 1949 map indicates all four ranges were infantry squad and platoon combat firing ranges. Available documentation does not provide any information regarding the purpose or layout of the ranges or ordnance used on the ranges. Because available maps do not show range safety fans around these ranges as they do for all the firing ranges, it is possible that only small arms blank rounds would have been used there. It is also believed that these ranges were used until the late 1940s or possibly early 1950s. Since then, no range on Camp Edwards has used the designation of L-1, L-2, L-3, or L-4.

Field sampling investigations were conducted at the L-2 under Phase IIb while L-3 Range was investigated in conjunction with the Northwest Corner Operable Unit. Phase IIb field sampling investigations were not conducted at the L-1 and/or L-4 Ranges since they were anticipated to be similar to L-2 and L-3 Ranges.

L-2 Range Sampling

Thirteen samples were collected from L-2 Range in January 2000 pursuant to the Phase IIb investigations. These samples were analyzed for explosives, metals and inorganics, pesticides/herbicides, SVOCs, VOCs, and PCBs.

The propellant-related compounds detected were a single detection of bis(2-ethylhexyl)phthalate at 3.6 mg/Kg and three trace detections of n-nitrosodiphenylamine (0.019 to 0.068 mg/Kg). PAHs, most metals and other inorganic compounds were detected at concentrations consistent with background levels. However, the maximum detected concentration of lead was 137 mg/Kg and exceeded its background concentration. The herbicide MCPA was detected in one sample, but this is likely to be a false positive. Dieldrin, DDE, and DDT were detected in a few samples, at low concentrations.

As part of the May 2013 Supplemental Investigation, two metal detector sweeps were made across this range, including one traverse running nearly the entire length of the range (Figure 5-21B). No metal detections indicative of possible accumulations of bullets were detected during either sweep. Based upon the visual observations and metal detector results, no multiple increment soil sampling was conducted at this range.

L-3 Range Sampling (Target Pits, Soil Piles)

Soil sampling was conducted at the L-3 Range in August and October 2004 as part of the Northwest Corner investigation to evaluate the potential for this area to be a source area for perchlorate in groundwater and as a source for contaminants in soil (metals and SVOCs) associated with the use of the area as a Small Arms Range. Surface soil samples were collected at eight target pits from 0 to 0.5 and 1.5 to 2 feet bgs for the analysis of perchlorate, metals, and SVOCs (208A through 208H).

Samples were also collected from the areas identified as having the highest bullet/fragmentation density (208AB through 208HB). Discrete samples were collected from 0 to 0.5 feet bgs and 1.5 to 2.0 feet bgs and submitted for the analysis of total metals and TCLP metals. In addition to the samples at the L-3 Range target pits, soil samples were also collected from each of three soil piles north of L-3 Range. These data including the TCLP data are included in Appendix A.

The propellant-related compounds detected were a single trace detection of perchlorate (0.00243 mg/Kg) and a single trace detection of bis(2-ethylhexyl)phthalate (0.032 mg/Kg). With the exception of lead, metals and inorganics were detected at concentrations comparable to background levels. The maximum detected concentration of lead was 354 mg/Kg. Three SVOCs (2-chlorobenzoic acid, benzoic acid, and pyrene) were each detected once or twice at trace levels.

As part of the May 2013 Supplemental Investigation, a visual inspection and one metal detector sweep was made through this range (Figure 5-22B). During this traverse, as many as three berms were visually identified. The concentration of metal detections in the berm areas was relatively low. Subsequently, a pit was visually identified to the west at the south end of the range and swept with the metal detector. At this location, a significant number of metal detections indicated the possible presence of an accumulation of bullets in and near the pit.

Based upon the metal detector results, a 30-point multiple increment sample (SSL3RNG01) was collected from an approximately 15 by 15-foot area at the target pit. The sample was screened using XRF at the site trailer (Section 3.2.7) and analyzed off-site for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (1.4 mg/Kg) and lead (77.4 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 15.2 mg/Kg.

L-4 Range

L-4 Range was investigated during the May 2013 Supplemental Investigation. As noted above, the range was located in current Training Area C-16 on the east side of Barlow Road. A metal detector sweep was conducted along the perimeter pathway around the range (Figure 5-23B). One earth pile and two pits were visually identified. No metals were detected in the pits; however, metal detections were recorded in the berm indicating the possibility of an accumulation of bullets in the earth pile.

Based upon the metal detector results, a 30-point multiple increment sample (SSL4RNG01) was collected from the soil pile. The sample was screened using XRF (Section 3.2.7) and analyzed off-site for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (0.9 mg/Kg) and lead (12 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 5.4 mg/Kg.

5.2.1.22 M Range

The first known range with the designation “M Range” was given to what is presumed to be the Former M-2 Range off Greenway Road at the southeast corner of MMR. In 1970, the M Range designation was given to what was possibly the Former M-1 Range approximately 500 yards south and west of the Former M-2 Range. After around 1980, the M Range is thought to have been moved north to the location of the J-1 Range; however, no references to M Range after 1983 have been discovered.

5.2.1.23 Former M-1 Range

The Former M-1 Range is a non-operational small arms training site located near the intersection of Greenway and Pocasset-Forestdale Roads. Records indicate this range was used for .45 cal submachine gun training in the 1940s. Other historical sources indicate this range may have been used for rifle grenade and mortar training as well. Inspection of the site revealed the remnants of wooden target bays in the now moderately-dense, wooded area where the Former M-1 Range was located. Phases II investigations indicated that the five bays appear to have been used for pop-up targets, and were spaced at 20-foot intervals and staggered up and downrange along what was presumed to be the former target line. No ordnance or evidence of a former firing line and backstop berm was discovered at the site.

Former M-1 Investigations

Because no obvious firing line remains at this range, during Phase IIb investigations, two soil grids (163A and 163B) were established within the cleared area visible in a 1955 aerial photograph to test soil for contaminant residuals associated with past small arms, rifle grenade, and mortar training (Figure 5-24A). The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of explosives, SVOCs, and metals.

Explosives compounds were not detected in the 13 soil samples collected from this range. Several SVOCs including 15 PAH samples were detected at low/trace levels primarily in one discrete subsurface sample from grid 163B. The detected concentrations of PAHs and metals were comparable to background.

2013 Soil Investigation

In April 2013, additional sampling was conducted at Former M-1 Range. Multiple increment samples were collected from the former firing line area (FMRM101A) and from an assumed stationary target (SIT) area (FMRM102A). The sampling locations are identified in Figure 5-24B. The 30-point multiple increment sample collected from the firing line area was analyzed for explosives including nitroglycerin. In addition, two replicate samples (FMRM102B and FMRM102C) were collected from this area. The 100-point multiple increment sample collected from the SIT area was analyzed for selected metals [antimony, copper and lead]. The results (Table 5-5) for the three former firing line samples were all non-detect for explosives. The results for metals from the SIT area were comparatively low. Antimony was detected at 0.5 mg/Kg, copper at 2.8 mg/Kg and lead at 22.3 mg/Kg.

5.2.1.24 Former M-2 Range

The Former M-2 Range is a non-operational small arms training site located on the original Greenway Road northeast of the Former M-1 Range. Records indicate this range was also used for .45 cal submachine gun, rifle grenade, and mortar training in the 1940s. The range has been used to stockpile soil and construction debris. The remnants of a north-south-trending earthen berm are located on the western side of the stockpiling area. It measures approximately 10 feet in elevation at its highest point and runs for approximately 250 feet. It is presumed, based on the presence of numerous .45 cal projectiles on the surface, to be the original backstop to the Former M-2 Range. This particular backstop was not treated during the 1998 Berm Maintenance Program. Steel pole brackets spaced at 8-foot intervals positioned on the eastern side of the berm are presumed to be the original target mounts. Based on this spacing and the length of the berm, the range may have accommodated as many as 30 firing points. The firing line was likely located in what is now an open area where construction materials have been stockpiled. Soil removal at the Former M-2 Range was included in the 2009 lead removal action.

Former M-2 Investigations

The objective of the Phase IIb investigation of the Former M-2 Range was to test soil for contaminant residuals related to past small arms, and possibly rifle grenade and mortar training. Soil samples were collected from 10 locations along the face of the backstop (164A through 164J) to measure the concentrations of residual metals present in soils there (Figure 5-25A). Discrete soil samples were obtained from the surface (0 to 6 inches bgs) and deeper (18 to 24 inches bgs) at these locations. The samples were submitted for TAL metals analysis.

Two soil grids (164K and 164L) were also established within the cleared area shown on the 1955 aerial photograph presumed to be in the uprange portion of the range. Because the soils have clearly been disturbed due to heavy equipment operation, the grids were sampled at two depth intervals: shallow (0 to 6 inches bgs) and deep (18 to 24 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of explosives, SVOCs, and TAL metals.

Explosives compounds were not detected in any of the eight samples from uprange of the backstop. Also, propellant-related SVOCs were not detected in any of these samples. Several PAH compounds were detected in these samples, including pyrene, fluoranthene and phenanthrene at maximum concentrations of 10 mg/Kg, 9.3 mg/Kg and 7.4 mg/Kg, respectively. Four metals (copper, antimony, lead and zinc) were detected in one or more surface and/or subsurface samples collected from the range backstop area. The maximum surface soil concentrations for antimony (6.9 mg/Kg) and lead (1,710 mg/Kg) were reported in a sample from location 164A. Soil from this location was subsequently excavated during removal actions.

Removal Action

In 2009, a removal action to reduce soil lead concentrations was implemented at Former M-2 Range. Under this removal action (discussed in Section 4), soils from portions of Former M-2 Range containing greater than 300 mg/Kg lead were excavated and stockpiled. Three feet of soil (approximately 329 cubic yards) was excavated from the berm face. This excavation area included all previous sampling locations (164A through 164J). The excavated soil was transported to Former D Range where it was mechanically screened. One 50-point multiple increment soil sample was collected (Location TTSARM2-1); the lead result from this post-excavation sample was 53.5 mg/Kg (Figure 5-25A). In addition, 100-point multiple increment samples (one sample plus two replicate samples) were collected from a 100-foot by 100-foot grid located behind the backstop berm (Location TTSARM2-2). The maximum lead concentration from this grid was 465 mg/Kg (Figure 5-25A).

2013 Soil Investigation

In April 2013, additional sampling was conducted at Former M-2 Range. Multiple increment samples were collected from the wooded area behind the backstop berm. The sampling area for the first 50-point sample (FMRM201A) extended along the length of the Berm (about 250 feet each) and approximately 20 feet behind the berm. Two replicate samples (FMRM201B and FMRM201C) were also collected from this sampling area. Five additional 50-point multiple increment samples (FMRM202A-FMRM206A) were collected in an area to the immediate west of the initial sample. Each sampling area was approximately 50 feet wide and 80 feet long. The sampling locations are identified in Figure 5-25B. The behind the berm sample (FMRM201A) and its replicates were analyzed for lead only. All of the remaining 50-point multiple increment samples were analyzed for selected metals [antimony, copper and lead]. The lead results (Table 5-5) for the Behind the Berm sample and the associated replicates ranged from 124 mg/Kg to 162 mg/Kg. In contrast, lead results for four of the five samples collected to the west of the initial sampling area were significantly higher with overall results ranging from 40.1 mg/Kg to 1,200 mg/Kg. Lead concentrations in four of the five samples exceeded 300 mg/Kg. Antimony results comparatively low and ranged from 0.88 mg/Kg to 6.5 mg/Kg and were in all cases below the MassDEP S-1/GW-1 standard. Copper results ranged from 6.9 mg/Kg to 70.7 mg/Kg.

5.2.1.25 Former M-3 and M-4 Ranges

The Former M-3 Range was located on the west side of Greenway Road south of the current J-3 Range (Figure 5-26A). The Former M-4 Range was located just south of the current J-3 Range on Greenway Road (Figure 5-27A). Both ranges are non-operational. These ranges are not mentioned in any of the available construction reports or range regulations. However, training diaries from the Anti-Aircraft Artillery Training Center (AAATC) from 1942 to 1944 clearly state that their units trained on these ranges.

According to the AAATC training diaries, the M-series Ranges were used to fire .45 cal submachine guns. Direction of fire on all the M-series Ranges would have been to the northwest. It is unknown whether or not berms existed on the ranges. Available historical maps also indicate these M-series Ranges were used as mortar positions in the 1940s and 1950s. Use of the M-series Ranges is believed to have lasted until the late 1940s or perhaps the early 1950s.

The Former M-3 Range was investigated during the May 2013 Supplemental Investigation. A visual inspection and several metal detector sweeps were made from north to south and back again on the hillside west of Greenway Road (Figure 5-26B). The Former M-3 Range has been extensively modified with the construction of Greenway Road Bypass and the FS 12 treatment facility. There are no obvious target areas and the metal sweep did not indicate any concentrations of metals. A few miscellaneous metal objects (primarily beer cans) were found near the road, but no other detections indicative of past small arms range activities were identified. A similar sweep conducted on the hillside east of the road also detected nothing of interest from a small arms perspective. Based upon the results of the metal detector sweeps, no XRF screening or off-site soil sampling was conducted at this range.

Former M-4 Range

The Former M-4 Range was investigated during the May 2013 Supplemental Investigation. The range was located just south of the current J-3 Range on Greenway Road. A horseshoe-shaped path was swept with the metal detector on the hillside identified as the likely backstop of the former range (Figure 5-27B). Several metal items were detected along this path but not at a density that suggested the presence of any bullet pockets. During a second range reconnaissance (with MassDEP present), an additional metal detector sweep was conducted in the middle of the horseshoe-shaped area to confirm that a similar density of metals was present throughout the area. The results of this metal detector sweep were essentially the same as the initial sweep with several detections, indicating the presence of widely scattered metal objects. The metal detections appeared to be consistent with the possible past use of the hillside as a backstop for the range. However concentrated bullet pockets, like those often observed at a heavily used 25-meter zeroing range, were not found.

Based upon the results of the metal detector sweeps, a 100-point multiple increment sample was collected at a 100 by 100-foot area on the hillside, centered on the area of the metal detector sweeps. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (0.3 mg/Kg) and lead (14.6 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 2.8 mg/Kg.

5.2.1.26 N Range

N Range is an inactive operational 25-meter rifle training range located on the western side of Greenway Road near the J-2 Range. Sometime between 1986 and 1989, the N Range was constructed at its present location. The range has 55 firing points positioned along its 378-foot long northeast–southwest trending firing line and target frames are located 25 meters downrange. An 8-foot high backstop berm, which was treated during the 1998 Berm Maintenance Program, is located approximately 13 feet west of the target frames. Records indicate that 5.56mm ball and tracer rounds have been authorized for use there. Numerous plastic 5.56mm projectiles are present on the uprange face of the backstop.

N Range Investigations

During the Supplemental Phase IIb investigations, five 5-point soil grids (165A through 165E) were established at the firing line to determine whether residual propellant compounds exist in soil there (Figure 5-28A). One grid (165C) was positioned near the center of the range, opposite the firing point presumed to be most frequently used. Two of the four remaining grids (165A and 165E) were positioned downrange of firing points located near the northern and southern limits to sample range soils where use is presumed to have been less frequent. The remaining two grids (165B and 165D) were located between the central and end grids at firing points where evidence of recent use was observed. The center nodes for each of the five grids were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

As indicated in Figure 5-28A, additional samples were collected from N Range during J-2 Range investigations conducted in 2000 and 2004. A combined total of 52 samples was collected from the range.

Six propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, 2,4-DNT, 2,6-DNT and n,n’-diethylcarbanilide) were detected in one or more of the 52 samples analyzed from N Range firing line. The first two of these compounds were detected in more than half of the samples analyzed. The maximum concentrations of di-n-butyl phthalate and n-nitrosodiphenylamine were 1.4 mg/Kg and 1.3 mg/Kg, respectively. The maximum detected concentration of 2,4-DNT was 1.0 mg/Kg. These maximum concentrations were all reported for surface samples from grid 165C. Several additional SVOCs including a few PAHs were reported in samples from N Range. Twelve metals were detected in one or more samples at concentrations above their respective MMR background levels. The maximum reported concentration of lead was 25 mg/Kg.

2013 Soil Investigation

In April 2013, additional sampling was conducted at N Range. Two 100-point multiple increment samples (NR01A and NR02A) were collected from Behind the Berm locations. The sampling area for the two samples extended along the length of the Berm (about 200 feet each) and approximately 40 feet behind the berm. The sampling locations are identified in Figure 28B. The multiple increment samples were analyzed for selected metals [antimony, copper and lead]. Results (Table 5-5) for antimony (4.3 and 1.8 mg/Kg) and copper (81.7 and 43.2 mg/Kg) were generally similar in the two samples. However, the lead result (724 mg/Kg) from sample NR01A was higher than the result (337 mg/Kg) from sample NR02A.

5.2.1.27 Former N-Range (Adjacent to Sierra Range)

Former N Range is an inactive operational range that is located to the immediate east of Sierra East Range to the south of Gibbs Road. This range was investigated during the May 2013 Supplemental Investigation. During past visual inspections of this range, several berms and other man-made earthworks were identified. Some of the berms observed have steel drums on them and those drums had apparently been used for target practice based on the number of holes in them. During this Supplemental Investigation, several of these features were acquired and swept with the metal detector (Figure 5-29). Significant accumulations of metals were detected at most of these features. Among the most significant was a berm with a drum on top located roughly east of the 250-meter firing line on Sierra East Range. A metal detector sweep was also conducted along portions of the range floor in between features. During this sweep scattered metal debris was detected at certain locations.

Based on the metal detector sweep results, a 30-point multiple increment sample (SSFRMN01) was collected from the area around the berm that appeared to have the highest concentration of metal detections. The multiple increment sampling location also encompassed the surrounding area (approximately 70 by 20 feet) where the metal detections were most frequent. The sample was screened using XRF at the site trailer (Section 3.2.7) and analyzed off-site for selected metals [antimony, copper and lead]. The result (Table 5-6) for antimony (8.1 mg/Kg) was below the MassDEP S-1/GW-1 standard. However, the lead concentration (1670 mg/Kg) was above the S-1/GW-1 standard. Copper was detected at a concentration of 175 mg/Kg. There is no MassDEP S-1/GW-1 standard for copper. However, this concentration is elevated in comparison to the MMR background level (11 mg/Kg) (Appendix B).

5.2.1.28 O Range

O Range is an inactive operational shotgun familiarization range located northeast of N Range on the western side of Greenway Road. The range was constructed sometime between 1986 and 1989 over a former range that was also used for shotgun training. The range is bordered on four sides by earthen berms. A series of parallel firing lines, each one 98 feet long, were marked at distances of 3, 5, 7, 10, 15, 25, and 50 yards from a line of wooden target frames. The frames are positioned approximately 28 feet east of, and parallel to, the westernmost berm, which is presumed to function as the backstop. This westernmost berm was treated during the 1998 Berm Maintenance Program.

O Range Investigations

During the Supplemental Phase IIb investigations, samples were collected from three of the seven firing lines (7-, 15-, and 50-yards) to determine whether residual propellant compounds exist in soil at this range (Figure 5-30A). Three 5-point soil grids (166A through 166I) were positioned on each of three selected firing lines. Three grids (166B, 166E, and 166H) were positioned along what is presumed to be the centerline of the range. The remaining six grid locations (166A, 166C, 166D, 166F, 166G, and 166I) were selected in the same manner, but located at the southern and northern limits of the range. The center nodes for all nine grids were positioned approximately 8 feet downrange of the firing line and centered in the firing lane.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Six propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, n,n'-diethylcarbanilide, di-n-octyl phthalate and diethyl phthalate) were detected in one or more of the 39 samples analyzed from the O Range. Di-n-butyl phthalate was the most frequently detected propellant-related compound and was detected in 16 samples, with a maximum detected concentration of 0.14 mg/Kg at grid 166B. N,n'-diethylcarbanilide was detected in 15 samples, with a maximum concentration of 0.85 mg/Kg also at grid 166B. Other SVOCs detected included 11 PAHs. In general, the detected concentrations of metals were comparable to background. The maximum detected concentrations of several metals, including copper (23.2 mg/Kg), and zinc (44.2 mg/Kg), were elevated. The maximum detected concentration of lead was 201 mg/Kg.

2013 Soil Investigation

In April 2013, additional sampling was conducted at O Range. A 50-point multiple increment sample (OR01A) was collected from a behind the berm location. The sampling area extended along the length of the berm (about 100 feet) and approximately 40 feet behind the berm. The sampling location is identified in Figure 5-30B. The multiple increment sample was analyzed for selected metals [antimony, copper and lead]. The results (Table 5-5) for antimony (1.3 mg/Kg) and lead (204 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. The copper result at 7.8 mg/Kg was comparable to MMR background levels.

5.2.1.29 P Range

P Range is an inactive operational pistol range located on the western side of Greenway Road just north of the O Range. This range was established around the same time as N and O Ranges, sometime between 1986 and 1989. It abuts the eastern side of the Former K rocket range. P Range was designed for pistol training and is authorized for all calibers of pistol ammunition. Twenty-five firing points are spaced at 10-foot intervals along the 250-foot long firing line. Target frames, which are located on the western side of the range, are positioned approximately 78 feet west of the firing line. An earthen berm situated 25 feet further west of the target frames functions as the range backstop. This backstop appears to have been constructed out of the remnants of a mounded Former K Range firing line. The P Range backstop berm face was treated during the 1998 Berm Maintenance Program.

P Range Investigations

During the Supplemental Phase IIb investigations, five 5-point soil grids (167A through 167E) were established at the firing line to determine whether residual propellant compounds exist in soil there (Figure 5-31A). One grid (167C) was positioned near the center of the range, opposite the firing point presumed to be most frequently used. Two of the four remaining grids (167A and 167E) were positioned downrange of firing points near the southern and northern limits of the range. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Six propellant-related compounds (including di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, n,n'-diethylcarbanilide, 2,4-DNT and diethyl phthalate) were detected in one or more of the 32 samples analyzed from the P Range. Di-n-butyl phthalate, n-nitrosodiphenylamine and n,n'-diethylcarbanilide were the most frequently detected compounds and were detected in 9, 11 and 12 samples, respectively. Maximum reported concentrations of these three compounds were 0.22 mg/Kg, 1.0 mg/Kg and 1.3 mg/Kg, all from a surface sample from grid 167B. Most metals were detected at concentrations comparable to their respective MMR background levels. The maximum detected concentration of zinc (76 mg/Kg) was elevated. The maximum zinc concentration in other locations (167B – 33.5 mg/Kg; 167C – 24.1 mg/Kg; 167D – 23.5 mg/Kg; and 167E – 26 mg/Kg) were generally similar to the MMR outwash background zinc concentration (25.6 mg/Kg) (Appendix B). The maximum reported concentration of lead was 17.2 mg/Kg.

2013 Soil Investigation

In April 2013, additional sampling was conducted at P Range. A 100-point multiple increment sample (PR01A) was collected from a behind the berm location. The sampling area extended along the length of the berm (about 200 feet) and approximately 40 feet behind the berm. The sampling location is identified in Figure 5-31B. The multiple increment sample was analyzed for selected metals [antimony, copper and lead]. The results (Table 5-5) for antimony (1.7 mg/Kg) and lead (118 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. The copper result at 13.4 mg/Kg was comparable to MMR background levels.

5.2.1.30 Q Range

Q Range is an inactive operational range that was first used in 1967 as an automatic rifle and machine gun transition range and was located close to the current location of the IBC Range (Figure 5-32A). Q Range continued to be used as a machine gun range until the early 1980s. Known ammunition usage at the range included .30 cal, 5.56mm, 7.62mm, and .50 cal ball and tracer rounds. The machine guns were fired in a southwesterly direction and it is unknown whether or not a berm was present on the range during this time frame. Since the early 1980s, no range on MMR has been designated as Q Range.

Field sampling investigations were not conducted at the Q Range during the Phase IIb investigation as the exact location of the range could not be established at that time.

2013 Soil Investigation

In April 2013, sampling was conducted at Q Range. A 100-point multiple increment sample (QR01A) was collected from the assumed downrange (south) side of the row of metal reinforced firing positions. The sample was extended along the firing line to encompass an area of approximately 10,000 square feet. The sampling location is identified in Figure 5-32B. The multiple increment sample was analyzed for explosives including nitroglycerin. All explosives results were non-detect (Table 5-5).

During the May 2013 Supplemental Investigation, two metal detector sweeps were conducted from the firing points southward toward what appeared to be target areas (Figure 5-32C). Significant detections of metal were observed in the target areas indicating the possibility that bullets had accumulated in those areas. Only scattered metal detections were encountered elsewhere along the metal detector sweeps.

Based on the metal detector sweep results, a 30-point multiple increment sample (SSQRNG03) was collected from an approximately 100 by 10-foot area at the target pit/target. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (1.1 mg/Kg) and lead (152 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 12.3 mg/Kg.

5.2.1.31 Former R Range

Former R Range is an inactive operational squad battle assault course located on the southern side of Gibbs Road west of the IBC Range. This range was originally established in 1967 and used as a battle assault course until the early 1980s. Records indicated ammunition used at this range included .30 cal and 7.62mm rounds. The range was used as a tactical firing position for 81mm and 4.2-inch mortars through much of the 1980s. High explosive mortars may have been used during this period, but no information on possible target locations has been identified. It is likely that mortars were fired at targets in the Impact Area. Beginning in the late 1980s and continuing to approximately 1990, the Former R Range was converted back to a squad and platoon attack course. During this last period of use, only blank ammunition was used.

A metal gate, presumed to be the former entrance to Former R Range, is located within the tree line off Gibbs Road. The range is heavily overgrown with dense scrub oak and other shrubs, and numerous soil piles are located at the extreme southern portions of the range. An overgrown winding road traverses the range from north to south. No evidence of a former firing line or backstops has been discovered at this site.

Former R Range Investigations

Based on the lack of discernible range features (i.e., firing line or backstops) during the Phase IIb investigation, a single sampling grid (168A) was established near the approximate center of the former range and within what appears on a 1994 aerial photograph to be a former clearing (Figure 5-33A).

The grid was sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of explosives, SVOCs, and TAL metals.

Explosives compounds or propellant-related SVOCs were not detected in any of the samples collected from the Former R Range. A few SVOCs (including benzoic acid and bis(2-ethylhexyl)phthalate were detected at trace/low levels. Metals and inorganics were detected at concentrations comparable to background levels. The maximum reported concentration of lead was 27.8 mg/Kg.

2013 Soil Investigation

In April 2013, sampling was conducted at Former R Range. A 100-point multiple increment sample (FMRR01A) was collected from a cleared area at the south end of the Range identified in aerial photographs. The sampling area was approximately 100 by 100 square feet. The sampling location is identified in Figure 5-33B. The multiple increment sample was analyzed for selected metals [antimony, copper and lead]. The results (Table 5-5) for antimony (0.88 mg/Kg) and lead (21.8 mg/Kg) were comparatively low and below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 6.8 mg/Kg.

5.2.1.32 SE Range/SW Range

The Sierra Range (also termed the Sierra Range Complex) consists of two adjacent active operational rifle and machine gun training ranges located on the southern side of Gibbs Road to the north of the Central Impact Area. The two ranges are denoted as the Sierra East (SE) and Sierra West (SW) Ranges. They were both constructed sometime between 1986 and 1989 at their current locations. Since that time both have been used as automatic rifle and machine gun transition ranges.

Mounded firing points exist at both ranges. At the SE Range, five firing points lie along the 280-meter-long firing line. At the SW Range, six firing points lie along the approximately 218-yard-long firing line. At each range, a series of pop-up targets are spaced between approximately 110 and 870 yards downrange from the firing points. Backstop berms do not exist at either range. Target berms, which protect pop-up mechanisms at each target, were treated during the 1998 Berm Maintenance Program (Ogden 1999).

SE/SW Ranges Investigations

2000 Live Fire Sampling

In September 2000, soil samples were collected from a central location (127A/B) along the firing line of SE range immediately after a live firing training exercise to evaluate possible impacts to soil from the airborne deposition of propellant-related compounds (Figure 5-34A).

Twelve samples were collected and analyzed for TAL metals and SVOCs. Detected propellant-related compounds included bis(2-ethylhexyl)phthalate, di-n-butyl phthalate, n-nitrosodiphenylamine, 2-nitrodiphenylamine, and n,n’-diethylcarbanilide. Detected concentrations of metals were consistent with background levels.

Phase IIb Sampling

During subsequent Phase IIb investigations, two grids (127C and 127D) were located at the SE Range downrange of firing points at the eastern and western limits of the range (i.e., at firing points 1 and 5) to determine whether residual propellant compounds existed in soil there. At SW, three 5-point soil grids (127E, 127F, and 127G) were established at the firing line. One grid (127F) was positioned near the center of the range, opposite the firing point presumed to be most frequently used. The two remaining grids (127E and 127G) were positioned downrange of firing points located near the eastern and western limits of the range (i.e., at firing points 1 and 6). The center nodes for all five proposed grids were positioned approximately 10 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

Several propellant-related SVOCs were detected in the 13 samples analyzed from the SE Range and the 20 samples analyzed from the SW Range. These included di-n-butyl phthalate, n-nitrosodiphenylamine, 2,4-DNT, 2-nitrodiphenylamine, and n,n'-diethylcarbanilide. Di-n-butyl phthalate was the most frequently detected propellant-related compound with a maximum detected concentration of 1.5 mg/Kg on SE Range. Most of the propellant-related compounds were reported in surface soil samples. A few other SVOCs (including six PAHS on SW Range) were also reported. Several metals including lead were detected in one or more samples from both ranges. The maximum lead concentration reported for the SE and SW Ranges were 27.8 mg/Kg and 24.3 mg/Kg, respectively.

Multiple Increment Sampling

During 2005 and 2006, soil multiple increment sampling was conducted at SE and SW Ranges to support MAARNG range construction plans. Multiple increment samples were collected from firing point berm, range floor, and pop-up target areas.

2005 SE Range Multiple Increment Sampling

In December 2005, four 30-point multiple increment samples were collected in the vicinity of grid 127D to determine whether significant concentrations of 2,4-DNT extended beyond the limits of this grid. This grid had previously displayed some of the higher concentrations of propellant-related compounds observed during the Phase IIb sampling program. 2,4-DNT was previously detected at 0.82 mg/Kg.

Results of the 2005 SE Sampling Program indicated the presence of both 2,4-DNT and nitroglycerin in the vicinity of grid 127D. Specifically, 2,4-DNT was detected in three of four multiple increment samples at a maximum concentration of 0.55 mg/Kg. Nitroglycerin was detected in the same three samples at a maximum concentration of 41 mg/Kg. Nitrobenzene was detected in one sample at a concentration of 0.17 mg/Kg.

2006 Multiple Increment Sampling

In 2006, an additional multiple increment soil sampling program was implemented to support the Sierra Range modernization program implemented by the Army.

In this sampling program, the SE and SW ranges were conceptually divided into a number of investigation areas based upon the known past use of the respective ranges and the range conditions at the time of sampling (Figure 5-34B). At each range, four specific sampling areas were established, as follows:

- Area 1 – the backside of the existing firing point berm
- Area 2 – the front side of the firing point berm
- Area 3 – the range floor of the berm in front of the 50 meter targets
- Area 4 – the range floor within the pop-up targets including the soil berms in front of the pop-up targets

One 50-point composite surface sample was collected from Area 1 at each range. One 50-point surface soil multiple increment sample and two subsurface multiple increment samples (3 to 6 inches and 9 to 12 inches) were collected from Area 2. In Area 3 (range floor), separate multiple increment samples were collected from native soil areas (100-point composites) and filled soil areas (50-point composites). In Area 4, 100-point composites were collected from subareas 4A and 4b at both ranges and replicates collected in Area 4A at SE Range.

Samples from Areas 1 and 2 were analyzed for explosives, SVOCs and metals (antimony, arsenic, copper, and lead). Area 3A samples were analyzed for explosives, SVOCs, metals, and tungsten. Area 3B samples were analyzed for SVOCs, metals, and tungsten. Area 4 and stockpile samples were analyzed for metals and tungsten.

Nitroglycerin was detected in three samples from SE Range with the maximum observed concentration (26 mg/Kg) reported for a sample from Area 2. Of these samples, 2,4-DNT was detected in one surface sample (Area 2) at a concentration of 0.35 mg/Kg.

Several propellant-related SVOCs were detected in the surface soil multiple increment samples from SE Range, including one detection of 2,4-DNT and one detection of 2-nitrodiphenylamine. The maximum reported concentration of 2-nitrodiphenylamine (0.21 mg/Kg) was reported for a sample from Area 2. N-nitrosodiphenylamine was also reported in four samples from three different depths from the sample from Area 2. The maximum reported concentration was 1.5 mg/Kg. N,n’-diethylcarbanilide was detected in one sample (0.056 mg/Kg) and di-n-butyl phthalate was detected in three samples at a maximum concentration of 0.61 mg/Kg. Bis(2-ethylhexyl)phthalate was also detected in one sample at an estimated concentration of 0.19 mg/Kg.

Metals were frequently detected in surface soil samples from SE Range. Antimony was detected in six samples with the maximum concentration (3.2 mg/Kg) reported for the sample from Area 4A - Target Berm. Arsenic was detected in all samples, although at a low maximum concentration (3.7 mg/Kg) reported for Area 4B, comparable to background. Copper was detected in all SE Range samples with the maximum concentration (55.2 mg/Kg) reported for the sample from Area 2. Lead was detected in all SE Range samples with the maximum concentration (710 mg/Kg) reported for the sample from Area 4A - Target Berm. Tungsten was detected in 10 samples with the maximum concentration (13 mg/Kg) again reported for the Target Berm (Area 4A).

Four SVOC compounds, which are propellant-related, were detected in one or more samples from the SW Range. 2-Nitrodiphenylamine was detected in two samples with a maximum observed concentration of 0.1 mg/Kg. N-nitrosodiphenylamine was detected in three samples with a maximum concentration of 0.7 mg/Kg. Di-n-butyl phthalate was detected in two samples with a maximum reported concentration of 0.27 mg/Kg. N,n'-diethylcarbanilide was detected in the surface soil sample from Area 2 (0.03 mg/Kg). In addition, one PAH compound, fluoranthene, was detected in the sample from Area 3B at a concentration of 0.093 mg/Kg.

Most of the metals that were analyzed from the SW Range were detected at concentrations comparable to background. Antimony (2.6 mg/Kg) was detected in the one sample from the Target Berm in Area 4A. Arsenic was detected in all of the samples for which it was analyzed, although the maximum observed concentration (5.3 mg/Kg) was relatively low and comparable to background. Copper was also detected in all of the analyzed samples with a maximum observed concentration of 37.8 mg/Kg. Lead was detected in all of the analyzed samples with the maximum concentration (624 mg/Kg) reported for the target berm sample from Area 4A. Tungsten was detected in samples from Areas 3A/3B and 4A/4B at concentrations ranging up to 9.2 mg/Kg.

2012 Range Floor and Target Berm Investigation

In February 2012, a Supplemental Sampling program was conducted at the Sierra West Range to confirm and expand previous investigation results regarding soil lead and tungsten distributions at range floor areas and target berms. XRF screening was performed to assess lead and tungsten concentrations in berm soils. Lead was detected in all range floor XRF samples at concentrations ranging from 17.7 mg/Kg to 157.7 mg/Kg. The results of the off-site confirmatory lead analyses (Method 6020A) were generally comparable to the XRF screening results. Off-site laboratory analyses (Method 6020A) were also performed to evaluate soil tungsten concentrations and indicated very low levels ranging from 0.04 mg/Kg to 3.6 mg/Kg.

Lead concentrations in the target berm samples were higher than those in the Range Floor. Target berm XRF lead screening results ranged from 12 mg/Kg to 888 mg/Kg and were again comparable with confirmatory off-site laboratory results. XRF screening results were largely non-detect for tungsten with the exception of low levels (8.7 mg/Kg and 15.3 mg/KG) reported in samples from the 500m berm. All results for the range floor and target berm samples were below the 3,000 mg/Kg target berm Action Level for lead and the 14 mg/Kg (range floor) and 37 mg/Kg (target berm) Action Levels for tungsten.

5.2.1.33 Skeet Range 1

Skeet Range 1 is a non-operational range, originally located in the northeast corner of Training Area BA-1 adjacent to Herbert and Turpentine Road, was one of two shot gun skeet ranges reportedly used during the 1940s (Figure 5-35A. Information on the layout of this range is not available and 1940s era aerial photographs provide little more than the possible limits of the range based on evidence of cleared areas.

Much of the cleared area shown on the 1943 aerial photographs continues to exist as open area in Training Area BA-1. With the exception of a single fragment of clay skeet; however, no other evidence (e.g., shot gun shell remnants) of the former range has been discovered to date. During one inspection to the site, dark, possibly stained soil was observed near the center of the current open area adjacent to Herbert Road.

Skeet Range 1 Investigations

Soil samples were collected from two 5-points grids at the stained soil at locations (170A and 170B). The grids were sampled at two depth intervals: 0 to 6 inches bgs and 18 to 24 inches bgs. One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

One propellant-related SVOC (2,4-DNT) was detected in two of four surface soil samples collected at a maximum concentration of 0.14 mg/Kg. A few non-propellant-related SVOCs (all PAHs) were detected in one or more samples. Two metals (lead and manganese) exceeded their respective background concentrations. The maximum reported concentration of lead was 56 mg/Kg.

2013 Soil Investigation

In April 2013, sampling was conducted at Skeet Range 1. The entire Range area was divided into four areas and one 100-point multiple increment sample (SK101A-SK104A) was collected from each area. The sampling locations are identified in Figure 35B. The multiple increment samples were analyzed for selected metals [antimony and lead]. Results (Table 5-5) for antimony ranged from 0.5 mg/Kg to 1.6 mg/Kg. Results for lead were quite consistent and ranged from 18.8 mg/Kg to 21.1 mg/Kg.

5.2.1.34 Skeet Range 2

The second Skeet Range is a non-operational range that was constructed during the 1940s and was located at a small cul de sac to the north of Howe Road. No information regarding the layout of ranges is currently available (Figure 5-36A). However, given the typical nature of skeet ranges, it is reasonable to assume that 10 or 12 gauge shotgun shells were used at the range. No field investigation information was conducted at Skeet Range 2 during the Phase IIb inspection.

Skeet Range 2 was investigated during the May 2013 Supplemental Investigation. A visual inspection of this range was made and accompanied by two metal detector sweeps across the area (Figure 5-36B). The southern metal detector sweep traversed the area within the cul de sac. Many detections of metal were made during this sweep indicating an accumulation of some type of metal. On the northern sweep, several detections of metal were made near a line of boulders that were identified in the northeast area of the range.

Based on the metal detector sweep results, a 30-point multiple increment sample (SSK2R01) was collected from an approximately 40 by 50-foot area in and around the cul de sac. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (0.8 mg/Kg) and lead (8.0 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 3.5 mg/Kg.

5.2.1.35 Succonsette Pond

Succonsette Pond is a non-operational range that is located within the southwest corner of the Impact Area just east of Pocasset-Sandwich Road (Figure 5-37A). Information gathered from personal interviews suggests that drums were, at one time, stacked on a ridge south of Succonsette Pond for use as .50 cal machine gun targets. Specific information on the exact location of these targets and associated firing points was not provided.

Succonsette Pond Investigations

An investigation of Succonsette Pond was conducted during the Phase I Investigation. Surface soil, sediment and surface water samples were collected from several locations around the shoreline. Analytical results from one soil sample collected at grid 08D (which is located on the southern side of the pond) indicate a concentration of lead below the MCP S-1/GW-1 standard. To date, no targets, firing lines, or other evidence of .50 cal projectiles or shell casings were discovered in the vicinity of Succonsette Pond.

During subsequent Phase IIb investigations, soil samples were collected from three locations around the Phase I soil grid 08D. The sampling points (08F, 08G, and 08H) were positioned 10 feet east, south, and west of the central node of the original grid 08D. The three samples were collected at 0 to 6 inches bgs and submitted for analysis for total metals. Several additional surface soil samples (SS11207-A, SS11209-A, and SS11211-A) were collected in the general vicinity of the northern side of the pond.

Metals concentrations were comparable to background in the three samples collected around soil grid 08D. The maximum reported concentration of lead (7.2 mg/Kg) was low. However, several phthalates, including di-n-butyl phthalate (maximum concentration 0.158 mg/Kg), benyl butyl phthalate (maximum 0.6 mg/Kg), and perchlorate (0.1 mg/Kg) were detected in the additional samples from the Succonsette Pond area. Several metals were elevated above MMR background in these samples, including cadmium, copper, iron, lead and zinc. The maximum concentration of cadmium was 30.9 mg/Kg (not shown in Figure 5-36A) and the maximum concentration of copper was 1,200 mg/Kg. The reason for the elevated value of cadmium is uncertain. All other cadmium results at this range were below 10 mg/Kg. The MMR surface soil background concentration for cadmium is 0.35 mg/Kg for moraine soil and 0.94 mg/Kg for outwash soil. The maximum lead concentration in these samples was 207 mg/Kg.

2013 Soil Investigation

In April 2013, sampling was conducted at Succonsette Pond. A 100-point multiple increment sample (SPN01A) was collected from the northern half of the shoreline surrounding the Pond and a similar 100-point sample (SPS02A) was collected from the south shore. The sampling locations are identified in Figure 5-37B. The multiple increment samples were analyzed for selected metals [antimony, cadmium, copper and lead] as well as perchlorate. The results (Table 5-5) for antimony (0.79 mg/Kg), cadmium (0.05 mg/Kg), copper (3.8 mg/Kg) and lead (11.7 mg/Kg) at the northern shore (SPN01A) were generally similar to the respective antimony (0.92 mg/Kg), cadmium (0.13 mg/Kg), copper (6.5 mg/Kg) and lead (24.5 mg/Kg) concentrations reported in sample SPS02A from the southern shore. Perchlorate was non-detect in both samples. In May 2013, a site reconnaissance and metal detector survey was conducted at Succonsette Pond.

As part of the May 2013 Supplemental Investigation, a further visual inspection of the pond area was made. This was accompanied by a metal detector sweep starting at the north side of the pond and continuing up and down the hillside, going clockwise around to the southwest side of the pond where the steepness of the slope lessens (Figure 5-37C). In the area to the north and northeast of the pond, many scattered individual metal detector ring-offs indicating the presence of metal were recorded. However, no concentrated accumulation of metal was detected in the area. Several pieces of frag from mortars were noted on the ground surface in this area, especially near the top of the hillside. The tail fins of a mortar were also found near the edge of the pond during a previous visit. Less metal was detected on the east side of the pond and little to none was detected on the south side. No accumulation of bullets was detected to indicate small arms use at this site. Based on the results of the visual inspection and metal detector sweep, no additional sampling was conducted at this location.

The overall results of the April and May 2013 investigations at Succonsette Pond do not indicate any significant additional evidence of small arms use. These results do not support the need for further investigation of the pond sediments.

5.2.1.36 T Range

T Range is an active operational rifle and pistol range located in the northern portion of MMR. It is located on the southern side of Gibbs Road just west of the SE and SW Ranges. The range was constructed between 1986 and 1989 at what was formerly P Range.

As Former P Range, the range was used first in 1967 as a night defense course where 5.56mm and 7.62mm blank ammunition were used and continued to be used until the mid-1970s when it was converted to a squad and platoon attack course. In the late 1980s, the range name was changed to the T Range designation and continued to be used as an assault course. During this time period, .50 cal plastic, including tracers, 5.56mm tungsten, .45 cal frangible, .40 cal frangible, 9mm frangible, 12 gauge shotgun, and M939 AT4 sub-caliber rounds were used on the range. In 1990 or 1991, T Range was converted to a .50-cal machine gun range. Since 2003 a 25-meter zero range has also been operated at T Range.

There were six elevated .50 cal firing points separated by intervals of approximately 50 feet along a 250-foot long firing line. A series of targets was established south of the firing points and set at different distances downrange, the furthest set measuring 600 feet from the firing line. Numerous plastic .50 cal projectiles were observed throughout the range. A second firing line, measuring 144 feet long and used for pistol training, was situated on the flat area immediately downrange (south) of the .50 cal firing line. There was no backstop berm at this range. An overview of this range is presented in Figure 5-38A.

T Range Investigations

Phase IIb Sampling

In 2001, three samples were collected from T Range and analyzed for explosives. During the Supplemental Phase IIb investigations, three 5-point soil grids were established at selected firing points along each firing line to determine whether residual propellant compounds exist in soil there. Central grids (169B and 169E) were positioned near the center of both firing lines, opposite the firing points presumed to be most frequently used. The four remaining grids (169A, 169C, 169D, and 169F) were positioned downrange of firing points located near the eastern and western limits of both firing lines. The center nodes for each grid were positioned approximately 8 feet downrange of the firing line and 2 feet to the right of their respective lane markers.

The grids were sampled at three depth intervals: surface (0 to 3 inches bgs), intermediate (3 to 6 inches bgs), and deep (6 to 12 inches bgs). One composite and one discrete soil sample (obtained from the center grid node) were collected at each depth interval. Each sample was submitted for analysis of SVOCs and TAL metals.

RDX was the only explosives compound detected during the 2001 Phase IIb investigation. It was detected at a concentration of 0.52 mg/Kg.

During the Supplemental Phase IIb investigation, three propellant-related SVOCs (di-n-butyl phthalate, n-nitrosodiphenylamine, and n,n’-diethylcarbanilide) were detected in one or more of the 38 samples that were analyzed at T Range. Essentially all of the relatively few propellant-related SVOCs were detected in samples from the .50 cal firing line (grids 169D, 169E and 169F). Several other SVOCs including eight PAHs were detected in one or more samples at generally low levels. Sixteen metals were detected at concentrations above background. The maximum reported lead concentration was 5,800 mg/Kg in a discrete subsurface sample from grid 169A. Most of the metals detections were found in samples from the pistol range grids (169A, 169B and 169C).

Multiple Increment Sampling

During 2006, multiple increment soil sampling was conducted at T Range to support MAARNG range construction plans. Multiple increment samples were collected from certain range floor, new berm and downrange areas.

T Range was conceptually divided into three investigation areas based upon known past use of the site and the conditions at the time of sampling. The three investigation areas were as follows:

- Area 1 – the area from the top of the machine gun firing points to the 25 meter targets
- Area 2 – the area for the planned new berm behind the 25-meter targets
- Area 3 – the remainder of the range downrange of Area 1 and Area 2

These three areas were further subdivided into three equal sampling areas (subareas) across the width of the parent area. Fifty-point- and/or 100-point multiple increment surface samples were collected from each area. This provided for samples from the most heavily used portions of the range. In addition, the center section of Area 1 was divided into north and south subsections. A subsurface (9 to 12 inches bgs) multiple increment soil sample was collected from Area 1/Center/South. Replicate samples were collected with surface soil samples from Area 1/Center/North, Area 1/West, Area 2/Center, and Area 3/Center.

Samples from the Area 1/Center/North sampling area were analyzed for explosives, SVOCs, perchlorate, and a suite of metals and tungsten. Area 1/Center/South was analyzed for explosives, perchlorate, and metals. The Area 2/Center sample was analyzed for explosives, perchlorate, metals, and tungsten. The sample from Area 3/Center was analyzed for metals and perchlorate. All other sampling areas were analyzed for metals.

The results of the June 2006 sampling program indicated nitroglycerin to be the predominant explosives-related propellant compound at T Range (Figure 5-44). Nitroglycerin was detected in three of the six samples for which it was analyzed. The highest concentration of nitroglycerin (47 mg/Kg) was detected in Area 1 Center/North at the center of the firing line. Nitroglycerin concentrations observed in surface soils from Area 1 Center/South were a factor of 10 lower than those observed in the northern area. Nitroglycerin was not detected in the subsurface soil sample (9 to 12 inches bgs) from Area 1 Center/South. (Based on these results, a soil excavation response action was implemented in 2007.)

One propellant-related SVOC (n,n’-diethylcarbanilide) was observed in two soil samples from the Area 1 Center/North sampling area at a maximum concentration of 2.3 mg/Kg.

Results for metals for the June 2006 sampling program were variable across the T Range. The maximum reported concentrations of a number of metals (antimony, beryllium, calcium, cobalt, copper, lead, molybdenum, nickel and vanadium) exceeded MMR background levels, although many of the maximum levels were only slightly above background. Antimony was reported in a number of surface soil samples with the maximum concentration (2 mg/Kg) observed in Area 1 Center/North. Arsenic was detected in all surface soil samples with the results for all samples at concentrations of 3.9 mg/Kg or less. Copper was detected in most surface soil samples with the maximum (742 mg/Kg) observed in the sample from Area 2 Center. Lead was detected in most surface soil samples at T Range with the maximum observed concentration (467 mg/Kg) reported for the Area 1 Center multiple increment sample. Tungsten was detected in most samples in which it was analyzed for with a maximum concentration of 77.1 mg/Kg in Area 2 Center.

2006 Removal Action

In 2006, a limited soil investigation was implemented at T Range as part of the Berm Maintenance Project (as discussed in Section 4.2). Limited XRF screening was conducted for tungsten at several soil piles on the range, but extensive XRF screening was not conducted for range soils. XRF screening results indicated only one existing surface soil pile sample above the 150 mg/Kg threshold established for the Berm Maintenance Project at T Range. Therefore, no soil excavation was conducted at T Range during this program. As such, no post-excavation XRF screening was conducted at this range. Surface soil was removed later from the target berm area as part of the construction of the new berm and STAPP™ bullet capture system.

April 2007 Firing Line Multiple Increment Sampling

In April 2007, a supplemental multiple increment sampling program was conducted at T Range (Figure 5-38B). The purpose of this sampling effort was to further define the nitroglycerin distributions in the vicinity of the firing line and assist in evaluating potential leaching processes. The sampling program was conducted in accordance with the Firing Line Sampling Plan Project Note (IAGWSP 2007b).

In this sampling program, the firing line area was subdivided into 12 sampling areas and multiple increment samples were collected at each area. In addition, in Center 1 and Center 2 sampling areas, soil depth profile samples were collected at 3 to 6 inches bgs, 6 to 9 inches bgs, 9 to 12 inches bgs, 12 to 18 inches bgs, and 18 to 24 inches bgs. All surface soil samples were 50-point multiple increment samples. All subsurface samples were 30-point multiple increment samples.

Samples were analyzed for explosives including nitroglycerin, nitroglycerin degradation by-products, metals, pH, and total organic carbon.

Nitroglycerin results for the April 2007 sampling program indicated that elevated nitroglycerin concentrations were limited to the area directly in front of the 50-cal firing line mounds (Center 1, West 1, and East 1 sampling areas). The maximum concentration (50 mg/Kg) was observed in the sample from Center 1. Further downrange, there was also one detection of nitroglycerin (2.7 mg/Kg) in the sample from the Center 3 sampling area. There was a single detection of 2-nitrotoluene (0.14 mg/Kg) in the sample from Center 1. The maximum detected concentration of lead was 518 mg/Kg.

2007 Removal Action

In 2007, a soil excavation response action was implemented to reduce firing line nitroglycerin levels. Portions of the East, Central and West firing line areas at T Range were excavated in 2007. The excavation area at T Range was estimated to be approximately 11,000 square feet. This area was excavated to a depth of approximately one foot, resulting in a soil removal volume of approximately 400 cubic yards.

As a consequence of these removal actions, the maximum residual concentration of nitroglycerin is 4.7 mg/Kg in the post-excavation sample collected from 2 feet bgs at location SSARCTRC1.

2010 Operations and Maintenance Sampling

In 2010, multiple increment samples were collected from five equal-sized grids identified as TR-1A through TR-1E. Each of these multiple increment samples consisted of soil from 100-point composites. All samples were collected from a depth of 0 to 3 inches bgs each. A sixth multiple increment sample was collected from Area 2 (grid TR-2A) between the target line and STAPP™ berm. Multiple increment samples were collected from the grid areas, homogenized, and divided for analysis with separate grinding protocol. The laboratory ground sample was analyzed for lead, copper, zinc, antimony, tungsten, and nitroglycerin. The unground sample was analyzed for lead, copper, zinc, antimony, and tungsten. Two additional replicate samples were collected from each of these grids.

During the 2010 operation and maintenance sampling program, 36 samples were collected and analyzed for nitroglycerin and metals. Nitroglycerin was detected in every sample, at concentrations ranging from 5.26 mg/Kg to 29.7 mg/Kg. Concentrations of antimony and zinc were generally low and many samples were comparable to background. Concentrations of copper and lead were variable. The maximum detected concentrations of copper (255 mg/Kg), lead (1,330 mg/Kg), and zinc (79.4 mg/Kg) were greater than background levels. The maximum detected concentration of tungsten was 43.5 mg/Kg.

2011 Operations and Maintenance Sampling

In accordance with established range-specific Best Management Practices and Operations, Maintenance, and Monitoring Plans, soil sampling was again conducted at T Range during May and October 2011. During each sampling event, multiple increment surface soil samples were collected from six equal-sized grid locations on the range. One hundred point multiple increment samples were collected from each grid with replicates collected from range floor locations. Samples were analyzed for nitroglycerin and selected metals (antimony, copper, lead, zinc and tungsten). The maximum nitroglycerin concentration was 23.2 mg/Kg. The maximum lead concentration was 522 mg/Kg. The maximum detected tungsten concentration was 13.7 mg/Kg.

2013 Soil Investigation

In April 2013, additional sampling was conducted at T Range. Sample Area 3 from the 2006/2007 sampling effort was subdivided into five sampling areas, all measuring approximately 8,000 square feet. One hundred-point multiple increment samples (TR01A-TR05A) were collected from each of the five sampling areas. Two field replicates (TR05B and TR05C) were also collected from sampling area TR05. The sampling locations are identified in Figure 5-38C. Each multiple increment sample was analyzed for tungsten. The results (Table 5-5) for tungsten were low and ranged from 0.24 to 1.9 mg/Kg.

5.2.1.37 500-Yard Rifle Range

A 500-yard rifle range, built in the early 1940s, once existed along the south side of Jefferson Road west of Greenway Road, although its exact location was uncertain. The only known purpose of the range was to zero rifles to 500 yards prior to firing on the transition range. Expected ordnance use on this range is limited to .30 cal ball rounds. An overview of this range is presented in Figure 5-39A. Historic documentation indicates that the 500-Yard Rifle Range may actually have been located on the south side of Wood west of Greenway Road. The Phase IIb inspection of this area did not identify any range features and no field investigation was performed.

As part of the May 2013 Supplemental Investigation, visual field inspections and metal detector sweeps were conducted at two sites that were identified as possible former locations of the 500-Yard Rifle Range. One location was concurrent with Jefferson Road within the cleared area associated with the Coast Guard transmitter antenna site, west of Greenway Road. The other location was parallel to Wood Road (Figure 5-39B). Both locations are non-operational.

The metal detector sweep of the Jefferson Road antenna site resulted in several scattered detections of metal, but no indication of any accumulations of bullets. Visual inspection of the Wood Road site revealed an earthen berm approximately 50 feet long perpendicular to Wood Road. A metal detector sweep of this berm indicated an accumulation of metal that was possibly indicative of bullets. Elsewhere, the detections of metal at this site were widely scattered.

Based on the metal detector sweep results, a 30-point multiple increment sample (SS500YDR01) was collected from the 50-foot long berm adjacent to Wood Road. The sample was analyzed for selected metals [antimony, copper and lead]. Results (Table 5-6) for antimony (1.2 mg/Kg) and lead (12.6 mg/Kg) were below their respective MassDEP S-1/GW-1 standards. Copper was detected at a concentration of 4.6 mg/Kg.

6.0 CONCEPTUAL SITE MODEL

The conceptual site model is a three-dimensional representation of site conditions that characterizes contaminant distributions, release mechanisms, exposure pathways, migration routes, and potential receptors. The conceptual site model is based on existing site data compiled during previous studies of the Small Arms Ranges as discussed in Sections 3.0, 4.0, and 5.0.

6.1 Contaminant Sources

As indicated in Section 2.1, available MMR historical information indicates that the majority of the Small Arms Ranges have been used largely or exclusively for small arms training (including automatic rifle and machine gun training) over their operational lifetimes. Potential Small Arms Range contaminants include propellant-related compounds deposited on surface soils in the vicinity of the firing lines and range floors, and projectile-related residuals deposited on surface soils at and in the vicinity of range targets and berms.

Sampling at MMR has revealed that propellant-related contamination consists, in part, as a result of a limited suite of explosives compounds and SVOCs produced or released during the combustion of small caliber ammunition propellants. These compounds are released to the environment and deposited as surface residues via airborne deposition. The primary small arms propellants contain nitrocellulose and nitroglycerin or 2,4-DNT. The nitrocellulose/nitroglycerin formulation is the more predominantly used Small Arms Range propellant. When fired, the unburned portion is distributed on the ground as small nitrocellulose fibers. As indicated in Section 5, nitroglycerin is the principal propellant-related compound observed at most Small Arms Ranges. Low levels of certain other propellant-related compounds have also been observed in some samples, including 2,4-DNT, 2-nitrodiphenylamine, n-nitrosodiphenylamine, and n,n'-diethylcarbanilide. In addition, lead styphnate, lead azide and/or antimony sulfide is a component of the primer for bullet cartridges.

Projectile-related residues consist mainly of the metallic constituents of various alloys used in the manufacturing of small caliber rounds. These metals (including antimony, lead, copper, and tungsten) are deposited on and near the surface as intact or fragmented remnants of projectiles. At most of the Small Arms Ranges, most of the higher concentrations of antimony, copper, and lead were observed in samples from the target berm or trough in front of the berm.

6.2 Pathway

In theory, transport of soluble contaminants through the soil column could at some time reach the underlying groundwater typically 80 to 160 feet bgs. Leachate would be subject to mixing and dispersion upon reaching the groundwater, and further subjected to these effects during transport in the groundwater. The fate and transport of potential contaminants would be largely controlled by the physical and chemical properties of the contaminants and by local soil and hydrogeologic conditions.

6.3 Geochemical Overview

The principal small arms-related constituents reported in surface soils at the Small Arms Ranges vary significantly with respect to their overall environmental mobility and potential for transport through subsurface soils to groundwater.

6.3.1 Explosives

The principal explosives constituent (nitroglycerin) detected at the ranges is considered to be moderately soluble in water (solubility approximately 1,380 mg/L) when present in its pure form.

To better characterize the potential leaching of propellant-related compounds, the USACE CRREL conducted a series of laboratory studies on the environmental migration of DNT and nitroglycerin in soils (USACE 2009) from certain Small Arms Ranges at MMR. These studies, which are summarized in Section 3.2.8, help support the conceptual site model.

Double-based propellants used in small arms contain nitroglycerin and nitrocellulose and other additives (including DNT) for stabilization and flash suppression. Nitrocellulose is a fibrous material made of cotton or similar organic materials treated with nitric and sulfuric acid. These organic compounds are bound together during the manufacturing process with the nitroglycerin and DNT essentially encapsulated in a hydrophobic matrix. Upon firing of a weapon, excess fired propellant and combustion products are scattered on the ground. For small arms, the propellant grains, both prior to and after firing, contain nitroglycerin (approximately 10 to 13 percent) and a smaller percentage of DNT. A portion (approximately 5 percent) of the nitroglycerin and DNT is exposed on the outer surfaces of the grains and is therefore available, or exposed, to the elements for dissolution during precipitation events. This small mass of available nitroglycerin and DNT will dissolve, or weather, over a relatively short period of a few months. Once in the aqueous phase, nitroglycerin and DNT are readily degraded through biodegradation and photodegradation processes. Subsequently, the remaining nitroglycerin and DNT remain encapsulated by bonds with the nitrocellulose and may slowly diffuse out of the grains at a nearly imperceptible rate.

Nitroglycerin and DNT are soluble in water; however, water is not a strong enough solvent to break the bond with nitrocellulose. Analytical laboratories use strong organic solvents, such as acetonitrile, for extraction as part of the laboratory analytical method for analyzing explosives. Analyses thus include all components of the residual but are not necessarily environmentally available.

Overall, the results of the CRREL study indicated that residual DNT and nitroglycerin in weathered fired propellants, such as those in Small Arms Ranges surface soils, is essentially immobile. This lack of mobility was considered to result from a slow dissolution rate and a high rate of degradation (including biodegradation and photodegradation). These study results are consistent with the continued detection of propellants in surface soil at Small Arms Ranges, many years, if not decades, after training ceased, but a general absence of propellants observed in groundwater during long-term monitoring in these same positions, including E, J, K, SE, SW, and T Ranges.

6.3.2 Metals and SVOCs

The nature of the soil at MMR serves to retard the migration of most metals detected in surface soils at the Small Arms Ranges. In particular, lead is relatively strongly sorbed by subsurface soils and is not anticipated to undergo rapid downward migration through range subsurface soils to groundwater. Given depths to groundwater of approximately 100 feet, models have predicted it will take in excess of 100 years to reach groundwater. A detailed summary of the environmental chemistry and mobility of lead, as well as antimony and tungsten is presented in Appendix D.

There is relatively limited available literature data on the environmental behavior of antimony. Available information suggests that antimony is more mobile than lead under certain soil chemical conditions (Appendix D, Section D.2). Available data also suggest that the migration of tungsten in subsurface soils may be more complex than that of most other metals at the Small Arms Ranges. Geochemical literature suggests that dissolved tungsten migrates as a tungstate anion and under certain conditions as a poly-tungstate species. These forms can be soluble under some conditions (Appendix D, Section D.3).

The SVOC PAHs detected at trace levels in certain range surface soils are not anticipated to migrate significantly into subsurface soils due to low water solubilities and strong adsorption to soils.

6.4 Receptor

A few limited impacts to groundwater have been observed as a result of use of the Small Arms Ranges. Specifically, tungsten has been detected in groundwater downgradient of the target berm at B Range. However, impacts to groundwater from other components of small arms ammunition have not been observed. The northern 15,000 acres of MMR are set aside by Memorandum of Agreement and Massachusetts State Law as a location for drinking water supply wells – including three supply wells operated by the Upper Cape Regional Water Supply Cooperative and a supply well operated by the Bourne Water District. The entire northern 15,000 acres of MMR are considered a Zone II for public drinking water wells. Small arms range contaminants have not been detected in the water supply wells, and, given the current conceptual site model, it is unlikely that the groundwater pathway from the source to the receptor will ever be complete.

7.0 RISK SCREENING

A Human Health Risk Screening was conducted for the 40 Small Arms Ranges discussed within this Investigation Report. The objective of the risk screening was to identify any analytes that warranted further evaluation. The Small Arms Ranges identified under this program are: A Range, B Range, Former B Range, C Range, Former C Range, D Range, Former D Range, E Range, E-1 Range, E-2 Range, G Range, GA/GB Range, H Range, I Range, J Range, K Range, KD Range (East), Former K Range, L-Range, L-1 Range, L-2 Range, L-3 Range, L-4 Range, M Range, Former M-1 Range, Former M-2 Range, Former M-3 Range, Former M-4 Range, N Range, Former N Range, O Range, P Range, Q Range, Former R Range, SE Range, SW Range, Succonsette Pond, Skeet Range 1, Skeet Range 2, T Range and the 500-Yard Rifle Range.

- Three of these ranges (E-1 Range, E-2 Range, Former K Range) are being evaluated under other MMR projects and are not discussed further in this report. As such, no sampling data from these ranges were included in the soil and groundwater data sets used for this evaluation.
- Soil characterization data were not available for two of the ranges: L Range (1950s to 1980s) and Former M-3 Range. Accordingly, only a qualitative assessment could be performed for these ranges.

Tables 7-1 (Site-Wide Groundwater Screening) and 7-2 (Site-Wide Soil Screening) present the maximum detected concentrations of each detected analyte in the groundwater and soil (respectively), the locations of those maximum detected concentrations, the detection frequency, the applicable risk screening criteria, and the results of the screening evaluation. As discussed in Section 3 of this report, soil and groundwater samples collected during the Phase I and Phase IIb investigations of the ranges were analyzed for a comprehensive suite of analytes. Over the course of investigating the ranges, a greater understanding of potential contaminant release was achieved through the evaluation of the earliest sampling results and review of the historical records. Based on this, an overall conceptual site model for the Small Arms Ranges was developed (see Section 6). These studies indicate that contaminants at the Small Arms Ranges are primarily constituents of propellants (which include nitroglycerin, 2,4-DNT, 2,6-DNT, n-nitrosodiphenylamine, di-n-butyl phthalate, and/or diethyl phthalate) and constituents of bullet or shell casings (which include antimony, copper, lead, and tungsten and potentially other metals such as chromium or nickel).

7.1 Site-Wide Groundwater Evaluation

Data from 54 monitoring wells were selected for inclusion in the groundwater risk screening. These wells were selected based on their proximity to the various Small Arms Ranges, their well screen depth, the groundwater flow direction, and the current understanding of water chemistry in these areas. The 54 selected wells were each associated with one or more of the ranges. The wells selected were: MW-471S and MW-472S (J Range); MW-473S and MW-474S (K Range); MW-468S (E Range); MW-465S and MW-466S (SW Range); MW-55S (SE/SW Ranges), MW-467S and MW-489S (T Range); MW-23S (A Range); MW-124M3, MW-455S, MW-490S, MW-72S, and the newly installed wells MW-537M1, MW-538M1, and MW-539M1 (B Range);

MW-123S (B Range and C Range); MW-103S, MW-456S and MW-491S (C Range); MW-102S (D Range); MW-34M3, MW-36S, and MW-470S (G Range); 03MW0006, 03MW0007A, 03MW0014A, 03MW0020, 03MW0025A 03MW0709, and 03MW0710 (GA/GB Range); MW-60S and MW-109S (KD Range [East]); MW-492S (O Range); DP-459 and MW-215 (P Range); MW-475S and MW-476S and XXLRWS8-2 (Former B Range); MW-219M4 (Former C Range); MW-174S and MW-282M2 (Former D Range); MW-56S (M Range and Former M-1 Range); XXLRWS6-1 and MW-264M2 (Former M-2 Range); MW-116S, MW-121S, and MW-154S (N Range); MW-63S (L Range 1950s to 1980s), MW-67S (L-2 Range); MW-344S (L-3 Range); and LRM0003 (L-4 Range).

Figure 5-1 shows the locations of these 54 wells. Groundwater data from the sampling events conducted at these wells from May 1999 to December 2012 were included in the data set used for the risk screening. The groundwater analytical program included explosives, SVOCs, VOCs, pesticides, herbicides, PCBs, metals and inorganics. These groundwater data are presented in Appendix A.

Table 7-1 presents the results of the screening evaluation that was performed on the compiled site-wide groundwater data set. The maximum concentration of each detected analyte was compared to its federal and Massachusetts (where available) Maximum Contaminant Level (MCL and MMCL), USEPA Drinking Water Life-Time Health Advisory (HA), EPA Regional Screening Level (RSL) for Tapwater, and MCP Method 1 GW-1 Standard.

Other factors that were considered in determining whether to further evaluate the detected analyte included whether the analyte was an essential human nutrient, its frequency of detection, specific characteristics of the analyte, and if the compound had a documented history of false positive analytical results. The subsections that follow summarize the results of these comparisons and considerations for the groundwater associated with the Small Arms Ranges by chemical group.

7.1.1 Explosives

Groundwater samples from 48 of the 54 wells were analyzed for 19 explosives by Method 8330. Samples from 03MW0025A, MW-490S, MW-491S, MW-492S, and the new B Range wells (MW-537M1, MW-538M1, and MW-539M1) were not analyzed for explosives. There was a single detection of RDX (0.37 µg/L) in MW-34M3 in November 2003. RDX was not detected in the 13 groundwater monitoring events conducted prior to this date or the 11 events conducted subsequently. Explosives were not detected in any other sample in the data set. Three additional explosives compounds also were analyzed for in the groundwater collected at MW-56S: hexahydro-1,3-dinitroso-5-mononitro-1,3,5-triazine (DNX), hexahydro-1-mononitroso-3,5-dinitro-1,3,5-triazine (MNX), and hexahydro-1,3,5-trinitroso-1,3,5-triazine (TNX). None of these compounds were detected in the groundwater samples from this well.

7.1.2 Perchlorate

Groundwater samples from 22 of the 54 wells were analyzed for perchlorate. Perchlorate was detected in MW-116S (N Range) and MW-344S (L-3 Range) and a few detections were reported in MW-215, MW-282M2, MW-34M3 and MW-67S. Of the 29 total reported detections of perchlorate, only one (at a concentration of 2.2 µg/L on April 24, 2007) exceeded the lowest (i.e., most stringent) of the groundwater screening criteria (the MMCL and the MCP GW-1 Standard of 2 µg/L). The reported concentration in the duplicate sample associated with this sample was 1.8 µg/L. The concentrations of perchlorate detected in MW-344S have been declining steadily since 2007, and have been below 2 µg/L since then. Perchlorate detections in this well were evaluated as part of the Northwest Corner Site, and the source of these detections is believed to be unrelated to the use of the proximate L-3 Small Arms Range. Because all other perchlorate detections in the data set were below its screening criteria and the presence of perchlorate in this well was not attributable to the Small Arms Ranges, perchlorate in groundwater was determined to not warrant further evaluation relative to these Small Arms Ranges.

7.1.3 Metals and Inorganics

Of the 54 wells, groundwater samples from 46 were analyzed for total metals, 30 were analyzed for filtered (dissolved) metals and 33 were analyzed for inorganics. Twenty-nine metals and inorganics were detected. However, only antimony, arsenic, chromium, thallium, tungsten, zinc, and nitrogen as nitrate-nitrite exceeded any of their respective screening criteria.

Antimony was detected in 2 of 262 unfiltered samples and 2 of 46 filtered samples. Each of these four detections was in a different monitoring well and antimony was not detected in subsequent sampling events. The maximum detected concentration (10.8 J µg/L in MW-538M1 on April 1, 2010) exceeds all of the listed screening criteria (which are all 6 µg/L).

Arsenic was detected in 19 of the 261 unfiltered samples included in the groundwater data set. The maximum detected concentration of arsenic in groundwater was 23.6 µg/L (from location MW-465S), which exceeded the MCL and MCP GW-1 Standard of 10 µg/L. However, this analytical result has been determined to be a false positive resulting from cross-contamination from a laboratory control spike and was confirmed as a non-detect in the Method 6020 ICP/MS analysis. The next highest detected concentration of arsenic in groundwater was 5.2 µg/L, which was below the MCL and MCP GW-1 Standards. Arsenic was not detected in any of the 49 filtered groundwater samples. Furthermore, many studies have been conducted to characterize the elevated levels of arsenic in groundwater throughout New England. Naturally occurring arsenic is common in alluvial aquifers of the United States (Korte 1991).

Chromium was detected in 41 of 261 unfiltered samples and 2 of 49 filtered samples. The maximum detected concentration of chromium was 25.8 µg/L from MW-465S in a sample collected October 13, 2006, which exceeded the EPA RSL for Tapwater (0.031 µg/L). This well was re-sampled two weeks later and chromium was not detected in either the original or duplicate sample. Chromium has been sporadically detected in 25 different wells, typically only once. The maximum detected concentration of chromium was less than the MCL and the MCP Method 1 GW-1 Standard.

There were four detections of thallium: an estimated concentration of 4.7 µg/L in MW-23S (on September 14, 1999), an estimated concentration of 4 µg/L in MW-56S (on September 5, 2000), 4 µg/L in MW-72S (May 27, 1999) and an estimated concentration of 2.6 µg/L in 03MW006 (April 15, 1999). Thallium has not been detected in the subsequent rounds of sampling at any of these wells.

Tungsten was detected in 31 of 200 unfiltered samples and 25 of 64 filtered samples included in the groundwater data set. Tungsten has been detected in 13 of the 26 monitoring wells that have been sampled for tungsten. The maximum detected concentration of tungsten in filtered samples (22 µg/L in MW-470S on October 30, 2006) exceeded the MassDEP Interim Drinking Water Guideline (20 µg/L, MassDEP 2006), but the unfiltered result for this same sample (2.6 µg/L) was well below this Guideline. The seven subsequent results for MW-470S have been non-detect for tungsten since July of 2007. The maximum detected concentration of tungsten in unfiltered samples (3.7 µg/L) was below the Interim Guideline. Although tungsten has historically been detected in MW-72S at B Range, since March 2011, detected concentrations have been less than 4 µg/L. As discussed in Section 5.2, results of some of the tungsten analyses in groundwater conducted prior to 2007 were later determined to be false positives (for low-level detections) due to not using nitric acid preservation or acidification prior to analysis. Consequently, the risk screening utilized only tungsten results collected since October 2006. Tungsten was detected in 31 of 200 unfiltered samples and 25 of 64 filtered samples included in the groundwater data set. Tungsten has been detected in 13 of the 26 monitoring wells that have been sampled for tungsten since October 2006. There have been no exceedances of the MassDEP Interim Drinking Water Guideline for tungsten since the method was modified.

Zinc was detected in 96 of 250 unfiltered samples and 15 of 46 filtered samples. The maximum detected concentration of zinc exceeded the HA but was less than the EPA RSL for Tapwater or the MCP GW-1 Standard.

Nitrogen measured as nitrate-nitrite was detected in 49 of 59 samples for which it was analyzed. Its maximum detected concentration exceeded the MCL for nitrite, but not the MCL for nitrate. The maximum detected concentration also did not exceed the RSL for nitrate or the HA for either nitrite or nitrite.

Based on the factors discussed above, antimony, arsenic, chromium, thallium, tungsten, zinc and nitrogen as nitrate-nitrite in groundwater were determined to not warrant further evaluation. Four of the detected inorganics had no published screening criteria from these sources but are considered to be essential human nutrients (i.e., calcium, magnesium, potassium, and sodium). As such, they were not considered for further evaluation. Therefore, no metals or inorganics in the groundwater were identified as warranting further evaluation.

7.1.4 Pesticides and Herbicides

Groundwater samples from 24 of the 54 wells were analyzed for 21 pesticides and 18 herbicides. No pesticides and five herbicides (i.e., 2,4,5-T, bentazon, chloramben, dichloroprop, and MCPP) were reported as detected in these groundwater samples. Chloramben and 2,4,5-T were detected four and two times, respectively, at estimated concentrations that were well below their respective groundwater screening criteria. Bentazon was detected once, at an estimated concentration well below screening criteria. Dichloroprop was detected once but there are no screening criteria for this compound. MCPP was detected once, at a concentration greater than screening criteria, but the MCPP detections have been associated with false positives obtained using an older analytical method (AMEC 2002a). Therefore, no pesticides or herbicides in the groundwater were identified as warranting further evaluation.

7.1.5 Semivolatile Organic Compounds

Groundwater samples from 38 of the 54 wells were analyzed for 79 SVOCs. Of the 79 SVOCs, 12 were detected. Of these 12 SVOCs, the maximum detected concentration of bis(2-ethylhexyl)phthalate (24 µg/L in MW-23S on October 27, 1997) and naphthalene (0.28 µg/L in MW-154S on July 25, 2001) exceeded groundwater screening criteria. However, bis(2-ethylhexyl)phthalate is a likely laboratory contaminant. In addition, the two subsequent sampling results for bis(2-ethylhexyl)phthalate at this same well were non-detect. The six subsequent sampling results for naphthalene at MW-154S were non-detect. Therefore, SVOCs were not considered further in the groundwater screening evaluation.

7.1.6 Volatile Organic Compounds

Groundwater samples from 27 of the 54 wells were analyzed for 45 VOCs. Of these 45 VOCs, 13 were detected in the groundwater. Of the 13 detected VOCs, the maximum detected concentrations of four exceeded screening criteria: chloroform, cis-1,3-dichloropropene, PCE and TCE. Chloroform was detected in 24 wells, and its degradation product (chloromethane) also was detected in three wells. In all cases, the reported concentrations of chloroform exceeded the lowest of its groundwater screening criteria (the EPA RSL for Tapwater of 0.19 µg/L), but were below its MCL, HA, and MCP GW-1 Standard. In addition, chloroform appears to be ubiquitous within the portion of the aquifer being studied. Chloroform, which has not been identified as a compound associated with historical Small Arms Range activities, has been widely observed in groundwater across the Upper Cape. Chloroform has been determined to be naturally present in much of the groundwater on Cape Cod (Earth Tech 2000). Thus, chloroform was not considered for further investigation. Cis-1,3-dichloropropene was detected in a single sample from monitoring well LMW0003 (estimated 0.5 µg/L on September 10, 2003) and was not detected in the 11 previous and 5 subsequent sampling events at this well. All the detections of PCE and several of the detections of TCE were observed in samples collected from GA/GB Range monitoring wells in April 1999. The presence of the PCE and TCE were likely due to Chemical Spill 10. The other detections of TCE were from an L-4 Range monitoring well (LRMW0003) and were observed in 2002, 2003, and 2004. More recent results from these wells were non-detect for PCE and TCE. Consequently, VOCs were not considered further in the groundwater screening evaluation as their occasional presence is likely due to non-SARs related sources (e.g., associated with fuel spill or chemical spill areas or naturally occurring [in the case of chloroform]).

7.1.7 Polychlorinated Biphenyls

Groundwater samples from 24 of the 54 wells were analyzed for PCBs. None of the seven Aroclors that were analyzed for were detected in these groundwater samples.

7.1.8 Summary of Site-Wide Groundwater Screening

Groundwater sampling data from 54 monitoring wells associated with the Small Arms Ranges were available for explosives, perchlorate, metals and inorganics, pesticides and herbicides, SVOCs, VOCs, and PCBs. Of the 219 analytes reported for groundwater, 15 were detected at maximum concentrations that exceeded risk-based groundwater screening criteria: perchlorate, antimony, arsenic, chromium, nitrogen as nitrate-nitrite, thallium, tungsten, zinc, MCPP, bis(2-

ethylhexyl)phthalate, naphthalene, chloroform, cis-1,3-dichloropropene, PCE and TCE. Of these, arsenic and chloroform have been previously associated with other sources, and their presence is not indicated to be related to Small Arms Range activities. In the cases of antimony, thallium, bis(2-ethylhexyl)phthalate, naphthalene, cis-1,3-dichloropropene, PCE and TCE, typically only the maximum detected concentrations of these analytes exceeded their most stringent screening criteria. More importantly, subsequent sampling results for the same wells were non-detect for these analytes. MCPP detections have been associated with false positives obtained using an older analytical method (AMEC 2002a). In addition, bis(2-ethylhexyl)phthalate is a common laboratory contaminant and its presence in these samples is believed to have been a laboratory artifact. Chromium has been sporadically detected in 24 different wells, typically only once or twice, and the maximum detected concentration of chromium was less than the MCL and the MCP Method 1 GW-1 Standard. The maximum detected filtered tungsten concentration exceeded the MassDEP Interim Drinking Water Guideline, but the paired unfiltered result was below the Guideline as were all subsequent samples for tungsten. Zinc has been sporadically detected in 36 different wells, and the maximum detected concentration of zinc was less than the MCP Method 1 GW-1 Standard (there is no MCL for zinc). Nitrogen measured as nitrate-nitrite exceeded the MCL for nitrite, but not the MCL for nitrate. The maximum detected concentration also did not exceed the RSL for nitrate or the HA for nitrate plus nitrite. Finally, the one well (MW-344S) with a perchlorate detection above the screening criteria has been evaluated as part of the Northwest Corner Site as documented in the *Final Northwest Corner Remedial Investigation/Feasibility Study* (Tetra Tech 2009). Therefore, no analytes detected in groundwater at the Small Arms Ranges were determined to warrant further evaluation in relation to potential risk.

7.2 Site-Wide Soil Evaluation

The initial risk screening for soil was conducted using a site-wide soil data set. This data set consisted of all validated soil sampling results from May 1999 to May 22, 2013 from all depth intervals for the 30 ranges that have been sampled. At those locations where maintenance or response actions involving soil excavation and removal have occurred (e.g., portions of I Range, J Range, K Range, SE/SW Range, T Range, Former B, Former D, and Former M-2), only post-removal soil sampling results were used. The initial risk screening was performed using the site-wide maximum detected concentration of each detected constituent to identify a subset of soil analytes that warranted further evaluation on a range-specific basis.

Comparisons of the maximum detected concentration of each analyte in the site-wide soil database to a series of analyte-specific screening criteria are presented in Table 7-2. These criteria included the MCP Method 1 S-1/GW-1 Standards, the MMR Soil Screening Levels (SSLs), and the EPA Risk-Based SSLs. MassDEP Leaching-Based Soil Concentrations and the MMR-specific outwash background soil concentration (see Appendix B) for each detected analyte were included in Table 7-2 for comparison purposes. The majority of the Small Arms Ranges are situated within the Mashpee Pitted Plain, which is geologically similar to the outwash soils.

Other factors that were considered in determining whether to evaluate a compound further included whether the compound was an essential human nutrient, its frequency of detection across the 30 sampled ranges, whether the compound was detected in both soil and groundwater, any specific circumstances regarding the presence of the compound, and whether there were documented prior false positive analytical results associated with the analyte. The subsections that follow summarize the results of these comparisons for the site-wide soil.

7.2.1 Explosives

Soil samples were analyzed for 19 explosives, and eight explosives were detected in at least one sample. The maximum detected concentrations of seven of the eight detected explosives compounds exceeded their respective MMR SSL (see Table 7-2) (there is no MMR SSL for nitrobenzene) and all eight exceeded their EPA Risk-Based SSL. Five explosives were detected once or twice in the set of samples from the ranges: 2,4,6-trinitrotoluene (detected twice, at a maximum concentration of 0.276 mg/Kg in sample SS04752-A from N Range); 2-amino-4,6-dinitrotoluene (detected once at an estimated concentration of 0.046 mg/Kg in sample SS02305-A from T Range); 4-amino-2,6-dinitrotoluene (detected twice at a maximum estimated concentration of 0.027 mg/Kg in sample SS02305-A from T Range); RDX (detected once at 0.52 mg/Kg in sample SS02305-A from T Range); and nitrobenzene (detected once at 0.17 mg/Kg in sample SS127D-SW from SW Range). All of these explosives were detected infrequently in soil (less than one percent of all samples analyzed for these explosives) at low levels and were not detected in groundwater. Therefore, they were not further evaluated.

The maximum detected concentrations of the compounds 2,4-DNT (0.55 mg/Kg by Method 8330 and 3.4 J mg/Kg by Method 8270) and 2,6-DNT (not detected by Method 8330 and 0.33 mg/Kg by Method 8270) exceeded their respective MMR SSLs and EPA Risk-Based SSLs. The 2,4-DNT Method 8330 result also exceeded the MCP S-1/GW-1 Standard for this compound. Neither of these compounds has been detected in the groundwater associated with any of the ranges. However, 2,4-DNT is a constituent of Small Arms Range propellants. The feed stocks for the propellants for most small arms ammunition have typically contained between 6 percent and 11 percent of DNT by weight (WSRL 1984). Upon reworking and refinement over time, a common manufacturing goal was to have the total weight of the propellant modifiers (of which DNT was the principal component) to be less than one percent by weight (ARSCD 1977). Recently tested small arms ammunition contained up to four mg of DNT per round (CRREL 2007b). As such, these detections of 2,4-DNT in soil at the ranges are likely to be the result of small arms firing. DNT encapsulated in nitrocellulose has been shown to be essentially immobile in the environment. As would then be expected, neither of these compounds has been detected in the groundwater associated with the Small Arms Ranges. Furthermore, the laboratory leaching studies (see Section 3.2.7) indicate that these compounds are readily degraded through biodegradation and photodegradation processes once in solution. Of the 673 samples analyzed for 2,4 –DNT by Method 8270, 14 exceeded the MCP S-1/GW-1 Standard (0.7 mg/Kg), but none of the 266 samples analyzed by Method 8330 exceeded this value. Eight of the 14 exceedances were in samples collected from G Range. The five ranges with exceedances of the MCP S-1/GW-1 Standard for 2,4-DNT are further discussed in Appendix E. Neither 2,4-DNT nor 2,6-DNT are expected to be a threat to groundwater and were not retained for further evaluation.

Soil samples from 19 ranges were analyzed for nitroglycerin. Nitroglycerin was detected in a number of soil samples from six of the 19 ranges (by either Method 8330 or Method 8270). All of the ranges where nitroglycerin was detected are currently active ranges. Nitroglycerin is likely to be present in the soil at these ranges since it is a component of small arms ammunition propellants. The maximum detected concentration of nitroglycerin exceeded both its MMR and EPA Risk-Based SSLs. No MCP Method 1 S-1/GW-1 Standard has been published for nitroglycerin. Therefore, an MCP Method 2 S-1 standard was calculated (4.4 mg/Kg) for screening purposes using the provisional oral reference dose (1E-4 mg/Kg) and the default exposure parameters of the S-1 Standards. In order to continue the approval process to continue to fire on the ranges, the MAARNG removed range floor soils containing levels of nitroglycerin that exceed 5 mg/Kg at selected ranges (J Range, K Range, and T Range) in 2007 and 2008 and moved this material to a stockpile at K Range. Thus, soil containing greater than 5 mg/Kg nitroglycerin remains at E Range, J Range, K Range, SE Range, SW Range, and T Range. However, laboratory leaching studies have indicated that nitroglycerin encapsulated in nitrocellulose is essentially immobile in the environment. Nitroglycerin has not been detected in groundwater associated with the Small Arms Ranges, a finding consistent with the leaching studies. Therefore, nitroglycerin in soil does not appear to be a threat to groundwater.

7.2.2 Perchlorate

Soil samples from five ranges were analyzed for perchlorate; one or two detections of perchlorate were found in samples from four of these ranges (L-3 Range, N Range, SE Range and Succonsette Pond). Of the four ranges with detectable concentrations of perchlorate, there were two ranges (N Range and Succonsette Pond) where the maximum detected concentration of perchlorate exceeded the lowest perchlorate screening criterion (the MMR SSL of 0.0031 mg/Kg). Exceedances of groundwater screening criteria for perchlorate were only observed in samples collected at monitoring well MW-344S (L-3 Range). As discussed in Section 7.1.2, this well was evaluated as part of the Northwest Corner Site and the source of these detections is believed to be unrelated to the use of the L-3 Range as a Small Arms Range. Perchlorate is not a typical component of small arms propellants. Consequently, perchlorate in soil was determined to not warrant further evaluation for the ranges.

7.2.3 Polychlorinated Naphthalenes

Samples from two ranges (N Range and Succonsette Pond) were analyzed for polychlorinated naphthalenes (PCNs). The presence of the PCNs is likely to be associated with their use as inert munitions fillers. Research on the relative potencies of these compounds indicates that naphthalenes with four or fewer chlorines or eight chlorines do not have apparent “TCDD-like” toxicity (AMEC 2001). At least some of the penta-, hexa-, and hepta-chlorinated-naphthalenes do have a mechanism of toxicity that is similar to TCDD although to a much lesser degree than TCDD. The cited letter proposed that relative experimental potency (REP) factors be assigned to the penta-, hexa- and hepta-chlorinated naphthalenes based upon the published cellular assays (AMEC 2001). These REPs were used to adjust screening criteria for TCDD as follows:

- Penta-chlorinated naphthalenes have REP factors of approximately 10^{-4} suggesting they are on the order of 10,000 times less toxic than TCDD; and

- Hexa- and hepta-chlorinated naphthalenes have REP factors of approximately $3x10^{-3}$ suggesting they are on the order of 300 times less toxic than TCDD.

The single detected concentration of heptachloronaphthalene exceeded the Relative Experimental Potency-adjusted MCP S-1/GW-1 Standard for TCDD. A second sample from this location was non-detect for polychlorinated naphthalenes.

7.2.4 Metals and Inorganics

Each of the 28 metals and inorganics were detected at least once in the soil samples from the various ranges. Of these, 19 were detected at maximum concentrations that exceeded at least one of their respective screening criteria (see Table 7-2). With the exception of antimony, arsenic, chromium, and thallium all of these metals were detected in the groundwater at maximum concentrations well below the most stringent groundwater screening criteria. Antimony, arsenic, chromium, and thallium were detected in groundwater at maximum concentrations that exceeded their most stringent screening criteria.

Antimony was detected in soil samples collected at 35 of the 36 sampled ranges. Although antimony was typically detected at levels consistent with its MMR background soil concentration (1.9 mg/Kg), concentrations above this value were observed at 20 of the 36 ranges. Of the 1,196 soil samples that were analyzed for antimony, the seven highest exceed the MCP S-1/GW-1 Standard (20 mg/Kg). Three of these seven samples were collected from H Range, two were collected from Former B Range, and there was one sample from T Range and one from G Range. Three replicate 2013 multiple increment samples from H Range were comparable to background. The two exceedances observed at Former B Range were both from location SS140L. This location also had elevated concentrations of copper and lead. The single exceedance observed at T Range was from location SS169A (0.5 to 1.0 feet bgs). The paired sample from this same location and depth was comparable to background, as were the other four samples from this location that were collected at shallower depths (0-0.25 and 0.25-0.5 feet bgs). A 2013 multiple increment sample from G Range was 25.4 mg/Kg. This sample location also was elevated for copper and lead. Antimony has been detected in 2 of 262 unfiltered groundwater samples (a G Range Well and a GA/GB Range well) and 2 of 46 filtered groundwater samples (two different B Range wells). Each of these four detections was in a different monitoring well and antimony was not detected in subsequent groundwater sampling events. Consequently, although there are exceedances of the MCP S-1/GW-1 standard for antimony, antimony has not been consistently detected in groundwater. The four ranges with exceedances of the MCP S-1/GW-1 Standard for antimony are further discussed in Appendix E.

Arsenic was detected in soil samples collected at 27 of the 28 sampled ranges, typically at levels consistent with its MMR background soil concentration. Arsenic concentrations marginally above background (5.5 mg/Kg) were observed at six of the 29 ranges: B Range (at a maximum concentration of 8.9 mg/Kg), Former B Range (at a maximum concentration of 5.8 mg/Kg), GA/GB Range (at a maximum concentration of 15.3 mg/Kg), P Range (at a maximum concentration of 6 mg/Kg), Former R Range (at a maximum concentration of 5.9 mg/Kg), and T Range (at a maximum concentration of 23.4 mg/Kg). While arsenic is sometimes a trace constituent in lead-antimony alloy small arms projectiles (on the order of 0.01 or 0.001 percent by weight), the arsenic concentrations observed in the soil are very likely due to natural origin.

The mobility of arsenic in subsurface soils and pore waters may be influenced by pH and redox conditions. However, arsenic has a distribution coefficient of 25 to 31 L/Kg (USEPA 1996). In addition, under the oxidizing conditions typically expected in shallow Small Arms Range soils, arsenic is likely immobilized by adsorption as arsenate or arsenite onto hydrous ferric oxide components of soils. As such, it is relatively immobile and it is unlikely that the detections in groundwater are related to the detections in the surface soil. The presence of arsenic in Small Arms Range soil is likely due to natural occurrence and does not warrant further evaluation.

Chromium was detected in soil samples collected at the 28 sampled ranges, typically at levels consistent with its MMR background soil concentration (19 mg/Kg). The notable exception was at T Range. At T Range, chromium concentrations in soil ranged from 11 mg/Kg to 313 mg/Kg. Fourteen of the 32 detected chromium concentrations in excess of the MCP Method 1 S-1/GW-1 Standard (30 mg/Kg) were collected at T Range and all of these were from the April 2006 multiple increment sampling event. The maximum detected concentration in T Range samples other than the 2006 multiple increment samples was 21 mg/Kg. The CRREL grinding method, Method 8330B, used for metals preparation has been shown to introduce significantly high levels of total chromium and iron from the grinding equipment into the samples during sample preparation. The samples that were analyzed for metals were first ground in a high chromium cast iron steel alloy puck mill grinder prior to acid digestion and analysis to thoroughly homogenize the samples. Laboratory reports have shown that chromium levels can increase in the ground blank samples vs. the un-ground lab blank samples. The maximum detected chromium concentration in recent samples since the grinding method was modified did not exceed the MCP S-1/GW-1 Standard. The four ranges with exceedances of the MCP S-1/GW-1 Standard for chromium are further discussed in Appendix E.

Thallium was detected in soil samples collected at six of the 29 ranges, at levels consistent with its MMR background soil concentration. Thallium concentrations marginally above background (1.6 mg/Kg) were observed at only one of the 29 ranges, Former B (at a maximum estimated concentration of 1.7 mg/Kg). Thallium is not associated with small arms munitions.

There are no EPA screening criteria for tungsten in soil but MassDEP has developed and Interim Risk-Based Soil Concentration of 160 mg/Kg (MassDEP 2012). There have been a number of investigations and tungsten-contaminated soil removals pursuant to the 2006 Berm Maintenance – Tungsten Removal Project at MMR. Seven ranges (B Range, C Range, G Range, I Range, J Range, K Range, and T Range) were included in the 2006 Berm Maintenance – Tungsten Removal Project. As a result of this project, soils containing greater than 150 mg/Kg tungsten (as measured by XRF) were removed. There are two samples remaining that exceed 150 mg/Kg tungsten (locations BHBRS03 6 to 8 feet [200 mg/Kg] and 8 to 10 feet [179 mg/Kg]). Both of these samples were collected from B Range. Tungsten has been detected in groundwater, but only sporadically. The maximum detected filtered tungsten concentration exceeded the MassDEP Interim Drinking Water Guideline and the paired unfiltered result was below the Guideline. All subsequent samples for tungsten also were below the Guideline. The B Range exceedances of the Interim Risk-Based Soil Concentration for tungsten are further discussed in Appendix E.

Five ranges (Former B Range, Former D Range, J Range, K Range, and Former M-2 Range) were included in the 2009 Lead Remediation Program. Pursuant to this program, soils containing greater than 300 mg/Kg lead (as measured by XRF screening results) have been removed from different portions of each range. However, there remain several sample locations from a number of ranges (B Range, Former B Range, C Range, Former C Range, D Range, Former D Range, E Range, G Range, H Range, I Range, K Range, L-3 Range, Former M-2, N Range, Former N Range, SE Range, SW Range and T Range) that exceed 300 mg/Kg lead. With the exception of H Range, Former N Range and T Range, average soil concentrations in these locations are below this threshold. At the Former B Range and Former D Range, the isolated residual samples exceeding 300 mg/Kg were collected in 2000/2001. Additional multiple increment samples will be collected at these locations. The ranges with exceedances of the MCP S-1/GW-1 Standard for lead are further discussed in Appendix E. Although lead has been detected in groundwater in 3.8 percent of all unfiltered groundwater samples, the maximum detected concentrations were always below the screening criterion. This finding is consistent with the 2007 CRREL study of the behavior of metallic lead in the environment which concluded (based on a literature search, a review of geochemical properties, and existing site data) that the soil at MMR retards the migration of lead to groundwater. However, as noted in the CRREL report, there is limited data to completely quantify possible lead migration in subsurface soils. Therefore, given its toxicity and the finite capacity of the soil to act as an absorbent, range design and maintenance programs, including Best Management Practices are prudent.

7.2.5 Pesticides and Herbicides

Fourteen of 36 pesticides and herbicides were detected at least once in soil samples collected from the ranges. Five of these analytes exceeded at least one of their respective soil screening criteria: MCPA, MCPP, dieldrin, gamma-chlordane, and p,p’-DDD. The MCPA and MCPP exceedances have been associated with false positives obtained using an older analytical method (AMEC 2002a). The analyses for herbicides performed prior to 2001 have been shown to be affected by interferences that have led to tentative identifications and estimated quantifications of MCPA and MCPP. In 2001, modifications were made to the analytical method for herbicides to minimize interferences. As such, the analytical data for this compound obtained prior to 2001 likely represent false positive results. Consequently, MCPA and MCPP were not considered for further evaluation. Most of the detections of dieldrin were at Former B Range, GA/GB Range, and L-2 Range. Although the maximum detected concentration of dieldrin exceeded its MCP Method 1 S-1/GW-1 Standard, the presence of this compound was likely due to the application of this pesticide in a manner consistent with its labeling. Dieldrin is no longer used for pest control, because it was banned in 1987. The four ranges with exceedances of the MCP S-1/GW-1 Standard for dieldrin are further discussed in Appendix E. A single detection of gamma-chlordane in a sample from GA/GB Range exceeded its MMR SSL and three detections of p,p’-DDD in two samples from GA/GB Range and one sample from Former B Range exceeded its EPA Risk-Based SSL. However, none of these compounds have been detected in the groundwater associated with these ranges. The only pesticides or herbicides that were detected in groundwater were 2,4,5-T, bentazon, chloramben, dichloroprop and MCPP (see Table 7-1). Of these, 2,4,5-T and chloramben were also detected in soil but at concentrations below any applicable screening criteria. As such, based on the generally low detected concentrations, low mobility in the environment and lack of significant groundwater detections, the pesticides and herbicides that were detected in Small Arms Range soils are unlikely to impact groundwater. Therefore, no pesticides or herbicides were retained for further evaluation.

7.2.6 Semivolatile Organic Compounds

Of the 66 SVOCs analyzed by Method 8270, 41 were detected in at least one soil sample. Three of the detected SVOCs, (2,4-DNT, 2,6-DNT, and nitroglycerin) have already been discussed in Section 7.2.1 on explosives and five were discussed in Section 7.2.3 on PCNs. The remaining 33 detected SVOCs are listed in Table 7-2 as SVOCs. Of these, the maximum detected concentration of one SVOC, benzo(a)pyrene, exceeded all three of its screening criteria and 16 others exceeded at least one SSL. Of these 16 SVOCs, nine were PAHs, four were phthalates, and the others were carbazole, dibenzofuran, and n-nitrosodiphenylamine. Carbazole, dibenzofuran, and n-nitrosodiphenylamine are structurally similar to PAHs (i.e., they are composed of aromatic rings, but unlike PAHs, these rings are joined by either nitrogen or oxygen), and consequently exhibit similar behavior in the environment. In general, PAHs are highly adsorbed or are chemically combined with soil. In addition, the high number of aromatic rings and molecular weight of PAHs results in low water solubility. Thus, their overall tendency is for low mobility in the environment and PAHs have not been detected in groundwater at the Small Arms Ranges (other than a single detection of naphthalene in 2001). With the exception of a single result for benzo(a)pyrene (2.5 mg/Kg in sample SS164K from the Former M-2 Range which exceeds the MCP S-1/GW-1 Standard of 2.0 mg/Kg), all PAHs are below MCP S-1/GW-1 Standards. Based on their low environmental mobility, lack of groundwater detections, generally low concentrations, none of the PAHs or similar compounds (carbazole, dibenzofuran, and n-nitrosodiphenylamine) detected in soil at the Small Arms Ranges warranted further evaluation.

The four phthalates detected above screening levels were benzyl butyl phthalate, bis(2-ethylhexyl)phthalate, diethylphthalate and di-n-butyl phthalate. Of these bis(2-ethylhexyl)phthalate, diethylphthalate and di-n-butyl phthalate were detected in groundwater. As only the maximum detected concentration of bis(2-ethylhexyl)phthalate exceeded a groundwater screening criteria and the two subsequent sampling results were non-detect, phthalates in Small Arms Range soils are not indicated to pose a threat to groundwater. The maximum detected concentrations of all four of the phthalates were below their respective MCP S-1/GW-1 Standards.

In general, SVOCs are highly adsorbed or chemically combined with soil. In addition, the high number of aromatic rings and molecular weight of SVOCs results in low water solubility. As such, their overall tendency is for low mobility in the environment. Based on their low environmental mobility and the lack of significant groundwater detections, these SVOCs are not believed to pose a threat to groundwater.

7.2.7 Volatile Organic Compounds

Ten of the 33 VOCs that were analyzed were detected at the various ranges. Six of the 10 detected VOCs exceeded one or both of their respective MMR and EPA Risk-Based SSLs, but none exceeded their respective MCP Method 1 S-1/GW-1 Standard. With the exception of acetone and chloroform, all of these VOCs exhibiting an exceedance had very low frequencies of detection and relatively low maximum detected concentrations compared to criteria. As such, they do not warrant further evaluation. As noted in Section 7.1.6, chloroform was the single VOC detected in groundwater at a maximum concentration exceeding an applicable groundwater screening criterion. The overall maximum detected concentration of chloroform in soil was an estimated 0.009 mg/Kg, which was well below its MCP Method 1 S-1/GW-1 Standard of 0.4 mg/Kg. Chloroform has not been identified as a compound associated with historical Small Arms Range activities. Based on these factors, it was determined that chloroform in soil did not warrant further evaluation.

Acetone was detected in 90 of 99 soil samples analyzed, but its maximum detected concentration (an estimated concentration of 0.73 mg/Kg) only exceeded its MMR SSL. Acetone is a common laboratory contaminant and was infrequently detected in groundwater at concentrations well below its screening criteria. As such, acetone was not selected for further evaluation.

7.2.8 PCBs

Of the seven Aroclors analyzed in the 128 collected soil samples, there was one detection of Aroclor 1260. This concentration of Aroclor 1260 exceeded its respective MMR and EPA Risk-Based SSLs. Since PCBs were very infrequently detected (less than one percent of the analyzed samples), were not detected in groundwater, and did not exceed their MCP Method 1 S-1/GW-1 Standard, they were not retained for further evaluation.

7.2.9 Summary of Site-Wide Soil Screening

Soil data were available for explosives, perchlorate, PCNs, metals and inorganics, pesticides and herbicides, SVOCs, VOCs, and PCBs. 2,4-DNT and nitroglycerin were the most frequently detected explosives compounds identified at the Small Arms Ranges. Both DNT and nitroglycerin are encapsulated in nitrocellulose and, consequently, are essentially immobile in the environment and neither compound has been detected in the groundwater associated with the ranges. In addition, any DNT or nitroglycerin not encapsulated in the nitrocellulose matrix will be quickly degraded through biodegradation and photo-degradation processes (USACE 2009 and CHPPM 2007). Thus, DNT and nitroglycerin residuals from small arms firing are not believed to pose a threat to groundwater. The six ranges with exceedances of the calculated MCP Method 2 S-1 Standard for nitroglycerin are active operational ranges currently governed by OMPP plans. These six ranges are further discussed in Appendix E.

Of the 187 soil analytes, 12 were detected at concentrations that exceeded both soil and groundwater screening criteria: perchlorate, antimony, arsenic, chromium, thallium, tungsten, zinc, MCPP, bis(2-ethylhexyl)phthalate, naphthalene, chloroform and PCE. The maximum detection of perchlorate in soil at the Small Arms Ranges (0.101 mg/Kg at Succonsette Pond) was marginally above its MCP Method 1 S-1/GW-1 Standard (0.1 mg/Kg). In addition, perchlorate is not a typical component of small arms propellants. As such, and in consideration of the low frequency of detection of perchlorate in Small Arms Range soils, perchlorate in soil was determined to not warrant further evaluation.

Although there are exceedances of the MCP S-1/GW-1 Standard for antimony in soil, antimony has rarely been detected in groundwater associated with the Small Arms Ranges. Antimony has been detected in 2 out of 262 groundwater samples analyzed for total antimony. The four ranges with exceedances of the MCP S-1/GW-1 Standard for antimony are further discussed in Appendix E. Arsenic and thallium in the soil and groundwater at the Small Arms Ranges are indicated to be attributed to natural occurrence and do not warrant further evaluation. Elevated chromium in soil samples appears to be largely attributable to sample preparation methods that are no longer used and not conditions at the ranges. The four ranges with exceedances of the MCP S-1/GW-1 Standard for chromium are further discussed in Appendix E.

Only the maximum detected filtered tungsten concentration exceeded the MassDEP Interim Drinking Water Guideline and the paired unfiltered result was below the Guideline, as were all subsequent groundwater samples for tungsten. The range with exceedances of the Interim Risk-Based Soil Concentration for tungsten is further discussed in Appendix E.

Zinc has been sporadically detected in 36 different wells, and the maximum detected concentration of zinc in groundwater was less than the MCP Method 1 GW-1 Standard (there is no MCL for zinc). The maximum detected concentration of zinc in soil was less than the MCP S-1/GW-1 Standard.

The MCPP exceedances have been associated with false positives obtained using an older analytical method (AMEC 2002a). While bis(2-ethylhexyl)phthalate was detected in both soil and groundwater above screening levels, the single groundwater detection has been shown to be an anomalous result that was not reproduced in subsequent sampling. The maximum detected concentration of bis(2-ethylhexyl)phthalate in soil was less than the MCP S-1/GW-1 Standard. Naphthalene has been detected in groundwater in a single sample, but was not detected in subsequent sampling events. The maximum detected concentration of naphthalene in groundwater was less than the MCP Method 1 GW-1 Standard (there is no MCL for naphthalene) and the maximum detected concentration of naphthalene in soil was less than the MCP S-1/GW-1 Standard.

Although chloroform was detected in soil and groundwater at levels exceeding screening criteria, the widespread presence of chloroform has been determined to be attributable to several sources unrelated to MMR operations (MMR 2001). As such, chloroform was judged to not warrant further evaluation.

PCE was detected in a single soil sample collected from GA/GB range. The concentration of PCE in soil is well below the MCP S-1/GW-1 Standard. All the groundwater detections of PCE were observed in samples collected from GA/GB Range monitoring wells in April 1999. The presence of the PCE was likely due to Chemical Spill 10. More recent results from these wells were non-detect for PCE.

Eleven soil analytes were detected at maximum concentrations that exceeded MCP Method 1 or 2 S-1/GW-1 Standards: 2,4-DNT, nitroglycerin, perchlorate, antimony, arsenic, cadmium, chromium, lead, nickel, dieldrin, and benzo(a)pyrene. Tungsten was detected at maximum concentrations that exceed the MassDEP Interim Risk-Based Soil Concentration (160 mg/Kg). Heptachloronaphthalene was detected in one sample that exceeded the Relative Experimental Potency-adjusted MCP S-1/GW-1 Standard. 2,4-DNT, nitroglycerin, arsenic, and chromium have already been discussed. For these other analytes, with the exception of lead, there are a handful of samples (less than 10) that exceed the MCP Method 1 S-1/GW-1 Standards. There are several sample locations at a number of the ranges (i.e., B Range, C Range, Former C Range, D Range, E Range, G Range, H Range, I Range, K Range, L-3 Range, Former M-2, N Range, Former N Range, SE Range, SW Range and T Range) where the lead concentration exceeded 300 mg/Kg. With the exception of H Range, Former N Range and T Range, average soil concentrations in these locations are below this threshold. Although lead has occasionally been detected in groundwater (3.8 percent of all unfiltered groundwater samples), the maximum detected concentration was always below the screening criterion. This finding is consistent with a recent study of the behavior of metallic lead in the environment which concluded (based on a literature search, a review of geochemical properties and existing Site data) that the soil at MMR retards the migration of lead to groundwater. Analytes that exceeded MCP S-1/GW-1 Standards are discussed in more detail in Appendix E.

There were two Small Arms Ranges at MMR that have not been sampled and did not have available analytical data for use in this risk screening. These were L Range (1950s to 1980s) and Former M-3 Range. During the May 2013 Supplemental Investigation, a visual investigation and metal detector sweep were performed at L Range. No significant metal debris was detected and there was no visual evidence of past use of the area as a range. In order to qualitatively evaluate the Former M-3 Range, information regarding their operational history, time frame when it was used, size and location was reviewed to identify whether there was a similar range that had sampling data that might provide an indication of the possible conditions at these ranges. The reference range for Former M-3 Range is Former M-1 Range. The soil concentrations at Former M-1 Range were found to either be below the detected constituents' screening criteria or were found to not present either a potential threat to groundwater.

As part of the operations and maintenance program, J, K, and T Ranges have been sampled annually to monitor the impacts of ongoing use of these ranges on soil, pore water, and groundwater. In addition, recent lysimeter sampling for tungsten and antimony at B and G Ranges indicates that there may be some soil sorption and subsequent leaching of these metals. Associated soil sampling at B Range supports the theory that this phenomenon may be limited to the surface or near surface soil.

8.0 INVESTIGATION FINDINGS

A detailed evaluation was undertaken to characterize and evaluate soil and groundwater at 40 Small Arms Ranges at MMR. This evaluation included assessment of recent (2005-2009) multiple increment soil sampling results at seven ranges (E, J, K, I, SE, SW, and T Ranges), operations and maintenance sampling at J, K and T Ranges (2010-2012), and multiple increment sampling at numerous ranges (2013), as well as extensive previous investigations at these and other ranges.

The results of groundwater monitoring investigations at the Small Arms Ranges indicated the presence of only a few groundwater constituents. No explosives were reported in any monitoring wells associated with these ranges. Trace levels of SVOC phthalate compounds (including bis(2-ethylhexyl)phthalate and di-n-butyl phthalate) were detected in certain samples but may be laboratory artifacts. Low levels of metals, including barium, chromium, copper, iron, and zinc, were detected in some samples from certain wells. Tungsten was reported in a few samples primarily from B Range. However, some results are potentially false positives that are artifacts of the sampling method used prior to 2007. Tungsten was detected at 560 µg/L in a groundwater sample from well MW-72S at B Range during a CRREL research study in 2006. Subsequent samples from this well have had much lower tungsten concentrations (less than 22 µg/L). The elevated tungsten level reported in 2006 may have been a transient pulse.

Investigation results indicate that some explosive and propellant-related compounds are present in surface soils at certain Small Arms Ranges. Metals normally associated with small arms projectiles are also present.

Results of the sampling programs indicated that nitroglycerin was the principal propellant-related constituent present in surface soils. In multiple increment sampling at the E, J, K, SE, SW, and T Ranges, this constituent was primarily detected in or near the firing lines. Lower concentrations were detected in certain range floor and/or target area samples at certain ranges. Following soil removal actions at several of these ranges, the overall highest nitroglycerin concentrations were observed at K Range (46 mg/Kg – firing line). Maximum nitroglycerin concentrations at SE Range (41 mg/Kg), SW Range (16 mg/Kg – Area 2), E Range (9.3 mg/Kg), T Range (29.7 mg/Kg – Center 1), and J Range (4.6 mg/Kg) were all somewhat lower.

2,4-DNT concentrations were significantly lower than nitroglycerin concentrations at all ranges and were non-detect in many samples. Certain other propellant-related constituents, including 2-nitrodiphenylamine, n-nitrosodiphenylamine, di-n-butyl phthalate, and n,n'-diethylcarbanilide were also detected at relatively low concentrations (generally less than 1 mg/Kg) at certain range locations.

Concentrations of metals associated with small arms projectiles (including antimony, copper and lead) were variable across the six range surface soils and also varied within individual ranges. Following soil excavations at several ranges, the highest concentrations of antimony (91.9 mg/Kg), lead (5,800 mg/Kg), and copper (742 mg/Kg) were reported for T Range samples. However, the average lead concentration for T Range (371 mg/Kg) was above the standard of 300 mg/Kg for this project.

A conceptual site model was developed for the Small Arms Ranges to further assess the potential impact of propellant and projectile-related surface soil contamination to groundwater. In developing the conceptual site model, laboratory studies conducted by the USACE CRREL on the leaching of 2,4-DNT and nitroglycerin in surface soils at Small Arms Ranges were considered. The laboratory propellant studies supported the findings of recent groundwater monitoring investigations at the ranges. Overall, the results of the study indicated that residual DNT and NG in weathered fired propellants, such as those in surface soils at most Small Arms Ranges, are essentially immobile. This lack of mobility was considered to result from a lack of availability of the total propellant mass for dissolution and high rates of degradation processes (including biodegradation and photodegradation). These study results are consistent with the continued detection of propellants in some surface soils at Small Arms Ranges, many years after training ceased but a general absence of propellants observed in groundwater during long-term monitoring.

Field data and geochemical evaluations by CRREL concerning the potential for subsurface migration of lead at Small Arms Ranges were also considered in developing the conceptual site model. The CRREL evaluation concluded from multiple lines of evidence that lead had not contaminated groundwater at MMR in any significant way. This conclusion was based upon evaluations indicating that no lead plumes had been observed in groundwater at the Small Arms Ranges. A high degree of lead adsorption based on site soil profile data, significant depth to groundwater, and site geochemical conditions that do not favor dissolution of metallic lead were also cited as factors supporting the lack of lead migration to groundwater.

A risk screening was conducted for the 40 operational and non-operational Small Arms Ranges within Camp Edwards to assess whether any of the analytes that were detected in soil or groundwater warranted further consideration. Four of the 40 Small Arms Ranges (E-1 Range, E-2 Range, Former K Range, and Former M-4 Range) are being addressed under other MMR projects and were not addressed in this evaluation. Also, ranges associated with the Otis Fish & Game property are included in another remedial program. Groundwater monitoring data were available for all but 10 of the remaining ranges for explosives, perchlorate, metals and inorganics, pesticides and herbicides, SVOCs, VOCs, and/or PCBs. Of the 219 analytes reported for groundwater, 15 were detected at maximum concentrations that exceeded risk-based groundwater screening criteria: perchlorate, antimony, arsenic, chromium, nitrogen as nitrate-nitrite, thallium, tungsten, zinc, MCPP, bis(2-ethylhexyl)phthalate, naphthalene, chloroform, cis-1,3-dichloropropene, PCE and TCE. Of these, arsenic and chloroform have been previously associated with other sources, and their presence is not indicated to be related to Small Arms Range activities. In the cases of antimony, thallium, bis(2-ethylhexyl)phthalate, naphthalene, cis-1,3-dichloropropene, PCE and TCE, typically only the maximum detected concentrations of these analytes exceeded their most stringent screening criteria. More importantly, subsequent sampling results for the same wells were non-detect for these analytes. MCPP detections have been associated with false positives obtained using an older analytical method (AMEC 2002a). In addition, bis(2-ethylhexyl)phthalate is a common laboratory contaminant and its presence in these samples is believed to have been a laboratory artifact. Chromium has been sporadically detected in 24 different wells, typically only once or twice, and the maximum detected concentration of chromium was less than the MCL and the MCP Method 1 GW-1 Standard. Only the maximum detected filtered tungsten concentration exceeded the

MassDEP Interim Drinking Water Guideline and the paired unfiltered result was below the Guideline as were all subsequent samples for tungsten. Zinc has been sporadically detected in 36 different wells, and the maximum detected concentration of zinc was less than the MCP Method 1 GW-1 Standard (there is no MCL for zinc). Nitrogen (measured as nitrate-nitrite) exceeded the MCL for nitrite, but not the MCL for nitrate. The maximum detected concentration of nitrogen also did not exceed the RSL for either nitrate or nitrite or the HA for nitrate plus nitrite. Finally, the one well (MW-344S) with a perchlorate detection above the screening criteria has been evaluated as part of the Northwest Corner Site as documented in the *Final Northwest Corner Remedial Investigation/Feasibility Study* (Tetra Tech 2009). Therefore, no analytes detected in groundwater at the Small Arms Ranges were determined to warrant further evaluation in relation to potential risk.

Soil data for the Small Arms Ranges were available for explosives, perchlorate, PCNs, metals and inorganics, pesticides and herbicides, SVOCs, VOCs, and PCBs. 2,4-DNT and nitroglycerin were the most frequently detected explosives compounds identified at the Small Arms Ranges. The principal findings for each family of chemical compounds in the Small Arms Range soil are discussed below.

- The maximum detection of perchlorate in soil at the Small Arms Ranges (0.101 mg/Kg at Succonsette Pond) exceeded its MCP Method 1 S-1/GW-1 Standard (0.1 mg/Kg). As such, and in consideration of the low frequency of detection (13 percent) of perchlorate in Small Arms Range soils, perchlorate in soil was determined to not warrant further evaluation. The maximum detected concentration of 2,4-DNT exceeded the MCP S-1/GW-1 Standard for this compound. The maximum detected concentration of nitroglycerin exceeded the calculated Method 2 S-1 Standard. Soil containing greater than 5 mg/Kg nitroglycerin remains at E Range, J Range, K Range, SE Range, SW Range, and T Range. As discussed above, both DNT and nitroglycerin are encapsulated in nitrocellulose and, consequently, are essentially immobile in the environment. Neither compound has been detected in the groundwater samples associated with the ranges. In addition, any DNT or nitroglycerin not encapsulated in the nitrocellulose matrix would be expected to quickly degrade through biodegradation and photo-degradation processes (USACE 2009 and CHPPM 2007). Thus, DNT and nitroglycerin residuals from small arms firing are not believed to pose a threat to groundwater.
- Most, but not all, metals detected in surface soil at the Small Arms Ranges are anticipated to be relatively immobile and resistant to downward migration through the vadose zone. Of the 19 metals detected in soil at concentrations exceeding at least one screening criterion, antimony, arsenic, chromium, thallium, tungsten and zinc were detected in both soil and groundwater above their respective screening levels. Although there are exceedances of the MCP S-1/GW-1 Standard for antimony, antimony has not been consistently detected in groundwater. The four ranges with exceedances of the MCP S-1/GW-1 Standard for antimony are further discussed in Appendix E. Arsenic is not a significant contributor to the mass of small arms ammunition. However, arsenic is sometimes a trace constituent in lead-antimony alloy small arms projectiles (on the order of 0.01 or 0.001 percent by weight). Given this very small percentage, the arsenic concentrations observed in the soil are very likely due to naturally occurring compounds

and not the result of release from the munitions. Similarly, chromium also is not a significant contributor to the mass of small arms ammunition, but small amounts of chromium are sometimes used as an alloying agent to harden the steel that is used in some small arms projectiles. This amount is, once again, very small relative to the mass of the munitions rounds. Thus, detections of arsenic and chromium are not believed to be related to activities conducted at the Small Arms Ranges. The four ranges with exceedances of the MCP S-1/GW-1 Standard for chromium are further discussed in Appendix E. Thallium was detected in soil samples collected at 6 of the 29 ranges, at levels consistent with its MMR background soil concentration. Thallium is not associated with small arms munitions. The maximum detected filtered tungsten groundwater concentration exceeded the MassDEP Interim Drinking Water Guideline, but the paired unfiltered result was below the Guideline (as were all subsequent groundwater samples for tungsten). The range with exceedances of the Interim Risk-Based Soil Concentration for tungsten is further discussed in Appendix E. Zinc has been sporadically detected in the groundwater from 36 different wells, and the maximum detected concentration of zinc in groundwater was less than the MCP Method 1 GW-1 Standard (there is no MCL for zinc). In addition, the maximum detected concentration of zinc in soil was less than the MCP S-1/GW-1 Standard. As such, zinc in soil is not a threat to groundwater. There are several sample locations from a number of ranges (B Range, Former B Range, C Range, Former C Range, D Range, Former D Range, E Range, G Range, H Range, I Range, K Range, L-3 Range, Former M-2, N Range, Former N Range, SE Range, SW Range and T Range) where the lead concentration in the soil at some locations exceeds 300 mg/Kg. This is the case after soil removal actions were performed as part of the 2009 Lead Remediation Program. With the exception of H Range, Former N Range and T Range, the average soil concentrations at these ranges would be below this screening value. Although lead has been detected in groundwater (3.8 percent of all unfiltered groundwater samples), the maximum detected concentration was always below the groundwater screening criterion. This finding is consistent with a recent study of the behavior of metallic lead in the environment, which concluded (based on a literature search, a review of geochemical properties and existing site data) that the soil at MMR retards the migration of lead to groundwater. However, as noted in the Environmental Assessment of Lead at Camp Edwards (CRREL 2007), there is limited data to completely quantify possible lead migration in subsurface soils. Therefore, given its toxicity, and the finite capacity of the soil to act as an absorbent, range design and maintenance programs, including Best Management Practices are prudent. Based on the available data and their chemical properties, most metals detected in Small Arms Range soils are unlikely to impact groundwater. Certain metals such as tungsten are mobile in the vadose zone under certain geochemical conditions. However, long-term monitoring results do not indicate any consistent adverse impacts of metals to groundwater beneath the Small Arms Ranges. In addition, Best Management Practices and OMMPs have been implemented at the active operational ranges.

- Most pesticides/herbicides bind strongly to soil and are therefore immobile in the environment. While five of these analytes were detected at concentrations exceeding at least one or both of their SSLs, most were detected at low concentrations in a few samples. A few (dieldrin, p,p’-DDD, p,p’-DDE, p,p’-DDT) were detected more frequently, but none of these pesticides or herbicides were detected in groundwater above screening levels. Based on the generally low detected concentrations, low mobility in the environment, and lack of significant groundwater detections, pesticides and herbicides are unlikely to impact groundwater at the Small Arms Ranges and were not selected for further evaluation. Although the maximum detected concentration of dieldrin exceeded its MCP Method 1 S-1/GW-1 Standard, the presence of this compound is assumed to be due to the application of this pesticide in a manner consistent with its labeling. Dieldrin is no longer used for pest control, because it was banned in 1987. The four ranges with exceedances of the MCP S-1/GW-1 Standard for dieldrin are further discussed in Appendix E.

- In general, SVOCs are highly adsorbed or chemically combined with the soil matrix and their overall tendency is for low mobility in the environment. The only SVOCs detected in both soil and groundwater at concentrations above screening criteria were bis(2-ethylhexyl)phthalate and naphthalene. While bis(2-ethylhexyl)phthalate was detected in both soil and groundwater above screening levels, only the maximum detected concentration of BEHP exceeded a groundwater screening criterion and the two subsequent sampling results from the same well were non-detect. The maximum detected concentration of naphthalene in soil was less than the MCP S-1/GW-1 Standard. Naphthalene was detected in groundwater in a single sample but was not detected in subsequent sampling events from any well, and the maximum detected concentration of naphthalene in groundwater was less than the MCP Method 1 GW-1 Standard (there is no MCL for naphthalene). With the exception of this single detection of bis(2-ethylhexyl)phthalate and naphthalene, all of the groundwater detections for these SVOC constituents were below their respective risk-based screening criteria. Based on their low environmental mobility and the lack of significant groundwater detections, SVOCs were not selected for further evaluation.

- Acetone and chloroform were the VOCs that exhibited an exceedance of a screening criterion and were most frequently detected in soil at a concentration above an SSL. Acetone is a common laboratory contaminant and was not detected in groundwater and was likely introduced into the soil samples during the analytical process and the detections likely do not represent actual site conditions. Although chloroform was detected in soil and groundwater at levels exceeding screening criteria, the widespread presence of chloroform in groundwater in the Upper Cape has been determined to be attributable to several sources unrelated to MMR operations (MMR 2001). As such, chloroform was judged to not warrant further evaluation. PCE was detected in a single soil sample collected from GA/GB range. The concentration of PCE in soil was well below its MCP S-1/GW-1 Standard. All the detections of PCE and several of the detections of TCE in groundwater were observed in samples collected from GA/GB Range monitoring wells in April 1999. The presence of the PCE and TCE were likely due to Chemical Spill 10. The other detections of TCE were from an L-4 Range monitoring well (LRMW0003) and were observed in 2002, 2003, and 2004. More recent results from these wells were non-detect for PCE and TCE. Other VOCs were detected infrequently at low concentrations and, thus, were not selected for further evaluation.

- One of the seven Aroclors mixtures of PCBs was detected in a single soil sample, at a concentration above both SSLs. PCBs exhibit low water solubility, are strongly adsorbed to organics, and preferentially partition to soil. Due to their low mobility in the environment and the absence of groundwater detections, PCBs are not a threat to leach to groundwater and were not further evaluated.

There were two Small Arms Ranges at MMR that have not been sampled and did not have available analytical data for use in this risk screening: L Range (1950s to 1980s) and Former M-3 Range During the May 2013 Supplemental Investigation, a visual investigation and metal detector sweep were performed at L Range. No significant metal debris was detected and there was no visual evidence of past use of the area as a range. In order to qualitatively evaluate the Former M-3 Range, information regarding their operational history, time frame when it was used, size and location was reviewed in order to identify whether there was a similar range that had sampling data that might provide an indication of the possible conditions at these ranges. The reference range for Former M-3 Range is Former M-1 Range. The soil concentrations at Former M-1 Range were found to either be below the detected constituents screening criteria or were found to not present a potential threat to groundwater.

As part of the operations and maintenance program, J, K, and T Ranges have been sampled annually to monitor the impacts of ongoing use of these ranges on soil, pore water, and groundwater. In addition, recent lysimeter sampling for tungsten and antimony at B and G Ranges indicates that there may be some soil sorption and subsequent leaching of these metals. Associated soil sampling at B Range supports the theory that this phenomenon may be limited to the surface or near surface soil.

9.0 CONCLUSIONS AND RECOMMENDATIONS

Extensive long-term groundwater monitoring has been conducted at over 40 wells associated with the Small Arms Ranges. Evaluation of monitoring well data indicates that groundwater beneath the ranges has not been significantly impacted by components found in small arms ammunition. No explosives (with one exception associated with the Demo 1 plume) were reported in any monitoring wells associated with the ranges. Trace levels of a few semivolatile compounds were sporadically reported in some samples from a few wells. However, most SVOC detections were below risk screening criteria. In addition, in some cases these detections may be laboratory artifacts. Low levels of certain metals [including barium, chromium, copper, and zinc] were detected in some monitoring well samples. In all but a few cases, these detections were below MCLs. Detections of tungsten have been reported, primarily in one well at B Range. In addition, an elevated concentration of tungsten (560 µg/L) was detected in May 2006 during a CRREL research study at B Range at well MW-72S, possibly reflecting a transient pulse. Subsequently, the berm at this range was excavated to reduce soil tungsten levels. Sampling results from this well have been much lower and less than 20 µg/L since February 2007. The overall results of groundwater sampling evaluations conducted to date indicate the Small Arms Ranges are not currently a source of groundwater contamination above action levels. These results may reflect the fact that maintenance and removal actions have been completed at the majority of the Small Arms Ranges. These activities have included extensive maintenance actions involving the removal of bullets and remedial actions involving the removal of lead impacted soils and tungsten impacted soils.

Results of investigations at the Small Arms Ranges indicate that a few explosive and/or propellant-related compounds (primarily nitroglycerin) are present in soils at some ranges. Explosive and propellant-related compounds were primarily detected in firing line soils. In addition, certain metals (including lead, tungsten and antimony) associated with small arms projectiles and primers are also present. Low levels of tungsten (<160 mg/Kg) have been detected in some berm soil samples from several ranges, primarily B Range. As would be expected, elevated lead concentrations were primarily detected in surface and subsurface soils from target berm locations. Lead concentrations in berm samples were quite variable both within samples from different locations at a given range and between different ranges. For many ranges, lead concentrations for all soil samples were below 300 mg/Kg. For a few ranges, elevated lead concentrations (>300 mg/Kg) were observed in multiple samples.

9.1 Range-Specific Recommendations

This section summarizes specific recommendations regarding future proposed actions for individual ranges. Overall information on range-specific recommendations and proposed actions has been summarized in Table 9-1.

9.1.1 A Range

A Range is currently an inactive operational .50 cal machine gun training range located at the intersection of Burgoyne and Wood Roads. Fifty (.50) cal ammunition was used at this range. Soil sampling results indicate that the maximum current conditions soil concentrations of antimony and lead are 5.1 mg/Kg and 29.3 mg/Kg, respectively. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results, the fact that the range is operational although inactive, and that soil concentrations are below action levels, no further action is recommended at this range.

9.1.2 B Range

B Range is currently an inactive operational rifle and pistol range located on Burgoyne Road just south of Wood Road. Ammunition used at this range has included 5.56mm ball, 5.56mm tungsten, 9mm ball, .45 cal and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations of antimony, lead and tungsten are 11.4 mg/Kg, 1430 mg/Kg and 200 mg/Kg, respectively. The maximum concentration of lead exceeds its S-1/GW-1 standard, but not the MassDEP UCL (3,000 mg/Kg). The maximum tungsten concentration is a subsurface sample.

Due to some uncertainties with respect to lead and tungsten distributions, including recent lysimeter pore water tungsten results, additional groundwater monitoring for antimony, lead and tungsten is recommended at this range. Limited soil removal at the berm face and behind the berm is also recommended.

9.1.3 Former B Range

Former B Range is a non-operational small arms range located on the northern side of Monument Beach Road in Training Area B-8. Ammunition used at this range has included 5.56mm ball, 7.62mm ball, .30 cal, .38 cal, .40 cal, .45 cal and .50 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 42.9 mg/Kg and 2810 mg/Kg, respectively. The maximum concentrations of both metals may exceed their respective S-1/GW-1 standards at two isolated locations. The maximum lead concentration is for a subsurface sample. However, the maximum concentrations of antimony and lead are from early Phase IIb sampling locations. The range area was subsequently re-evaluated (through extensive XRF screening) and excavated followed by off-site post-excavation confirmatory lead analysis as part of the 2009 Soil Removal Program.

Extensive removal actions have been conducted at this range. Additional multiple increment soil samples will be collected to confirm that the removal action is complete.

9.1.4 C Range

C Range is an inactive operational rifle and pistol range located on Burgoyne Road just south of B Range. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, .30 cal, .38 cal, .40 cal and .45 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 9.1 mg/Kg, 749 mg/Kg and 50.5 mg/Kg. The maximum lead concentration exceeds its S-1/GW-1 standard, but is below the MassDEP UCL.

Although C Range is an inactive operational range, some additional groundwater monitoring for antimony, lead and tungsten is recommended. Limited soil removal at the berm face and behind the berm is also recommended.

9.1.5 Former C Range

Former C Range is a non-operational rifle and machine gun range located on the northern side of Frank Perkins Road southeast of Former B Range. Ammunition used on this range has included 5.56mm ball, 7.62mm ball, .30 cal, .50 cal and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 18 mg/Kg and 1560 mg/Kg, respectively. The maximum lead concentration exceeds its S-1/GW-1 standard. However, the average concentration of lead is below its S-1/GW-1 standard.

Based upon an overall review of investigation results and the absence of S-1/GW-1 average soil concentration exceedances, no further action is recommended.

9.1.6 D Range

D Range is currently an inactive operational M60 machine gun range located on Burgoyne Road just south of C Range. Ammunition used on this range has included 5.56mm tungsten and 7.62mm ball rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 12.1 mg/Kg, 1840 mg/Kg and 0.25 mg/Kg. The maximum lead concentration exceeds its S-1/GW-1 standard, but is below the MassDEP UCL for lead (3,000 mg/Kg).

Based upon an overall review of the investigation results, the fact that the range is operational and there are no exceedances of MassDEP UCLs, no further action is recommended assuming future use is as a Small Arms Range.

9.1.7 Former D Range

Former D Range is a non-operational rifle, pistol and machine gun range located on the northern side of Frank Perkins Road at Pine Hill just northwest of MMR Range Control. Ammunition used on this range has included 7.62mm ball, .22 cal, .30 cal and .50 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 18.1 mg/Kg and 2900 mg/Kg, respectively. The maximum lead concentration exceeds its S-1/GW-1 standard and the average concentration (398 mg/Kg) at one location (135GSTUWY) exceeds the S-1/GW-1 standard. However, the maximum concentration of lead is from an early Phase IIb location. The range area was subsequently re-evaluated (through extensive XRF screening) and excavated followed by off-site post-excavation confirmatory laboratory lead analysis as part of the 2009 Soil Removal Program.

Extensive removal actions have been conducted at this range. Additional multiple increment soil samples will be collected to confirm that the removal action is complete.

9.1.8 E Range

E Range is currently an inactive operational pistol range located on the eastern side of Burgoyne Road south of D Range. Ammunition used on this range has included 5.56mm tungsten, 9mm ball, .30 cal, .38 cal, .40 cal, .45 cal and 12 gauge rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 3.8 mg/Kg, 555 mg/Kg and 5.1 mg/Kg. The maximum lead concentration exceeds its S-1/GW-1 standard, but does not exceed the MassDEP UCL for lead.

Based upon an overall review of the investigation results, the fact that the range is operational and that MassDEP UCLs are not exceeded, no further action is recommended assuming future use is as a Small Arms Range.

9.1.9 E-1 Range

The original E Range (E-1) is non-operational and was constructed in 1941, and at that time, access to the range was gained via a road extending north from Pocasset-Forestdale Road. The range was designed and used as an anti-tank training range until the late 1950s or early 1960s. Records indicate that 2.36-inch and 3.5-inch rockets, 37mm and 75mm practice artillery rounds, and .30 cal ball ammunition were fired at the E-1 Range.

This range was investigated as part of Phase IIb and has been transferred to the Training Areas Operable Unit because of the reported use of munitions containing high explosives in this area.

9.1.10 E-2 Range

E-2 Range was used for combat training in the 1970s and is located in the area of the current Demolition Area 1. Ammunition used on this range has included .30 cal rounds.

This range was investigated as part of the Demolition Area 1 Operable Unit. No further action is recommended.

9.1.11 G Range

G Range is currently an inactive operational rifle and machine gun range located on Pocasset-Forestdale Road. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, 7.62mm ball and .30 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 25.4 mg/Kg, 3850 mg/Kg and 84.5 mg/Kg. The maximum lead concentration exceeds its S-1/GW-1 standard and also exceeds the MassDEP UCL for lead. SPLP results for lead were 2,020 µg/L. The SPLP results indicate that leaching of lead is possible from certain Small Arms Range surface soil.

Based upon an overall review of the investigation results, the fact that the range is operational, and that maximum lead levels exceed the MassDEP UCL, additional delineation, sampling and some localized soil removal behind the berm is recommended. Soil removal should also be considered at locations at which tungsten is above action levels. Given the lead exceedance of action levels, additional groundwater monitoring is also recommended.

9.1.12 GA/GB Ranges

GA/GB Ranges are non-operational ranges located north of Dolan Road near the UTES facility. Ammunition used on these ranges included .30 cal ball rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 2.8 mg/Kg and 128 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards. During May 2013 Supplemental Investigation, whole intact bullets were noted in certain areas downrange of these ranges.

Based upon an overall review of the investigation results, the fact that the ranges are non-operational but there are no S-1/GW-1 exceedances, no further action is recommended at these ranges.

9.1.13 H Range

H Range is an inactive operational rifle and machine gun training range located off Pocasset-Forestdale Road on the eastern side of the access road to Demolition Area 1. Ammunition used on this range has included 5.56mm ball and 5.56mm tungsten rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 33.7 mg/Kg, 2600 mg/Kg (in a subsurface sample) and 2.1 mg/Kg. The maximum concentrations of antimony and lead exceed respective S-1/GW-1 standards, but not their respective MassDEP UCL values.

Based upon an overall review of the investigation results, the fact that the range is operational, and that maximum soil antimony and lead concentrations do not exceed MassDEP UCLs, no further action is recommended as long as it remains a Small Arms Range.

9.1.14 I Range

I Range is an active operational 25-meter rifle range located on Pocasset-Forestdale Road east of the H Range. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, 7.62mm ball, .30 cal and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 2.2 mg/Kg, 585 mg/Kg and 2.5 mg/Kg. The maximum lead concentration exceeds its S-1/GW-1 standard, but not its MassDEP UCL. An OMMP is in place at this range to address current training.

This range is active and operational and maximum soil lead and antimony levels do not exceed the MassDEP UCLs. However, it is recommended that no further action, other than long-term groundwater monitoring be conducted at this range as long as it remains a Small Arms Range.

9.1.15 J Range

The J Range is an active operational pistol range located immediately west of the K Range on Pocasset-Forestdale Road. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, 9mm ball, .30 cal, .38 cal, .40 cal, .45 cal and 12 gauge rounds. Annual sampling events are conducted at the J Range in accordance with established range-specific Best Management Practices and Operations, Maintenance, and Monitoring Plans. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 1.1 mg/Kg, 192 mg/Kg and 18.2 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards. An OMMP is in place at this range.

This range is operational, and the maximum soil lead and antimony levels do not exceed MassDEP UCLs. However, it is recommended that long-term groundwater monitoring be continued at this range.

9.1.16 K Range

The K Range is an active operational pistol range located immediately east of the J Range on Pocasset-Forestdale Road. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, 9mm ball, .30 cal, .38 cal, .40 cal, .45 cal and 12 gauge rounds. Annual sampling events are conducted at the K Range in accordance with established range-specific Best Management Practices and Operations, Maintenance, and Monitoring Plans. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 5.7 mg/Kg, 955 mg/Kg and 47.2 mg/Kg. The maximum lead concentration exceeds its S-1/GW-1 standard, but not the MassDEP UCL. An OMMP is in place at this range.

This range is operational, and the maximum soil lead and antimony levels do not exceed MassDEP UCLs. However, it is recommended that long-term groundwater monitoring be continued at this range.

9.1.17 KD Range East

KD Range East is an inactive operational range located on Pocasset-Forestdale Road east of the K Range. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, 7.62mm ball, .30 cal, .38 cal, .40 cal, .45 cal and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony, lead and tungsten are 2.3 mg/Kg, 147 mg/Kg and 21 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards. Chromium was detected in one sample at 57.4 mg/Kg, which is above the S-1/GW-1 standard of 20 mg/Kg but is below the UCL of 2,000 mg/Kg.

This range is operational and there are no exceedances of MassDEP UCLs. However, since the maximum chromium concentration exceeds the S-1/GW-1 standard, confirmatory soil sampling for chromium is recommended to determine if the range can be closed under the MCP.

9.1.18 Former K Range

The original K Range is a non-operational range that was constructed as a moving target rifle range in 1941 off Greenway Road just north of Wood Road, in the area now known as the USCG Communications Station.

This range is under the Military Munitions Response Program managed by the Air Force Civil Engineering Center.

9.1.19 L Range (1941-1950s)/L-1 Range

The L-1 Range is a non-operational small arms training range that was located along Greenway Road running from the northern end of the USCG Communications Station almost to Gibbs Road. Only blank rounds have been used on this range. Recent soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 0.9 mg/Kg and 60.2 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the May 2013 investigation results and the fact that the range is non-operational and there are no S-1/GW-1 exceedances, no further action is recommended at this range.

9.1.20 L Range (1950s – Late 1980s)

In the 1950s, L Range moved to a location south of Gibbs Road. This range is a non-operational combat training range. Ammunition used on this range has included 5.56mm ball, 7.62mm ball, .30 cal and tracer rounds. No sampling has been conducted at this range. No significant metal debris was observed during the May 2013 site reconnaissance.

Based upon an overall review of the May 2013 investigation results, the absence of evidence of small arms use and uncertainties about the historical existence of the range, no further action is recommended.

9.1.21 L-2, L-3 and L-4 Ranges

A series of four L Ranges, including L-1 Range discussed above, existed primarily in the 1940s. L-2 Range was located west of Gibbs Road in the current Training Area B-11. L-3 Range was also located in the current Training Area B-11 north of Cat Road and west of Jefferson Road. L-4 Range existed in the current Training Area C-16 on the east side of Barlow Road. All ranges are non-operational combat training ranges and records indicate that only blank rounds have been used on these ranges.

Soil sampling results indicate that the maximum current conditions soil concentrations at the L-2 Range for antimony and lead are 0.99 mg/Kg and 137 mg/Kg. Recent soil sampling results indicate that the maximum current conditions soil concentrations at the L-3 Range for antimony and lead are 1.4 mg/Kg and 77.4 mg/Kg and 0.9 mg/Kg and 12 mg/Kg at the L-4 Range. These results are below the respective S-1/GW-1 standards.

Based upon an overall review of the investigation results, the fact that the L-2, L-3 and L-4 Ranges are non-operational and there are no exceedances of the S-1/GW-1 standards for lead and antimony, no further action is recommended at these ranges.

9.1.22 M Range

The first known range with the designation “M Range” was given to what is presumed to be the Former M-2 Range off Greenway Road at the southeast corner of MMR. After around 1980, the M Range is thought to have been moved north to the location of the J-1 Range; however, no references to M Range after 1983 have been discovered.

Based on the fact that a M Range does not currently exist, no further action is recommended.

9.1.23 Former M-1 Range

The Former M-1 Range is a non-operational small arms training range located near the intersection of Greenway and Pocasset-Forestdale Roads. Ammunition used on this range has included .45 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 0.67 and 22.3 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results and the fact that the range is non-operational and there are no S-1/GW-1 exceedances, no further action is recommended at this range.

9.1.24 Former M-2 Range

The Former M-2 Range is a non-operational small arms training range located on the original Greenway Road northeast of the Former M-1 Range. Ammunition used on this range has included .45 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 6.5 and 1200 mg/Kg. The maximum concentration of lead exceeds its S-1/GW-1 standard.

Based upon an overall review of the investigation results and the exceedance of the S-1/GW-1 standard for lead, additional multiple increment sampling and soil removal is recommended.

9.1.25 Former M-3 and M-4 Ranges

The Former M-3 Range was a non-operational small arms training range located on the west side of Greenway Road south of the current J-3 Range. The Former M-4 Range was a non-operational small arms training range located just south of the current J-3 Range on Greenway Road. Ammunition used on these ranges has included .45 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 0.6 and 14.6 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results and the fact that the ranges are non-operational and there are no S-1/GW-1 exceedances, no further action is recommended at these ranges.

9.1.26 N Range

The N Range is an inactive operational 25-meter rifle training range located on the western side of Greenway Road near the J-2 Range. Ammunition used on this range has included 5.56mm ball, .30 cal and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 4.3 and 724 mg/Kg. The maximum concentration of lead exceeds its S-1/GW-1 standard, but not the MassDEP UCL.

This range is operational and the MassDEP UCLs are not exceeded. However, soil removal for lead is recommended to facilitate possible future closure under the MCP.

9.1.27 Former N Range

The Former N Range was first established at the location immediately to the east of SE Range. It was designated as a night assault course until the early 1970s and utilized only blank small arms ammunition. Metals sweeps performed near bullet-impacted drums in 2013 discovered scattered metal debris around identified features to the east of the SE Range. Recent soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 8.1 and 1,670 mg/Kg. The maximum concentration of lead exceeds its S-1/GW-1 standard, but not the MassDEP UCL.

Based upon an overall review of the investigation results and the fact that the range is inactive but designated as operational, further investigation and soil removal is recommended at this range in support of potential range development in the future.

9.1.28 O Range

The O Range is an inactive operational shotgun familiarization range located northeast of N Range on the western side of Greenway Road. Ammunition used on this range has included 12 gauge shotgun ammunition. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 1.5 and 204 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards. This range may be closed under the MCP.

Based upon an overall review of the investigation results, the fact that the range is operational and that MassDEP S-1/GW-1 standards are not exceeded, no further action is recommended at this range.

9.1.29 P Range

The P Range is an inactive operational pistol range located on the western side of Greenway Road just north of the O Range. Ammunition used on this range has included .30 cal, .38 cal, .40 cal and .45 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 1.7 and 118 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards. This range may be closed under the MCP.

Based upon an overall review of the investigation results, the fact that the range is operational and that MassDEP S-1/GW-1 standards are not exceeded, no further action is recommended at this range.

9.1.30 Q Range

The Q Range is an inactive operational automatic rifle and machine gun transition range and was located close to the current location of the IBC Range. Ammunition used on this range has included 5.56mm ball, 7.62mm ball, .30 cal, .38 cal, .50 cal and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 1.1 and 152 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results, the fact that the range is operational and that MassDEP S-1/GW-1 standards are not exceeded, no further action is recommended at this range.

9.1.31 Former R Range

The Former R Range is an inactive operational squad battle assault course located on the southern side of Gibbs Road west of the IBC Range. Ammunition used on this range has included 7.62mm ball and .30 cal rounds. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 0.88 and 27.8 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results, the fact that the range is operational and that MassDEP S-1/GW-1 standards are not exceeded, no further action is recommended at this range.

9.1.32 SE Range/SW Range

The SE and SW Ranges (also termed the Sierra Range Complex) are now one active operational rifle training range located on the southern side of Gibbs Road to the north of the Central Impact Area. Ammunition used on this range has included 5.56mm ball, 5.56mm tungsten, 7.62mm ball and tracer rounds. Soil sampling results indicate that the maximum current conditions soil concentrations are 4.5 and 3.6 mg/Kg for antimony; 710 and 734 mg/Kg for lead and 13 and 9.2 mg/Kg for tungsten, respectively. The maximum concentration of lead exceeds its S-1/GW-1 standard, but not the MassDEP UCL. An OMMP is in place at these ranges.

These ranges are operational (active) and MassDEP UCLs are not exceeded. However, it is recommended that long-term groundwater monitoring be continued at these ranges.

9.1.33 Skeet Range 1

Skeet Range 1 is a non-operational shotgun range that was originally located in the northeast corner of Training Area BA-1 adjacent to Herbert and Turpentine Road. Ammunition used on this range included 12-gauge shotgun ammunition. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 1.6 and 56 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results and the fact that the range is non-operational and there are no S-1/GW-1 exceedances, no further action is recommended.

9.1.34 Skeet Range 2

Skeet Range 2 is a non-operational shotgun range that was located at the northeast corner of the intersection of Herbert and Frank Perkins Roads. Ammunition used on this range included 12-gauge shotgun ammunition. Recent soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 0.88 and 8 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards.

Based upon an overall review of the investigation results and the fact that the range is non-operational and there are no S-1/GW-1 exceedances, no further action is recommended.

9.1.35 Succonsette Pond

Succonsette Pond is a non-operational range located within the southwest corner of the Impact Area just east of Pocasset-Sandwich Road. Information gathered from personal interviews suggests that drums were, at one time, stacked on a ridge south of the Pond for use as .50 cal machine gun targets. Soil sampling results indicate that the maximum current conditions soil concentrations for antimony and lead are 0.92 and 207 mg/Kg. The maximum concentrations of antimony and lead are below their respective S-1/GW-1 standards. The maximum cadmium concentration (30.9 mg/Kg) exceeds the MassDEP S-1/GW-1 standard (2 mg/Kg). However, the average concentration (0.49 mg/Kg) is below the S-1/GW-1 standard.

Based upon an overall review of the investigation results and the fact that the area is non-operational and there are no exceedances of the S-1/GW-1 standards, no further action is recommended.

9.1.36 T Range

The T Range is an active operational rifle, machine gun and pistol range located in the northern portion of MMR on the southern side of Gibbs Road just west of the SE and SW Ranges. Ammunition used on this range has included 5.56mm tungsten, 7.62mm, .40 cal, .45 cal, .50 cal, 12 gauge and tracer rounds. Soil sampling results indicate that the maximum detected soil concentrations for antimony and lead are 91.9 and 5800 mg/Kg from subsurface samples (0.5 foot to 1 foot) collected in 2002. The maximum soil concentration for tungsten is 77.1 mg/Kg. The maximum reported concentrations of antimony and lead exceed respective S-1/GW-1 standards. The maximum lead concentration exceeds the MassDEP UCL. An OMMP is in place at this range.

This range is operational and it is recommended that long-term groundwater monitoring be continued at this range.

9.1.37 500-yard Rifle Range

The 500-yard Rifle Range is an inactive rifle range that was thought to have once existed along the south side of Jefferson Road west of Greenway Road, although the exact location is uncertain. Ammunition used on this range was believed to have been limited to .30 cal rounds. Visual inspections and a metal detector survey during May 2013 revealed no evidence of past range use at this location.

Based upon completion of the field investigation and a review of the investigation results, no further action is recommended.

9.2 Overall Recommendations

Based upon the absence of any groundwater plumes or groundwater detections above action levels beneath the Small Arms Ranges, no measures to remediate groundwater are recommended at this time. However, given uncertainties with the soil sample results, long-term groundwater monitoring should be continued at a limited array of wells consistent with the range-specific recommendations of Section 9.1. (Monitoring wells will be selected through mutual agreement between EPA, MassDEP and the IAGWSP.)

Elevated levels of a few propellant-related compounds and/or select metals (primarily lead) exist in some surface soils at certain Small Arms Ranges. These surface soil contaminants pose a threat to groundwater. In addition, they might pose some concerns with respect to exceedance of MCP S-1/GW-1 standards for exposure from direct contact depending upon future range use. The levels of lead observed at the Small Arms Ranges are in almost all cases below the applicable action levels. For other ranges that are likely to remain non-operational in the future, some additional investigation is recommended, as indicated in Section 9.1. Overall, given the toxicity of lead and some uncertainties in the total soil sorption capacity for lead, range design and/or maintenance programs to limit lead exposure remain prudent.

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TABLES

Table 1-1
Small Arms Ranges

A Range
B Range
Former B Range
C Range
Former C Range
D Range
Former D Range
E Range
E-1 and E-2 Ranges
G Range
GA and GB Ranges
H Range
I Range
J Range
K Range
KD East Range
Former K Range (1940s-1950s)
L Range (1940s-1950s)/L-1 Range
L Range (1950s-1980s)
L-2 Range
L-3 Range
L-4 Range
Former M-1 Range (M Range)
Former M-2 Range (M Range)
Former M-3 Range
Former M-4 Range
N Range
Former N Range
O Range
P Range
Q Range
Former R Range
S East/S West Ranges
Skeet Range 1
Skeet Range 2
Succonsette Pond
T Range
500-Yard Rifle Range

Table 2-1
Small Arms Ranges Ammunition Use

	5.56 ball	5.56 tungsten	7.62 ball	9mm ball	.22 caliber	.30 caliber	.38 caliber	.40 caliber	.45 caliber	Tracer	.50 caliber	12 gauge	Primary Uses
E Range				●		●	●	●	●			●	Pistol
J Range	●	●		●		●	●	●	●			●	Pistol/Rifle
K Range	●	●		●		●	●	●	●			●	Pistol/Rifle
SE Range	●	●	●							●			Rifle/Machine gun
SW Range	●	●	●							●			Rifle/Machine gun
T Range		●						●	●	●	●	●	Pistol/Machine gun/Rifle
A Range											●		Machine gun
B Range	●	●		●					●	●			Rifle/Pistol
C Range	●	●				●	●	●	●				Rifle/Pistol
D Range		●	●										Machine gun
G Range	●	●	●			●							Rifle/Machine gun
H Range	●	●											Rifle/Machine gun
I Range	●	●	●			●				●			Rifle
KD Range East	●	●	●			●	●	●	●	●			Rifle
N Range	●					●				●			Rifle
O Range												●	Shotgun
P Range						●	●	●	●				Pistol
Former B Range	●		●			●	●		●		●		Machine gun/Pistol
Former C Range	●		●			●				●	●		Machine gun/Rifle
Former D Range			●		●	●					●		Rifle/Pistol/Machine gun
E-1 Range						●							Combat Training
E-2 Range						●							Combat Training
Former K Range						●							Rifle
Former M-1									●				Submachine gun
Former M-2 (M Range)									●				Submachine gun
Former M-3 Range									●				Submachine gun

Table 2-1
Small Arms Ranges Ammunition Use

	5.56 ball	5.56 tungsten	7.62 ball	9mm ball	.22 caliber	.30 caliber	.38 caliber	.40 caliber	.45 caliber	Tracer	.50 caliber	12 gauge	Primary Uses
Former M-4 Range									●				Submachine gun
Former R Range			●			●							Combat Training
GA/GB Range						●							Rifle
L Range (Musketry)						●							Rifle
L-1/L-2/L-3/L-4 Ranges													Combat Training/Only Blank Rounds
L Range (1950s to late 1980s)	●		●			●				●			Combat Training
Q Range	●		●			●				●	●		Rifle/Machine gun
Skeet Range 1												●	Shotgun
Skeet Range 2												●	Shotgun
Five Hundred Yard Rifle Range						●							Rife
Succonsette Pond											●		Machine gun

Table 2-4
Sediment Units at Small Arms Ranges

	Buzzards Bay Moraine	Buzzards Bay Outwash	Sandwich Moraine	Mashpee Pitted Plain
E Range	x			
J Range (STAPP)				x
K Range (STAPP)				x
SE Range				x
SW Range				x
A Range	x			
B Range	x			
C Range	x			
D Range	x			
G Range				x
H Range				x
I Range				x
KD East SAR				x
N Range				x
O Range				x
P Range				x
Unbermed Ranges (Active)				
T Range (STAPP)				x
Unbermed Ranges (Inactive)				
Former B Range	x	x		
Former C Range	x			
Former D Range	x			
Former M-1				x
Former M-2 (M-Range)				x
Former N Range				x
Former R Range				x
GA/GB Range				x
L-2 Range (GP-20)	x			
L-3 Range	x			
Skeet Range 1				x
Succonsett Pond				x
Former K Range (MMRP)				x
500-Yard Rifle Range				x
E-1 Range (North of Demo 1?)				x
E-2 Range (At Demo 1)				x
Former M-3 Range				x
Former M-4 Range				x
L Range (Musketry)				x
L Range 1950s - 1980s				x
L-1 Range				x
L-4 Range			x	
Q Range				x
Skeet Range 2				x

Table 3-1

Small Arms Range Phase IIb and TM-02-2 Sampling Information

Range	Historical Use	Features	Phase IIb Sampling	TM 02-2 Sampling	Representative TM 02-2 Results and Findings
A Range	• Machine gun training range constructed in mid-1970s • .50 caliber machine gun • .50 caliber ball and plastic rounds	• Active machine gun training range • Two fixed firing points • Two wooden frame targets located south of West Road • Natural embankment-backstop berm		**Firing Points**: 3-5 Point Grids (157A-C) SVOC & Metals at 3 depths	• Most SVOCs and metals were detected in the surface (0 to 3 inches bgs) interval of three grid sampling locations consistent with airborne deposition. • In general, the highest concentrations of detected SVOCs and metals were reported in grids located downrange of the fixed firing points. • Antimony, a constituent of lead alloy projectiles, exceeded its background concentration.
B Range	• Rifle and pistol range constructed in 1991 • Ammunition authorized includes .45 caliber, 9mm ball rounds, 5.56mm ball and tracer rounds	• Active rifle and pistol range • 55 firing points along 615 ft. firing line • Target line is 25 meters from firing line • Backstop berm approximately 5 ft. beyond target line		**Firing Points**: 5-5 Point Grids (154A-E) SVOC & Metals at 3 depths	• Most SVOCs and metals were detected in the surface (0 to 3 inches bgs) interval of five grid sampling locations consistent with airborne deposition. • In general, the highest concentrations of detected propellant-related SVOCs and metals were reported downrange of the central, and presumably most frequently used, firing points. • A nitroglycerin TIC detection was observed in grid 154E.
C Range	• Rifle and pistol range established in mid to late-1980s • Authorized ammunition includes 5.56mm ball rounds and all caliber pistol rounds	• Active rifle and pistol range • 55 firing points along 615 ft. firing line • Target line is 25 meters from firing line • Backstop berm at southern half (firing points 30 to 55)		**Firing Points**: 5-5 Point Grids (155A-E) SVOC & Metals at 3 depths	• Most SVOCs and metals were detected in the surface (0 to 3 inches bgs) interval of five grid sampling locations similar to B Range. • In general, the highest concentrations of detected propellant-related SVOCs and metals were reported downrange of the central firing points, as was observed at B Range. • A nitroglycerin TIC detection was observed in grid 155E.
D Range	• M60 machine gun range constructed in mid to late-1980s • Original use as a machine gun zeroing range • Designed to accommodate 7.62mm ball round ammunition	• Active M60 machine gun training range • 8 firing points along an 83 ft. firing line • Target line is 10 meters downrange of firing line • Backstop immediately beyond targets		**Firing Points**: 2-5 Point Grids (158A-B) SVOC & Metals at 3 depths	• Most SVOCs were detected in the surface (0 to 3 inches bgs) interval of both grid sampling locations consistent with airborne deposition. • The highest concentrations of detected propellant-related SVOCs were reported downrange of the central firing point in grid 158A. • Lead, antimony, and arsenic concentrations exceeded their MMR background concentrations in several samples.
E Range	• Pistol range constructed in mid to late-1980s • Designed to accommodate all calibers of pistol ammunition	• Active pistol range • 15 firing points along 461 ft. firing line • 5 rows of targets located 29 to 97 ft. from firing line • Each target has small earthern berm • Backstop berm 40 ft. beyond targets (no backstop behind northernmost targets)		**Firing Points**: 5-5 Point Grids (159A-E) SVOC & Metals at 3 depths	• Propellant-related SVOCs and metals were detected at elevated concentrations in all three depth intervals and at all grid locations suggesting that soil at this range has been reworked. • Lead and arsenic concentrations exceeded their MMR background concentrations in several samples.
G Range	• M16 and M60 machine gun training range constructed in late 1980s • Authorized ammunition includes 5.56mm and 7.62 mm ball rounds	• Active rifle and machine gun range • 27 firing points along 185 ft. firing line • Backstop berm 23 ft. beyond targets	**Firing Line**: 1-9 Point Grid at 1 depth (128A), 1-5 Point Grid (128B) at 2 depths for SVOCs and Metals	**Firing Points**: 2-5 Point Grids (128C-D) SVOC & Metals at 3 depths **Beyond Backstop**: Discrete samples at 3 locations (128E-G) at 2 depths for Metals	• Propellant-related SVOCs and metals were detected in all four grids (128A through 128D) sampled at the firing line. • Lead and antimony concentrations exceeded their MMR background concentrations in several samples collected from the firing line grids. • In some samples collected from beyond the G Range backstop, lead, antimony, aluminum, and arsenic concentrations exceeded MMR background.
H Range	• Rifle and machine gun range established in late-1980s	• Active M16 rifle and M60 machine gun range • 27 firing points along 185 ft. firing line • Target line 25 meters from firing line • Backstop berm 33 ft. beyond targets		**Firing Points:** 3-5 Point Grids (160A-C) SVOC & Metals at 3 depths	• Propellant-related SVOCs and metals were detected at elevated concentrations in three grids sampled at the firing line. • Lead and antimony concentrations exceeded their MMR background concentrations in several samples collected from the firing line grids.
I Range	• Formerly called F Range • 1960s to late 1980s used as rifle and tank-mounted machine gun range • Rifle range established in early 1990s • Late 1980s to 1991 used as tank-mounted machine gun range under I Range designation	• Active rifle range • 27 firing points along a 185 ft. firing line • Backstop berms 15 ft. beyond target line	**Firing Line:** 1-9 Point Grid at 1 depth (129A), 1-5 Point Grid (129B) at 2 depths for SVOCs and Metals	**Firing Points:** 2-5 Point Grids (129C-D) SVOC & Metals at 3 depths **Beyond Backstop**: Discrete samples at 3 locations (129E-G) at 2 depths for Metals	• Propellant-related SVOCs and metals were detected at elevated concentrations in four grids sampled at the firing line. • There were nine firing line samples collected from where lead was detected at a concentration exceeding its MMR background. • There were no significantly elevated concentrations of metals detected in soil collected from beyond the I Range backstop.
J Range	• Former Air Force A Pistol Range • Pistol Range established in late 1980s	• Active pistol range • 16 Firing Points along 104-ft firing line • Target line 25 meters from firing line • Backstop berm 53 ft. beyond targets		**Firing Points:** 3-5 Point Grids (161A-C) SVOC & Metals at 3 depths **Beyond Backstop**: Discrete samples at 3 locations (161D-F) at 2 depths for Metals	• The types and distribution of these SVOCs and metals is generally consistent with airborne deposition of small arms, propellant-related residuals. • Lead, and to a lesser extent, aluminum, antimony, and manganese exceeded MMR background concentrations in some firing line soils. • Lead and antimony exceeded MMR background concentrations in certain soils collected from beyond the backstop.

Table 3-1 (Continued)

Range	Historical Use	Features	Phase IIb Sampling	TM 02-2 Sampling	Representative TM 02-2 Results and Findings
K Range	• Former Air Force B Pistol Range • Approximately 30 firing points • Ammunition used includes 5.56mm and .38 caliber rounds • Pistol Range established in late 1980s	• Active pistol range • 26 Firing Points along 191-ft firing line • Target line 25 meters from firing line • Backstop berm 142 ft beyond targets		**Firing Points:** 3-5 Point Grids (156A-C) SVOC & Metals at 3 depths **AF B Firing Line**: 3-5 Point Grids (156D-F) SVOC & Metals at 3 depths	• Propellant-related SVOCs and metals were detected at elevated concentrations in all six grids sampled at the firing lines. The greatest number and highest concentrations of these analytes were detected in surface samples. • 2,4-Dinitrotoluene was detected at several sampling locations. • Some nitroglycerin TIC detections were observed. • Lead concentrations exceeded their MMR background concentrations in three samples collected from the firing line currently used at this range.
KD Range	• Formerly called CTR-1 and CTR-2 Aerial Gunnery Range which was constructed in mid-1970s • KD Range designation in mid to late 1980s • Authorized ammunition includes all calibers of pistol ammunition, 5.56mm and 7.62mm ball and tracer rounds, 14.5mm subcaliber training rounds, 40mm HE grenades, HEAT rounds, 90mm HEAT rounds	• Used for rifle, grenade launching and missile training • 55 Firing Points • Target line 25 meters from firing line • 600 meter rifle range	Previous Investigation on Western Side	**Firing Points:** 3-5 Point Grids at 3 of 6 firing lines (100, 300, 500 yard) (162A-I) SVOC & Metals at 3 depths **55 Gal Drum**: 1-5 Point Grid (161K) at 3 depths, Full Suite **CN Gernades**: 1 – Discrete (161J) at 3 depths, SVOCs	• Propellant-related SVOCs were detected throughout the range (primarily in surface soils), but the greatest number and highest concentrations were detected in the 100-yard firing line. • Lead was the predominantly detected metal at concentrations exceeding MMR background. The highest concentrations were reported in samples collected from grid 162K among the 55-gallon drums and Coast Guard boats. • The highest concentrations of lead were limited in nearly all cases to samples collected from the surface interval at this range.
N Range	• Rifle range established in mid to late 1980s • Authorized ammunitions includes 5.56mm ball and tracer rounds	• Active rifle range • 55 Firing Points along 378 ft. firing line • Target line 25 meters from firing line • Backstop berm 13 ft. beyond target line		**Firing Points:** 5-5 Point Grids (165A-E) SVOC & Metals at 3 depths	• Most SVOCs and metals were detected in the surface (0 to 3 inches bgs) interval of all grid sampling locations consistent with airborne deposition. • 2,4-Dinitrotoluene and 2,6-dinitrotoluene were detected at certain locations. • The majority of PAHs were detected in grids 165A, 165B, and 165C, but none were reported in excess of their respective MMR background concentrations.
O Range	• Formerly used as a shot gun range • Shot gun range established in same location mid to late 1980s	• Active shot gun familiarization range established mid to late 1980s • Parallel firing lines at varying distances from target line • Berms on all four sides		**Firing Points:** 3-5 Point Grids at 3 of 7 firing lines (7, 15, 50 yard) (166A-I) SVOC & Metals at 3 depths	• Most of the propellant-related SVOCs were detected in the surface (0 to 3 inches bgs) interval consistent with airborne deposition of propellant residuals. • The majority of maximum concentrations for propellant SVOCs and some metals were detected in the central, most down range grid (166B). • Lead and manganese concentrations exceeded their MMR background concentrations in certain samples.
P Range	• Pistol Range established in mid to late 1980s • Authorized for all calibers of pistol ammunition	• Active pistol range • 25 Firing Points along 250 ft. firing line • Targets 78 ft. from firing line • Backstop berm 25 ft. beyond target line		**Firing Points:** 5-5 Point Grids (167A-E) SVOC & Metals at 3 depths	• Most of the propellant-related SVOCs were detected in the surface (0 to 3 inches bgs) interval consistent with airborne deposition of propellant residuals.
S-E & S-W Range	• Rifle and machine gun training range established in mid to late 1980s • Authorized ammunition includes 5.56mm and 7.62mm ball and tracer rounds	• Active rifle and machine gun training • 5 Firing Points along 280 ft. firing line (S-E) • 6 Firing Points along 200 ft. firing line (S-W)	**Firing Line**: 1-9 Point Grid at 1 depth (127A), 1-5 Point Grid (127B) at 2 depths for SVOCs and Metals	**S-E Firing Points:** 2-5 Point Grids (127C-D) SVOC & Metals at 3 depths **S-W Firing Points**: 3-5 Point Grids (127E-G) SVOC & Metals at 3 depths	• Propellant-related SVOCs and metals were detected in seven grids sampled at the firing line of these ranges (127A through 127G). • Manganese and antimony concentrations exceeded their MMR background concentrations in several samples collected from the firing line grids. • Because all the elevated manganese detections were reported in intermediate and deep samples, the source of this metal is not likely associated with small arms range use.
T Range	• Machine gun and pistol range established in mid to late 1980s • Former P Range (T Range designation in late 1980s) • First used in 1967 as night defense course • Converted to Squad and Platoon attach course in mid 1970s	• Active machine gun and pistol range • 6 firing points along 250 ft firing line • Series of targets at varying distances downrange • No backstop berm		**Firing Points:** 5-5 Point Grids (169A-E) SVOC & Metals at 3 depths	• Relatively few propellant-related SVOCs were detected in soils sampled from T Range, and only 1,3-diethyl-1,3-diphenyl urea was reported in more than a few (3) samples. • Lead, copper, and antimony, typical of small arms ranges in general, were detected in excess of MMR background concentrations in soils sampled from this range, primarily at the pistol firing line.
Former B Range	• Constructed between 1935 and 1941 and used for machine gun and pistol training. • In mid-1950s starting being used exclusively for pistol training. • In 1967 converted to a rifle range.	• Inactive small arms range	**Backstop:** 10 Discrete (140A-J) for Metals at 2 depths. Gun & Mortar Old MP-2 Investigation	12 Discrete Samples (140K-V) Metals at 2 depths	• Elevated concentrations of lead, antimony, and copper were detected at two depth intervals in sampling locations 140K through 140V. A majority of the detections exceeded MMR background concentrations. • The highest concentrations of lead, copper, and antimony were generally detected in soil collected from sediment depositional areas at the base of the hillside.

Table 3-1 (Continued)

Range	Historical Use	Features	Phase IIb Sampling	TM 02-2 Sampling	Representative TM 02-2 Results and Findings
Former C Range	• Originally called Machine Gun B Range. • Constructed with 20 firing points between 1935 and 1941. • Around mid-1950s converted to 1,000-inch machine gun range. • Early 1960s, converted to 1,000-inch rifle range with 40 firing points. • In early 1980s, 15 firing points were added. • Training activities ceased in mid to late 1980s.	• Inactive small arms range • Bowl-shaped natural embankment used as backstop berm	**Target Area:** 2 – Discrete (136A-B) for Metals at 2 depths. **Backstop Area**: 10-Discrete 136D-M) for Metals at 2 depths. **Firing Line Slope**: 2-5 Point Grids (136C & N) for SVOCs and Metals at 2 depths. **Firing Line**: 4-5 Point Grids (136O-R) for SVOCs and Metals at 2 depths.	12 Discrete Samples (136S-AD) Metals at 2 depths	• Elevated concentrations of lead, copper, and antimony were detected at two depth intervals in sampling locations 136S through 136AD. Most of concentrations reported in surface samples exceeded MMR background concentrations. Concentrations in the deep samples were generally lower.
Former D Range	• Formerly called Anti-Aircraft Miniature Range. • Constructed between 1935 and 1941 and used as anti-aircraft range until 1950s. • In 1950s, converted to 1,000-inch machine gun range with 20 firing points. • Between early 1960s and late 1980s converted to a rifle range.	• Inactive small arms range	**Backstop:** 8 Discrete (135A-H) for Metals at 2 depths. **Firing Line**: 5-5 Point Grids (135I-M) for SVOCs and Metals at 3 depths. **Groundwater**: MW-174S, soil borings.	15 Discrete Samples (135N-AB) Metals at 2 depths	• Elevated concentrations of lead, copper, and antimony were detected at two depth intervals in sampling locations 135N through 135AB. Most of the concentrations reported surface samples exceeded MMR background concentrations. Concentrations in the deep samples were generally lower.
Former R Range	• Clearing on 1994 aerial photo • No discernable site features (e.g., Targets, firing line)	• No current use		**Range Center**: 1-5 Point Grid (168A) SVOC, Explosive, & Metals at 3 depths	• No explosive compounds or propellant-related SVOCs were detected in soils collected from Former R Range. • No significant elevated concentrations of metals were detected in soils collected from Former R Range.
Former L-1	• No adverse environmental impacts from small arms training have been observed • Apparent pyrotechnic smoke observed in 1958 aerial photo	• Inactive small arms training site		No Samples Collected	
Former M-1 Range	• Used for .45 caliber submachine gun training in the 1940s • Other uses: Rifle, grenade and mortar training	• Inactive small arms training site		**Cleared Area**: 2-5 Point Grids (163A-B) SVOC, Explosives & Metals at 3 depths	• No significant concentrations of propellant-related compounds were detected in samples collected from this range. • No significant concentrations of metals were detected in the samples collected from this range. • Several PAHs were detected above MMR background concentrations, but all were detected in the deep discrete sample collected from grid 163B. No PAHs were detected in the composite collected from this interval. The source of these compounds is not clear, but it is not likely widespread at this range based on their presence in only 1 of 12 samples (i.e., 8.3 percent).
Former M-2 Range	• Used for .45 caliber submachine gun, rifle, grenade and mortar training in 1940s • May have accommodated as many as 30 Firing Points	• Inactive small arms training site		**Backstop**: 10-Discrete (164A-J) Metals at 2 depths **Cleared Area**: 2-5 Point Grids (164K-L) SVOC, Explosives & Metals at 2 depths	• Backstop berm samples contained elevated concentrations of lead, copper, and antimony consistent with the presence of small caliber projectiles and projectile fragments. • Lead was the most widespread metal exceeding its MMR background concentration. • A suite of PAHs was detected in the surface composite and discrete samples collected from grid 164K, but only the deep composite sample at grid 164L, suggesting the source of these PAHs is not widespread.
Succonsette Pond	• Interviews suggest drums were stacked on a ridge south of the pond and used for .50 caliber machine gun targets. • No specific information regarding target location or firing points available.	• No current use		3 Discrete Samples (08F-H) Metals at 1 depth	• No elevated concentrations of small caliber projectile metals (i.e., lead, copper, and antimony) were detected in the soil collected around sampling grid 08D.
Skeet Range 1	• One of 2 skeet ranges reportedly used during the 1940s. • Information regarding range layout not available. • Aerial photographs provide probable range limits.	• No current use		2-5 Point Grids (170A-B) SVOC and Metals at 2 depths	• SVOCs were detected in the surface samples collected from grids 170A and 170B, including one propellant-related compound (2,4-dinitrotoluene) and several PAHs. None of the PAHs exceeded background. • Two metals, lead and manganese, were detected at concentrations that exceeded MMR background in surface samples. The source of this manganese is unclear and not likely associated with small arms range training.

Table 3-2
Small Arms Ranges
Sample Type by Area and Analytes and Removal Actions
(2000-2012)

Range Name	Mon. Wells	Lysimeters	Historic Soil Sampling - Areas and Analytes																Tungsten Use	Removal Actions			2013 Soil Sampling
			Firing Point				Range Floor				Target Berm - Target Area				Down Range - Behind Berm					1998 Lead	2006 Tungsten	2009 Lead	
			MIS	Discrete	Comp.	XRF	MIS	Discrete	Comp.	XRF	MIS	Discrete	Comp.	XRF	MIS	Discrete	Comp.	XRF					
Bermed Ranges (Active)																							
E Range	•		M S	M S	M S						M S			M	M				•	•			None
J Range (STAPP)	•	•	M S	M S	M S		M S				M			M	M	M			•	•	•	•	None
K Range (STAPP)	•	•	M S	M S	M S		M S				M			M	M				•	•	•	•	None
SE Range	•	•	M S	M S	M S	M	M S			M	M			M	M			M	•	•			None*
SW Range	•	•	M S	M S	M S	M	M S			M	M			M	M			M	•	•			None
A Range	•			M S	M S						P									•			MIS berm face and behind berm
B Range	•	•	M S	M S	M S		M				M	M		M					•	•	•		MIS berm face and behind berm
C Range	•	•	M S	M S	M S		M				M			M					•	•	•		MIS berm face and behind berm
D Range	•			M S	M S									M					•	•			MIS behind berm
G Range	•	•		M S	M S									M		M			•	•	•		MIS berm face and behind berm
H Range				M S	M S														•	•			MIS behind berm and beneath berm
I Range		•	M S	M S	M S		M				M			M		M			•	•	•		MIS behind berm
KD East SAR	•	•		M S	M S									M					•	•			MIS berm face and behind berm
N Range				M S	M S															•			MIS behind berm
O Range	•			M S	M S															•			MIS behind berm
P Range				M S	M S															•			MIS behind berm
Unbermed Ranges (Active)																							
T Range (STAPP)	•	•	M S P	M S	M S		M S P				M S P				M P			M	•		•		MIS behind berm
Unbermed Ranges (Inactive)																							
Former B Range	•			M	S			M			M	M		M		M		M				•	MIS firing lines
Former C Range					M S							M											MIS firing line
Former D Range	•			M	M S	M	M	M		M	M	M		M		M		M				•	MIS firing line/sifting area
Former M-1								M S V	M S V														MIS target area and firing line
Former M-2 (M-Range)								M S V	M S V		M	M		M	M			M				•	MIS behind berm
Former R Range								M S	M S														MIS presumed target area
GA/GB Range				M S PH	M S PH							M S V PH											MIS firing lines and field recon with metal detector and XRF downrange and MIS
L-2 Range (GP-20)								M S V PH															Field recon metal detector and XRF and MIS
L-3 Range												M S P											MIS
Skeet Range 1									M S														MIS entire range
Succonsett Pond												M S P											MIS around pond perimeter and metal detector
Former K Range (MMRP)																							None - transferred to MMRP
500-Yard Rifle Range																							Field recon metal detector and XRF and MIS
E-1 Range (North of Demo 1?)				M S	M S			M S	M S			S											Transferred to Training Areas OU
E-2 Range (At Demo 1)																							Covered under Demo 1 OU
Former M-3 Range																							Field recon metal detector and XRF
Former M-4 Range																							Field recon metal detector and XRF and MIS
L Range (Musketry)																							Field recon metal detector and XRF
L Range 1950s - 1980s																							Field recon metal detector and XRF
L-1 Range																							Field recon metal detector and XRF and MIS
L-4 Range																							Field recon metal detector and XRF and MIS
Q Range																							MIS firing line. Field recon metal detector and XRF
Skeet Range 2																							Field recon metal detector and XRF and MIS

Analytes:	M = Metals	Acronyms:	MIS = multi-increment sample
	S = Semivolatiles/Explosives		MMRP = Military Munitions Response Program
	V = Volatiles		XRF = X-Ray Fluorescence field screening instrument for metals
	P = Perchlorate		OU = Operable Unit
	PH = Pesiticides and Herbicides		
	* = Field recon metal detector, XRF and MIS sampling conducted at Former N Range located at Sierra East.		

Table 3-3A
Small Arms Ranges
2013 Surface Berm Samples
XRF Screening Results

Range	Description	Sample ID	XRF Result1*				XRF Result2*				XRF Result3*			
			Pb	Sb	W	Cr	Pb	Sb	W	Cr	Pb	Sb	W	Cr
B Range Berms	Top (NE)	B1A	79±4	ND<69	ND<8	ND<67	94±5	ND<68	ND<7	ND<66	82±5	ND<69	12±3	ND<66
B Range Berms	Mid (NE)	B2A	98±5	ND<70	13±3	ND<66	52±4	ND<69	11±3	ND<65	90±5	ND<69	15±3	ND<69
B Range Berms	Bot (NE)	B3A	73±4	ND<68	14±3	ND<63	63±4	ND<68	15±3	ND<63	92±5	ND<67	11±3	ND<58
B Range Berms	Top (MID)	B4A	191±7	ND<69	18±4	ND<69	193±7	ND<69	15±3	ND<61	125±5	ND<68	15±3	ND<66
B Range Berms	Mid (MID)	B5A	129±5	ND<69	10±3	ND<59	142±6	ND<68	11±3	ND<66	198±7	ND<68	21±4	81±24
B Range Berms	Mid R1	B5B	175±6	ND<69	16±3	ND<68	143±6	ND<68	25±4	ND<65	149±6	ND<68	13±3	ND<63
B Range Berms	Mid R2	B5C	110±5	ND<69	18±3	ND<66	132±5	ND<69	15±3	ND<64	201±7	ND<69	13±3	ND<68
B Range Berms	Bot (MID)	B6A	120±5	ND<68	10±3	ND<66	132±5	ND<67	17±3	ND<63	116±5	ND<67	21±4	ND<67
B Range Berms	Top (SW)	B7A	183±6	ND<68	ND<8	ND<66	205±7	ND<69	ND<9	ND<69	256±8	ND<69	ND<9	ND<69
B Range Berms	Mid (SW)	B8A	257±8	ND<70	13±3	ND<73	408±10	ND<70	ND<9	ND<69	245±7	ND<69	14±3	ND<65
B Range Berms	Bot (SW)	B9A	202±7	ND<69	9±3	ND<65	206±7	ND<69	ND<9	ND<72	359±9	ND<72	ND<9	ND<72
B Range Berms	Bot Rep1	B9B	170±6	ND<69	12±3	ND<66	230±7	ND<68	14±3	ND<70	200±7	ND<69	ND<9	ND<66
B Range Berms	Bot Rep2	B9C/B9C01A	414±10	ND<68	10±3	ND<70	226±7	ND<69	14±3	ND<68	232±7	ND<69	10±3	ND<63
C Range Berms	Bot1	C1A	28±3	ND<68	ND<8		22±3	ND<69	ND<8		69±4	ND<68	ND<7	
C Range Berms	Bot2	C2A	72±5	ND<70	ND<9		30±3	ND<71	ND<8		50±4	ND<69	ND<8	
C Range Berms	Bot3	C3A	62±4	ND<68	ND<8		71±4	ND<69	ND<8		75±4	ND<69	ND<8	
C Range Berms	Bot3 Rep1	C3B	64±4	ND<69	18±4		72±4	ND<69	25±4		74±4	ND<68	20±4	
C Range Berms	Bot3 Rep2	C3C	71±4	ND<67	ND<8		73±4	ND<68	ND<8		102±5	ND<68	ND<8	
C Range Berms	Bot4	C4A	210±7	ND<70	11±3		191±6	ND<68	ND<8		220±7	ND<68	11±3	
C Range Berms	Bot4 Rep1	C4B	205±7	ND<68	11±3		213±7	ND<69	11±3		203±7	ND<67	11±3	
C Range Berms	Bot4 Rep2	C4C	248±7	ND<66	ND<8		296±8	ND<71	ND<9		225±7	ND<69	12±3	
C Range Berms	Bot5	C5A	286±8	ND<69	23±4		267±8	ND<69	24±4		291±8	ND<69	73±6	
C Range Berms	Bot6	C6A	332±9	ND<68	29±4		275±7	ND<64	30±4		392±9	ND<69	34±4	
C Range Berms	Bot7	C7A	298±8	ND<68	11±3		341±9	ND<69	10±3		253±7	ND<68	10±3	
C Range Berms	Bot8	C8A	235±7	ND<69	ND<9		208±7	ND<68	10±3		209±7	ND<67	ND<9	
C Range Berms	Mid9	C9A	160±8	ND<95	15±5		184±7	ND<73	19±4		184±6	ND<68	16±3	
C Range Berms	Mid10	C10A	465±10	ND<70	21±4		446±10	ND<70	14±3		429±10	ND<68	20±4	
C Range Berms	Mid11	C11A	221±7	ND<71	13±3		172±6	ND<70	ND<9		185±6	ND<70	10±3	
C Range Berms	Mid12	C12A	253±7	ND<68	13±3		292±8	ND<70	11±3		228±7	ND<69	16±3	
C Range Berms	Back13	C13A	416±10	ND<67	13±3		584±12	ND<70	25±4		421±10	ND<68	15±3	
C Range Berms	Back14	C14A	356±9	ND<70	ND<9		638±13	ND<70	ND<9		331±9	ND<69	ND<8	

Table 3-3A
Small Arms Ranges
2013 Surface Berm Samples
XRF Screening Results

Range	Description	Sample ID	XRF Result1*				XRF Result2*				XRF Result3*			
			Pb	Sb	W	Cr	Pb	Sb	W	Cr	Pb	Sb	W	Cr
C Range Berms	Back15	C15A	418±10	ND<68	ND<8		378±9	ND<70	ND<9		370±9	ND<68	ND<9	
C Range Berms	Back15 Rep1	C15B	3252±41	ND<74	ND<10		404±9	ND<66	ND<8		384±9	ND<69	ND<8	
C Range Berms	Back15 Rep2	C15C	405±10	ND<68	ND<8		334±8	ND<67	ND<8		360±9	ND<69	ND<9	
G Range Berms	Top	G1A	432±10	ND<69	12±3		427±10	ND<70	ND<10		450±10	ND<70	ND<10	
G Range Berms	Mid	G2A	500±11	ND<70	29±4		481±11	ND<72	28±4		443±10	ND<70	27±4	
G Range Berms	Mid Rep1	G2B	475±11	ND<71	18±4		430±10	ND<72	21±4		378±10	ND<73	23±4	
G Range Berms	Mid Rep2	G2C/G2C01A	385±9	ND<68	24±4		379±9	ND<71	20±4		926±16	ND<72	28±4	
G Range Berms	Bot	G3A	276±8	ND<71	30±4		289±8	ND<72	31±4		319±9	ND<71	28±4	
G Range Berms	Top	G4A	404±10	ND<70	ND<9		414±20	ND<71	ND<9		359±10	ND<74	ND<9	
G Range Berms	Mid	G5A	520±11	ND<68	ND<9		466±10	ND<70	11±3		432±10	ND<71	ND<10	
G Range Berms	Bot	G6A	287±8	ND<71	15±4		260±8	ND<69	15±3		273±8	ND<69	15±3	
G Range Berms	Bot Rep1	G6B	283±8	ND<69	17±4		354±9	ND<69	18±4		342±9	ND<70	22±4	
G Range Berms	Bot Rep2	G6C	285±8	ND<70	13±3		273±8	ND<69	13±3		334±9	ND<71	25±4	
KD Range Berms	Top	KD1A/KD1A01A	110±5	ND<68	ND<8		84±5	ND<69	13±3		90±5	ND<68	21±4	
KD Range Berms	Mid	KD2A	62±4	ND<68	10±3		82±5	ND<68	ND<8		66±4	ND<67	9±3	
KD Range Berms	Mid Rep1	KD2B	93±5	ND<66	ND<7		73±4	ND<69	ND<9		68±4	ND<67	ND<8	
KD Range Berms	Mid Rep2	KD2C	95±5	ND<68	14±3		84±5	ND<68	ND<9		72±4	ND<69	ND<8	
KD Range Berms	Bot	KD3A	78±4	ND<68	ND<8		100±5	72±23	ND<8		80±5	ND<69	ND<7	

Notes:

* = Three one minute readings were recorded for each sample.

R1/R2 = Replicate Samples

ND = Non-detect

Split samples submitted to off-site laboratory. (Table 3-4)

Table 3-3B
Small Arms Ranges
2013 Subsurface Boring Samples
XRF Screening Results

Range	Sample ID	Depth (feet)	XRF Result 1*				XRF Result 2*				XRF Result 3*			
			Pb	Sb	W	Cr	Pb	Sb	W	Cr	Pb	Sb	W	Cr
B Range	B4	1 - 2	ND<8	ND<69	9±3	ND<69	ND<8	ND<69	ND<8	ND<62	22±3	ND<68	13±3	ND<68
B Range		3 - 4	ND<8	ND<66	9±3	ND<62	ND<8	ND<66	24±4	ND<64	9±3	ND<68	17±3	ND<62
B Range		5 - 6	16±3	ND<69	ND<7	ND<67	11±3	ND<69	ND<8	ND<66	ND<8	ND<69	ND<8	ND<67
B Range		7 - 8	Refusal at 6'											
B Range	B5	1 - 2	12±3	ND<68	19±3	ND<61	ND<8	ND<68	16±3	ND<64	10±3	ND<68	15±3	ND<66
B Range		3 - 4	Refusal at 2.75'											
B Range		5 - 6												
B Range		7 - 8												
B Range	B6_SB1-2	1 - 2	151±3	ND<69	25±4	ND<66	148±6	ND<69	27±4	ND<62	175±6	ND<71	25±4	ND<68
B Range		3 - 4	11±3	ND<66	29±4	ND<61	11±3	ND<67	19±3	ND<60	16±3	ND<66	15±3	ND<67
B Range		5 - 6	Refusal at 4.5'											
B Range		7 - 8												
C Range	C5	1 - 2	295±8	ND<70	ND<8		284±8	ND<71	ND<9		336±9	ND<69	ND<8	
C Range		3 - 4	13±3	ND<68	ND<7		11±3	ND<68	ND<7		ND<8	ND<69	ND<7	
C Range		5 - 6	9±3	ND<70	ND<7		ND<8	ND<66	ND<7		10±3	ND<68	ND<7	
C Range		7 - 8	Refusal at 6'											
C Range	C6	1 - 2	380±10	ND<71	ND<8		433±10	ND<70	ND<8		401±10	ND<70	ND<8	
C Range		3 - 4	29±3	ND<67	ND<7		13±3	ND<70	ND<7		55±4	ND<67	ND<7	
C Range		5 - 6	19±3	ND<69	ND<8		23±3	ND<69	ND<8		ND<8	ND<68	ND<7	
C Range		7 - 8	Refusal at 6'											
C Range	C10_SB1-2	1 - 2	426±10	ND<70	ND<8		608±12	ND<70	ND<8		493±11	ND<71	ND<8	
C Range		3 - 4	443±10	ND<69	ND<8		429±10	ND<70	ND<8		455±10	ND<70	ND<8	
C Range		5 - 6	25±3	ND<67	ND<7		67±4	ND<69	ND<7		21±3	ND<67	ND<7	
C Range		7 - 8	Refusal at 6'											
G Range	G2	1 - 2	15±3	ND<71	ND<8		29±4	ND<73	ND<8		20±3	ND<69	ND<8	
G Range		3 - 4	Refusal at 2.4'											
G Range		5 - 6												
G Range		7 - 8												
G Range	G3	1 - 2	359±9	ND<71	ND<8		215±7	ND<71	ND<8		226±7	ND<70	ND<8	
G Range		3 - 4	229±7	ND<71	ND<8		270±8	ND<73	ND<8		246±7	ND<69	ND<8	
G Range		5 - 6	166±6	ND<70	ND<8		124±6	ND<72	ND<8		134±6	ND<74	ND<8	
G Range		7 - 8	Refusal at 6.1'											
G Range	G6_SB1-2	1 - 2	296±8	ND<73	ND<8		266±8	ND<70	ND<9		305±8	ND<71	ND<7	
G Range		3 - 4	462±11	ND<72	ND<8		515±11	ND<69	ND<8		220±7	ND<70	ND<9	
G Range		5 - 6	Refusal at 4'											
G Range		7 - 8												
KD Range	KD1	1 - 2	71±4	ND<69	ND<8		67±4	ND<66	ND<7		93±5	ND<69	ND<8	
KD Range		3 - 4	18±3	ND<69	ND<7		35±4	ND<69	ND<8		22±3	ND<66	ND<7	

Table 3-3B
Small Arms Ranges
2013 Subsurface Boring Samples
XRF Screening Results

Range	Sample ID	Depth (feet)	XRF Result 1*				XRF Result 2*				XRF Result 3*			
			Pb	Sb	W	Cr	Pb	Sb	W	Cr	Pb	Sb	W	Cr
KD Range		5 - 6	13±3	ND<69	ND<7		16±3	ND<70	ND<7		16±3	ND<72	ND<8	
KD Range		7 - 8	Refusal at 6'											
KD Range	KD2_SB1-2	1 - 2	86±5	ND<69	ND<8		148±6	ND<69	ND<8		93±5	ND<68	ND<8	
KD Range		3 - 4	23±3	ND<69	ND<8		9±3	ND<69	ND<7		13±3	ND<71	ND<7	
KD Range		5 - 6	19±3	ND<68	ND<7		17±3	ND<71	ND<7		22±3	ND<69	ND<8	
KD Range		7 - 8	Refusal at 6'											
KD Range	KD3A	1 - 2	45±4	ND<68	ND<8		47±4	ND<71	ND<8		52±4	ND<71	ND<9	
KD Range		3 - 4	17±3	ND<70	ND<8		9±3	ND<69	ND<8		18±3	ND<70	ND<8	
KD Range		5 - 6	Refusal at 4.5'											
KD Range		7 - 8												

Notes:

Boring locations selected from berm samples with highest Tungsten XRF readings.

* = Three one minute readings were recorded for each sample.

ND = Non-detect

Split samples submitted to off-site laboratory. (Table 3-4)

Table 3-4
Small Arms Ranges
Comparison of 2013 XRF and Off-site Laboratory Data for Split Samples

Range	Sample ID	Analyte	Average XRF Result (mg/kg) *	SW6010/6020 Result (mg/kg)
B Range Berms	B9C01A	Lead	291	453
		Antimony	ND<69	1.8 J
		Tungsten	11	10.1
		Chromium	ND<67	ND
B Range Boring	B6_SB1-2	Lead	158	375
		Antimony	ND<69	2.8 J
		Tungsten	26	48.1
		Chromium	ND<65	ND
C Range Berms	C15B	Lead	1347	785
		Antimony	ND<70	3.1
		Tungsten	ND<9	65.5
C Range Boring	C10_SB1-2	Lead	509	1240
		Antimony	ND<70	7.0
		Tungsten	ND<8	0.48
G Range Berms	G2C01A	Lead	563	731
		Antimony	ND<70	3.7
		Tungsten	24	26.1
G Range Boring	G6_SB1-2	Lead	289	888
		Antimony	ND<71	4.9
		Tungsten	ND<8	18.3
KD Range Berms	KD1A01A	Lead	95	102
		Antimony	ND<68	2.1 J
		Tungsten	17	6.1
KD Range Boring	KD2_SB1-2	Lead	109	141
		Antimony	ND<69	1.2 J
		Tungsten	ND<8	ND

Notes:
* = XRF results presented in Tables 3-3A and 3-3B.
mg/kg = milligram per kilogram
ND = non-detect
J = Estimated Result

Table 3-5
Small Arms Ranges
Supplemental Sampling
XRF Data
July 2013

Range	Sample ID	XRF Result 1*			XRF Result 2*			XRF Result 3*			%RSD**
		Pb	Sb	Cu	Pb	Sb	Cu	Pb	Sb	Cu	Pb only
500 Yard Range	500YD1A	15±3	ND<59	ND<18	14±3	ND<57	ND<17	19±3	ND<57	ND<17	1.35
L1 Range	L1A	71±4	ND<60	ND<19	89±5	ND<65	ND<22	76±4	ND<65	32±7	0.96
Former M4 Range	FMRM41A	25±3	ND<61	ND<19	14±3	ND<62	ND<18	14±3	ND<63	ND<19	2.93
Former N Range	FMRN1A	1195±19	ND<69	79±9	1224±19	ND<66	99±9	1153±19	ND<66	71±9	0.24
GA/GB Range	GAGB5A	202±6	ND<62	ND<21	95±5	ND<62	ND<20	42±3	ND<62	ND<19	2.89
GA/GB Range	BA61A	40±3	ND<59	ND<19	38±3	ND<58	ND<19	42±3	ND<58	ND<20	0.41
L3 Range	L31A	103±5	ND<64	ND<21	74±4	ND<62	ND<21	97±5	ND<60	ND<20	1.37
L4 Range	L41A	12±3	ND<65	ND<19	16±3	ND<65	ND<20	20±3	ND<62	ND<20	2.04
Q Range	Q3A 1	131±5	ND<64	ND<21	119±5	ND<65	ND<21	91±5	ND<65	ND<21	1.48
Skeet Range 2	SKEET21A	13±3	ND<67	ND<20	11±3	ND<67	ND<21	10±3	ND<67	ND<20	1.10

Notes:

* Results in mg/Kg (milligrams per kilogram)

** %RSD calculated for postiive lead results only.

ND = Not detected

Table 3-6
Small Arms Ranges
Supplemental Sampling
XRF/Laboratory Confirmation Results
July 2013

Range	Sample ID	Analyte	Average XRF Result (mg/Kg)	SW6010 Result (mg/Kg)
500 YARD RIFLE RANGE	500YD1A	Antimony	ND<59	1.2 J
	500YD1A	Copper	ND<17	4.6
	500YD1A	Lead	16	12.6
FORMER L-1 RANGE	L1A	Antimony	ND<65	0.93 J
	L1A	Copper	ND<25	15.4
	L1A	Lead	79	60.2
FORMER M-4 RANGE	FMRM41A	Antimony	ND<62	0.31 J
	FMRM41A	Copper	ND<19	2.8
	FMRM41A	Lead	18	14.6
FORMER N RANGE	FMRN1A	Antimony	ND<69	8.1
	FMRN1A	Copper	83	175
	FMRN1A	Lead	1191	1670
GA RANGE	GAGB5A	Antimony	ND<62	0.96 J
	GAGB5A	Copper	ND<21	14.6
	GAGB5A	Lead	113	94.1
GA RANGE	BA61A	Antimony	ND<59	0.42 J
	BA61A	Copper	ND<20	12.1 J
	BA61A	Lead	40	34.1
L-3 RANGE	L31A	Antimony	ND<64	1.4 J
	L31A	Copper	ND<21	15.2
	L31A	Lead	91	77.4
L-4 RANGE	L41A	Antimony	ND<65	0.91 J
	L41A	Copper	ND<20	5.4
	L41A	Lead	16	12
Q RANGE	L41A	Antimony	ND<65	1.1 J
	L41A	Copper	ND<21	12.3
	L41A	Lead	114	152
SKEET RANGE 2	SKEET21A	Antimony	ND<67	0.88 J
	SKEET21A	Copper	ND<21	3.5
	SKEET21A	Lead	11	8

Notes:
mg/Kg = milligram per kilogram
ND = non-detect
J = Estimated Result

Table 4-1
Summary of Response Actions and Range Maintenance Activities

Range Name	1998 Lead Removal	2006 Berm Maintenance Tungsten	2009 Lead Removal	2007 / 2008 Nitroglycerin Removal
E Range	●			
J Range	●	●	●	●
K Range	●	●	●	●
SE Range	●			
SW Range	●			
T Range		●		●
A Range	●			
B Range	●	●		
C Range	●	●		
D Range	●			
G Range	●	●		
H Range	●			
I Range	●	●		
KD SAR	●			
N Range	●			
O Range	●			
P Range	●			
Former B Range			●	
Former C Range				
Former D Range			●	
Former M-1				
Former M-2 (M Range)			●	
Former N Range				
Former R Range				
GA/GB Range				
L-2 Range				
L-3 Range				
Skeet Range 1				
Succonsette Pond				
500-Yard Rifle Range				
Former M-3 Range				
L Range				
L-1 Range				
L-4 Range				
Q Range				
Skeet Range 2				

Table 5-1
Small Arms Ranges
Maximum Groundwater Contaminant Concentrations

Analyte	Detection Frequency	Maximum Detected Concentration (ug/L)	Location of Maximum Detected Concentration	Date of Maximum Detected Concentration	Range Closest to Location of Maximum Detected Concentration
PEP Compounds					
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE (RDX)	1 / 275	0.37	MW-34M3	11/12/2003	G Range
PERCHLORATE	29 / 185	2.2	MW-344S	4/24/2007	L-3 Range
Metals and Inorganics					
ALUMINUM (total)	20 / 112	3360	MW-264M2	12/19/2012	Former M-2 Range
ALUMINUM (filtered)	3 / 11	58.4	MW-23S	10/27/1997	A Range
ANTIMONY (total)	2 / 262	6.7 J	MW-36S	8/17/1999	G Range
ANTIMONY (filtered)	2 / 46	10.8 J	MW-538M1	4/1/2010	B Range
ARSENIC (total)	19 / 261	23.6	MW-465S	3/25/2009	SW Range
ARSENIC (filtered)	0 / 49				
BARIUM (total)	135 / 261	66.9	MW-72S	2/7/2007	B Range
BARIUM (filtered)	25 / 49	53.6 J	MW-72S	3/30/2007	B Range
BERYLLIUM (total)	1 / 98	0.42 J	MW-63S	9/21/1999	N Range
BORON (total)	55 / 94	42.3	03MW0014A	4/13/1999	GA/GB Range
BORON (filtered)	1 / 3	7.9	MW-23S	6/13/2000	A Range
CADMIUM (total)	19 / 261	2.7 J	MW-465S	3/25/2009	SW Range
CADMIUM (filtered)	4 / 49	1.7 J	XXLRWS6-1	1/28/1999	Former M-1 Range
CALCIUM (total)	94 / 98	8430	MW-264M2	12/19/2012	Former M-2 Range
CALCIUM (filtered)	7 / 7	4310	MW-63S	9/21/1999	N Range
CHROMIUM, TOTAL [e] (total)	41 / 261	25.8	MW-465S	10/13/2006	SW Range
CHROMIUM, TOTAL [e] (filtered)	2 / 49	2.5 J	MW-474S	3/29/2007	K Range
COBALT (total)	4 / 98	3.6	MW-23S	10/27/1997	A Range
COBALT (filtered)	1 / 7	2.6	MW-23S	10/27/1997	A Range
COPPER (total)	50 / 260	103	MW-67S	4/28/2000	L-2 Range
COPPER (filtered)	11 / 46	8.3 J	MW-473S	5/25/2011	K Range
IRON (total)	75 / 234	8380	XXLRWS6-1	11/17/1997	Former M-1 Range
IRON (filtered)	7 / 32	2500	XXLRWS8-2	10/15/1997	Former B Range
LEAD (total)	11 / 287	7.7 J	MW-470S	3/12/2012	G Range
LEAD (filtered)	1 / 49	2.3	MW-538M1	4/1/2010	B Range
MAGNESIUM (total)	97 / 98	6650	03MW0014A	4/13/1999	GA/GB Range
MAGNESIUM (filtered)	7 / 7	1660	MW-63S	9/21/1999	N Range
MANGANESE (total)	102 / 112	286	MW-63S	9/21/1999	N Range
MANGANESE (filtered)	11 / 11	200	MW-23S	10/27/1997	A Range
MERCURY [f] (total)	4 / 246	0.19 J	MW-36S	6/9/2000	G Range
MERCURY [f] (filtered)	2 / 45	0.13 J	MW-473S	3/29/2007	K Range
MOLYBDENUM (total)	15 / 94	15.9	MW-55S	5/17/1999	SE/SW Range
MOLYBDENUM (filtered)	1 / 3	11.1	MW-63S	9/21/1999	N Range
NICKEL (total)	20 / 98	8.2	MW-63S	8/13/2001	N Range
NICKEL (filtered)	4 / 7	5.3	XXLRWS6-1	1/28/1999	Former M-1 Range
NITROGEN, AMMONIA (AS N)	24 / 59	100	MW-63S	1/4/2000	N Range
NITROGEN, NITRATE-NITRITE [g]	49 / 59	2100	03MW0014A	4/13/1999	GA/GB Range
PHOSPHORUS, TOTAL ORTHOPHOSPHATE (AS PO4)	24 / 59	150	MW-63S	9/21/1999	N Range
POTASSIUM (total)	74 / 98	2760	03MW0014A	4/13/1999	GA/GB Range
POTASSIUM (filtered)	5 / 7	1190	MW-23S	10/27/1997	A Range
SELENIUM (total)	6 / 247	21.5 J	MW-465S	3/25/2009	SW Range
SELENIUM (filtered)	2 / 45	4 J	MW-475S	3/30/2007	Former B Range
SILVER (total)	3 / 246	2.2 J	MW-67S	10/27/1999	L-2 Range
SODIUM (total)	98 / 98	11200	03MW0014A	4/13/1999	GA/GB Range
SODIUM (filtered)	7 / 7	10000	MW-63S	9/21/1999	N Range
THALLIUM (total)	4 / 100	4.7 J	MW-23S	9/14/1999	A Range
TUNGSTEN [h] (total)	31 / 200	3.7	MW-72S	3/30/2007	B Range
TUNGSTEN [h] (filtered)	25 / 64	22	MW-470S	10/30/2006	G Range
VANADIUM [i] (total)	4 / 98	4.1 J	MW-264M2	12/19/2012	Former M-2 Range
ZINC (total)	96 / 250	3480	XXLRWS6-1	11/17/1997	Former M-1 Range
ZINC (filtered)	15 / 46	2600	XXLRWS6-1	11/17/1997	Former M-1 Range
Pesticides and Herbicides					
2,4,5-T (TRICHLOROPHENOXYACETIC ACID)	2 / 68	0.13 J	MW-67S	10/27/1999	L-2 Range
BENTAZON	1 / 58	1.5 NJ	MW-63S	9/21/1999	N Range
CHLORAMBEN	4 / 58	0.4 J	MW-67S	4/28/2000	L-2 Range
DICHLOROPROP	1 / 68	1.2 J	MW-63S	9/21/1999	N Range
2-(2-METHYL-4-CHLOROPHENOXY) PROPIONIC ACID (MCPP)	1 / 68	230 NJ	XXLRWS8-2	10/15/1997	Former B Range
SVOCs					
2-CHLOROPHENOL	2 / 183	1.1 J	MW-264M2	8/2/2005	Former M-2 Range
4-METHYLPHENOL (p-CRESOL)	3 / 173	30	MW-264M2	8/2/2005	Former M-2 Range
BENZOIC ACID	5 / 171	50 J	MW-264M2	5/22/2003	Former M-2 Range
BENZYL ALCOHOL	1 / 179	11 J	MW-264M2	5/22/2003	Former M-2 Range
bis(2-ETHYLHEXYL) PHTHALATE	17 / 183	24	MW-23S	10/27/1997	A Range
DIETHYL PHTHALATE	2 / 183	3 J	MW-67S	4/28/2000	L-2 Range
DI-n-BUTYL PHTHALATE	5 / 183	0.55 J	MW-264M2	5/22/2003	Former M-2 Range
DI-n-OCTYLPHTHALATE	1 / 183	0.43 J	MW-465S	3/25/2009	SW Range
DIBENZOFURAN	1 / 183	0.48 J	MW-264M2	5/22/2003	Former M-2 Range
HEXADECANOIC ACID	2 / 2	13 NJ	MW-264M2	5/22/2003	Former M-2 Range
NAPHTHALENE	1 / 183	0.28 J	MW-154S	7/25/2001	N Range
PHENOL	3 / 183	2.9 J	MW-264M2	8/2/2005	Former M-2 Range
VOCs					
1,2,4-TRICHLOROBENZENE	1 / 108	0.3 J	MW-67S	8/9/2001	L-2 Range
1,4-DICHLOROBENZENE	1 / 112	0.2 J	MW-264M2	5/22/2003	Former M-2 Range
ACETONE	4 / 101	20 J	MW-264M2	12/9/2003	Former M-2 Range
CARBON DISULFIDE	1 / 112	0.3 J	MW-264M2	8/19/2003	Former M-2 Range
CHLOROFORM [j]	88 / 112	7	MW-56S	9/5/2000	Former M-1 Range
CHLOROMETHANE	6 / 112	33 J	LRMW0003	5/17/2004	L-4 Range
cis-1,3-DICHLOROPROPENE	1 / 112	0.5 J	LRMW0003	9/10/2003	L-4 Range
ETHYLBENZENE	1 / 112	0.4 J	MW-264M2	8/19/2003	Former M-2 Range
METHYL ETHYL KETONE [2-BUTANONE]	3 / 112	4 J	MW-264M2	5/22/2003	Former M-2 Range
STYRENE	1 / 112	1	MW-264M2	5/22/2003	Former M-2 Range
TETRACHLOROETHYLENE (PCE)	3 / 112	12	03MW0020	4/14/1999	GA/GB Range
TOLUENE	3 / 112	0.3 J	MW-264M2 / MW-55S	5/22/2003 / 5/17/1999	Former M-2 Range / SE/SW Range
TRICHLOROETHYLENE (TCE)	17 / 112	2	LRMW0003 / 03MW0020	3/25 and 10/7/1999 / 4/14/1999	L-4 Range / GA/GB Range

Notes:

Data set consists of all sampling events between May 1999 and December 2012 for monitoring wells: 03MW0006, 03MW0007A, 03MW0014A, 03MW0020, 03MW0025A, 03MW0709, 03MW0710, DP-459 , LRMW0003, MW-102S, MW-103S, MW-109S, MW-116S, MW-121S, MW-123S, MW-124M3, MW-154S, MW-174S, MW-215 , MW-219M4, MW-23S , MW-264M2, MW-282M2, MW-344S, MW-34M3, MW-36S , MW-455S, MW-456S, MW-465S, MW-466S, MW-467S, MW-468S, MW-470S, MW-471S, MW-472S, MW-473S, MW-474S, MW-475S, MW-476S, MW-489S, MW-490S, MW-491S, MW-492S, MW-537M1, MW-538M1, MW-539M1, MW-55S , MW-56S , MW-60S , MW-63S , MW-67S , MW-72S , XXLRWS6-1 and XXLRWS8-2.
Laboratory data validation qualifier codes used for the "Maximum Concentration" are as follows:
J = The associated numerical value is an esimated quantity.
N = Presumptive evidence of presence of material (tentative identification).

Table 5-2
May 2013 Supplemental Investigation Pore Water Results

Site/SLX List	Location ID	Field Sample ID	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL
B RANGE	LYBR001	LYBRNG_JUN13A	06/05/2013	SW6020A	Antimony	18.5	J	UG/L	0.073	20.0
B RANGE	LYBR001	LYBRNG_JUN13A	06/05/2013	SW6020A	Lead	1.5	J	UG/L	0.024	2.0
B RANGE	LYBR001	LYBRNG_JUN13A	06/05/2013	SW6020A	Chromium	ND	U	UG/L	0.11	4.0
B RANGE	LYBR001	LYBRNG_JUN13A	06/05/2013	SW6020A	Tungsten	844		UG/L	0.16	2.0
G RANGE	LYGR001	LYGRNG_JUN13A	06/05/2013	SW6020A	Antimony	61.6		UG/L	0.073	20.0
G RANGE	LYGR001	LYGRNG_JUN13A	06/05/2013	SW6020A	Lead	9.7		UG/L	0.024	2.0
G RANGE	LYGR001	LYGRNG_JUN13A	06/05/2013	SW6020A	Chromium	ND	U	UG/L	0.11	4.0
G RANGE	LYGR001	LYGRNG_JUN13A	06/05/2013	SW6020A	Tungsten	32		UG/L	0.16	2.0

Table 5-3
Synthetic Leaching Procedure Results

Range	Sample ID	XRF Lead Result (mg/Kg)	Total Lead (mg/Kg)	SPLP Lead (µg/L)	Phosphorous (mg/Kg)
G Range	G2A	393±9	419	2020	1000
B Range	B8A	232±7	360	160	1370
C Range	C15A	399±9	450	42.8	1020

Note: Submitted samples were 30 point MIS samples selected based on the XRF results of respective berm samples.

Table 5-4
Range-Specific Groundwater Data Summary

RANGE	WELL ID	Depth to water (ft)	Date Recorded	TOP OF SCREEN	BOTTOM OF SCREEN	2,4-DINITROTOLUENE		RDX	NITROGLYCERIN	N-NITROSODI-PHENYLAMINE	PERCHLORATE	ANTIMONY		COPPER		LEAD		TUNGSTEN	
						8330	8270	8330	8330	8270	E314.0,6850,6860	TOTAL	FILTERED	TOTAL	FILTERED	TOTAL	FILTERED	TOTAL	FILTERED
A RANGE	MW-23S	129.37	Jun-00	122.5	132.5	ND	ND	ND	ND	ND	--	ND	ND	5.2 J	ND	4.6	ND	--	--
B RANGE	MW-124M3	135.65	Dec-04	160	170	ND	--	ND	ND	--	ND	ND	--	--	--	--	--	--	--
	MW-455S	120.66	Jun-13	118	128	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	ND	ND	ND	0.21 J
	MW-490S	110.77	Jun-12	108	118	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	ND	ND
	MW-537M1	110.64	Jun-13	106	116	--	--	--	--	--	--	ND	ND	ND	ND	ND	--	0.5 J	ND
	MW-538M1	109.68	Mar-12	107	117	--	--	--	--	--	--	ND	10.8	6.2 J	ND	23.8	2.3 J	14.3	10.4
	MW-539M1	115.41	Jun-13	113	123	--	--	--	--	--	--	ND	ND	13.3 J	ND	ND	ND	ND	ND
	MW-72S	110.03	Jun-13	106	116	ND	ND	ND	ND	ND	ND	ND	--	2.3 J	ND	0.37 J	ND	3.7	3.3
FORMER B RANGE	MW-475S	53.78	Jun-13	50	60	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	ND	ND	ND	ND
	MW-476S	61.95	Jun-13	60	70	ND	ND	ND	ND	ND	--	ND	ND	ND	4.9 J	ND	ND	ND	ND
	XXLRWS8-2	56.79	Jan-99	90.05	105.05	ND	ND	ND	--	ND	--	ND	ND	ND	ND	ND	ND	--	--
C RANGE	MW-103S	145	Jan-01	143	153	ND	--	ND	ND	--	--	ND	3.1 J	--	--	--	--	--	--
	MW-123S	138.94	Oct-12	139	149	ND	--	ND	ND	--	--	ND	--	--	--	ND	ND	ND	ND
	MW-456S	153.2	Jun-13	150.3	160.3	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	ND	ND	ND	0.45 J
	MW-491S	149.3	Jun-13	146.5	156.5	--	--	--	--	--	--	--	ND	ND	ND	ND	ND	0.9	0.33 J
FORMER C RANGE	MW-219M4	174.39	Oct-12	225	235	ND	--	ND	ND		ND	--	--	--	--	--	--	--	--
D RANGE	MW-102S	144.4	Jan-06	145	155	ND	--	ND	ND	--	ND	6.7 J	--	--	--	--	--	--	--
FORMER D RANGE	MW-174S	191.83	Jun-13	190	200	ND	ND	ND	ND	ND	ND	ND	ND	3.6 J	ND	7.3 J	ND	0.32	0.38 J
	MW-282M2	182.76	Oct-11	206	216	ND	--	ND	ND		0.043 J	--	--	--	--	--	--	--	--
E RANGE	MW-468S	173.62	Jun-13	170	180	ND	ND	ND	ND	ND	--	ND	ND	6.3 J	ND	ND	ND	ND	0.39 J
G RANGE	MW-34M3	78.72	Mar-13	111	121	ND	ND	0.37	ND	ND	1.12	ND	--	ND		ND	--	--	--
	MW-36S	76.9	Mar-13	73	83	ND	ND	ND	ND	ND	ND	--	--	4.3 J		ND	--	--	--
	MW-470S	78.71	Mar-13	76	86	ND	ND	ND	ND	ND	--	--	ND	ND	ND	7.7 J	ND	0.23	0.81 J
GA/GB RANGE	03MW0006	86.63	Aug-03	81	91	ND	ND	ND	ND	ND	--	2.9 J	--	ND	--	ND	--	--	--
	03MW0007A	88.47	Jan-00	104	109	ND	ND	ND	ND	ND	--	ND	--	ND	--	ND	--	--	--
	03MW0014A	86.35	Jan-00	119	124	ND	ND	ND	ND	ND	--	ND	--	ND	--	ND	--	--	--
	03MW0020	84.25	Jan-00	114	124	ND	ND	ND	ND	ND	--	ND	--	ND	--	ND	--	--	--
	03MW0709	86.2	Jan-00	76	86	ND	ND	ND	ND	ND	--	ND	--	ND	--	ND	--	--	--
	03MW0710	82.6	Jan-00	82	87	--	--	--	--	--	--	ND	--	ND	--	ND	--	--	--
KD SAR	MW-109S	86.79	Mar-12	89	99	ND	ND	ND	ND	ND	ND	ND	--	3 J	--	0.96 J	ND	ND	ND
	MW-60S	95.25	Aug-03	90.7	100.7	ND	ND	ND	ND	ND	ND	ND	--	2.2 J	--	ND	--	--	--
J RANGE	MW-471S	87.71	Sep-12	85	95	ND	ND	ND	ND	ND	--	ND	ND	3.6 J	7.3 J	ND	ND	ND	0.33 J
	MW-472S	88.49	Sep-12	85	95	ND	ND	ND	ND	ND	--	ND	ND	1.4 J	1.9 J	ND	ND	ND	ND
K RANGE	MW-473S	86.95	Sep-12	83	93	ND	ND	ND	ND	ND	--	ND	ND	1.2 J	8.3 J	0.18 J	ND	ND	ND
	MW-474S	89.46	Sep-12	86	96	ND	ND	ND	ND	ND	--	ND	ND	0.82 J	1.7 J	0.042 J	ND	ND	ND
L2 RANGE	MW-67S	155.99	Oct-12	161	171	ND	ND	ND	ND	ND	0.043 J	ND	--	103	--	ND		ND	ND
L3 RANGE	MW-344S	114.33	May-13	115.5	125.5	ND	--	ND	ND		2.2	--	--	--	--	--	--	--	--
L4 RANGE	LRMW0003	24.39	Jun-05	95	105	ND	ND	ND	ND	ND	ND	ND	ND	1.1 J	ND	ND	ND	--	--
FORMER M1 RANGE	MW-56S	77.36	Sep-05	76	86	ND	ND	ND	ND	ND	ND	ND	--	ND	--	ND	--	--	--
	XXLRWS6-1	56.43	Jan-99	111.56	126.56	ND	ND	ND	ND	ND	--	ND	ND	ND	ND	ND	ND	--	--
FORMER M2 RANGE	MW-264M2	28.59	Dec-12	136	146	ND	ND	ND	ND	ND	ND	--	--	--	--	--	--	--	--
N RANGE	MW-116S	100.28	Aug-13	102	112	--	--	--	--	--	0.64 J	ND	--	5.8 J	--	ND	--	--	--
	MW-121S	93.26	Aug-02	87.95	97.95	ND	ND	ND	ND	ND	ND	ND	--	5.7 J	--	ND	--	--	--
	MW-154S	96.64	Sep-05	98	108	ND	ND	ND	ND	ND	ND	ND	--	2.6	--	ND	--	--	--
	MW-63S	156.88	Jul-05	153	163	ND	ND	ND	ND	ND	ND	ND	ND	3.4 J	ND	ND	ND	--	--
O RANGE	MW-492S	82.4	Jun-13	79.5	89.5	--	--	--	--	--	--	ND	ND	1.8 J	ND	0.43 J	ND	ND	--
P RANGE	DP-459	not recorded	DP drilled 20	107.5	112.5	ND	--	ND	ND	--	ND	--	--	--	--	--	--	--	--
	MW-215S	102.22	Feb-09	104	114	--	--	--	--	--	1.4 J	ND	--	ND	--	ND	--	--	--
SE/SW RANGE	MW-465S	141.02	Jun-13	136	146	ND	ND	ND	ND	ND	--	ND	ND	3.2 J	ND	ND	ND	0.49	1.3 J
	MW-466S	137.8	Jun-13	133	143	ND	ND	ND	ND	ND	--	ND	ND	0.32 J	ND	ND	ND	1.2	0.88 J
	MW-55S	139.33	Aug-03	133	143	ND	ND	ND	ND	ND	ND	ND	--	2.3 J	--	ND	--	--	--
T RANGE	MW-467S	128.26	Sep-12	125	135	ND	ND	ND	ND	ND	--	ND	ND	2.5 J	2.2 J	7.1 J	ND	0.7	0.59 J
	MW-489S	125.08	Oct-11	124	134	--	--	ND	--	--	--	ND	ND	3.6 J	0.88 J	ND	--	ND	ND

Note:

Maximum detected concentrations for all wells through Fall 2012; for the yellow highlighted wells the maximum is up through May 2013.

Table 5-5
Small Arms Ranges
2013 Multiple Increment Sample Results for Individual Ranges

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Sample Type	Remarks
A RANGE	SSARNG01	AR01A	4620482.17	370799.28	04/24/2013	SW6010C	Antimony	0.34	J	MG/KG	0.24	3.0	N1	BF 100PT MIS
A RANGE	SSARNG01	AR01A	4620482.17	370799.28	04/24/2013	SW6010C	Copper	11.5		MG/KG	0.11	1.2	N1	BF 100PT MIS
A RANGE	SSARNG01	AR01A	4620482.17	370799.28	04/24/2013	SW6010C	Lead	15.6		MG/KG	0.22	0.50	N1	BF 100PT MIS
A RANGE	SSARNG02	AR02A	4620471.47	370827.82	04/24/2013	SW6010C	Antimony	0.67	J	MG/KG	0.25	3.0	N1	BB 100PT MIS
A RANGE	SSARNG02	AR02A	4620471.47	370827.82	04/24/2013	SW6010C	Copper	18.0		MG/KG	0.11	1.3	N1	BB 100PT MIS
A RANGE	SSARNG02	AR02A	4620471.47	370827.82	04/24/2013	SW6010C	Lead	16.6		MG/KG	0.22	0.50	N1	BB 100PT MIS
B RANGE	SSBRNG01	BR01A	4620487.25	370504.16	04/15/2013	SW6010C	Antimony	5.0		MG/KG	0.24	3.0	N1	BB 100PT MIS
B RANGE	SSBRNG01	BR01A	4620487.25	370504.16	04/15/2013	SW6010C	Copper	35.0		MG/KG	0.11	1.2	N1	BB 100PT MIS
B RANGE	SSBRNG01	BR01A	4620487.25	370504.16	04/15/2013	SW6010C	Lead	593		MG/KG	0.22	0.49	N1	BB 100PT MIS
B RANGE	SSBRNG01	BR01A	4620487.25	370504.16	04/15/2013	SW6010C	Chromium	ND	U	MG/KG	0.054	111	N1	BB 100PT MIS
B RANGE	SSBRNG01	BR01A	4620487.25	370504.16	04/15/2013	SW6020A	Tungsten	23.4		MG/KG	0.012	0.096	N1	BB 100PT MIS
B RANGE	SSBRNG02	BR02A	4620431.59	370484.6	04/15/2013	SW6010C	Antimony	8.2		MG/KG	0.25	3.0	N1	BB 100PT MIS
B RANGE	SSBRNG02	BR02A	4620431.59	370484.6	04/15/2013	SW6010C	Copper	133		MG/KG	0.11	1.3	N1	BB 100PT MIS
B RANGE	SSBRNG02	BR02A	4620431.59	370484.6	04/15/2013	SW6010C	Lead	826		MG/KG	0.22	0.50	N1	BB 100PT MIS
B RANGE	SSBRNG02	BR02A	4620431.59	370484.6	04/15/2013	SW6010C	Chromium	ND	U	MG/KG	0.055	134	N1	BB 100PT MIS
B RANGE	SSBRNG02	BR02A	4620431.59	370484.6	04/15/2013	SW6020A	Tungsten	133		MG/KG	0.12	0.98	N1	BB 100PT MIS
B RANGE	SSBRNG02	BR02B	4620431.59	370484.6	04/15/2013	SW6010C	Antimony	4.6		MG/KG	0.24	3.0	FR1	BB 100PT MIS
B RANGE	SSBRNG02	BR02B	4620431.59	370484.6	04/15/2013	SW6010C	Copper	77.0		MG/KG	0.11	1.2	FR1	BB 100PT MIS
B RANGE	SSBRNG02	BR02B	4620431.59	370484.6	04/15/2013	SW6010C	Lead	605		MG/KG	0.22	0.50	FR1	BB 100PT MIS
B RANGE	SSBRNG02	BR02B	4620431.59	370484.6	04/15/2013	SW6010C	Chromium	ND	U	MG/KG	0.055	3.4	FR1	BB 100PT MIS
B RANGE	SSBRNG02	BR02B	4620431.59	370484.6	04/15/2013	SW6020A	Tungsten	110		MG/KG	0.13	1.0	FR1	BB 100PT MIS
B RANGE	SSBRNG02	BR02C	4620431.59	370484.6	04/15/2013	SW6010C	Antimony	5.1		MG/KG	0.24	3.0	FR2	BB 100PT MIS
B RANGE	SSBRNG02	BR02C	4620431.59	370484.6	04/15/2013	SW6010C	Copper	2970		MG/KG	0.11	1.2	FR2	BB 100PT MIS
B RANGE	SSBRNG02	BR02C	4620431.59	370484.6	04/15/2013	SW6010C	Lead	585		MG/KG	0.22	0.50	FR2	BB 100PT MIS
B RANGE	SSBRNG02	BR02C	4620431.59	370484.6	04/15/2013	SW6010C	Chromium	ND	U	MG/KG	0.054	132	FR2	BB 100PT MIS
B RANGE	SSBRNG02	BR02C	4620431.59	370484.6	04/15/2013	SW6020A	Tungsten	104		MG/KG	0.12	0.99	FR2	BB 100PT MIS
B RANGE	SSBRNG03	BR03A	4620372.77	370462.39	04/15/2013	SW6010C	Antimony	3.0		MG/KG	0.24	3.0	N1	BB 100PT MIS
B RANGE	SSBRNG03	BR03A	4620372.77	370462.39	04/15/2013	SW6010C	Copper	36.0		MG/KG	0.11	1.2	N1	BB 100PT MIS
B RANGE	SSBRNG03	BR03A	4620372.77	370462.39	04/15/2013	SW6010C	Lead	464		MG/KG	0.22	0.50	N1	BB 100PT MIS
B RANGE	SSBRNG03	BR03A	4620372.77	370462.39	04/15/2013	SW6010C	Chromium	ND	U	MG/KG	0.054	7.6	N1	BB 100PT MIS
B RANGE	SSBRNG03	BR03A	4620372.77	370462.39	04/15/2013	SW6020A	Tungsten	9.9		MG/KG	0.012	0.097	N1	BB 100PT MIS
C RANGE	SSCRNG01	CR01A	4620118.15	370363.73	04/24/2013	SW6010C	Antimony	4.4		MG/KG	0.24	3.0	N1	BB 100PT MIS
C RANGE	SSCRNG01	CR01A	4620118.15	370363.73	04/24/2013	SW6010C	Copper	59.6		MG/KG	0.11	1.2	N1	BB 100PT MIS
C RANGE	SSCRNG01	CR01A	4620118.15	370363.73	04/24/2013	SW6010C	Lead	480		MG/KG	0.22	0.50	N1	BB 100PT MIS
C RANGE	SSCRNG01	CR01A	4620118.15	370363.73	04/24/2013	SW6020A	Tungsten	36.7		MG/KG	0.013	0.10	N1	BB 100PT MIS
C RANGE	SSCRNG02	CR02A	4620155.54	370377.78	04/24/2013	SW6010C	Antimony	9.1		MG/KG	0.25	3.0	N1	BB 100PT MIS
C RANGE	SSCRNG02	CR02A	4620155.54	370377.78	04/24/2013	SW6010C	Copper	104		MG/KG	0.11	1.3	N1	BB 100PT MIS
C RANGE	SSCRNG02	CR02A	4620155.54	370377.78	04/24/2013	SW6010C	Lead	749		MG/KG	0.22	0.50	N1	BB 100PT MIS

Table 5-5
Small Arms Ranges
2013 Multiple Increment Sample Results for Individual Ranges

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Sample Type	Remarks
C RANGE	SSCRNG02	CR02A	4620155.54	370377.78	04/24/2013	SW6020A	Tungsten	42.0		MG/KG	0.013	0.10	N1	BB 100PT MIS
C RANGE	SSCRNG03	CR03A	4620177.21	370405.57	04/24/2013	SW6010C	Antimony	0.86	J	MG/KG	0.24	3.0	N1	BB 100PT MIS
C RANGE	SSCRNG03	CR03A	4620177.21	370405.57	04/24/2013	SW6010C	Copper	14.0		MG/KG	0.11	1.2	N1	BB 100PT MIS
C RANGE	SSCRNG03	CR03A	4620177.21	370405.57	04/24/2013	SW6010C	Lead	103		MG/KG	0.22	0.50	N1	BB 100PT MIS
C RANGE	SSCRNG03	CR03A	4620177.21	370405.57	04/24/2013	SW6020A	Tungsten	7.9		MG/KG	0.012	0.10	N1	BB 100PT MIS
C RANGE	SSCRNG04	CR04A	4620207.76	370387.86	04/24/2013	SW6010C	Antimony	2.6	J	MG/KG	0.25	3.0	N1	BB 100PT MIS
C RANGE	SSCRNG04	CR04A	4620207.76	370387.86	04/24/2013	SW6010C	Copper	32.8		MG/KG	0.11	1.3	N1	BB 100PT MIS
C RANGE	SSCRNG04	CR04A	4620207.76	370387.86	04/24/2013	SW6010C	Lead	192		MG/KG	0.22	0.50	N1	BB 100PT MIS
C RANGE	SSCRNG04	CR04A	4620207.76	370387.86	04/24/2013	SW6020A	Tungsten	17.9		MG/KG	0.013	0.10	N1	BB 100PT MIS
D RANGE	SSDRNG01	DR01A	4620037.31	370337.52	04/16/2013	SW6010C	Antimony	12.1		MG/KG	0.24	3.0	N1	BB 30PT MIS
D RANGE	SSDRNG01	DR01A	4620037.31	370337.52	04/16/2013	SW6010C	Copper	31.8		MG/KG	0.11	1.2	N1	BB 30PT MIS
D RANGE	SSDRNG01	DR01A	4620037.31	370337.52	04/16/2013	SW6010C	Lead	1840		MG/KG	0.22	0.50	N1	BB 30PT MIS
D RANGE	SSDRNG01	DR01A	4620037.31	370337.52	04/16/2013	SW6020A	Tungsten	0.25		MG/KG	0.012	0.097	N1	BB 30PT MIS
FORMER B RANGE	SSFMRB01	FMRB01A	4619872.95	368870.76	04/16/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.8	96.3	N1	FL 100PT MIS
FORMER B RANGE	SSFMRB02	FMRB02A	4619993.22	368946.28	04/16/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	2210	96.0	N1	FL 100PT MIS
FORMER C RANGE	SSFMRC01	FMRC01A	4619332	369356.08	04/17/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.9	97.1	N1	FL 100PT MIS
FORMER C RANGE	SSFMRC01	FMRC01B	4619332	369356.08	04/17/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	93.3	FR1	FL 100PT MIS
FORMER C RANGE	SSFMRC01	FMRC01C	4619332	369356.08	04/17/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.8	95.2	FR2	FL 100PT MIS
FORMER D RANGE	SSFMRD01	FMRD01A	4618808.26	369711.78	04/16/2013	SW6010C	Lead	194		MG/KG	0.22	0.49	N1	100PT MIS
FORMER D RANGE	SSFMRD01	FMRD01A	4618808.26	369711.78	04/16/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.6	92.6	N1	100PT MIS
FORMER D RANGE	SSFMRD02	FMRD02A	4618834.34	369733.83	04/16/2013	SW6010C	Lead	169		MG/KG	0.22	0.49	N1	100PT MIS
FORMER D RANGE	SSFMRD02	FMRD02A	4618834.34	369733.83	04/16/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	93.5	N1	100PT MIS
FORMER D RANGE	SSFMRD03	FMRD03A	4618815.51	369755.02	04/15/2013	SW6010C	Lead	156		MG/KG	0.21	0.49	N1	100PT MIS
FORMER D RANGE	SSFMRD03	FMRD03A	4618815.51	369755.02	04/15/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	93.8	N1	100PT MIS
FORMER D RANGE	SSFMRD03	FMRD03B	4618815.51	369755.02	04/15/2013	SW6010C	Lead	199		MG/KG	0.22	0.50	FR1	100PT MIS
FORMER D RANGE	SSFMRD03	FMRD03B	4618815.51	369755.02	04/15/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.9	97.5	FR1	100PT MIS
FORMER D RANGE	SSFMRD03	FMRD03C	4618815.51	369755.02	04/15/2013	SW6010C	Lead	179		MG/KG	0.22	0.50	FR2	100PT MIS
FORMER D RANGE	SSFMRD03	FMRD03C	4618815.51	369755.02	04/15/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	93.5	FR2	100PT MIS
FORMER D RANGE	SSFMRD04	FMRD04A	4618802.26	369730.69	04/16/2013	SW6010C	Lead	91.6		MG/KG	0.22	0.50	N1	100PT MIS
FORMER D RANGE	SSFMRD04	FMRD04A	4618802.26	369730.69	04/16/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	93.2	N1	100PT MIS
FORMER R RANGE	SSFMRR01	FMRR01A	4621303.25	372993.03	04/25/2013	SW6010C	Antimony	0.88	J	MG/KG	0.25	3.0	N1	SOUTHEND OF RANGE 100PT MIS

Table 5-5
Small Arms Ranges
2013 Multiple Increment Sample Results for Individual Ranges

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Sample Type	Remarks
FORMER R RANGE	SSFMRR01	FMRR01A	4621303.25	372993.03	04/25/2013	SW6010C	Copper	6.8		MG/KG	0.11	1.3	N1	SOUTHEND OF RANGE 100PT MIS
FORMER R RANGE	SSFMRR01	FMRR01A	4621303.25	372993.03	04/25/2013	SW6010C	Lead	21.8		MG/KG	0.22	0.50	N1	SOUTHEND OF RANGE 100PT MIS
G RANGE	SSGRNG01	GR01A	4616844.81	370593.27	04/15/2013	SW6010C	Antimony	25.4		MG/KG	0.24	3.0	N1	BB 100PT MIS
G RANGE	SSGRNG01	GR01A	4616844.81	370593.27	04/15/2013	SW6010C	Copper	207		MG/KG	0.11	1.2	N1	BB 100PT MIS
G RANGE	SSGRNG01	GR01A	4616844.81	370593.27	04/15/2013	SW6010C	Lead	3850		MG/KG	0.22	0.49	N1	BB 100PT MIS
G RANGE	SSGRNG01	GR01A	4616844.81	370593.27	04/15/2013	SW6020A	Tungsten	33.0		MG/KG	0.025	0.20	N1	BB 100PT MIS
GA RANGE	SSGARNG01	GAR01A	4615393.68	371617.04	04/29/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	5.0	2400	N1	FL1 100PT MIS
GA RANGE	SSGARNG02	GAR02A	4615298.64	371616.31	04/29/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	656	N1	FL2 100PT MIS
GA RANGE	SSGARNG03	GAR03A	4615282.85	372069.13	04/29/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.6	455	N1	FL3 100PT MIS
GA RANGE	SSGARNG03	GAR03B	4615282.85	372069.13	04/29/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.9	623	FR1	FL3 100PT MIS
GA RANGE	SSGARNG03	GAR03C	4615282.85	372069.13	04/29/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.8	773	FR2	FL3 100PT MIS
GA RANGE	SSGARNG04	GAR04A	4615209.83	372010.66	04/26/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.8	301	N1	FL4 100PT MIS
H RANGE	SSHRNG01	HR01A	4616750.08	371113.76	04/24/2013	SW6010C	Antimony	2.0	J	MG/KG	0.24	3.0	N1	BB 100PT MIS
H RANGE	SSHRNG01	HR01A	4616750.08	371113.76	04/24/2013	SW6010C	Copper	20.4		MG/KG	0.11	1.2	N1	BB 100PT MIS
H RANGE	SSHRNG01	HR01A	4616750.08	371113.76	04/24/2013	SW6010C	Lead	193		MG/KG	0.22	0.50	N1	BB 100PT MIS
H RANGE	SSHRNG01	HR01A	4616750.08	371113.76	04/24/2013	SW6020A	Tungsten	2.1		MG/KG	0.012	0.10	N1	BB 100PT MIS
H RANGE	SSHRNG01	HR01B	4616750.08	371113.76	04/24/2013	SW6010C	Antimony	2.2	J	MG/KG	0.24	2.9	FR1	BB 100PT MIS
H RANGE	SSHRNG01	HR01B	4616750.08	371113.76	04/24/2013	SW6010C	Copper	20.2		MG/KG	0.11	1.2	FR1	BB 100PT MIS
H RANGE	SSHRNG01	HR01B	4616750.08	371113.76	04/24/2013	SW6010C	Lead	211		MG/KG	0.22	0.49	FR1	BB 100PT MIS
H RANGE	SSHRNG01	HR01B	4616750.08	371113.76	04/24/2013	SW6020A	Tungsten	1.3		MG/KG	0.012	0.098	FR1	BB 100PT MIS
H RANGE	SSHRNG01	HR01C	4616750.08	371113.76	04/24/2013	SW6010C	Antimony	2.4	J	MG/KG	0.24	3.0	FR2	BB 100PT MIS
H RANGE	SSHRNG01	HR01C	4616750.08	371113.76	04/24/2013	SW6010C	Copper	24.8		MG/KG	0.11	1.2	FR2	BB 100PT MIS
H RANGE	SSHRNG01	HR01C	4616750.08	371113.76	04/24/2013	SW6010C	Lead	262		MG/KG	0.22	0.50	FR2	BB 100PT MIS
H RANGE	SSHRNG01	HR01C	4616750.08	371113.76	04/24/2013	SW6020A	Tungsten	1.7		MG/KG	0.012	0.10	FR2	BB 100PT MIS
I RANGE	SSIRNG01	IR01A	4616545.49	371662.22	04/18/2013	SW6010C	Antimony	2.2	J	MG/KG	0.25	3.0	N1	BB 100PT MIS
I RANGE	SSIRNG01	IR01A	4616545.49	371662.22	04/18/2013	SW6010C	Copper	14.7		MG/KG	0.11	1.3	N1	BB 100PT MIS
I RANGE	SSIRNG01	IR01A	4616545.49	371662.22	04/18/2013	SW6010C	Lead	167		MG/KG	0.22	0.50	N1	BB 100PT MIS
I RANGE	SSIRNG01	IR01A	4616545.49	371662.22	04/18/2013	SW6020A	Tungsten	2.2		MG/KG	0.012	0.10	N1	BB 100PT MIS
I RANGE	SSIRNG01	IR01B	4616545.49	371662.22	04/18/2013	SW6010C	Antimony	1.5	J	MG/KG	0.24	3.0	FR1	BB 100PT MIS
I RANGE	SSIRNG01	IR01B	4616545.49	371662.22	04/18/2013	SW6010C	Copper	17.8		MG/KG	0.11	1.2	FR1	BB 100PT MIS
I RANGE	SSIRNG01	IR01B	4616545.49	371662.22	04/18/2013	SW6010C	Lead	230		MG/KG	0.22	0.50	FR1	BB 100PT MIS
I RANGE	SSIRNG01	IR01B	4616545.49	371662.22	04/18/2013	SW6020A	Tungsten	2.5		MG/KG	0.012	0.10	FR1	BB 100PT MIS
I RANGE	SSIRNG01	IR01C	4616545.49	371662.22	04/18/2013	SW6010C	Antimony	1.9	J	MG/KG	0.24	2.9	FR2	BB 100PT MIS
I RANGE	SSIRNG01	IR01C	4616545.49	371662.22	04/18/2013	SW6010C	Copper	20.5		MG/KG	0.11	1.2	FR2	BB 100PT MIS

Table 5-5
Small Arms Ranges
2013 Multiple Increment Sample Results for Individual Ranges

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Sample Type	Remarks
I RANGE	SSIRNG01	IR01C	4616545.49	371662.22	04/18/2013	SW6010C	Lead	146		MG/KG	0.22	0.49	FR2	BB 100PT MIS
I RANGE	SSIRNG01	IR01C	4616545.49	371662.22	04/18/2013	SW6020A	Tungsten	2.4		MG/KG	0.012	0.098	FR2	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01A	4616776.29	372332.56	04/18/2013	SW6010C	Antimony	1.6	J	MG/KG	0.25	3.0	N1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01A	4616776.29	372332.56	04/18/2013	SW6010C	Copper	11.2		MG/KG	0.11	1.3	N1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01A	4616776.29	372332.56	04/18/2013	SW6010C	Lead	45.3		MG/KG	0.22	0.50	N1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01A	4616776.29	372332.56	04/18/2013	SW6020A	Tungsten	0.54		MG/KG	0.013	0.10	N1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01B	4616776.29	372332.56	04/18/2013	SW6010C	Antimony	0.75	J	MG/KG	0.24	3.0	FR1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01B	4616776.29	372332.56	04/18/2013	SW6010C	Copper	10.7		MG/KG	0.11	1.2	FR1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01B	4616776.29	372332.56	04/18/2013	SW6010C	Lead	41.7		MG/KG	0.22	0.50	FR1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01B	4616776.29	372332.56	04/18/2013	SW6020A	Tungsten	0.73		MG/KG	0.012	0.096	FR1	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01C	4616776.29	372332.56	04/18/2013	SW6010C	Antimony	1.4	J	MG/KG	0.24	2.9	FR2	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01C	4616776.29	372332.56	04/18/2013	SW6010C	Copper	13.4		MG/KG	0.11	1.2	FR2	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01C	4616776.29	372332.56	04/18/2013	SW6010C	Lead	49.5		MG/KG	0.22	0.49	FR2	BB 100PT MIS
KD SAR	SSKDRNG01	KDR01C	4616776.29	372332.56	04/18/2013	SW6020A	Tungsten	1.1		MG/KG	0.012	0.099	FR2	BB 100PT MIS
FORMER M-1	SSFMRM101	FMRM101A	4616002.1	372649.49	04/25/2013	SW6010C	Antimony	0.50	J	MG/KG	0.25	3.0	N1	SITS 100PT MIS
FORMER M-1	SSFMRM101	FMRM101A	4616002.1	372649.49	04/25/2013	SW6010C	Copper	2.8	J	MG/KG	0.11	1.3	N1	SITS 100PT MIS
FORMER M-1	SSFMRM101	FMRM101A	4616002.1	372649.49	04/25/2013	SW6010C	Lead	22.3		MG/KG	0.22	0.50	N1	SITS 100PT MIS
FORMER M-1	SSFMRM102	FMRM102A	4615982.28	372673.32	04/25/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.7	93.5	N1	FL 30PT MIS
FORMER M-1	SSFMRM102	FMRM102B	4615982.28	372673.32	04/25/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.9	97.1	FR1	FL 30PT MIS
FORMER M-1	SSFMRM102	FMRM102C	4615982.28	372673.32	04/25/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.8	95.1	FR1	FL 30PT MIS
FORMER M-2	SSFMRM201	FMRM201A	4616233.48	373044.31	04/22/2013	SW6010C	Lead	162		MG/KG	0.22	0.50	N1	BB EDGE LENGTH 50PT MIS
FORMER M-2	SSFMRM201	FMRM201B	4616233.48	373044.31	04/22/2013	SW6010C	Lead	124		MG/KG	0.22	0.50	FR1	BB EDGE LENGTH 50PT MIS
FORMER M-2	SSFMRM201	FMRM201C	4616233.48	373044.31	04/22/2013	SW6010C	Lead	124		MG/KG	0.22	0.49	FR1	BB EDGE LENGTH 50PT MIS
FORMER M-2	SSFMRM202	FMRM202A	4616213.48	373015	04/22/2013	SW6010C	Antimony	0.88	J	MG/KG	0.24	3.0	N1	BB 50PT MIS
FORMER M-2	SSFMRM202	FMRM202A	4616213.48	373015	04/22/2013	SW6010C	Copper	51.7		MG/KG	0.11	1.2	N1	BB 50PT MIS
FORMER M-2	SSFMRM202	FMRM202A	4616213.48	373015	04/22/2013	SW6010C	Lead	365		MG/KG	0.22	0.50	N1	BB 50PT MIS
FORMER M-2	SSFMRM203	FMRM203A	4616229.3	373024.28	04/22/2013	SW6010C	Antimony	3.9		MG/KG	0.24	3.0	N1	BB 50PT MIS
FORMER M-2	SSFMRM203	FMRM203A	4616229.3	373024.28	04/22/2013	SW6010C	Copper	56.9		MG/KG	0.11	1.2	N1	BB 50PT MIS
FORMER M-2	SSFMRM203	FMRM203A	4616229.3	373024.28	04/22/2013	SW6010C	Lead	1200		MG/KG	0.22	0.50	N1	BB 50PT MIS
FORMER M-2	SSFMRM204	FMRM204A	4616241.73	373030.63	04/22/2013	SW6010C	Antimony	6.5		MG/KG	0.24	3.0	N1	BB 50PT MIS
FORMER M-2	SSFMRM204	FMRM204A	4616241.73	373030.63	04/22/2013	SW6010C	Copper	53.6		MG/KG	0.11	1.2	N1	BB 50PT MIS
FORMER M-2	SSFMRM204	FMRM204A	4616241.73	373030.63	04/22/2013	SW6010C	Lead	631		MG/KG	0.22	0.49	N1	BB 50PT MIS
FORMER M-2	SSFMRM205	FMRM205A	4616253.83	373038.14	04/22/2013	SW6010C	Antimony	1.5	J	MG/KG	0.24	2.9	N1	BB 50PT MIS
FORMER M-2	SSFMRM205	FMRM205A	4616253.83	373038.14	04/22/2013	SW6010C	Copper	70.7		MG/KG	0.11	1.2	N1	BB 50PT MIS
FORMER M-2	SSFMRM205	FMRM205A	4616253.83	373038.14	04/22/2013	SW6010C	Lead	332		MG/KG	0.22	0.49	N1	BB 50PT MIS
FORMER M-2	SSFMRM206	FMRM206A	4616267.96	373046.88	04/22/2013	SW6010C	Antimony	1.5	J	MG/KG	0.24	3.0	N1	BB 50PT MIS
FORMER M-2	SSFMRM206	FMRM206A	4616267.96	373046.88	04/22/2013	SW6010C	Copper	6.9		MG/KG	0.11	1.2	N1	BB 50PT MIS

Table 5-5
Small Arms Ranges
2013 Multiple Increment Sample Results for Individual Ranges

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Sample Type	Remarks
FORMER M-2	SSFMRM206	FMRM206A	4616267.96	373046.88	04/22/2013	SW6010C	Lead	40.1		MG/KG	0.22	0.50	N1	BB 50PT MIS
N RANGE	SSNRNG01	NR01A	4617872.76	374269.63	04/17/2013	SW6010C	Antimony	4.3		MG/KG	0.24	3.0	N1	BB 100PT MIS
N RANGE	SSNRNG01	NR01A	4617872.76	374269.63	04/17/2013	SW6010C	Copper	81.7		MG/KG	0.11	1.2	N1	BB 100PT MIS
N RANGE	SSNRNG01	NR01A	4617872.76	374269.63	04/17/2013	SW6010C	Lead	724		MG/KG	0.22	0.50	N1	BB 100PT MIS
N RANGE	SSNRNG02	NR02A	4617840.25	374231.67	04/17/2013	SW6010C	Antimony	1.8	J	MG/KG	0.25	3.0	N1	BB 100PT MIS
N RANGE	SSNRNG02	NR02A	4617840.25	374231.67	04/17/2013	SW6010C	Copper	43.2		MG/KG	0.11	1.3	N1	BB 100PT MIS
N RANGE	SSNRNG02	NR02A	4617840.25	374231.67	04/17/2013	SW6010C	Lead	337		MG/KG	0.22	0.50	N1	BB 100PT MIS
O RANGE	SSORNG01	OR01A	4617974.77	374599.54	04/17/2013	SW6010C	Antimony	1.3	J	MG/KG	0.24	3.0	N1	BB 50PT MIS
O RANGE	SSORNG01	OR01A	4617974.77	374599.54	04/17/2013	SW6010C	Copper	7.8		MG/KG	0.11	1.2	N1	BB 50PT MIS
O RANGE	SSORNG01	OR01A	4617974.77	374599.54	04/17/2013	SW6010C	Lead	204		MG/KG	0.22	0.50	N1	BB 50PT MIS
P RANGE	SSPRNG01	PR01A	4618107.82	374637.39	04/17/2013	SW6010C	Antimony	1.7	J	MG/KG	0.24	3.0	N1	BB 100PT MIS
P RANGE	SSPRNG01	PR01A	4618107.82	374637.39	04/17/2013	SW6010C	Copper	13.4		MG/KG	0.11	1.2	N1	BB 100PT MIS
P RANGE	SSPRNG01	PR01A	4618107.82	374637.39	04/17/2013	SW6010C	Lead	118		MG/KG	0.22	0.50	N1	BB 100PT MIS
Q RANGE	SSQRNG01	QR01A	4621164.21	373512.28	04/26/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.9	6330	N1	NORTH OF FP 100PT MIS
Q RANGE	SSQRNG02	QR02A	4621155.56	373505.86	05/08/2013	SW8330	ND all explosives compounds	ND	U	UG/KG	4.9	21500	N1	SOUTH OF FP 100PT MIS
SKEET RANGE 1	SSSK1R01	SK101A	4615548.79	371264.82	04/22/2013	SW6010C	Antimony	1.6	J	MG/KG	0.24	3.0	N1	100PT MIS AREA1
SKEET RANGE 1	SSSK1R01	SK101A	4615548.79	371264.82	04/22/2013	SW6010C	Lead	21.1		MG/KG	0.22	0.49	N1	100PT MIS AREA1
SKEET RANGE 1	SSSK1R02	SK102A	4615557.43	371323.01	04/22/2013	SW6010C	Antimony	0.51	J	MG/KG	0.24	3.0	N1	100PT MIS AREA2
SKEET RANGE 1	SSSK1R02	SK102A	4615557.43	371323.01	04/22/2013	SW6010C	Lead	19.2		MG/KG	0.22	0.50	N1	100PT MIS AREA2
SKEET RANGE 1	SSSK1R03	SK103A	4615511.14	371263.39	04/22/2013	SW6010C	Antimony	1.5	J	MG/KG	0.24	2.9	N1	100PT MIS AREA3
SKEET RANGE 1	SSSK1R03	SK103A	4615511.14	371263.39	04/22/2013	SW6010C	Lead	18.8		MG/KG	0.22	0.49	N1	100PT MIS AREA3
SKEET RANGE 1	SSSK1R04	SK104A	4615490.13	371299.66	04/22/2013	SW6010C	Antimony	1.5	J	MG/KG	0.24	3.0	N1	100PT MIS AREA4
SKEET RANGE 1	SSSK1R04	SK104A	4615490.13	371299.66	04/22/2013	SW6010C	Lead	20.0		MG/KG	0.22	0.50	N1	100PT MIS AREA4
SUCCONSETTE POND	SSSP001	SPN01A	4618494.89	370958.71	04/29/2013	SW6010C	Antimony	0.79	J	MG/KG	0.24	3.0	N1	NORTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP001	SPN01A	4618494.89	370958.71	04/29/2013	SW6010C	Cadmium	0.048	J	MG/KG	0.039	0.25	N1	NORTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP001	SPN01A	4618494.89	370958.71	04/29/2013	SW6010C	Copper	3.8		MG/KG	0.11	1.2	N1	NORTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP001	SPN01A	4618494.89	370958.71	04/29/2013	SW6010C	Lead	11.7		MG/KG	0.22	0.50	N1	NORTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP002	SPS02A	4618418.95	370954.68	04/29/2013	SW6010C	Antimony	0.92	J	MG/KG	0.24	2.9	N1	SOUTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP002	SPS02A	4618418.95	370954.68	04/29/2013	SW6010C	Cadmium	0.13	J	MG/KG	0.038	0.25	N1	SOUTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP002	SPS02A	4618418.95	370954.68	04/29/2013	SW6010C	Copper	6.5		MG/KG	0.11	1.2	N1	SOUTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SSSP002	SPS02A	4618418.95	370954.68	04/29/2013	SW6010C	Lead	24.5		MG/KG	0.22	0.49	N1	SOUTH SIDE OF POND 100PT MIS

Table 5-5
Small Arms Ranges
2013 Multiple Increment Sample Results for Individual Ranges

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Sample Type	Remarks
SUCCONSETTE POND	SPN01A	SSSP01A	4618494.89	370958.71	04/29/2013	SW6850	Perchlorate	ND	U	UG/KG	0.067	0.77	N1	NORTH SIDE OF POND 100PT MIS
SUCCONSETTE POND	SPS02A	SSSP02A	4618418.95	370954.68	04/29/2013	SW6850	Perchlorate	ND	U	UG/KG	0.067	0.78	N1	SOUTH SIDE OF POND 100PT MIS
T RANGE	SSTRNG01	TR01A	4620895.84	373647.75	04/23/2013	SW6020A	Tungsten	0.24		MG/KG	0.012	0.099	N1	RF EAST 100PT MIS
T RANGE	SSTRNG02	TR02A	4620917.73	373657.54	04/23/2013	SW6020A	Tungsten	0.27		MG/KG	0.012	0.098	N1	RF EAST 100PT MIS
T RANGE	SSTRNG03	TR03A	4620940.15	373670.42	04/23/2013	SW6020A	Tungsten	0.59		MG/KG	0.013	0.10	N1	RF EAST 100PT MIS
T RANGE	SSTRNG04	TR04A	4620959.57	373681.79	04/23/2013	SW6020A	Tungsten	0.27		MG/KG	0.013	0.10	N1	RF EAST 100PT MIS
T RANGE	SSTRNG05	TR05A	4620982.09	373702.81	04/22/2013	SW6020A	Tungsten	1.5		MG/KG	0.012	0.099	N1	RF EAST 100PT MIS
T RANGE	SSTRNG05	TR05B	4620982.09	373702.81	04/22/2013	SW6020A	Tungsten	1.4		MG/KG	0.012	0.098	FR1	RF EAST 100PT MIS
T RANGE	SSTRNG05	TR05C	4620982.09	373702.81	04/22/2013	SW6020A	Tungsten	1.9		MG/KG	0.012	0.099	FR2	RF EAST 100PT MIS

mg/kg = milligram per kilogram
ug/kg = microgram per kilogram
ND/U - non-detect
J = Estimated result
MDL = Method Detection Limit
RL = Reporting Limit
N1 = Normal Sample
FR = Filed Replicate Sample

Table 5-6
Small Arms Range Supplemental Soil Sample Results
July 2013

Site/SLX List	Location ID	Field Sample ID	Northing	Easting	Date Sampled	Test Method	Analyte	Result Value	Qualifier	Units	MDL	RL	Remarks
500 YARD RIFLE RANGE	SS500YDR01	500YD1A	4618284.04	374816.52	05/16/2013	SW6010C	Antimony	1.2	J	mg/Kg	0.24	3.0	30PT MIS 50FT BERM ADJACENT TO WOOD RD
500 YARD RIFLE RANGE	SS500YDR01	500YD1A	4618284.04	374816.52	05/16/2013	SW6010C	Copper	4.6		mg/Kg	0.11	1.2	30PT MIS 50FT BERM ADJACENT TO WOOD RD
500 YARD RIFLE RANGE	SS500YDR01	500YD1A	4618284.04	374816.52	05/16/2013	SW6010C	Lead	12.6		mg/Kg	0.22	0.49	30PT MIS 50FT BERM ADJACENT TO WOOD RD
FORMER L-1 RANGE	SSFMRL101	L1A	4619941.49	375738.45	05/16/2013	SW6010C	Antimony	0.93	J	mg/Kg	0.24	3.0	30PT MIS 40FT BY 40FT
FORMER L-1 RANGE	SSFMRL101	L1A	4619941.49	375738.45	05/16/2013	SW6010C	Copper	15.4		mg/Kg	0.11	1.2	30PT MIS 40FT BY 40FT
FORMER L-1 RANGE	SSFMRL101	L1A	4619941.49	375738.45	05/16/2013	SW6010C	Lead	60.2		mg/Kg	0.22	0.49	30PT MIS 40FT BY 40FT
FORMER M-4 RANGE	SSFMRM401	FMRM41A	4617005.61	373445.82	05/22/2013	SW6010C	Antimony	0.31	J	mg/Kg	0.24	3.0	100PT MIS 100FT BY 100FT HILLSIDE
FORMER M-4 RANGE	SSFMRM401	FMRM41A	4617005.61	373445.82	05/22/2013	SW6010C	Copper	2.8		mg/Kg	0.11	1.2	100PT MIS 100FT BY 100FT HILLSIDE
FORMER M-4 RANGE	SSFMRM401	FMRM41A	4617005.61	373445.82	05/22/2013	SW6010C	Lead	14.6		mg/Kg	0.22	0.50	100PT MIS 100FT BY 100FT HILLSIDE
FORMER N RANGE	SSFMRN01	FMRN1A	4620608.7	373966.54	05/21/2013	SW6010C	Antimony	8.1		mg/Kg	0.24	3.0	30PT MIS 70FT BY 20FT AREA
FORMER N RANGE	SSFMRN01	FMRN1A	4620608.7	373966.54	05/21/2013	SW6010C	Copper	175		mg/Kg	0.11	1.2	30PT MIS 70FT BY 20FT AREA
FORMER N RANGE	SSFMRN01	FMRN1A	4620608.7	373966.54	05/21/2013	SW6010C	Lead	1670		mg/Kg	0.22	0.50	30PT MIS 70FT BY 20FT AREA
GA RANGE	SSGARNG05	GAGB5A	4615658.37	371541.62	05/20/2013	SW6010C	Antimony	0.96	J	mg/Kg	0.24	2.9	100PT MIS DOWNRANGE OF GAGB
GA RANGE	SSGARNG05	GAGB5A	4615658.37	371541.62	05/20/2013	SW6010C	Copper	14.6		mg/Kg	0.11	1.2	100PT MIS DOWNRANGE OF GAGB
GA RANGE	SSGARNG05	GAGB5A	4615658.37	371541.62	05/20/2013	SW6010C	Lead	94.1		mg/Kg	0.22	0.49	100PT MIS DOWNRANGE OF GAGB
GA RANGE	SSGARNG06	BA61A	4616239.08	371899.3	05/21/2013	SW6010C	Antimony	0.42	J	mg/Kg	0.24	3.0	100PT MIS NORTH END OF AREA NEAR BA6
GA RANGE	SSGARNG06	BA61A	4616239.08	371899.3	05/21/2013	SW6010C	Copper	12.1	J	mg/Kg	0.11	1.2	100PT MIS NORTH END OF AREA NEAR BA6
GA RANGE	SSGARNG06	BA61A	4616239.08	371899.3	05/21/2013	SW6010C	Lead	34.1		mg/Kg	0.22	0.50	100PT MIS NORTH END OF AREA NEAR BA6
L-3 RANGE	SSL3RNG01	L31A	4622821.59	370028.68	05/20/2013	SW6010C	Antimony	1.4	J	mg/Kg	0.25	3.0	30PT MIS 15FT BY15FT TARGET PIT
L-3 RANGE	SSL3RNG01	L31A	4622821.59	370028.68	05/20/2013	SW6010C	Copper	15.2		mg/Kg	0.11	1.3	30PT MIS 15FT BY15FT TARGET PIT
L-3 RANGE	SSL3RNG01	L31A	4622821.59	370028.68	05/20/2013	SW6010C	Lead	77.4		mg/Kg	0.22	0.50	30PT MIS 15FT BY15FT TARGET PIT
L-4 RANGE	SSL4RNG01	L41A	4621527.93	375260.75	05/17/2013	SW6010C	Antimony	0.91	J	mg/Kg	0.25	3.0	30PT MIS SOIL PILE
L-4 RANGE	SSL4RNG01	L41A	4621527.93	375260.75	05/17/2013	SW6010C	Copper	5.4		mg/Kg	0.11	1.3	30PT MIS SOIL PILE
L-4 RANGE	SSL4RNG01	L41A	4621527.93	375260.75	05/17/2013	SW6010C	Lead	12.0		mg/Kg	0.22	0.50	30PT MIS SOIL PILE
Q RANGE	SSQRNG03	Q3A	4621091.09	373455	05/21/2013	SW6010C	Antimony	1.1	J	mg/Kg	0.25	3.0	30PT MIS 100FT BY 10FT TARGET PIT
Q RANGE	SSQRNG03	Q3A	4621091.09	373455	05/21/2013	SW6010C	Copper	12.3		mg/Kg	0.11	1.3	30PT MIS 100FT BY 10FT TARGET PIT
Q RANGE	SSQRNG03	Q3A	4621091.09	373455	05/21/2013	SW6010C	Lead	152		mg/Kg	0.22	0.50	30PT MIS 100FT BY 10FT TARGET PIT
SKEET RANGE 2	SSSK2R01	SKEET21A	4615840.04	370317.64	05/21/2013	SW6010C	Antimony	0.88	J	mg/Kg	0.24	2.9	30PT MIS 40FT BY 50FT CUL DE SAC
SKEET RANGE 2	SSSK2R01	SKEET21A	4615840.04	370317.64	05/21/2013	SW6010C	Copper	3.5		mg/Kg	0.11	1.2	30PT MIS 40FT BY 50FT CUL DE SAC
SKEET RANGE 2	SSSK2R01	SKEET21A	4615840.04	370317.64	05/21/2013	SW6010C	Lead	8.0		mg/Kg	0.22	0.49	30PT MIS 40FT BY 50FT CUL DE SAC

Notes:

J = Estimated Results

mg/Kg = milligram per kilogram

MDL = Method Detection Limit

RL = Reporting Limit

Table 7-1
Small Arms Ranges
Site-Wide Groundwater Screening

Analyte	Maximum Detected Concentration (ug/L)	Location of Maximum Detected Concentration	Date of Maximum Detected Concentration	Range Closest to Location of Maximum Detected Concentration	Detection Frequency	Maximum Contaminant Level [a] (ug/L)	EPA Chronic (Lifetime) Health Advisory (HA) for Drinking Water [b] (ug/L)	EPA Regional Screening Level for Tapwater [c] (ug/L)	MCP GW-1 Standard [d] (ug/L)
PEP Compounds									
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE (RDX)	0.37	MW-34M3	11/12/2003	G Range	1 / 275	-	2	0.61	1
PERCHLORATE	2.2	MW-344S	4/24/2007	L-3 Range	29 / 185	15	15	11	2
Metals and Inorganics									
ALUMINUM (total)	3360	MW-264M2	12/19/2012	Former M-2 Range	20 / 112	-	-	16,000	-
ALUMINUM (filtered)	58.4	MW-23S	10/27/1997	A Range	3 / 11	-	-	16,000	-
ANTIMONY (total)	6.7 J	MW-36S	8/17/1999	G Range	2 / 262	6	6	6	6
ANTIMONY (filtered)	10.8 J	MW-538M1	4/1/2010	B Range	2 / 46	6	6	6	6
ARSENIC (total)	23.6	MW-465S	3/25/2009	SW Range	19 / 261	10	2	0.045	10
ARSENIC (filtered)					0 / 49	10	0.02	0.045	10
BARIUM (total)	66.9	MW-72S	2/7/2007	B Range	135 / 261	2,000	-	2,900	2,000
BARIUM (filtered)	53.6 J	MW-72S	3/30/2007	B Range	25 / 49	2,000	-	2,900	2,000
BERYLLIUM (total)	0.42 J	MW-63S	9/21/1999	N Range	1 / 98	4	-	16	4
BORON (total)	42.3	03MW0014A	4/13/1999	GA/GB Range	55 / 94	-	6,000	3,100	-
BORON (filtered)	7.9	MW-23S	6/13/2000	A Range	1 / 3	-	6,000	3,100	-
CADMIUM (total)	2.7 J	MW-465S	3/25/2009	SW Range	19 / 261	5	5	6.9	5
CADMIUM (filtered)	1.7 J	XXLRWS6-1	1/28/1999	Former M-1 Range	4 / 49	5	5	6.9	5
CALCIUM (total)	8430	MW-264M2	12/19/2012	Former M-2 Range	94 / 98	-	-	-	-
CALCIUM (filtered)	4310	MW-63S	9/21/1999	N Range	7 / 7	-	-	-	-
CHROMIUM, TOTAL [e] (total)	25.8	MW-465S	10/13/2006	SW Range	41 / 261	100	100	0.031	100
CHROMIUM, TOTAL [e] (filtered)	2.5 J	MW-474S	3/29/2007	K Range	2 / 49	100	100	0.031	100
COBALT (total)	3.6	MW-23S	10/27/1997	A Range	4 / 98	-	-	4.7	-
COBALT (filtered)	2.6	MW-23S	10/27/1997	A Range	1 / 7	-	-	4.7	-
COPPER (total)	103	MW-67S	4/28/2000	L-2 Range	50 / 260	1,300	-	620	-
COPPER (filtered)	8.3 J	MW-473S	5/25/2011	K Range	11 / 46	1,300	-	620	-
IRON (total)	8380	XXLRWS6-1	11/17/1997	Former M-1 Range	75 / 234	-	-	11,000	-
IRON (filtered)	2500	XXLRWS8-2	10/15/1997	Former B Range	7 / 32	-	-	11,000	-
LEAD (total)	7.7 J	MW-470S	3/12/2012	G Range	11 / 287	15	-	-	15
LEAD (filtered)	2.3	MW-538M1	4/1/2010	B Range	1 / 49	15	-	-	15
MAGNESIUM (total)	6650	03MW0014A	4/13/1999	GA/GB Range	97 / 98	-	-	-	-
MAGNESIUM (filtered)	1660	MW-63S	9/21/1999	N Range	7 / 7	-	-	-	-
MANGANESE (total)	286	MW-63S	9/21/1999	N Range	102 / 112	-	300	320	-
MANGANESE (filtered)	200	MW-23S	10/27/1997	A Range	11 / 11	-	300	320	-
MERCURY [f] (total)	0.19 J	MW-36S	6/9/2000	G Range	4 / 246	2	2	0.63	2
MERCURY [f] (filtered)	0.13 J	MW-473S	3/29/2007	K Range	2 / 45	2	2	0.63	2
MOLYBDENUM (total)	15.9	MW-55S	5/17/1999	SE/SW Range	15 / 94	-	40	78	-
MOLYBDENUM (filtered)	11.1	MW-63S	9/21/1999	N Range	1 / 3	-	40	78	-
NICKEL (total)	8.2	MW-63S	8/13/2001	N Range	20 / 98	-	100	300	100
NICKEL (filtered)	5.3	XXLRWS6-1	1/28/1999	Former M-1 Range	4 / 7	-	100	300	100
NITROGEN, AMMONIA (AS N)	100	MW-63S	1/4/2000	N Range	24 / 59	-	30,000	-	-
NITROGEN, NITRATE-NITRITE [g]	2100	03MW0014A	4/13/1999	GA/GB Range	49 / 59	1,000	10,000	1,600	-
PHOSPHORUS, TOTAL ORTHOPHOSPHATE (AS PO4)	150	MW-63S	9/21/1999	N Range	24 / 59	-	-	-	-
POTASSIUM (total)	2760	03MW0014A	4/13/1999	GA/GB Range	74 / 98	-	-	-	-
POTASSIUM (filtered)	1190	MW-23S	10/27/1997	A Range	5 / 7	-	-	-	-
SELENIUM (total)	21.5 J	MW-465S	3/25/2009	SW Range	6 / 247	50	50	78	50
SELENIUM (filtered)	4 J	MW-475S	3/30/2007	Former B Range	2 / 45	50	50	78	50
SILVER (total)	2.2 J	MW-67S	10/27/1999	L-2 Range	3 / 246	-	100	71	100
SODIUM (total)	11200	03MW0014A	4/13/1999	GA/GB Range	98 / 98	-	-	-	-
SODIUM (filtered)	10000	MW-63S	9/21/1999	N Range	7 / 7	-	-	-	-
THALLIUM (total)	4.7 J	MW-23S	9/14/1999	A Range	4 / 100	2	7	0.16	2
TUNGSTEN [h] (total)	3.7	MW-72S	3/30/2007	B Range	31 / 200	-	-	-	20
TUNGSTEN [h] (filtered)	22	MW-470S	10/30/2006	G Range	25 / 64	-	-	-	20
VANADIUM (total)	4.1 J	MW-264M2	12/19/2012	Former M-2 Range	4 / 98	-	-	78	30
ZINC (total)	3480	XXLRWS6-1	11/17/1997	Former M-1 Range	96 / 250	-	2,000	4,700	5000
ZINC (filtered)	2600	XXLRWS6-1	11/17/1997	Former M-1 Range	15 / 46	-	2,000	4,700	5000
Pesticides and Herbicides									
2,4,5-T (TRICHLOROPHENOXYACETIC ACID)	0.13 J	MW-67S	10/27/1999	L-2 Range	2 / 68	-	70	120	-
BENTAZON	1.5 NJ	MW-63S	9/21/1999	N Range	1 / 58	-	200	440	-
CHLORAMBEN	0.4 J	MW-67S	4/28/2000	L-2 Range	4 / 58	-	100	220	-
DICHLOROPROP	1.2 J	MW-63S	9/21/1999	N Range	1 / 68	-	-	-	-
2-(2-METHYL-4-CHLOROPHENOXY) PROPIONIC ACID (MCPP)	230 NJ	XXLRWS8-2	10/15/1997	Former B Range	1 / 68	-	-	12	-
SVOCs									
2-CHLOROPHENOL	1.1 J	MW-264M2	8/2/2005	Former M-2 Range	2 / 183	-	40	71	10
4-METHYLPHENOL (p-CRESOL)	30	MW-264M2	8/2/2005	Former M-2 Range	3 / 173	-	-	1,400	-
BENZOIC ACID	50 J	MW-264M2	5/22/2003	Former M-2 Range	5 / 171	-	-	58,000	-
BENZYL ALCOHOL	11 J	MW-264M2	5/22/2003	Former M-2 Range	1 / 179	-	-	1,500	-
bis(2-ETHYLHEXYL) PHTHALATE	24	MW-23S	10/27/1997	A Range	17 / 183	6	700	4.8	6
DIETHYL PHTHALATE	3 J	MW-67S	4/28/2000	L-2 Range	2 / 183	-	-	11,000	2,000
DI-n-BUTYL PHTHALATE	0.55 J	MW-264M2	5/22/2003	Former M-2 Range	5 / 183	-	-	670	-
DI-n-OCTYLPHTHALATE	0.43 J	MW-465S	3/25/2009	SW Range	1 / 183	-	-	190	-
DIBENZOFURAN	0.48 J	MW-264M2	5/22/2003	Former M-2 Range	1 / 183	-	-	5.8	-
HEXADECANOIC ACID	13 NJ	MW-264M2	5/22/2003	Former M-2 Range	2 / 2	-	-	3,100	-
NAPHTHALENE	0.28 J	MW-154S	7/25/2001	N Range	1 / 183	-	100	0.14	140
PHENOL	2.9 J	MW-264M2	8/2/2005	Former M-2 Range	3 / 183	-	2,000	4,500	1,000
VOCs									
1,2,4-TRICHLOROBENZENE	0.3 J	MW-67S	8/9/2001	L-2 Range	1 / 108	70	70	0.99	70
1,4-DICHLOROBENZENE	0.2 J	MW-264M2	5/22/2003	Former M-2 Range	1 / 112	75	75	0.42	5
ACETONE	20 J	MW-264M2	12/9/2003	Former M-2 Range	4 / 101	-	-	12,000	6,300
CARBON DISULFIDE	0.3 J	MW-264M2	8/19/2003	Former M-2 Range	1 / 112	-	-	720	-
CHLOROFORM [i]	7	MW-56S	9/5/2000	Former M-1 Range	88 / 112	80	70	0.19	70
CHLOROMETHANE	33 J	LRMW0003	5/17/2004	L-4 Range	6 / 112	-	400	190	-
cis-1,3-DICHLOROPROPENE	0.5 J	LRMW0003	9/10/2003	L-4 Range	1 / 112	-	40	0.41	0.4
ETHYLBENZENE	0.4 J	MW-264M2	8/19/2003	Former M-2 Range	1 / 112	700	700	1.3	700
METHYL ETHYL KETONE [BUTANONE]	4 J	MW-264M2	5/22/2003	Former M-2 Range	3 / 112	-	400	4,900	4,000
STYRENE	1	MW-264M2	5/22/2003	Former M-2 Range	1 / 112	100	100	1,100	100
TETRACHLOROETHYLENE (PCE)	12	03MW0020	4/14/1999	GA/GB Range	3 / 112	5	10	9.7	5
TOLUENE	0.3 J	MW-264M2 / MW-55S	5/22/2003 / 5/17/1999	Former M-2 Range / SE/SW Range	3 / 112	1,000	-	860	1,000
TRICHLOROETHYLENE (TCE)	2	LRMW0003 / 03MW0020	3/25 and 10/7/1999 / 4/14/1999	L-4 Range / GA/GB Range	17 / 112	5	300	0.44	5

Notes:
Data set consists of all sampling events for monitoring wells: 03MW0006, 03MW0007A, 03MW0014A, 03MW0020, 03MW0025A, 03MW0709, 03MW0710, DP-459 , LRMW0003, MW-102S, MW-103S, MW-109S, MW-116S, MW-121S, MW-123S, MW-124M3, MW-154S, MW-174S, MW-215 , MW-219M4, MW-23S , MW-264M2, MW-282M2, MW-344S, MW-34M3, MW-36S , MW-455S, MW-456S, MW-465S, MW-466S, MW-467S, MW-468S, MW-470S, MW-471S, MW-472S, MW-473S, MW-474S, MW-475S, MW-476S, MW-489S, MW-490S, MW-491S, MW-492S, MW-537M1, MW-538M1, MW-539M1, MW-55S , MW-56S , MW-60S , MW-63S , MW-67S , MW-72S , XXLRWS6-1 and XXLRWS8-2.
Laboratory data validation qualifier codes used for the "Maximum Concentration" are as follows:
J = The associated numerical value is an esimated quantity.
N = Presumptive evidence of presence of material (tentative identification).
"-" = No listed value.
* = Value is also the Massachusetts Maximum Contaminant Level
Yellow highlighting indicates those groundwater criteria that have been exceeded.

(a) Federal Maximum Contaminant Level
(b) HA is the Federal EPA Lifetime Health Advisory value (April 2012) (http://water.epa.gov/drink/standards/hascience.cfm#dw-standards). If no lifetime HA was available, the cancer-based endpoint values is shown. If neither a lifetime HA or a cancer-based HA
(c) The USEPA Regional Screening Level (RSL) for Tapwater, May 2013 (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm)
(d) MCP Method 1 GW-1 Standards, May 2009 (http://www.mass.gov/dep/service/compliance/riskasmt.htm).
(e) The RSL for chromium III insoluble salts is 16,000 ug/L. Value shown is for chromium VI, which was conservatively chosen for screening purposes. The Tapwater RSL for chromium VI changed from 110 ug/L to 0.031 ug/L based on a new oral slope factor
(f) The MCL and EPA Tapwater RSL listed are for elemental mercury.
(g) The Tapwater RSL for nitrate is 25,000 ug/L. Values shown are for nitrite which was conservatively chosen for screening purposes. The HA shown is the 10-day HA for nitrate + nitrite.
(h) The MCP GW-1 value shown for tungsten is an Interim Drinking Water Guideline from MassDEP/ORS (MassDEP, 2006).
(i) The MCL for total trihalomethanes is used for chloroform.

Table 7-2
Small Arms Ranges
Site-Wide Soil Screening

Analyte	Maximum Detected Concentration (mg/Kg)	Location of Maximum Detected Concentration	Range Assoicated with Maximum Detected Concentration	Detection Frequency	MCP S-1/GW-1 Standard [a] (mg/Kg)	MMR SSL (mg/Kg)	EPA Risk-Based SSL [b] (mg/Kg)	MassDEP Leaching-Based Soil Concentration [c] (mg/Kg)	MMR Outwash Background Concentration (0 - 2 ft bgs) [d] (mg/Kg)
PEP Compounds									
2,4,6-TRINITROTOLUENE (TNT)	0.276	SS04752-A	N Range	2 / 266	-	0.00021	0.013	-	-
2,4-DINITROTOLUENE by 8330 (2,4-DNT)	0.55	SS127D-NW	SE Range	12 / 266	0.7	0.02	0.00028	0.057	-
2,4-DINITROTOLUENE by 8270 (2,4-DNT)	3.4 J	SS128A	G Range	110 / 673	0.7	0.02	0.00028	0.057	-
2,6-DINITROTOLUENE by 8270 (2,6-DNT)	0.33 J	SS159D	E Range	10 / 673	-	0.0088	0.000058	-	-
2-AMINO-4,6-DINITROTOLUENE	0.046 J	SS02305-A	T Range	1 / 266	-	0.00038	0.023	-	-
4-AMINO-2,6-DINITROTOLUENE	0.027 J	SS02305-A	T Range	2 / 266	-	0.00038	0.023	-	-
HEXAHYDRO-1,3,5-TRINITRO-1,3,5-TRIAZINE (RDX)	0.52	SS02305-A	T Range	1 / 241	1	0.00011	0.00023	0.0017	-
NITROBENZENE	0.17	SS127D-SW	SW Range	1 / 243	-	-	0.000079	-	-
NITROGLYCERIN by 8330 [e]	46	TTSARKRFL2	K Range	150 / 390	4.4	0.001	0.00066	-	-
NITROGLYCERIN by 8270 [e]	1.1	TTSARKRFL2 / SSSRE25001	K Range / SE Range	12 / 12	4.4	0.001	0.00066	-	-
PERCHLORATE	0.101	SS11207-A	Succonsette Pond	6 / 47	0.1	0.0031	-	-	-
Polychlorinated Naphthalenes									
1-CHLORONAPHTHALENE	0.068	SS11209-A	Succonsette Pond	1 / 10	-	-	-	-	-
2-CHLORONAPHTHALENE	0.0268	SS11209-A	Succonsette Pond	1 / 683	-	-	2.9	-	-
1,4-DICHLORONAPHTHALENE	0.0902	SS11211-A	Succonsette Pond	1 / 9	-	-	-	-	-
PENTACHLORONAPHTHALENE	0.0526	SS11211-A	Succonsette Pond	1 / 9	-	-	-	-	-
HEPTACHLORONAPHTHALENE	0.024	SS11209-A	Succonsette Pond	1 / 10	-	-	-	-	-
Metals and Inorganics									
ALUMINUM	28,900	SS143K	GA/GB Range	891 / 891	-	54,006	23,000	-	16,000
ANTIMONY	91.9	SS169A	T Range	426 / 1196	20	0.27	0.27	-	1.9
ARSENIC	23.4 J	SS169A	T Range	806 / 954	20	0.009	0.0013	-	5.5
BARIUM	233	SS157C	A Range	887 / 892	1,000	120	120	-	24
BERYLLIUM	0.81	SS143F	GA/GB Range	635 / 769	100	2.6	13	-	0.38
BORON	39	SS143M	GA/GB Range	452 / 769	-	9.5	9.9	-	9.6
CADMIUM	30.9	SS11211-A	Succonsette Pond	261 / 914	2	0.4	0.52	-	0.94
CALCIUM	19,400	SS159E	E Range	709 / 769	-	-	-	-	-
CHROMIUM, TOTAL	313	SSTR1W01	T Range	911 / 932	30	7	180,000	-	19
COBALT	9.8	SS166B	O Range	695 / 769	-	132	0.21	-	4
COPPER	2,970	SSBRNG02	B Range	1063 / 1192	-	46	22	-	11
IRON	52,000	SS11207-A	Succonsette Pond	891 / 891	-	2,422	270	-	17,800
LEAD	5,800 J	SS169A	T Range	1278 / 1280	300	4.1	14	-	19
MAGNESIUM	7,320	SS44A	KD East Range	765 / 769	-	-	-	-	2,010
MANGANESE	1,320	SS162H	KD East Range	911 / 911	-	44	21	-	134
MERCURY	0.12	SS167B	P Range	48 / 770	20	0.02	0.033	-	0.12
MOLYBDENUM	2.5	SSSRW4A10001	SW Range	334 / 769	-	0.18	1.6	-	1.2
NICKEL	73.1 J	SS127A	SE Range	794 / 819	20	292	20	-	10
NITROGEN, AMMONIA (AS N)	53.6 J	SS143F	GA/GB Range	72 / 84	-	-	-	-	38
NITROGEN, NITRATE-NITRITE	3.3	SS73H	Former B	76 / 87	-	-	-	-	0.5
PHOSPHORUS, TOTAL (AS P)	5,110	BHBRSBR04	B Range	122 / 122	-	-	-	-	-
PHOSPHORUS, TOTAL ORTHOPHOSPHATE (AS PO4)	291	SS73K	Former B	82 / 83	-	-	-	-	291
POTASSIUM	2,290	SS44A	KD East Range	751 / 769	-	-	-	-	766
SELENIUM	1.8	SS169B	T Range	179 / 770	400	2.8	0.4	-	1.7
SILVER	0.57	SS166A, SS169A	O Range, T Range	24 / 770	100	16	0.6	-	0.74
SODIUM	1,070	SS140E	Former B	117 / 769	-	-	-	-	-
THALLIUM	1.7 J	SS73R	Former B	18 / 769	8	3	0.011	-	1.6
TUNGSTEN [f]	200	BHBRSBR03	B Range	326 / 480	160	-	-	160	-
VANADIUM	59.7	SS143K	GA/GB Range	768 / 769	600	-	78	-	-
ZINC	320	SS11207-A	Succonsette Pond	1040 / 1073	2,500	2,202	290	-	25.6
Pesticides and Herbicides									
TRICHLOROPHENOXYACETIC ACID (2,4,5-T)	0.01 J	SS73F	Former B	1 / 128	-	0.49	0.052	-	-
CHLORAMBEN	0.032 J	SS73H	Former B	5 / 113	-	0.12	0.055	-	-
2-METHYL-4-CHLOROPHENOXYACETIC ACID (MCPA)	5.6	SS67B	L-2 Range	1 / 128	-	0.0014	0.0015	-	-
2-(2-METHYL-4-CHLOROPHENOXY) PROPIONIC ACID (MCPP)	18 J	SS73O	Former B	2 / 128	-	0.05	0.0035	-	-
PICLORAM	0.012 J	SS73H	Former B	3 / 88	-	0.088	0.29	-	-
DIELDRIN	0.7	SS73J	Former B	46 / 128	0.05	0.0008	0.000061	-	0.03
ENDOSULFAN SULFATE	0.0046 NJ	SS143E	GA/GB Range	3 / 128	0.5	2.2	1.1	0.54	-
ENDRIN	0.0026 J	SS143E	GA/GB Range	2 / 128	8	0.19	0.068	-	-
ENDRIN ALDEHYDE	0.0095 J	SS73P	Former B	7 / 128	8	0.19	0.068	-	-
ENDRIN KETONE	0.0092	SS73P	Former B	4 / 128	8	0.19	0.068	-	-
GAMMA-CHLORDANE	0.0024 J	SS143G	GA/GB Range	1 / 128	0.7	0.000038	0.013	-	-
p,p'-DDD	0.015 J	SS143G	GA/GB Range	7 / 128	4	0.28	0.0064	-	-
p,p'-DDE	0.0089	SS73J	Former B	14 / 128	3	0.88	0.046	-	0.012
p,p'-DDT	0.018	SS73H	Former B	30 / 128	3	0.53	0.067	-	-
SVOCs									
2-CHLOROBENZOIC ACID	0.88 J	SS129C	I Range	3 / 385	-	-	-	-	-
2-METHYLNAPHTHALENE	0.031 J	SS164K	Former M-2	4 / 673	0.7	0.072	0.14	0.36	-
2-METHYLPHENOL (o-CRESOL)	0.026 J	SS168A	Former R	1 / 672	-	0.47	0.58	-	-
2-NITRODIPHENYLAMINE	2.5 J	SS128A	G Range	114 / 611	-	-	-	-	-
ACENAPHTHENE	0.9	SS164K	Former M-2	4 / 673	4	2.7	4.1	3.88	-
ACENAPHTHYLENE	0.15 J	SS143G	GA/GB Range	3 / 673	1	0.068	-	1.18	-
ANTHRACENE	1.5	SS164K	Former M-2	14 / 673	1,000	54	42	-	-
BENZO(a)ANTHRACENE	3.9	SS164K	Former M-2	69 / 673	7	0.037	0.01	-	0.46
BENZO(a)PYRENE	2.5	SS164K	Former M-2	61 / 673	2	0.2	0.0035	-	0.46
BENZO(b)FLUORANTHENE	4.1	SS164K	Former M-2	63 / 673	7	0.11	0.035	-	0.46
BENZO(g,h,i)PERYLENE	1.7	SS164K	Former M-2	30 / 673	1,000	554	-	-	0.46
BENZO(k)FLUORANTHENE	4.2	SS164K	Former M-2	59 / 672	70	0.11	0.35	-	0.46
BENZOIC ACID	0.62	SS143R	GA/GB Range	152 / 619	-	-	14	-	-
BENZYL ALCOHOL	0.24 J	TTSARKRRF3	K Range	25 / 620	-	-	0.37	-	-
BENZYL BUTYL PHTHALATE	0.606	SS11209-A	Succonsette Pond	2 / 673	-	491	0.2	-	-
bis(2-ETHYLHEXYL) PHTHALATE	10 J	SS157A	A Range	189 / 673	200	72	1.1	-	-
CARBAZOLE	0.53	SS164K	Former M-2	7 / 673	-	0.012	-	-	-
CHRYSENE	4.2	SS164K	Former M-2	94 / 673	70	3.4	1.1	-	0.46
DIBENZ(a,h)ANTHRACENE	0.38 J	SS143G	GA/GB Range	15 / 673	0.7	0.038	0.011	-	-
DIBENZOFURAN	0.38	SS164K	Former M-2	4 / 673	-	0.26	-	-	-
DIETHYL PHTHALATE	5.3	SS160B	H Range	9 / 673	10	13	4.7	9.98	-
DIMETHYL PHTHALATE	0.093 J	SSER1C2501	E Range	3 / 673	30	-	-	33.01	-
DI-n-BUTYL PHTHALATE	3.3 J	SS128A	G Range	259 / 673	-	151	1.7	-	-
DI-n-OCTYLPHTHALATE	0.063 J	SS166E	O Range	5 / 673	-	0.48	-	-	-
FLUORANTHENE	9.3	SS164K	Former M-2	120 / 673	1,000	108	70	-	0.46
FLUORENE	0.79	SS164K	Former M-2	7 / 673	1,000	14	4	-	-
INDENO(1,2,3-c,d)PYRENE	1.6	SS164K	Former M-2	30 / 673	7	0.32	0.2	-	0.46
N,N'-DIETHYLCARBANILIDE	1.9	SS157B	A Range	128 / 611	-	-	-	-	-
NAPHTHALENE	0.1 J	SS143O	GA/GB Range	8 / 673	4	0.014	0.00047	4.48	-
N-NITROSODIPHENYLAMINE	4.6 J	SS128A	G Range	225 / 673	-	0.0078	0.057	-	-
PHENANTHRENE	7.4	SS164K	Former M-2	68 / 673	10	48	-	10.87	0.46
PHENOL	0.026 J	SS165E	N Range	4 / 672	1	0.77	2.6	0.95	-
PYRENE	10	SS164K	Former M-2	120 / 673	1,000	19	9.5	-	0.46

Table 7-2
Small Arms Ranges
Site-Wide Soil Screening

Analyte	Maximum Detected Concentration (mg/Kg)	Location of Maximum Detected Concentration	Range Assoicated with Maximum Detected Concentration	Detection Frequency	MCP S-1/GW-1 Standard [a] (mg/Kg)	MMR SSL (mg/Kg)	EPA Risk-Based SSL [b] (mg/Kg)	MassDEP Leaching-Based Soil Concentration [c] (mg/Kg)	MMR Outwash Background Concentration (0 - 2 ft bgs) [d] (mg/Kg)
VOCs									
ACETONE	0.73 J	SS101FA	N Range	90 / 99	6	0.11	2.4	6.3	-
BENZENE	0.002 J	SS143O	GA/GB Range	1 / 99	2	0.0001	0.0002	1.50	-
BROMOFORM	0.002 J	SS143I,SS143J,SS143K,SS14	GA/GB Range	9 / 99	0.1	0.0022	0.0021	0.007	-
BROMOMETHANE	0.003 J	SS135U	Former D	5 / 99	0.5	0.0018	0.0018	0.05	-
CHLOROFORM	0.009 J	SS136AC	Former C	7 / 99	0.4	0.000036	0.000053	0.35	-
CHLOROMETHANE	0.002 J	SS143F	GA/GB Range	1 / 99	-	0.0004	0.049	-	-
METHYL ETHYL KETONE [BUTANONE]	0.039 J	SS143I	GA/GB Range	75 / 99	4	0.34	1	4	-
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	0.033 J	SS162F	KD East Range	3 / 99	0.4	-	0.23	0.35	-
TETRACHLOROETHYLENE (PCE)	0.002 J	SS143K	GA/GB Range	1 / 99	1	0.00044	0.0044	1.235	-
TOLUENE	0.006 J	SS162F	KD East Range	40 / 99	30	0.27	0.59	32	-
PCBs									
PCB-1260 (AROCLOR 1260)	0.036	SS143F	GA/GB Range	1 / 128	2	0.01	0.024	-	-

Notes:

Data set consisted of all soil data available and applicable for the Small Arms Range Report except samples from soil that was removed pursuant to rapid response actions or berm maintenance projects. Data was available and applicable for the following: A Range, B Range, C Range, D Range, E Range, G Range, GA Range, GB Range, H Range, I Range, J Range, K Range, KD East Range, L-2 Range, L-3 Range, N Range, Former N Range, O Range, P Range, Q Range, SE Range, SW Range, T Range, Former B Range, Former C Range, Former D Range, L-3 Range, L-4 Range, Former L-1 Range, Former M-1 Range (M Range), Former M-2 Range (M Range), Former M-4 Range, Q Range, Former R Range, Skeet Range 1, Skeet Range 2, Succonsette Pond, and the 500 Yard Rifle Range.

Laboratory data validation qualifier codes used for the "Maximum Concentration" are as follows:
J = Estimated Concentration
F = Positively Identified Below Reporting Limit
NJ = Presumptively Identified Compound, Estimated Concentration
"-" = No listed value.
Yellow highlighting indicates those soil criteria that were exceeded by the maximum detected site-wide soil concentration.

[a] MCP Method 1 S-1/GW-1 Standards, December 2009 (http://www.mass.gov/dep/service/compliance/riskasmt.htm)

MCP standards for Chromium VI conservatively used as a surrogate for Chromium, Total.
MCP standards for Endosulfan used as a surrogate for Endosulfan sulfate.
MCP standards for Endrin used as a surrogate for Endrin Aldehyde and Endrin Ketone.
MCP standards for Chlordane used as a surrogate for gamma Chlordane.

[b] EPA Risk-Based SSLs taken from the USEPA Regional Screening Level (RSL) Table, May 2013. (http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/index.htm)
EPA MCL-Based SSL for Lead used as there is no Risk-Based SSL for this compound.
EPA MCL-Based SSL for Chromium used as the Risk-Based SSLs are specific to either Chromium III or Chromium VI.
EPA Risk-Based SSL for Thallium, Soluable Salts used as a surrogate for Thallium.
EPA Risk-based SSL for Endrin used as a surrogate for Endrin Aldehyde and Endrin Ketone.

[c] MassDEP Leaching-Based Soil Concentrations (GW-1) were not used as screening criteria, but for comparison purposes only. MCP Numerical Standards Development Spreadsheets, May 2009 (http://www.mass.gov/dep/service/compliance/riskasmt.htm#m

[d] The majority of the small arms ranges are situated within the Buzzard's Bay Outwash. The outwash background values included the maximum of the 0-2 ft depth interval and were not used as screening criteria, but for comparison purposes only.

[e] The value shown for MCP S-1/GW-1 standard is a calculated value using the provisional oral reference dose (1E-4 mg/kg-day) and the default exposure parameters of the S-1 direct contact standards.

[f] The value shown for MCP S-1/GW-1 standard is an Interim Risk-Based Soil Concentration for tungsten developed by the MassDEP Office of Research and Standards (MassDEP, 2012).

Table 9-1
Small Arms Ranges
Range Summaries and Proposed Actions

Range Name	Mon. Wells	Lysi-meters	Ammunition Use			Soil Sampling - Areas and Analytes																Metal Detector	Removal Actions			Max . Pb (mg/Kg)	Max. W (mg/Kg)	Rood W MASC (mg/Kg)	Max NG (mg/Kg)	Proposed Action
						Firing Point				Range Floor				Target Berm - Target Area				Down Range - Behind Berm												
			Lead	Tungsten	Copper	MIS	Discrete	Comp.	XRF	MIS	Discrete	Comp.	XRF	MIS	Discrete	Comp.	XRF	MIS	Discrete	Comp.	XRF		1998 Lead	2006 Tungsten	2009 Lead					
Operational Ranges (Active)																														
J Range (STAPP)	•	•	HC	H		M WS	M S	M S		MW S				MW			M	MW	M				•	•	•	192	18.2		11.5	Continue long-term monitoring
K Range (STAPP)	•	•	HC	H		M WS	M S	M S		MW S				MW			M	MW					•	•	•	955	47.2		46	Continue long-term monitoring
SE Range	•	•	H	H	C	M S	M S	M S	M	MW S			M	MW			M	MW			M		•			710	13		41	Continue long-term monitoring
SW Range	•	•	H	H	C	M S	M S	M S	M	MW S			MW	MW			MW	MW			MW		•			734	9.2		16	Continue long-term monitoring
T Range (STAPP)	•	•	HC	H		M WS P	M S	M S		MW S P				MW S P				MW P			M			•		5800	77.1		29.7	Continue long-term monitoring
I Range		•	H	H	C	M S	M S	M S		M				MW			MW	MW	M				•	•		585	2.5		ns	Continue long-term monitoring
Operational Ranges (Inactive)																														
A Range	•		H (1)				M S	M S						M P				M					•			29	na		ns	None
B Range	•	•	H	H		MW S	M S	M S		MW				MW	M		MW	MW					•	•		1430	200	19	ns	Soil removal behind berm - Monitor GW for lead, tungsten, antimony
C Range	•	•	H	H		M WS	M S	M S		MW				MW			MW	MW					•	•		749	50.5	11	ns	Soil removal behind berm - Monitor GW for lead, tungsten, antimony
D Range			H	H			M S	M S									M	MW					•			1840	0.25	28	ns	None*
E Range	•		H	H		MW S	M S	M S						MW S			M	MW					•			555	5.1	7	9.3	None*
G Range	•	•	H	H			M S	M S						MW			MW	MW	M				•	•		3850	84	17	ns	Soil removal - lead behind berm above UCL and elevated tungsten. Monitor GW for lead, tungsten, antimony
H Range			H	H			M S	M S										MW					•			1760	2.1	35	ns	None*
KD East SAR	•	•	H	H			M S	M S						MW			M	MW					•			147	21	22	ns	Confirmatory soil sampling for chromium
N Range	•		H				M S	M S										M					•			724	na		ns	Conduct soil removal for lead - close under MCP
O Range	•		H				M S	M S										M					•			204	na		ns	None (close under MCP)
P Range	•		H				M S	M S										M					•			118	na		ns	None (close under MCP)
Former N Range			H											M			M					•				1670	na		ns	Further investigation - possible range development
Q Range			H			S								M			M					•				152	na		ns	None
Former R Range			H								M S	M S		M												28	na		ns	None
Non-operational Ranges																														
Former B Range	•		H			S	M	S			M			M	M		M		M		M				•	2410	na		ND	MIS soil sampling to confirm removal action complete
Former C Range			H			S		M S							M											1560	na		ND	None (need MassDEP approval of averaging method prior to DD)
Former D Range	•		H			MS	M	M S	M	M	M		M	M	M		M		M		M				•	2900	na		ND	MIS soil sampling to confirm removal action complete
E-1 Range (North of Demo 1)			H				M S	M S			M S	M S			S											na	na		na	None - Transferred to Training Areas OU
E-2 Range (At Demo 1)			H																							na	na		na	None - Covered under Demo 1 OU
GA/GB Range	•		H			S	M S PH	M S PH							M S V PH			M			M	•				128	na		ND	None - (note intact bullets present down range)
Former K Range (MMRP)			H																							ns	na		ns	MMRP Site
L-1 Range (L Range 41-50s)			H											M			M					•				60	na		ns	None
L Range 1950s - 1980s	•		H																			•				ns	na		ns	None
L-2 Range (GP-20)	•		H								M S V PH											•				137	na		ns	None
L-3 Range	•		H											M	M S P		M					•				354	na		ns	None (lead average less than 300)
L-4 Range			H											M			M					•				12	na		ns	None
Former M-1			H			S					M S V	M S V		M												22	na		ND	None
Former M-2 (M-Range)	•		H								M S V	M S V		M	M		M	M			M				•	1200	na		ns	Additional MIS and soil removal for lead
Former M-3 Range			H																			•				ns	na		ns	None
Former M-4 Range			H											M			M					•				15	na		ns	None
Skeet Range 1			H							M		M S														56	na		ns	None
Skeet Range 2			H							M			M									•				8	na		ns	None
Succonsette Pond			H (1)											M P	M S P											207	na		ns	None
500-Yard Rifle Range			H											M			M									13	na		ns	None

Ammunition Use: H = Historic C=Current (1) 0.50 cal steel(very small amount of lead) or plastic

Analytes:
M = Metals (W=Tungsten)
S = Semivolatiles/Explosives
V = Volatiles
P = Perchlorate
PH = Pesticides and Herbicides

Acronyms:
MIS = multiple increment sample
MMRP = Military Munitions Response Program
XRF = X-Ray Fluorescence field screening instrument for metals
OU = Operable Unit

Notes:
B, C and I Ranges were part of CRREL Tungsten Study
na = not applicable, ns = not sampled, ND = non-detect
Rood calculation = length across berm face and back berm to a depth of 3 inches
Current calculation of S-1/GW-1 for nitroglycerine is 4 mg/Kg
KD (West) is being evaluated under the Training Ranges Operable Unit
* Assumes future use as a Small Arms Range

Appendix A
Analytical Data
(Available on CD)

Appendix B
Background Soil Data

Appendix B
MMR Program
Soil Screening Values

	Soil Screening Values									
						Background				
						Moraine		Outwash		
Detected Compounds	**Units**	**MMR SSL**	**MMR PRG**	**S-1/GW-1**	**RCS1**	**0-1 foot**	**1-2 feet**	**0-1 foot**	**1-2 feet**	**MassDEP "natural" soils**
1,1,1-TRICHLOROETHANE	UG/KG		1.20E+06	3.00E+04	3.00E+04					
1,1,2-TRICHLOROETHANE	UG/KG		7.30E+02	1.00E+02	1.00E+02					
1,1,1,2-TETRACHLOROETHANE	UG/KG		3.20E+03	1.00E+02	1.00E+02					
1,1,2,2-TETRACHLOROETHANE	UG/KG		4.10E+02	5.00E+00	5.00E+00					
1,1-DICHLOROETHANE	UG/KG		5.10E+05	4.00E+02	4.00E+02					
1,1-DICHLOROETHYLENE	UG/KG		1.20E+05	3.00E+03	3.00E+03					
1,2,4-TRICHLOROBENZENE	UG/KG		6.20E+04	2.00E+03	2.00E+03					
1,2-DIBROMO-3-CHLOROPROPANE (DBCP)	UG/KG		4.60E+02		1.00E+04					
1,2-DIBROMOETHANE (ETHYLENE DIBROMIDE)	UG/KG		3.20E+01	1.00E+02	1.00E+02					
1,2-DICHLOROETHANE	UG/KG		2.80E+03	1.00E+02	1.00E+02					
1,2-DICHLOROPROPANE	UG/KG		3.40E+02	1.00E+02	1.00E+02					
1,3-DICHLOROPROPENE	UG/KG		7.80E+02	1.00E+01	1.00E+01					
1,3,5-TRINITROBENZENE	UG/KG		1.80E+06		5.00E+04					
1,3-DINITROBENZENE	UG/KG		6.10E+03		1.00E+05					
1,2-DICHLOROBENZENE	UG/KG		6.00E+05	9.00E+03	9.00E+03					
1,3-DICHLOROBENZENE	UG/KG		5.30E+05	1.00E+03	1.00E+03					
1,4-DICHLOROBENZENE	UG/KG		3.40E+03	7.00E+02	7.00E+02					
2,4 DB (2,4-Dichlorophenoxyacetic acid)	UG/KG	5.17E+01	6.90E+05		1.00E+05					
2,4,5-T (TRICHLOROPHENOXYACETIC ACID)	UG/KG	4.93E+02	6.10E+05		1.00E+05					
2,4,6-TRINITROTOLUENE	UG/KG	2.12E-01	1.60E+04		1.00E+05					
2,4-DINITROTOLUENE	UG/KG	1.96E+01	1.20E+05	7.00E+02	7.00E+02					
2,6-DINITROTOLUENE	UG/KG	8.76E+00	6.10E+04		1.00E+05					
2-AMINO-4,6-DINITROTOLUENE	UG/KG	3.85E-01	1.20E+04							
2-METHYLNAPHTHALENE	UG/KG	7.23E+01	5.60E+04	7.00E+02	7.00E+02					5.00E+02
2-NITROTOLUENE	UG/KG	2.18E+00	8.80E+02		5.00E+05					
3-NITROTOLUENE	UG/KG		7.30E+05		5.00E+05					
4-NITROTOLUENE	UG/KG	2.60E+01	1.20E+04		5.00E+05					
4-AMINO-2,6-DINITROTOLUENE	UG/KG	3.85E-01	1.20E+04							
4-METHYLPHENOL (P-CRESOL)	UG/KG	3.88E+01	3.10E+05		5.00E+05					
ACENAPHTHENE	UG/KG	2.71E+03	3.70E+06	4.00E+03	4.00E+03					5.00E+02
ACENAPHTHYLENE	UG/KG	6.76E+01	3.70E+06	1.00E+03	1.00E+03					5.00E+02
ACETONE	UG/KG	1.07E+02	1.40E+07	6.00E+03	6.00E+03					
ALDRIN	UG/KG	9.81E+00	2.90E+01	4.00E+01	4.00E+01					
ALPHA BHC (ALPHA HEXACHLOROCYCLOHEXANE)	UG/KG	6.18E-02	9.00E+01		5.00E+04					
ALUMINUM	MG/KG	5.40E+04	7.60E+04			1.55E+04	1.24E+04	1.60E+04		1.00E+04
ANTHRACENE	UG/KG	5.38E+04	2.20E+07	1.00E+06	1.00E+06					
ANTIMONY	MG/KG	2.71E-01	3.10E+01	2.00E+01	2.00E+01	1.40E+00	2.30E+00	1.90E+00		1.00E+00
ARSENIC	MG/KG	9.01E-03	3.90E-01	2.00E+01	2.00E+01	3.90E+00	3.90E+00	5.50E+00		2.00E+01
BARIUM	MG/KG	1.20E+02	1.50E+04	1.00E+03	1.00E+03	1.56E+01	2.02E+01	2.40E+01		5.00E+01
BENZENE	UG/KG	1.03E-01	6.40E+02	2.00E+03	2.00E+03					
BENZO(A)ANTHRACENE	UG/KG	3.69E+01	6.20E+02	7.00E+03	7.00E+03	4.60E+02		4.60E+02		2.00E+03

Appendix B
MMR Program
Soil Screening Values

		Soil Screening Values								
						Background				
						Moraine		Outwash		
Detected Compounds	**Units**	**MMR SSL**	**MMR PRG**	**S-1/GW-1**	**RCS1**	**0-1 foot**	**1-2 feet**	**0-1 foot**	**1-2 feet**	**MassDEP "natural" soils**
BENZO(A)PYRENE	UG/KG	2.03E+02	6.20E+01	2.00E+03	2.00E+03	4.60E+02		4.60E+02		2.00E+03
BENZO(B)FLUORANTHENE	UG/KG	1.14E+02	6.20E+02	7.00E+03	7.00E+03	4.60E+02		4.60E+02		2.00E+03
BENZO(G,H,I)PERYLENE	UG/KG	5.54E+05	5.60E+04	1.00E+06	1.00E+06	4.60E+02		4.60E+02		1.00E+03
BENZO(K)FLUORANTHENE	UG/KG	1.14E+02	6.20E+03	7.00E+04	7.00E+04	4.60E+02		4.60E+02		1.00E+03
BENZOIC ACID	UG/KG		1.00E+08		1.00E+06					
BUTYLBENZYL PHTHALATE	UG/KG	4.91E+05	1.20E+07		1.00E+05					
BERYLLIUM	MG/KG	2.60E+00	1.50E+02	1.00E+02	1.00E+02	3.30E-01	4.10E-01	3.80E-01		4.00E-01
BETA BHC (BETA HEXACHLOROCYCLOHEXANE)	UG/KG	1.99E-01	3.20E+02		1.00E+04					
BIS(2-CHLOROETHYL) ETHER	UG/KG		2.90E+03	7.00E+02	7.00E+02					
BIS(2-ETHYLHEXYL) PHTHALATE	UG/KG	7.20E+04	3.50E+04	2.00E+05	2.00E+05					
BORON	MG/KG	9.52E+00	1.60E+04			1.73E+01	8.10E+00	9.60E+00		
BROMODICHLOROMETHANE	UG/KG		8.20E+02	1.00E+02	1.00E+02					
BROMOFORM	UG/KG	2.17E+00	6.20E+04	1.00E+02	1.00E+02					
BROMOMETHANE	UG/KG	1.82E+00	3.90E+03	5.00E+02	5.00E+02					
C5 to C8 RANGE ALIPHATIC COMPOUNDS	UG/KG			1.00E+05	1.00E+05					
C9 to C12 RANGE ALIPHATIC COMPOUNDS	UG/KG			1.00E+06	1.00E+06					
C9 to C18 RANGE ALIPHATIC COMPOUNDS	UG/KG			1.00E+06	1.00E+06					
C19 to C36 RANGE ALIPHATIC COMPOUNDS	UG/KG			3.00E+06	3.00E+06					
C9 to C10 RANGE AROMATIC COMPOUNDS	UG/KG			1.00E+05	1.00E+05					
C11 to C22 RANGE AROMATIC COMPOUNDS	UG/KG			1.00E+06	1.00E+06					
CADMIUM	MG/KG	4.01E-01	3.70E+01	2.00E+00	2.00E+00	3.50E-01	3.20E-01	9.40E-01		2.00E+00
CARBAZOLE	UG/KG	1.21E+01	2.40E+04							
CARBON DISULFIDE	UG/KG	4.14E+02	3.60E+05		1.00E+05					
CARBON TETRACHLORIDE	UG/KG	7.76E-02	2.50E+02	1.00E+04	5.00E+03					
CHLORDANE	UG/KG		1.60E+03	7.00E+02	7.00E+02					
CHLOROBENZENE	UG/KG		1.50E+05	1.00E+03	1.00E+03					
CHLOROETHANE	UG/KG		3.00E+03		1.00E+05					
CHLOROFORM	UG/KG	3.64E-02	2.20E+02	4.00E+02	3.00E+02					
CHLOROMETHANE	UG/KG	3.99E-01	4.70E+04		1.00E+05					
CHROMIUM, TOTAL	MG/KG	7.02E+00	2.10E+02	3.00E+01	3.00E+01	1.47E+01	1.55E+01	1.90E+01		3.00E+01
CHRYSENE	UG/KG	3.40E+03	6.20E+04	7.00E+05	7.00E+05	4.60E+02		4.60E+02		2.00E+03
CIS-1,2-DICHLOROETHENE	UG/KG		4.30E+04	3.00E+02						
TRANS-1,2-DICHLOROETHENE	UG/KG		6.90E+04	1.00E+03	1.00E+03					
COBALT	MG/KG	1.32E+02	9.00E+02		5.00E+02	2.90E+00	4.50E+00	4.00E+00		4.00E+00
COPPER	MG/KG	4.57E+01	3.00E+02		1.00E+03	1.10E+01	7.40E+00	1.10E+01		4.00E+01
CYANIDE	MG/KG	1.09E-03	1.10E+01	1.00E+02	1.00E+02					
DDD (1,1-BIS(CHLOROPHENYL)-2,2-DICHLOROETHANE	UG/KG	2.78E+02	2.40E+03	4.00E+03	4.00E+03					
DDE (1,1-BIS(CHLOROPHENYL)-2,2-DICHLOROETHANE	UG/KG	8.84E+02	1.70E+03	3.00E+03	3.00E+03	1.20E+01		1.20E+01		
DDT (1,1-BIS(CHLOROPHENYL)-2,2,2-TRICHLOROETHANE	UG/KG	5.25E+02	1.70E+03	3.00E+03	3.00E+03	2.20E+01		2.20E+01		
DELTA BHC (DELTA HEXACHLOROCYCLOHEXANE)	UG/KG		3.20E+02		1.00E+04					
DI-N-BUTYL PHTHALATE	UG/KG	1.51E+05	6.10E+06		5.00E+04					

Appendix B
MMR Program
Soil Screening Values

	Soil Screening Values									
						Background				
						Moraine		Outwash		
Detected Compounds	**Units**	**MMR SSL**	**MMR PRG**	**S-1/GW-1**	**RCS1**	**0-1 foot**	**1-2 feet**	**0-1 foot**	**1-2 feet**	**MassDEP "natural" soils**
DI-N-OCTYLPHTHALATE	UG/KG		2.40E+07		1.00E+06					
DIBENZ(A,H)ANTHRACENE	UG/KG	3.77E+01	6.20E+01	7.00E+02	7.00E+02					5.00E+02
DIBENZOFURAN	UG/KG	2.60E+02	1.50E+05		1.00E+05					
DIBROMOCHLOROMETHANE	UG/KG	3.20E-02	1.10E+03	5.00E+00	5.00E+00					
DIELDRIN	UG/KG	7.99E-01	3.00E+01	5.00E+01	5.00E+01	3.00E+01		3.00E+01		
DIETHYL PHTHALATE	UG/KG	1.34E+04	4.90E+07	1.00E+04	1.00E+04					
DIMETHYL PHTHALATE	UG/KG		1.00E+08	3.00E+04	3.00E+04					
ENDOSULFAN	UG/KG		3.70E+05	5.00E+02	5.00E+02					
ENDRIN	UG/KG	1.89E+02	1.80E+04	8.00E+03	8.00E+03					
ETHYLBENZENE	UG/KG	1.89E+03	4.00E+05	4.00E+04	4.00E+04					
FLUORANTHENE	UG/KG	1.08E+05	2.30E+06	1.00E+06	1.00E+06	4.60E+02		4.60E+02		4.00E+03
FLUORENE	UG/KG	1.39E+04	2.70E+06	1.00E+06	1.00E+06					1.00E+03
GAMMA BHC (GAMMA HEXACHLOROCYCLOHEXANE)	UG/KG	7.27E-01	4.40E+02	3.00E+00	3.00E+00					
HEPTACHLOR	UG/KG	2.15E+01	1.10E+02	2.00E+02	2.00E+02					
HEPTACHLOR EPOXIDE	UG/KG	6.10E+00	5.30E+01	9.00E+01	9.00E+01					
HEXACHLOROBENZENE	UG/KG	6.98E+00	3.00E+02	7.00E+02	7.00E+02					
HEXACHLOROETHANE	UG/KG		3.50E+04	7.00E+02	7.00E+02					
HEXAHYDRO-1,3,5-TRINITROSO-1,3,5-TRIAZINE (RDX)	UG/KG	1.09E-01	4.40E+03	1.00E+03	1.00E+03					
INDENO(1,2,3-C,D)PYRENE	UG/KG	3.17E+02	6.20E+02	7.00E+03	7.00E+03	4.60E+02		4.60E+02		1.00E+03
IRON	MG/KG	2.42E+03	2.30E+04			1.21E+04	1.20E+04	1.78E+04		2.00E+04
LEAD	MG/KG	4.05E+00	4.00E+02	3.00E+02	3.00E+02	1.90E+01	1.02E+01	1.90E+01		1.00E+02
MAGNESIUM	MG/KG					1.49E+03	1.98E+03	2.01E+03		5.00E+03
MANGANESE	MG/KG	4.42E+01	1.80E+03			1.06E+02	1.22E+02	1.34E+02		3.00E+02
MCPA	UG/KG	1.43E+00	3.10E+04		1.00E+05					
MCPP	UG/KG	5.00E+01	6.10E+04							
MERCURY	MG/KG	2.04E-02	2.30E+01	2.00E+01	2.00E+01	1.00E-01	1.00E-01	1.20E-01		3.00E-01
METHOXYCHLOR	UG/KG	3.95E+03	3.10E+05	2.00E+05	2.00E+05					
METHYLENE CHLORIDE (DICHLOROMETHANE)	UG/KG		9.10E+03	1.00E+02	1.00E+02					
METHYL TERT-BUTYL ETHER (MTBE)	UG/KG		3.20E+04	1.00E+02	1.00E+02					
METHYL ETHYL KETONE (2-BUTANONE)	UG/KG	3.35E+02	2.20E+07	4.00E+03	4.00E+03					
METHYL ISOBUTYL KETONE (4-METHYL-2-PENTANONE)	UG/KG		5.30E+06	4.00E+02	4.00E+02					
MOLYBDENUM	MG/KG	1.83E-01	3.90E+02			1.10E+00	8.90E-01	1.20E+00		
N-NITROSODI-N-PROPYLAMINE	UG/KG		6.90E+01		5.00E+04					
N-NITROSODIPHENYLAMINE	UG/KG	7.77E+00	9.90E+04		1.00E+05					
NAPHTHALENE	UG/KG	1.36E+01	5.60E+04	4.00E+03	4.00E+03					5.00E+02
NICKEL	MG/KG	2.92E+02	1.60E+03	2.00E+01	2.00E+01	6.90E+00	9.40E+00	1.00E+01		2.00E+01
NITRATE/NITRITE (AS N)	MG/KG					9.40E-01	8.50E-01	5.00E-01		
NITROBENZENE	UG/KG		2.00E+04		5.00E+05					
NITROGEN, AMMONIA (AS N)	MG/KG				1.00E+02	2.00E+01	1.33E+01	3.80E+01		
NITROGLYCERIN	UG/KG	1.02E+00	3.50E+04		5.00E+04					

Appendix B
MMR Program
Soil Screening Values

		Soil Screening Values								
						Background				
						Moraine		Outwash		
Detected Compounds	**Units**	**MMR SSL**	**MMR PRG**	**S-1/GW-1**	**RCS1**	**0-1 foot**	**1-2 feet**	**0-1 foot**	**1-2 feet**	**MassDEP "natural" soils**
OCTAHYDRO-1,3,5,7-TETRANITRO-1,3,5,7-TETRAZOCINE (HMX)	UG/KG	3.21E+02	3.10E+06	2.00E+03	2.00E+03					
PCB-1232 (AROCHLOR 1232)	UG/KG		2.20E+02	2.00E+03	2.00E+03					
PCB-1248 (AROCHLOR 1248)	UG/KG		2.20E+02	2.00E+03	2.00E+03					
PCB-1254 (AROCHLOR 1254)	UG/KG	1.04E+01	2.20E+02	2.00E+03	2.00E+03					
PCB-1260 (AROCHLOR 1260)	UG/KG	1.04E+01	2.20E+02	2.00E+03	2.00E+03					
PENTACHLOROPHENOL	UG/KG	4.29E-01	3.00E+03	3.00E+03	3.00E+03					
PERCHLORATE	UG/KG	3.14E+00	5.50E+04	1.00E+02	1.00E+02					
PHENANTHRENE	UG/KG	4.81E+04	2.30E+06	1.00E+05	1.00E+05	4.60E+02		4.60E+02		3.00E+03
PHENOL	UG/KG	7.66E+02	1.80E+07	1.00E+03	1.00E+03					
PHOSPHORUS, TOTAL ORTHOPHOSPHATE (AS PO4	MG/KG					1.23E+02	1.43E+02	2.91E+02		
PICRIC ACID	UG/KG		6.10E+05		1.00E+05					
POTASSIUM	MG/KG					5.63E+02	7.33E+02	7.66E+02		
PYRENE	UG/KG	1.90E+04	2.30E+06	1.00E+06	1.00E+06	4.60E+02		4.60E+02		4.00E+03
SELENIUM	MG/KG	2.76E+00	3.90E+02	4.00E+02	4.00E+02	1.10E+00	1.10E+00	1.70E+00		5.00E-01
SILVER	MG/KG	1.62E+01	3.90E+02	1.00E+02	1.00E+02	5.20E-01	6.10E-01	7.40E-01		6.00E-01
SILVEX (2,4,5-TP)	UG/KG		4.90E+05		1.00E+05					
STYRENE	UG/KG	2.34E+03	1.70E+06	3.00E+03	3.00E+03					
TCDD, 2,3,7,8- (equivalents)	PG/G	5.00E-07	3.90E+00	2.00E+01	2.00E+01					
TETRACHLOROETHYLENE(PCE)	UG/KG	4.35E-01	4.80E+02	1.00E+03	1.00E+03					
TETRYL	UG/KG		6.10E+05		1.00E+05					
TUNGSTEN										
THALLIUM	MG/KG	3.00E+00	5.20E+00	8.00E+00	8.00E+00	1.60E+00	1.60E+00	1.60E+00		6.00E-01
TOLUENE	UG/KG	2.72E+02	5.20E+05	3.00E+04	3.00E+04					
TRICHLOROETHYLENE (TCE)	UG/KG	4.96E-01	5.00E+01	3.00E+02	3.00E+02					
VANADIUM	MG/KG	2.60E+02	7.80E+01	6.00E+02	6.00E+02	2.17E+01	2.01E+01	2.88E+01		3.00E+01
VINYL CHLORIDE	UG/KG		7.90E+01	6.00E+02	6.00E+02					
XYLENES, TOTAL	UG/KG	8.08E+02	2.70E+05	4.00E+05	3.00E+05					
ZINC	MG/KG	2.20E+03	2.30E+04	2.50E+03	2.50E+03	2.56E+01	2.44E+01	2.56E+01		1.00E+02

NOTE: These standards are from the most recent guidance; users should verify the values before using for reports.

References:
PRGs: Region 9 PRG Table for Resdientail Soils (October 2004). Note PRGs may change based on site-specific risk calculations.
Note: All PRGs are based on a total Hazard Quotient of 1.
S-1/GW-1 and RCS-1: MCP 310CMR 40.0974(2) Method 1 Soil Category Standards (effective February 14, 2008)
Background: Draft Final Tach Memo 01-1 Soil Background Evaluation (AMEC, July 3, 2003)
MassDEP: MADEP Identified Background Levels in Soil (MassDEP, May 2002)
http://public.dep.state.ma.us/momhl/hazmat.aspx
http://www.mass.gov/dep/cleanup/laws/0975_6a.htm

updated : August 2010

Appendix C
Range Aerial Photographs

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1991

300 0 300 600 Feet

TITLE

A Range

N

FIGURE
C1

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\ARange.mxd

Impact Area Groundwater Study Program

LEGEND

▭ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

150 0 150 300 Feet

TITLE

B Range

N

FIGURE

C2

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\BRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown:1943

TITLE

Former B Range

FIGURE
C3

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerBRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

100 0 100 200 Feet

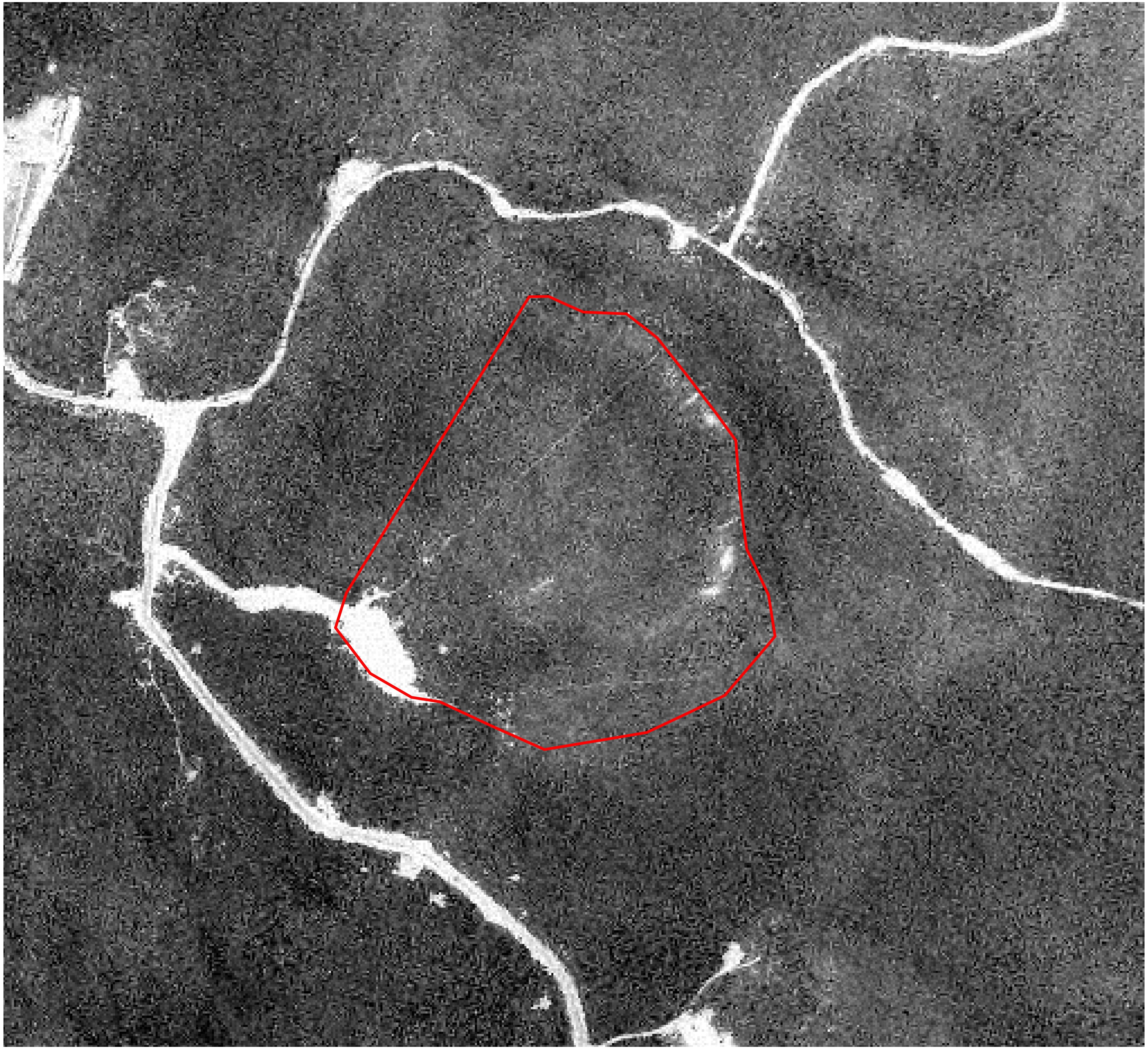
TITLE

C Range

N

FIGURE
C4

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\CRange.mxd



Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

300 0 300 600 Feet

TITLE

Former C Range

N

FIGURE
C5

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerCRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

60 0 60 120 Feet

TITLE

D Range

N

FIGURE
C6

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\DRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

325 0 325 650 Feet

TITLE

Former D Range

N

FIGURE
C7

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

100 0 100 200 Feet

TITLE

E Range

N

FIGURE
C8

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\ERange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: NAD83,
UTM Zone 19N, Meters
Historical Photo Flown:1991

250 0 250 500 Feet

TITLE

G Range

N

DEPARTMENT OF THE ARMY
UNITED STATES OF AMERICA
1775

FIGURE
C9

P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\GRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

300 0 300 600 Feet

TITLE

GA/GB Range

N

FIGURE
C10A

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\GAGBRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

300 0 300 600 Feet

TITLE

Down Range of
GA/GB

N

DEPARTMENT OF THE ARMY UNITED STATES OF AMERICA 1775

FIGURE
C10B

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\DownRange_GAGBRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

130 0 130 260 Feet

TITLE

H Range

N

FIGURE
C11

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\HRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

100 0 100 200 Feet

TITLE

I Range

N

FIGURE
C12

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\IRange.mxd

Impact Area Groundwater Study Program

LEGEND

☐ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

40 0 40 80 Feet

TITLE

J Range

N

FIGURE
C13

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

80 0 80 160 Feet

TITLE

K Range

N

FIGURE
C14

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\KRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1986

300 0 300 600 Feet

TITLE

KD East Range

N

FIGURE
C15

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\KD_EastRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

280 0 280 560 Feet

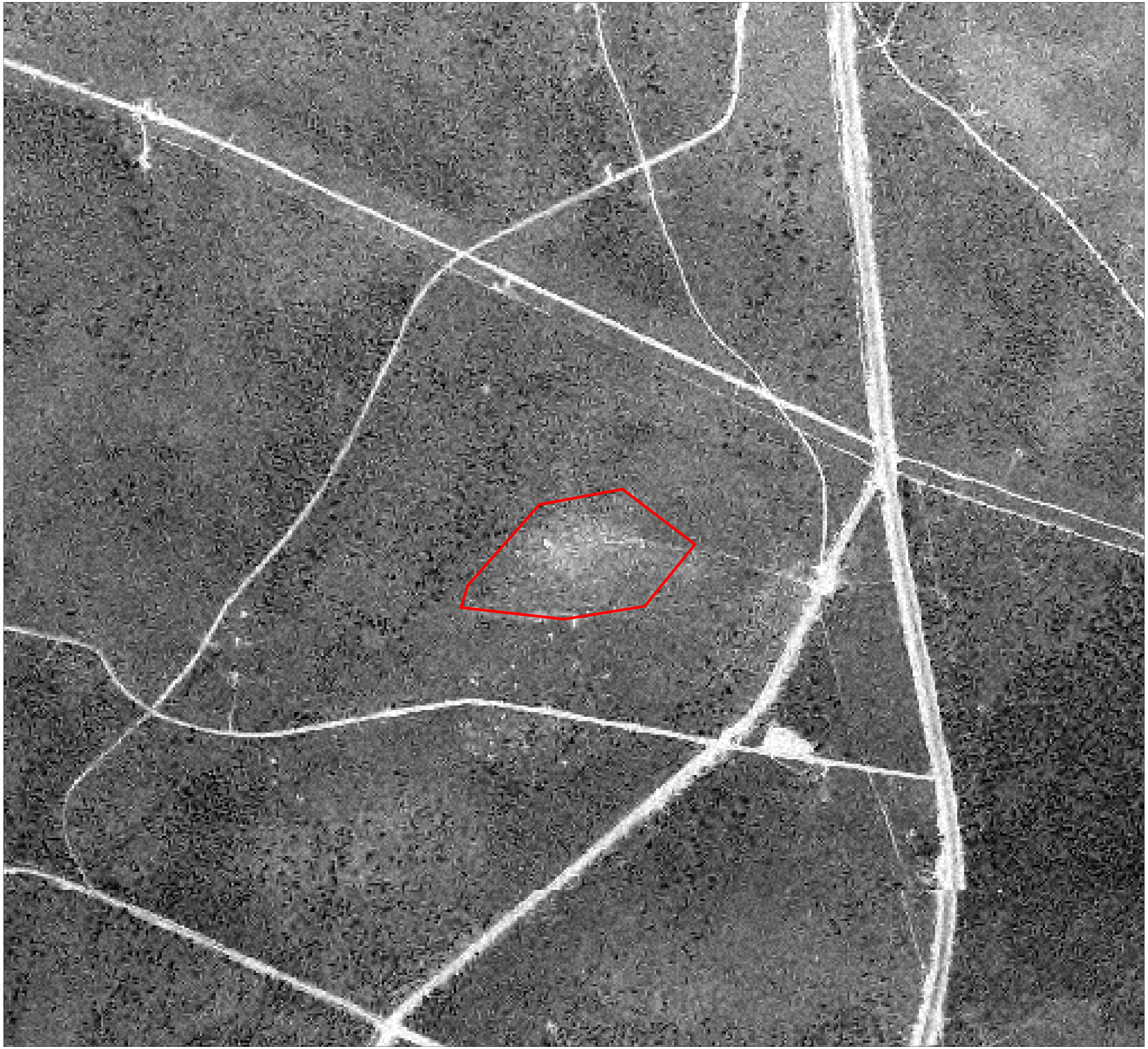
TITLE

Former K Range (1940s - 1950s)

N

FIGURE
C16

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerKRange.mxd



Impact Area Groundwater Study Program

LEGEND

□ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

290 0 290 580 Feet

TITLE

L Range (1941 - 1950s)/
L-1 Range

N

FIGURE
C17

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\L1Range.mxd

Impact Area Groundwater Study Program

LEGEND

▭ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

310 0 310 620 Feet

TITLE

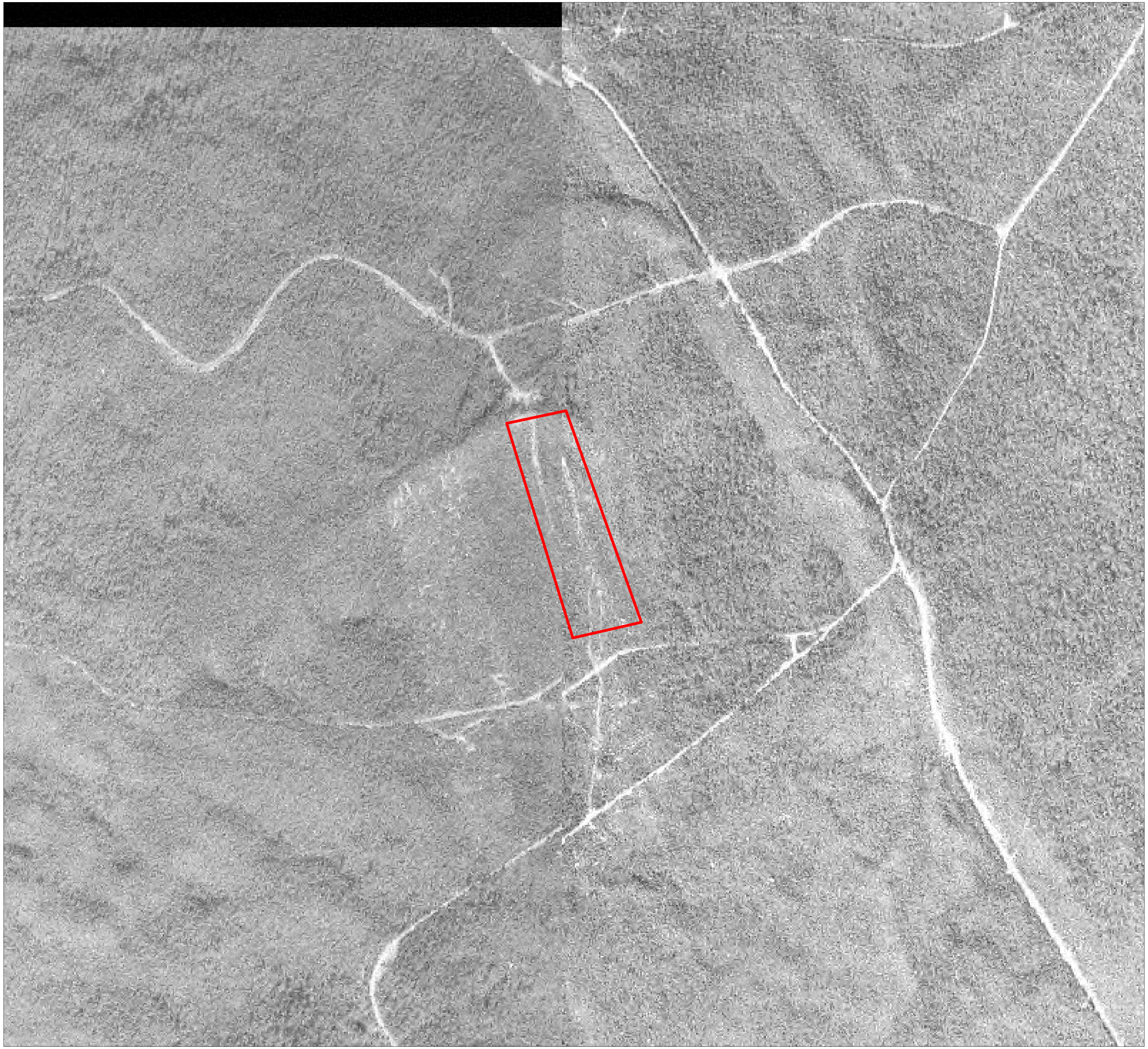
L Range (1950s - 1980s)

N

DEPARTMENT OF THE ARMY · UNITED STATES OF AMERICA · 1775

FIGURE
C18

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\LRange.mxd



Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

320 0 320 640 Feet

TITLE

L-2 Range

N

FIGURE
C19

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\L2Range.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1966

320 0 320 640 Feet

TITLE

L-3 Range

N

FIGURE
C20

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\L3Range.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

275 0 275 550 Feet

TITLE

L-4 Range

N

FIGURE
C21

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\L4Range.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

300 0 300 600 Feet

TITLE

Former M-1 Range (M Range)

N

FIGURE
C22

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerM1Range.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

290 0 290 580 Feet

TITLE

Former M-2 Range
(M Range)

N

FIGURE
C23

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerM2Range.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

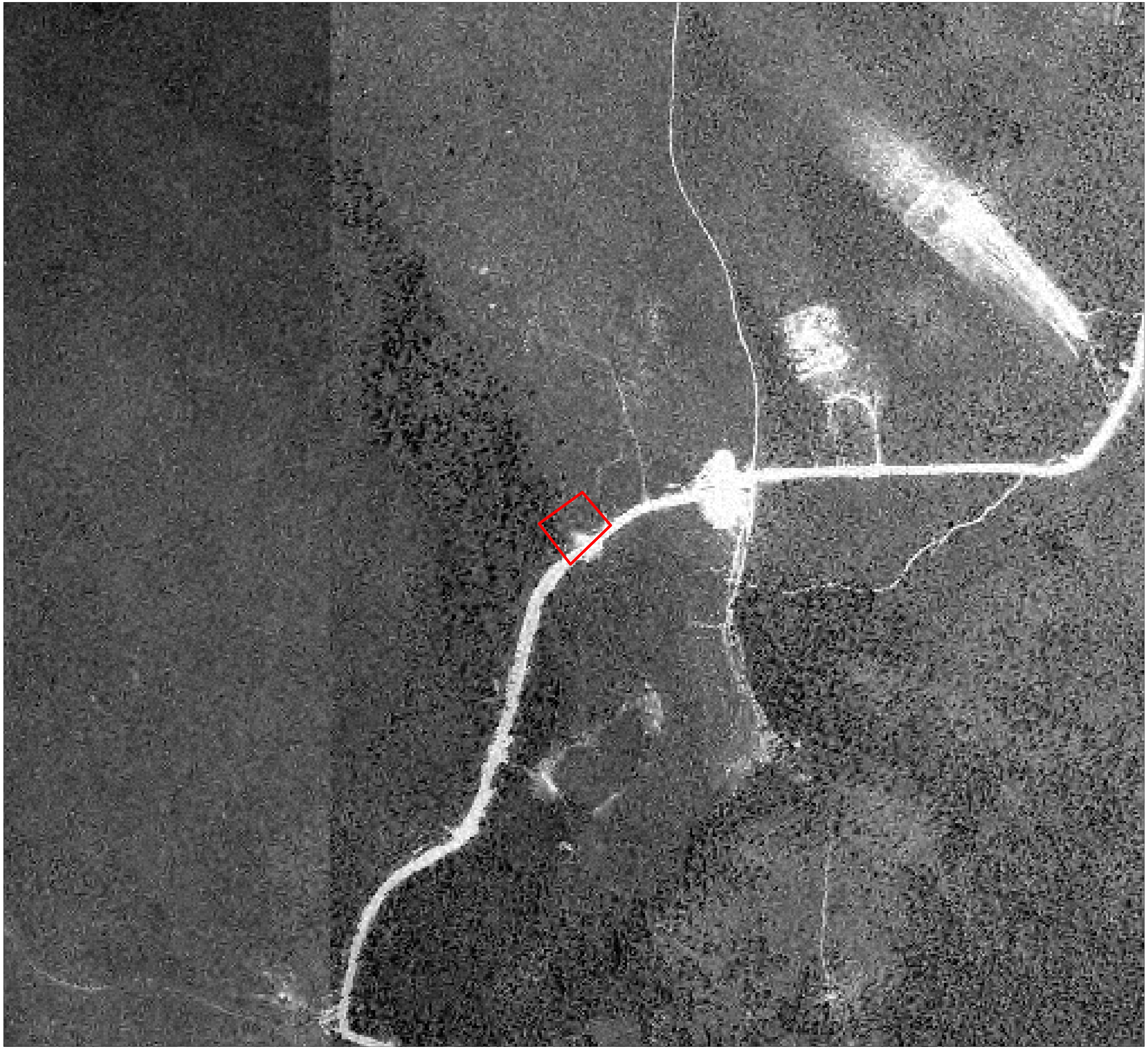
Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

TITLE

Former M-3 Range

FIGURE
C24

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerM3Range.mxd



Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

320 0 320 640 Feet

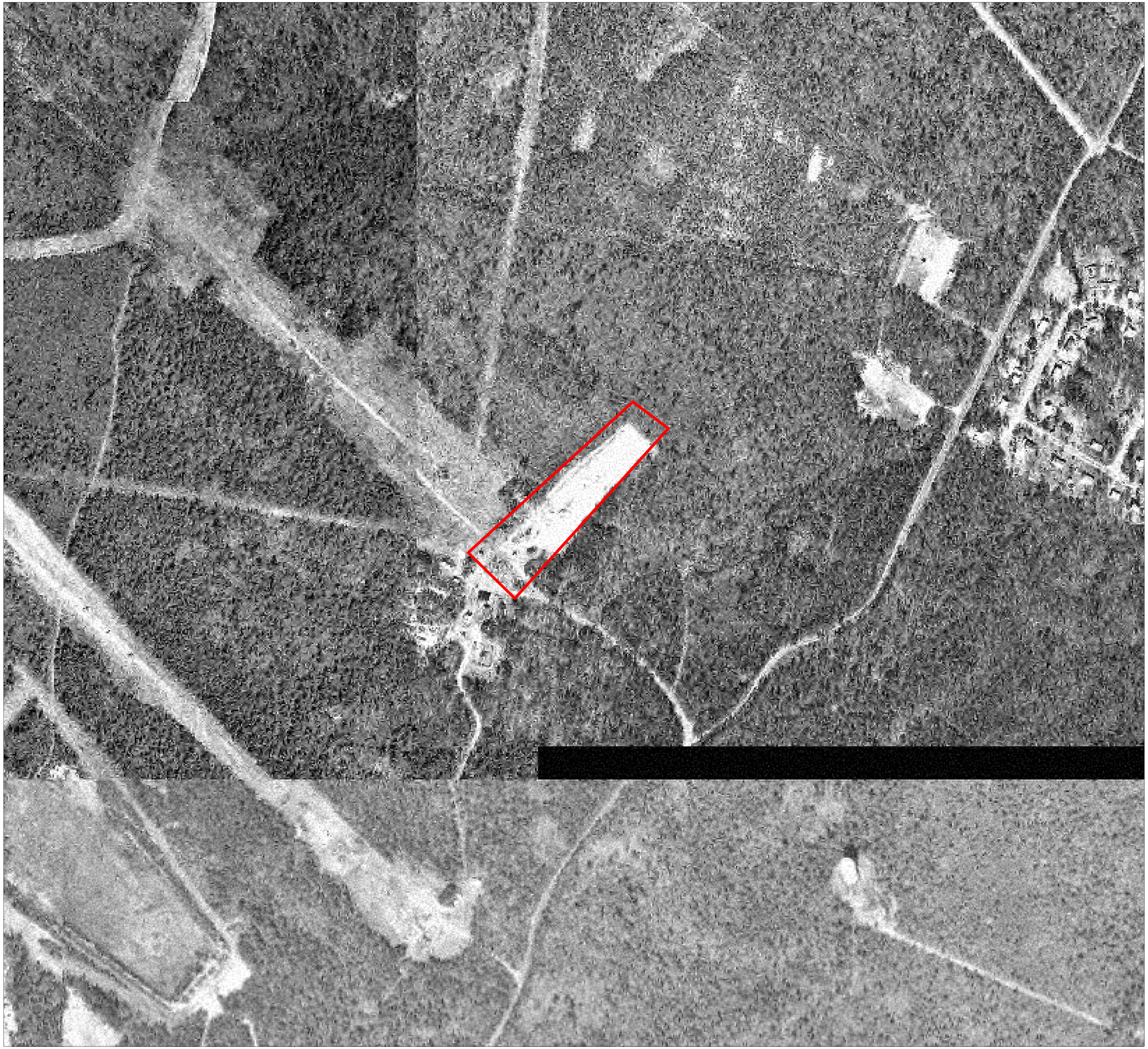
TITLE

Former M-4 Range

N

FIGURE
C25

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerM4Range.mxd



Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1986

290 0 290 580 Feet

TITLE

N Range

N

FIGURE
C26

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\NRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1966

330 0 330 660 Feet

TITLE

Former N Range

N

FIGURE
C27

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerNRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

110 0 110 220 Feet

TITLE

O Range

N

FIGURE
C28

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\ORange.mxd

Impact Area Groundwater Study Program

LEGEND

□ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1994

130 0 130 260 Feet

TITLE

P Range

N

DEPARTMENT OF THE ARMY
UNITED STATES OF AMERICA
1775

FIGURE
C29

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\PRange.mxd

Impact Area Groundwater Study Program

LEGEND

□ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1966

325 0 325 650 Feet

TITLE

Q Range

N

Department of the Army United States of America

FIGURE
C30

Impact Area Groundwater Study Program

LEGEND

□ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1966

330 0 330 660 Feet

TITLE

Former R Range

N

FIGURE
C31

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\FormerRRange.mxd

Impact Area Groundwater Study Program

LEGEND

☐ Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1986

325 0 325 650 Feet

TITLE

S East and
S West Ranges

N

FIGURE
C32

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\S_EW_Ranges.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

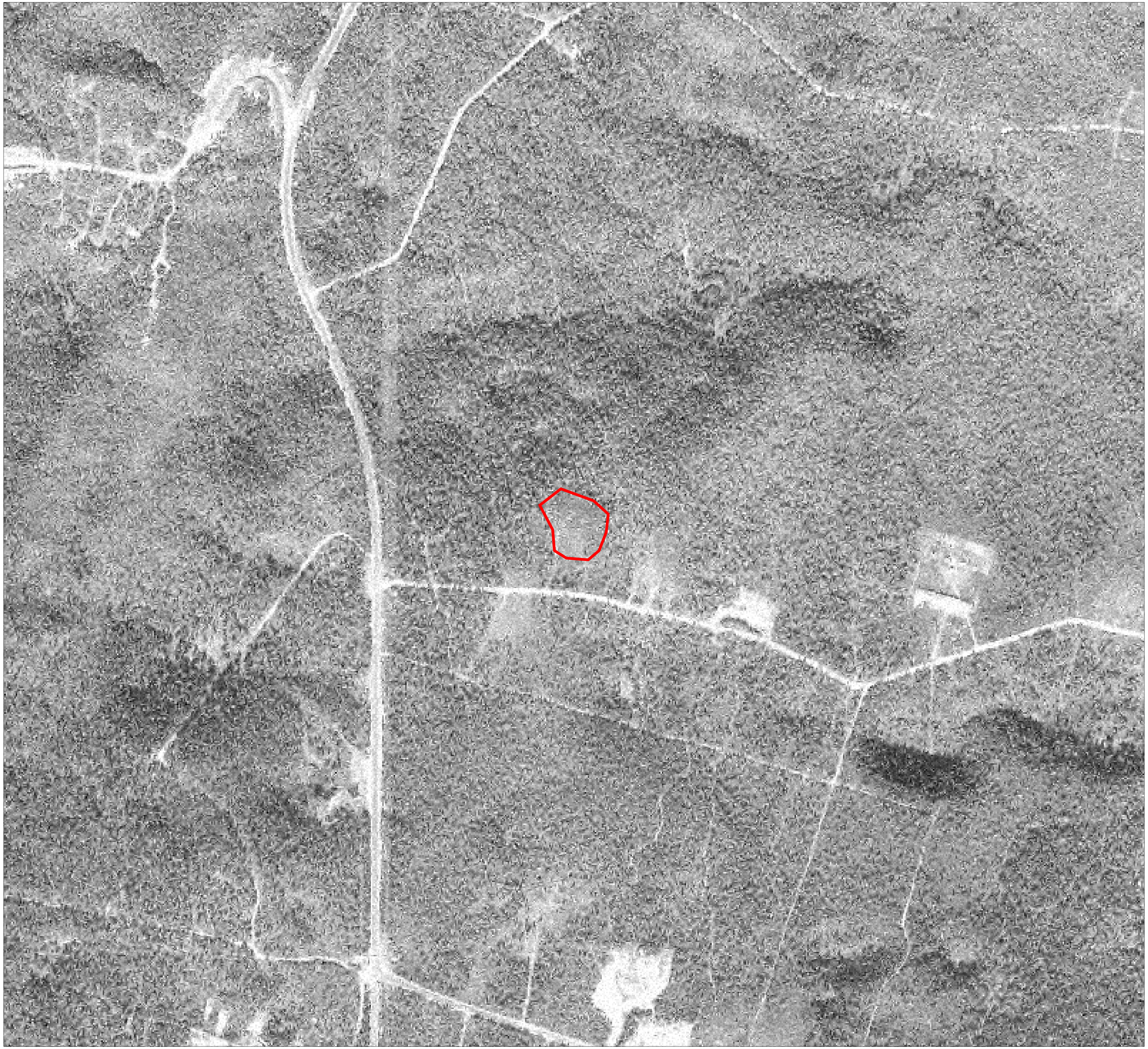
330 0 330 660 Feet

TITLE

Skeet Range 1

N

FIGURE
C33



Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1955

325 0 325 650 Feet

TITLE

Skeet Range 2

N

FIGURE
C34

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\SkeetRange2.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1986

300 0 300 600 Feet

TITLE

T Range

N

FIGURE
C35

Document Path: P:\GIS\MMR\SmallArmsRange\GIS\Spatial\MXD\20130815_HistoricAerials\TRange.mxd

Impact Area Groundwater Study Program

LEGEND

🟥 Area of Interest

NOTES & SOURCES

Map Coordinates: Stateplane, NAD83,
FIPS Zone 2001, Meters
Historical Photo Flown: 1943

300 0 300 600 Feet

TITLE

500-yard Rifle Range

N

FIGURE
C36

Appendix D
Environmental Chemistry of Lead, Antimony and Tungsten

Appendix D
Environmental Chemistry of Lead, Antimony and Tungsten

This appendix briefly summarizes components of the environmental chemistries of lead, antimony and tungsten of potential relevance to the Small Arms Ranges.

D.1 Lead

A significant body of literature exists on the environmental chemistry of lead (Pb), including a detailed evaluation of lead at the MMR Small Arms Ranges (discussed in Section 3.2.5 and below) by Clausen et al. (2007). The following is a brief summary of some of the principal aspects of the environmental chemistry of lead.

Lead is primarily present in the +2 oxidation state in the environment including surface soils, sediments and associated mineral phases. In natural surface waters, across the primary natural range of Eh and pH conditions, lead is primarily found as the hydrated Pb^{+2} cation where it bonds directly to other inorganic or organic species. A relatively small amount of lead in the environment is associated with organic compounds, primarily as tetravalent lead, much of which was historically associated with fuels including gasoline. Lead (+2) in the solid phase and as dissolved Pb^{+2} in water is relatively immobile in the environment. Lead can form a variety of stable mineral phases including lead phosphate related minerals (discussed in Section 4.1.1.2).

In soil-water systems, dissolved lead (as Pb^{+2}) may form a variety of adsorption complexes on soil particle surfaces, including quartz, organic humic material and iron, aluminum, and manganese oxides. Lead is often significantly more strongly adsorbed to mineral surfaces than other related divalent metals including copper (Cu^{+2}), cadmium (Cd^{+2}) and zinc (Zn^{+2}). This behavior is attributed lead's larger hydrolysis constant ($\log K = -7.71$). Clausen et al. (2007) note that due to its ability to form covalent bonds with oxygen atoms on mineral surfaces and humic matter, lead is capable of significantly adsorbing to soil particles even under mildly acidic conditions ($pH>4$). This strong tendency of lead to sorb to soil/mineral surfaces is reflected in the relatively high range of equilibrium constant K_d values (27-185 ml/g) that have been estimated for soils at the Small Arms Ranges.

Some recent research (Sauvé et al. 2000a,b) has suggested that in the dissolved phase, lead may frequently not be present as the Pb^{+2} cation but rather may be bound to dissolved organic carbon (DOC), if present. Complexation to DOC may tend to increase the solubility of lead over levels predicted based upon theoretical mineral solubility products. However, as noted by Clausen et al. (2007), although dissolved organic carbon data is not available for pore-water at the Small Arms Ranges, DOC concentrations are believed to be low. This conclusion was based upon measured total organic carbon levels (TOC) in pore waters at certain ranges.

As discussed in Section 5.1.2, SPLP results indicate that leaching of lead is possible from certain Small Arms Range surface soils (such as was observed for G Range soil). This behavior is consistent with recent TCLP evaluations of firing lines reported in the literature (Dermatas et al. 2006), indicating lead leaching from firing line soils (possibly through lead carbonate precipitation dissolution). However, as emphasized by Clausen et al. (2007), lead leaching from surface soils under TCLP conditions does not correlate to significant lead migration in subsurface soils. In studies at selected Small Arms Ranges, these authors noted that essentially no lead was detected in lysimeter pore water beneath multiple ranges despite surface soil lead concentrations in excess of 1,000 mg/Kg at certain locations. These results are also consistent with the fact that there have been very few detections of lead in groundwater at monitoring wells beneath the Small Arms Ranges.

Bricka et al. (1998) quantitatively modeled the potential for lead migration from surface soils to groundwater at MMR Small Arms Ranges, estimating a potential migration time of 150-300 years. Clausen et al. (2007) noted that a number of the technical assumptions used by Bricka were relatively conservative. It was also noted that some more recent modeling efforts have suggested migration times may be significantly longer than those estimated by Bricka et al.

D.2 Antimony

The environmental chemistry of antimony (Sb) has been somewhat less studied than that of lead. However, available literature information suggests that antimony might be somewhat more mobile in certain soil-water environments than lead, particularly under oxic conditions.

In a detailed review of the environmental chemistry of antimony, Krupta and Serne (2002) noted that under natural environmental conditions, antimony exists in the +5 and +3 oxidation states. In natural aqueous systems, Sb^{+5} and Sb^{+3} are considered to be the stable oxidation states under both oxidizing and reducing conditions, based upon equilibrium thermodynamic considerations. However, contrary to thermodynamic predictions, Sb+5 and Sb+3 have been found to co-exist under some aqueous environmental conditions. Thermodynamic Eh-pH calculations suggest that under oxic conditions and low to moderate chloride, sulfate, nitrate, and carbonate concentrations (<100 mg/L), the dominant dissolved antimony species may be the hydrolytic species $Sb(OH)_6^-$ and/or a series of oxyanion species.

Only limited information is available on the sorption behavior of antimony in soil-water systems. Some research (Crecelius et al. 1975) has indicated that in relatively clean Puget Sound sediments the majority of the total antimony present was bound to amorphous/extractable iron and aluminum compounds. If dissolved antimony (as Sb^{+5}) is present in a soil-water system as an anionic species (such as $Sb(OH)_6^-$ or an oxyanion) then it may be somewhat mobile. Under these conditions, adsorption to oxide and hydroxide mineral surfaces is predicted to become negligible as pH increases from neutral to more basic levels. Under more acidic pH conditions, the adsorption of Sb^{+5} to mineral surfaces is predicted to be more significant.

Relatively little quantitative partition coefficient research data is available for antimony. Results from a series of equilibrium batch experiments (Legoux et al. 1992) for sandy clay soil samples containing a significant quartz fraction, indicated K_d values (mL/g) ranging from ~2 to 122. [The dissolved antimony concentration was 1.6×10^{-8} M]. The strongest adsorption (highest K_d value) was observed under the most acidic conditions (pH -~5.9) while the weakest adsorption was observed under mildly alkaline conditions (pH - ~8.0). These quantitative results are consistent with the predicted adsorption behavior noted above.

Overall, available geochemical literature information suggests that antimony may be somewhat mobile in surface soils at certain Small Arms Ranges depending upon the range surface and subsurface soil mineralogy and geochemical conditions. This literature based prediction appears to be consistent with the detection of antimony in certain lysimeter samples, such as those from G Range and B Range. Literature information also suggests that the extent of any antimony mobility and possible migration into the vadose zone may be closely related to the total antimony concentration in surface soil and the localized aqueous pH conditions. The potential for antimony migration into the vadose zone may be highest at locations where soil pH levels are slightly alkaline. Conversely, slightly acidic conditions would likely favor significant antimony adsorption to soil particles inhibiting subsurface migration.

D.3 Tungsten

Tungsten (W) is a Group VI transition metal with the highest boiling point (except carbon) and lowest vapor pressure of any element. Tungsten may exist in a variety of oxidation states (-2 to +6) and coordination numbers (5-9) making its chemical behavior among the more complex of the transition elements. Due to its rather unique properties, it is frequently alloyed with carbon or other metals and has been used in various munitions related components including bullets used at the Small Arms Ranges. Historically, tungsten had been considered to have somewhat limited chemical activity. However, recent studies suggest that the environmental chemistry of tungsten may be relatively complex.

In natural terrestrial systems, tungsten exists primarily in the form of oxo-rich tungstate minerals either as scheelite ($CaWO_4$) or wolframite ($[Fe/Mn]WO_4$). Surface rocks have been reported to typically contain tungsten in the range of 1.0-1.3 mg/Kg and natural surface soils at levels ranging from approximately 0.7 -2.7 mg/Kg. However, available terrestrial data is limited and localized areas may diverge significantly from these ranges.

As discussed in the detailed review by Koutsopyros et al. (2006), limited available information suggests that metallic tungsten will, in fact, slowly dissolve in water. Studies (Lassner and Schubert 1999) suggest that tungsten dissolution rates in distilled water, although generally slow at lower temperatures (38C) can over sufficient time periods generate measurable equilibrium tungsten aqueous phase concentrations. In more recent work on metallic tungsten, short term dissolution into distilled water has been reported to result in equilibrium aqueous phase concentrations of approximately 500 µg/L within three days (Braida et al. 2002). Dissolution rates on the order of 500 µg per day were reported over approximately one week time frames. In natural systems dissolution rates would be expected to vary markedly depending upon the chemistry of the natural water aqueous phase including the presence of complexing ligands. The solid phase form of tungsten (metallic or alloy), solid phase-water mixing ratios and overall hydrologic exposure factors are also expected to influence dissolution rates.

Under alkaline to neutral pH conditions, monomeric tungstate ($WO_4{}^{2-}$) is believed to the primary soluble phase. It is considered to be primarily stable above pH 6.2 in aqueous systems in the absence of complexing agents. However, in the presence of inorganic anions (including F and Cl) and/or naturally occurring organic matter, the formation of multiple soluble complexes is possible. Conversely, under even mildly acidic conditions, recent information (Koutsopyros et al. 2006) suggests that the monomeric tungstate may tend to polymerize to form multiple forms of isopolytungstates (including $W_7O_{24}{}^{-6}$) of potentially complex chemical structure.

Soluble aqueous phase tungsten species have been shown to undergo sorption reactions with various types of soils, as has been observed for a number of transition metals. Tungsten adsorption to naturally occurring clays (montmorillanite, illite, sigma sand and peat) has been observed (Dermatas et al. 2004). In these laboratory studies the most extensive adsorption of aqueous phase tungsten (initially dissolved from munitions alloys) was found to occur to organic containing peat, suggesting W/organic humic-matter interactions may be environmentally important. For inorganic clays and sand, tungsten adsorption from the aqueous phase was also observed, albeit at lower levels. For inorganic mineral phases the primary mechanism for sorption was postulated to be chemisorption of the tungstate anion on reactive metal hydroxyl sites on the solid phase.

In these sorption studies, adsorbed tungsten was found to desorb from soils although the desorption isotherms were noted to be hysteretic, suggesting partial irreversibility. The extent of tungsten adsorption to clays and soils was observed to be potentially impacted by the presence of other anions in the aqueous phase. Soluble phosphate was observed to inhibit the adsorption of tungsten by organic containing peat soil, essentially enhancing the mobility of the tungsten. In other recent studies (Bednar et al. 2008), tungstate partition coefficients for soils were found to increase somewhat over time suggesting gradually increased soil sorption and potentially decreased mobility. Overall, these laboratory studies suggested that in environmental systems soluble aqueous phase tungsten can adsorb to soils and sediments with the strength of adsorption and extent of subsequent desorption dependent upon multiple soil chemistry factors.

Clausen et al. (2007, 2010) conducted detailed laboratory and field studies on the fate and transport of tungsten from ammunition fragments at small arms ranges at the Massachusetts Military Reservation (MMR). Results of these studies suggested that under certain conditions tungsten could be solubilized from residual metal fragments from small arms ammunition in surface soils and migrate into the relatively sandy subsurface soils. Surface soil tungsten concentrations ranging from 100 mg/Kg to in excess of 1,000 mg/Kg were observed in some small arms range berm areas (Clausen and Korte 2009). Background tungsten concentrations were reported to be less than 2 mg/Kg. Soil pore water results from shallow subsurface lysimeters indicated soluble aqueous tungsten concentrations ranging up to in excess of 300 mg/L at some locations. In one localized area groundwater monitoring data indicated that tungsten had, in fact, reached the relatively deep groundwater table (greater than 50 feet). Groundwater concentrations were generally found to be less than 25 µg/L although a significantly elevated (spike) concentration of approximately 560 µg/L was reported in one sample. Recent pore water tungsten concentrations at the Small Arms Ranges have generally been less than 1 mg/L. Recent groundwater concentrations have been less than 20 µg/L.

Results of associated laboratory soil tungsten migration studies (Clausen et al. 2010) suggested that rates of tungsten migration were likely impacted by a competition between soil sorption processes and variations in rainfall patterns and localized hydrogeologic conditions over time. Preliminary results of laboratory column studies suggested that although both tungstate and polytungstate species were found in near surface pore water, tungstate was the primary species found in groundwater.

D.4 References

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Appendix E
Information for MassDEP

Appendix E
Information for MassDEP

As discussed in the main body of the report, none of the soil analytes detected at the Small Arms Ranges was determined to be a threat to groundwater. However, 10 analytes (i.e., 2,4-DNT, perchlorate, antimony, arsenic, cadmium, chromium, lead, nickel, dieldrin, and benzo(a)pyrene) were detected in soil at one or more Small Arms Ranges at concentrations exceeding MCP Method 1 S-1/GW-1 Standards (see Table 7-2 of the main Investigation Report). Nitroglycerin was detected at six active operational ranges at concentrations exceeding the calculated MCP Method 2 S-1 Standard. In addition, tungsten was detected at certain ranges at concentrations exceeding its Interim Risk-Based Soil Concentration (MassDEP 2012) and heptachloronaphthalene was detected at Succonsette Pond in one sample at a concentration that exceeded its Relative Experimental Potency (REP)-adjusted MCP Method 1 S-1/GW-1 Standard equivalent. A summary of these exceedances, including the Small Arms Range name, the analyte exhibiting the exceedance of its criterion, a descriptor for the averaging area, the analyte's frequency of detection, the number of exceedances of its criterion, its maximum detected concentration, and its average concentration within that averaging area, is provided in Table E.1. The MCP Method 1 S-1/GW-1 Standard (or its specifically noted alternative) and the MCP Method 2 S-1 Standard (for direct contact exposure only) also are shown in Table E.1.

The summary statistics provided in Table E.1 were calculated using data from all investigations conducted at the respective Small Arms Ranges. Various sampling methodologies were used during these investigations, including discrete samples; 5-point and 9-point composites samples; and multiple increment samples. Separate averages were computed for the identified averaging areas within each Small Arms Range using the combined discrete and composite sampling results and using the available multiple increment sampling results. Only those samples that were collected from within 3 feet of the ground surface (i.e., MCP "accessible" soil) were included in the averages.

The average concentration for each analyte provided in Table E.1 is range-specific and was calculated using all sample results (including the reported non-detections). Each Small Arms Range exhibiting an exceedance of its MCP Method 1 S-1/GW-1 Standard (or its specifically noted constituent-specific alternative comparison criterion) was subdivided into contiguous areas of approximately 10,000 square feet (or less) for the averaging. In general, the multiple increment sample footprints that were previously defined within these Small Arms Ranges were approximately 10,000 square feet or less, with the notable exceptions of the downrange multiple increment samples collected at SE Range, SW Range, and T Range. If multiple increment samples were collected from contiguous smaller areas, these smaller sampling areas were combined with adjacent parcels to create an averaging area of approximately 10,000 square feet. If an analyte was not detected in a sample being used to calculate an average, it was conservatively assumed that the analyte was present in that sample at ½ the sample-specific reporting limit. 2,4-DNT and nitroglycerin were detected in Range soils using both the SVOC (Methods 8270 and 8270C) and explosives (Method 8330 and 8330b) analytical methods. All of these methods are considered to be valid and each result was counted as a unique sample for this assessment. Results for the SVOC and explosives methods were tabulated separately.

At those locations where maintenance or response actions involving soil excavation and removal have been performed since 1999, (e.g., most of J Range and portions of K Range, T Range, Former B Range, Former D Range, and Former M-2 Range), only post-removal soil sampling results were utilized in the calculation of the averages to ensure that the contaminated soil that has already been removed from a range does not bias the assessment of the current conditions for that range. For those locations where tungsten-contaminated soil was removed as part of the 2006 Berm Maintenance Project (i.e., at B Range, C Range, G Range, I Range, J Range, K Range, and T Range), the results for the pre-remedial action (pre-removal) samples were not utilized if that portion of the berm has been scraped and removed.

At locations where replicate multiple increment samples were collected (i.e., B Range, Former B Range, C Range, Former C Range, D Range, Former D Range, E Range, G Range, GA and GB Ranges, H Range, I Range, J Range, K Range, KD Range (East), Former M-2 Range, N Range, O Range, SE Range, SW Range, T Range, and Succonsette Pond), each of the replicate results was used in the calculation of the average concentration.

As seen in Table E.1, in general, area average concentrations do not exceed the MCP Method 1 S-1/GW-1 or the Method 2 S-1 Standards (i.e., there are few bolded and yellow highlighted listed average concentrations). But at several (13) ranges there are average lead concentrations in a particular averaging area that exceed the Method 1 S-1/GW-1 Standard for lead. There were also three ranges with areas where the area-average concentration of dieldrin exceeded its Method 1 S-1/GW-1 Standard. There also were a few exceedances of 2,4-DNT, nitroglycerin, antimony, cadmium, and chromium. These exceedances are discussed below by specific range, averaging area, and sample type.

- <u>B Range</u> - The 2013 multiple increment samples for lead in Areas multiple increment 1, 2 and 3, (corresponding to the footprints of BR01A, BR02A and BR03A, see Figure 5-4B) and the sample for Rectangle 789 exceeded 300 mg/Kg.

- <u>Former B Range</u> - There were two areas where the average concentration of dieldrin exceeded its MCP Method 1 S-1/GW-1 Standard. These two areas correspond to the locations of samples SS73G, SS73J, and SS73K (Area 73FGIK) and samples SS73O and SS73M (Area 73OM1A) (see Figure 5-5A). Also at Former B Range, the average concentration of lead in discrete/composite samples from area 140KLMN exceeded the MCP Method 1 S-1/GW-1 Standard. Area 140KLMN includes sample locations SS140K through SS140N (see Figure 5-5A). The exceedances were observed in 2002 at location SS140L (2,410 mg/Kg at 0 to 0.5 feet bgs and 477 at 1.5 to 2.0 feet bgs). Three multiple increment post-excavation confirmatory samples collected in 2008 (SSARFBBB3 and SSSARFBTL10) and 2009 (TTSARFB1) from nearby excavation areas were below the MCP Method 1 S-1/GW-1 Standard.

- <u>C Range</u> - The 2013 multiple increment samples for lead in Areas multiple increment 1 and multiple increment 2 (corresponding to the footprints of CR01A and CR02A, see Figure 5-6B) exceeded 300 mg/Kg. There were no previous samples collected from these areas.

- <u>D Range</u> - The 2013 multiple increment sample for lead from Area 1 (corresponding to the footprint of DR01A) exceeded the MCP Method 1 S-1/GW-1 Standard. There were no previous samples collected from this area.

- Former D Range - The average concentration of lead in the combined discrete/composite samples from Area 135GSTUWY exceeded the MCP Method 1 S-1/GW-1 Standard. This area lies between two previously excavated areas (see Figure 5-9A). A 2010 multiple increment sample from this area (SSFDRNG06) had a reported lead concentration of 162 mg/Kg, which is lower than the MCP Method 1 S-1/GW-1 Standard for lead.

- E Range - The average concentration of lead in the two multiple increment samples from Area 4/South (2006 sample location SSER4S5001 – the embankment at the back of the range) exceeded 300 mg/Kg. The average concentration of nitroglycerin in multiple increment samples collected from Area 1/Center exceeded the calculated MCP Method 2 S-1 standard for those samples analyzed by explosives Method 8330, but the corresponding multiple increment average calculated using the results from the samples analyzed by SVOC Method 8270 was well below this value. The various areas for E Range are shown in Figure 5-10B.

- G Range - The average concentration of 2,4-DNT (0.74 mg/Kg using SVOC Method 8270) in Area SS128A-SS128D slightly exceeds the Method 1 S-1/GW-1 Standard (0.7 mg/Kg), but is below the MCP Method 2 S-1 Standard (2.0 mg/Kg). The 2013 multiple increment sample results for antimony and lead for Area 1A (corresponding to the footprint of GR01A, see Figure 5-12B) exceeded their respective MCP Method 1 S-1/GW-1 Standards. A 2006 performance evaluation sample (SSGRS01) from Area 1A also exceeded the MCP Method 1 S-1/GW-1 Standard for lead.

- GB Range - The average concentration of dieldrin in the discrete/composite samples collected from Area 4A (which corresponds to the footprint of the 2013 multiple increment sample GAR04A) exceeded the Method 1 S-1/GW-1 Standard due to a single detection in sample SS143X, (see Figure 5-13B).

- H Range - The average concentration of lead in the discrete/composite samples from the area of SS160A-SS160C (see Figure 5-14B) exceeded its Method 1 S-1/GW-1 Standard. All of the samples used to calculate this average were collected in 2002. More recent data from this area is not available.

- K Range - The average concentrations of lead in multiple increment samples from the areas Behind Targets 1&2 and Range Floor 5&6 (see Figure 5-17C) exceed the MCP Method 1 S-1/GW-1 Standard for lead. A single discrete/composite 2006 performance evaluation sample from the area Range Floor 3&4 slightly exceeded the MCP Method 1 S-1/GW-1 Standard for lead (304 mg/Kg versus 300 mg/Kg). The average concentration of nitroglycerin in multiple increment samples collected from Firing Line 2 exceeded the calculated MCP Method 2 S-1 standard for those samples analyzed by explosives Method 8330, but the corresponding multiple increment average calculated using the results from the samples analyzed by SVOC Method 8270 was well below this value.

- KD Range (East) - The average concentrations of chromium (total) and dieldrin in discrete/composite samples from Area 44A exceed their respective MCP Method 1 S-1/GW-1 Standards (see Figure 5-18B). These samples were collected in 1999 from three depth intervals at a single location. More recent data from this area is not available.

- Former M-2 Range - The concentration in several multiple increment samples for lead exceeded the MCP Method 1 S-1/GW-1 Standard for lead. These include samples from Areas 2, 3, ARM2/ 4, and 5 (see Figure 5-25B).
- N Range - The 2013 multiple increment samples for lead from Areas 1 and 2 (corresponding to the footprints of NR01A and NR02A, see Figure 5-28B) exceeded its MCP Method 1 S-1/GW-1 Standard. There were no previous samples collected from this area.
- Former N Range - The 2013 multiple increment sample for lead from Area 1 (corresponding to the footprint of SSFMRN01, see Figure 5-29) exceeded its MCP Method 1 S-1/GW-1 Standard. There were no previous samples collected from this range.
- SE Range - The average concentration of nitroglycerin in discrete/composite samples collected from areas SE Area, SE Area 1, SE Area 3, and SE Area behind Firing Line (see Figure 5-34B) exceeded the calculated MCP Method 2 S-1 Standard. All of these averages were calculated using sampling results for samples that were analyzed by explosives Method 8330. The average concentration of nitroglycerin in multiple increment samples collected from SE Area 2 exceeded the calculated MCP Method 2 S-1 Standard for those samples analyzed by explosives Method 8330, but the corresponding multiple increment average calculated using the results from the samples analyzed by SVOC Method 8270 was well below this value.
- Succonsette Pond - The average concentration of cadmium in discrete/composite samples collected in 2002 Area 1 (8.5 mg/Kg) is greater than the Method 1 S-1/GW-1 Standard (which is based on background), but is below the Method 2 S-2 and S-3 Standard (30 mg/Kg). A 2013 multiple increment sample from this area was well below the Method 1 and Method 2 Standards. The locations of discrete/composite samples are shown on Figure 5-37A. The locations of the 2013 multiple increment samples are shown on Figure 5-37B.
- SW Range - The average concentration of nitroglycerin in multiple increment samples collected from SW Area 2 (see Figure 5-34B) exceeded the calculated MCP Method 2 S-1 Standard for those samples analyzed by explosives Method 8330, but the corresponding multiple increment average calculated using the results from the samples analyzed by SVOC Method 8270 was below the Standard.
- T Range - The average concentration of lead in discrete/composite samples from Area 1 exceeds the MCP Method 1 S-1/GW-1 standard (see Figure 5-38B). These samples were collected in 2002 from along the Firing Line. The average concentration of lead in more recent multiple increment samples from this area was just below the MCP Method 1 S-1/GW-1 Standard, although a number of individual multiple increment samples (35) exceeded the Standard. The average concentration of chromium in multiple increment samples from several areas (i.e., Area 1, Area 2, Area 3C, Area 3E, and Area 3W - see Figure 5-38B) at T Range is greater than the Method 1 S-1/GW-1 Standard,

but the elevated chromium levels have been attributed to the grinding procedure previously used for the preparation of collected samples for analysis.

With the exception of two samples (5,800 mg/Kg at SS169A from T Range and 3,850 mg/Kg at GR01A from G Range), the maximum detected concentrations of lead at each of the ranges evaluated is below the MCP Upper Concentration Limit (UCL) value of 3,000 mg/Kg. The maximum detected concentration of cadmium at Succonsette Pond (30.9 mg/Kg) is below the cadmium UCL (i.e., 300 mg/Kg). The maximum detected concentrations of chromium at KD Range (East) and at T Range are below the chromium UCL value of 2,000 mg/Kg. The maximum detected concentrations of dieldrin at Former B Range and KD Range (East) are below the dieldrin UCL of 20 mg/Kg. The maximum detected concentration of 2,4-DNT at G Range is below its UCL value of 700 mg/Kg. The maximum detected concentration of antimony at G Range is below the antimony UCL of 300 mg/Kg. There is no published MCP UCL for nitroglycerin.

Table E.1
Summary of Ranges with MCP Method 1* Exceedances

Range	Analyte	Area Descriptor	Sample Type	Frequency of Detection	Number of MCP Method 1 S-1/GW-1 Exceedances	Maximum Detected Concentration (mg/Kg)	Average Concentration (mg/Kg)	MCP Method 1 S-1/GW-1 Standard (mg/Kg)	MCP Method 2 S-1 Standard (mg/Kg)
B RANGE	CHROMIUM, TOTAL	MIS 1	MIS	0 / 1	0	Not Detected	Not Applicable	30	30
		MIS 2	MIS	0 / 3	0	Not Detected	Not Applicable	30	30
		MIS 3	MIS	0 / 1	0	Not Detected	Not Applicable	30	30
		456	Discrete/Composite	2 / 2	0	6.2	6.05	30	30
		456	MIS	28 28	0	10.8	5.04	30	30
		154_458	Discrete/Composite	6 / 6	0	4.8	2.98	30	30
		154_490	Discrete/Composite	12 / 12	0	8.1	4.41	30	30
		154_539	Discrete/Composite	12 / 12	0	11.1	4.18	30	30
	LEAD	MIS 1	MIS	1 / 1	1	**593**	**593**	300	300
		MIS 2	MIS	3 / 3	3	**826**	**672**	300	300
		MIS 3	MIS	1 / 1	1	**464**	**464**	300	300
		123	Discrete/Composite	1 / 1	0	85.7	85.7	300	300
		456	Discrete/Composite	3 / 3	0	122	64.54	300	300
		456	MIS	28 / 28	5	**1430**	150.19	300	300
		789	Discrete/Composite	1 / 1	1	**378**	**378**	300	300
		154_458	Discrete/Composite	6 / 6	0	16.4	6.53	300	300
		154_490	Discrete/Composite	12 / 12	0	23.4	11.3	300	300
		154_539	Discrete/Composite	12 / 12	0	20.5	10.93	300	300
	TUNGSTEN	MIS 1	MIS	1 / 1	0	23.4	23.4	160	160
		MIS 2	MIS	3 / 3	0	133	116	160	160
		MIS 3	MIS	1 / 1	0	9.9	9.90	160	160
		123	Discrete/Composite	1 / 1	0	18.2	18.2	160	160
		456	Discrete/Composite	3 / 3	0	77.2	50.8	160	160
		456	MIS	28 / 28	0	159	44.1	160	160
		789	Discrete/Composite	1 / 1	0	17.3	17.3	160	160
FORMER B RANGE	ANTIMONY	140AB	Discrete/Composite	0 / 7	0	Not Detected	Not Applicable	20	20
		140CDE	Discrete/Composite	0 / 4	0	Not Detected	Not Applicable	20	20
		140FG	Discrete/Composite	0 / 5	0	Not Detected	Not Applicable	20	20
		140HIJ	Discrete/Composite	0 / 6	0	Not Detected	Not Applicable	20	20
		140KLMN	Discrete/Composite	8 / 10	2	**42.9**	9.47	20	20
		140OQ	Discrete/Composite	2 / 4	0	9.6	2.97	20	20
		Area 4,5,6	Discrete/Composite	3 / 9	0	3.2	0.618	20	20
		73B	Discrete/Composite	1 / 2	0	0.44	0.350	20	20
		73C	Discrete/Composite	2 / 2	0	0.97	0.880	20	20
		73FGJK	Discrete/Composite	0 / 8	0	Not Detected	Not Applicable	20	20
		73LH	Discrete/Composite	2 / 4	0	0.86	0.510	20	20
		73OM_1A	Discrete/Composite	1 / 8	0	0.71	0.330	20	20
		73PQR	Discrete/Composite	0 / 6	0	Not Detected	Not Applicable	20	20
	DIELDRIN	140KLMN	Discrete/Composite	0 / 2	0	Not Detected	Not Applicable	0.05	0.05
		Area 4,5,6	Discrete/Composite	0 / 4	0	Not Detected	Not Applicable	0.05	0.05
		73B	Discrete/Composite	0 / 2	0	Not Detected	Not Applicable	0.05	0.05
		73C	Discrete/Composite	2 / 2	0	0.041	0.0253	0.05	0.05
		73FGJK	Discrete/Composite	4 / 8	1	**0.7**	**0.0944**	0.05	0.05
		73LH	Discrete/Composite	4 / 4	1	**0.081**	0.0378	0.05	0.05
		73OM_1A	Discrete/Composite	5 / 8	4	**0.15**	**0.066**	0.05	0.05
		73PQR	Discrete/Composite	4 / 6	0	0.046	0.0143	0.05	0.05
	LEAD	140AB	Discrete/Composite	7 / 7	0	9.1	5.80	300	300
		140CDE	Discrete/Composite	4 / 4	0	24.6	10.6	300	300
		140FG	Discrete/Composite	5 / 5	0	21.4	9.82	300	300
		140HIJ	Discrete/Composite	6 / 6	0	64.5	28.0	300	300
		140KLMN	Discrete/Composite	11 / 11	2	**2410**	**363**	300	300
		140KLMN	MIS	3 3	0	251	174	300	300
		140OQ	Discrete/Composite	4 / 4	1	**833**	242	300	300
		140OQ	MIS	1 1	0	169	169	300	300
		Area 4,5,6	Discrete/Composite	9 / 9	0	251	61.4	300	300
		Area 4,5,6	MIS	8 / 8	0	215	134	300	300
		73B	Discrete/Composite	2 / 2	0	9.8	6.95	300	300
		73C	Discrete/Composite	2 / 2	0	112	60.5	300	300
		73FGJK	Discrete/Composite	8 / 8	0	58.3	17.7	300	300
		73LH	Discrete/Composite	4 / 4	0	34.9	20.3	300	300
		73OM_1A	Discrete/Composite	7 / 7	0	21.6	13.8	300	300
		73PQR	Discrete/Composite	6 / 6	0	52.9	23.0	300	300
C RANGE	LEAD	MIS 1	MIS	1 / 1	1	**480**	**480**	300	300
		MIS 2	MIS	1 / 1	1	**749**	**749**	300	300
		MIS 3	MIS	1 / 1	0	103	103	300	300
		MIS 4	MIS	1 / 1	0	192	192	300	300
		155AB	Discrete/Composite	6 / 6	0	16.9	7.17	300	300
		155CD	Discrete/Composite	7 / 7	0	112	23.8	300	300
		155E	Discrete/Composite	8 / 8	1	**383**	55.4	300	300
FORMER C RANGE	LEAD	136ABSTUV	Discrete/Composite	13 / 13	1	**573**	128	300	300
		136CN	Discrete/Composite	4 / 4	0	53.6	21.1	300	300
		136DJLM	Discrete/Composite	17 / 17	4	**1560**	223	300	300
		136EF	Discrete/Composite	4 / 4	0	118	48.1	300	300
		136GHWXYZ	Discrete/Composite	12 / 12	2	**446**	99.6	300	300
		136I	Discrete/Composite	3 / 3	0	14.8	12.1	300	300
		136K	Discrete/Composite	2 / 2	0	4	3.95	300	300
		136OPQR_1A	Discrete/Composite	9 / 9	0	54.2	32.4	300	300
D RANGE	LEAD	AB	Discrete/Composite	12 / 12	1	**1030**	135	300	300
		Area 1	MIS	1 / 1	1	**1840**	**1840**	300	300
FORMER D RANGE	LEAD	135AB	Discrete/Composite	4 / 4	0	8	4.80	300	300
		135GSTUWY	Discrete/Composite	12 / 12	3	**2900**	**398**	300	300
		135GSTUWY	MIS	1 / 1	0	162	162	300	300
		1A_135JK	Discrete/Composite	10 / 10	0	57.6	20.0	300	300
		1A_135JK	MIS	3 / 3	0	194	151	300	300
		2A	Discrete/Composite	1 / 1	0	169	169	300	300
		3A	Discrete/Composite	3 / 3	0	199	178	300	300
		4A_135LM	Discrete/Composite	7 / 7	0	29.4	12.6	300	300
		4A_135LM	MIS	2 / 2	0	96.8	94.2	300	300
		D1E	MIS	1 / 1	0	165	165	300	300
		D2	MIS	3 / 3	0	104	75.7	300	300
		D3A3B	MIS	1 / 1	0	80.4	80.4	300	300
		D3C3D	MIS	2 / 2	0	107	84.9	300	300
		D4S4N	MIS	3 / 3	0	39	32.8	300	300

Table E.1
Summary of Ranges with MCP Method 1* Exceedances

Range	Analyte	Area Descriptor	Sample Type	Frequency of Detection	Number of MCP Method 1 S-1/GW-1 Exceedances	Maximum Detected Concentration (mg/Kg)	Average Concentration (mg/Kg)	MCP Method 1 S-1/GW-1 Standard (mg/Kg)	MCP Method 2 S-1 Standard (mg/Kg)
E RANGE	LEAD	Area 1/Center	Discrete/Composite	7 / 7	0	15.9	8.07	300	300
		Area 1/Center	MIS	4 / 4	0	12.7	9.9	300	300
		Area 1/North	Discrete/Composite	13 / 13	0	142	31.4	300	300
		Area 1/North	MIS	1 / 1	0	70.4	70.4	300	300
		Area 1/South	Discrete/Composite	12 / 12	0	261	73.0	300	300
		Area 1/South	MIS	1 / 1	0	17	17.0	300	300
		Area 2/Center	MIS	1 / 1	0	26.4	26.4	300	300
		Area 2/North	MIS	1 / 1	0	34	34.0	300	300
		Area 2/South	MIS	1 / 1	0	23	23.0	300	300
		Area 3/Center	MIS	3 / 3	0	108	97.8	300	300
		Area 3/North	MIS	1 / 1	0	68.2	68.2	300	300
		Area 4/North	MIS	1 / 1	0	264	264	300	300
		Area 4/South	MIS	2 / 2	2	**555**	**495**	300	300
		Area 5/Soil Pile 1	MIS	1 / 1	0	140	140	300	300
		Area 5/Soil Pile 2	MIS	1 / 1	0	170	170	300	300
	NITROGLYCERIN	Area 1/Center	MIS / 8330	4 / 5	3	**9.3**	**5.49**	-	4.4
		Area 1/Center	MIS / 8270	3 / 3	0	0.12 NJ	0.117	-	4.4
		Area 1/North	MIS / 8330	1 / 1	0	2.7 J	2.7 J	-	4.4
		Area 1/South	MIS / 8300	0 / 1	0	Not Detected	Not Applicable	-	4.4
		Area 2/Center	MIS / 8330	0 / 3	0	Not Detected	Not Applicable	-	4.4
G RANGE	2,4-DINITROTOLUENE	128ABCD	Discrete/Composite / 8270	17 / 24	8	**3.4**	**0.739**	0.7	2.0
		SSGPO01	Discrete/Composite / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
	ANTIMONY	128ABCD	Discrete/Composite	17 / 24	0	14.2	2.27	20	20
		Area 1A	MIS	1 / 1	1	**25.4**	**25.4**	20	20
	LEAD	128ABCD	Discrete/Composite	24 / 24	1	**497**	88.4	300	300
		Area 1A	Discrete/Composite	1 / 1	1	**566**	**566**	300	300
		Area 1A	MIS	1 / 1	1	**3,850**	**3,850**	300	300
GA RANGE	2,4-DINITROTOLUENE	143ABCDEFGHIJK	Discrete/Composite / 8330	0 / 17	0	Not Detected	Not Applicable	0.7	2.0
		143ABCDEFGHIJK	Discrete/Composite / 8270	1 / 24	1	**0.96**	0.22	0.7	2.0
		143LMNO	Discrete/Composite / 8330	0 / 9	0	Not Detected	Not Applicable	0.7	2.0
		143LMNO	Discrete/Composite / 8270	0 / 9	0	Not Detected	Not Applicable	0.7	2.0
		143PR	Discrete/Composite / 8270	0 / 8	0	Not Detected	Not Applicable	0.7	2.0
		143UV	Discrete/Composite / 8270	1 / 9	0	0.29	0.195	0.7	2.0
		1A_143Q	Discrete/Composite / 8270	0 / 5	0	Not Detected	Not Applicable	0.7	2.0
		1A_143Q	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
		2A_143ST	Discrete/Composite / 8270	0 / 9	0	Not Detected	Not Applicable	0.7	2.0
		2A_143ST	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
	CHROMIUM, TOTAL	143ABCDEFGHIJK	Discrete/Composite	24 / 24	2	**54**	10.6	30	30
		143LMNO	Discrete/Composite	9 / 9	0	15.6	7.11	30	30
		143PR	Discrete/Composite	8 / 8	0	14.2	9.25	30	30
		143UV	Discrete/Composite	9 / 9	0	9.3	7.33	30	30
		1A_143Q	Discrete/Composite	5 / 5	0	20.5	13.8	30	30
		2A_143ST	Discrete/Composite	9 / 9	0	9	5.54	30	30
	NICKEL	143ABCDEFGHIJK	Discrete/Composite	24 / 24	1	**25.2**	5.19	20	20
		143LMNO	Discrete/Composite	9 / 9	0	7.1	4.46	20	20
		143PR	Discrete/Composite	8 / 8	0	7.3	4.15	20	20
		143UV	Discrete/Composite	8 / 9	0	4	3.27	20	20
		1A_143Q	Discrete/Composite	5 / 5	0	8	5.76	20	20
		2A_143ST	Discrete/Composite	5 / 9	0	5.5	2.09	20	20
GB RANGE	2,4-DINITROTOLUENE	Area 3A	MIS / 8330	0 / 3	0	Not Detected	Not Applicable	0.7	2.0
		Area 4A	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
	DIELDRIN	Area 3A	Discrete/Composite	1 / 9	0	0.0041	0.00200	0.05	0.05
		Area 4A	Discrete/Composite	4 / 4	1	**0.17**	**0.057**	0.05	0.05
H RANGE	2,4-DINITROTOLUENE	160ABC	Discrete/Composite / 8270	16 / 18	2	**1.1**	0.386	0.7	2.0
	ANTIMONY	160ABC	Discrete/Composite	18 / 18	2	**33.7**	10.0	20	20
		1A	MIS	3 / 3	0	2.4	2.20	20	20
	LEAD	160ABC	Discrete/Composite	18 / 18	10	**2600**	**820**	300	300
		1A	MIS	3 / 3	0	262	222	300	300
I RANGE	LEAD	129ABCD	Discrete/Composite	25 / 25	1	**585**	56.4	300	300
		129EFG	Discrete/Composite	6 / 6	0	35.3	10.4	300	300
		1A	MIS	4 / 4	0	230	172	300	300
J RANGE	ANTIMONY	Range Floor 1,2,3	MIS	1 / 33	0	0.1	0.990	20	20
	LEAD	Range Floor 1,2,3	MIS	51 / 51	0	192	45.5	300	300
	NITROGLYCERIN	Firing Line 1,2,3	MIS / 8330	0 / 3	0	Not Detected	Not Applicable	--	4.4
		Range Floor 1,2,3	MIS / 8330	29 36	7	**11.9**	3.2	--	4.4
K RANGE	LEAD	Behind Targets 1&2	MIS	8 / 8	8	**955**	**755**	300	300
		Firing Line 2	MIS	8 / 8	0	137	79.2	300	300
		Range Floor 1&2	MIS	4 / 4	0	55.3	49.7	300	300
		Range Floor 3&4	Discrete/Composite	1 / 1	1	**304**	**304**	300	300
		Range Floor 3&4	MIS	44 / 44	0	35.5	24.7	300	300
		Range Floor 5&6	MIS	2 / 2	2	**706**	**585**	300	300
	NITROGLYCERIN	Behind Targets 1&2	MIS / 8330	3 / 4	0	3	2.412	--	4.4
		Firing Line 2	Discrete/Composite / 8330	2 / 2	0	1.9	1.6	--	4.4
		Firing Line 2	MIS / 8330	3 4	3	**46**	**27.8**	--	4.4
		Firing Line 2	MIS / 8270	5 5	0	1.1	0.6	--	4.4
		Range Floor 1&2	MIS / 8330	2 / 3	0	3.9	2.65	--	4.4
		Range Floor 3&4	MIS / 8330	26 / 36	8	**22.4**	3.9	--	4.4
		Range Floor 5&6	MIS / 8330	1 / 1	0	Not Detected	Not Applicable	--	4.4

Table E.1
Summary of Ranges with MCP Method 1* Exceedances

Range	Analyte	Area Descriptor	Sample Type	Frequency of Detection	Number of MCP Method 1 S-1/GW-1 Exceedances	Maximum Detected Concentration (mg/Kg)	Average Concentration (mg/Kg)	MCP Method 1 S-1/GW-1 Standard (mg/Kg)	MCP Method 2 S-1 Standard (mg/Kg)
KD Range (East)	CHROMIUM, TOTAL	162ABC	Discrete/Composite	18 / 18	0	17.7	10.9	30	30
		162DEF	Discrete/Composite	20 / 20	0	11.2	8.99	30	30
		162GHI	Discrete/Composite	20 / 20	0	19.5	11.5	30	30
		162JK	Discrete/Composite	6 / 6	0	19	16.1	30	30
		44A	Discrete/Composite	3 / 3	1	**57.4**	**33.2**	30	30
	DIELDRIN	162JK	Discrete/Composite	1 / 6	0	0.0094	0.0033	0.05	0.05
		44A	Discrete/Composite	3 / 3	1	**0.15**	**0.078**	0.05	0.05
	NICKEL	162ABC	Discrete/Composite	18 / 18	0	8.8	4.53	20	20
		162DEF	Discrete/Composite	20 / 20	0	5.2	3.33	20	20
		162GHI	Discrete/Composite	20 / 20	0	15.6	5.59	20	20
		162JK	Discrete/Composite	6 / 6	0	8.7	6.12	20	20
		44A	Discrete/Composite	3 / 3	1	**28.3**	16.7	20	20
L-2 RANGE	DIELDRIN	67ADF	Discrete/Composite	0 / 7	0	Not Detected	Not Applicable	0.05	0.05
		67BCE	Discrete/Composite	3 / 6	1	**0.068**	0.0145	0.05	0.05
L-3 RANGE	LEAD	208ABABBBO	Discrete/Composite	9 / 9	1	**354**	102	300	300
		208CDCBHB	Discrete/Composite	8 / 8	0	96.5	29.8	300	300
FORMER M-2	BENZO(a)PYRENE	164KL	Discrete/Composite	4 / 8	1	**2.5**	0.598	2	2
	LEAD	164KL	Discrete/Composite	8 / 8	3	49.9	16	300	300
		ARM1 / 1ABC	MIS	4 / 4	0	162	116	300	300
		2	MIS	1 / 1	1	**365**	**365**	300	300
		3	MIS	1 / 1	1	**1200**	**1200**	300	300
		ARM2 / 4	MIS	4 / 4	3	**631**	**439**	300	300
		5	MIS	1 / 1	1	**332**	**332**	300	300
		6	MIS	1 / 1	1	40.1	40.1	300	300
		164KL	MIS	8 / 8	3	49.9	16	300	300
N RANGE	2,4-DINITROTOLUENE	101EK	Discrete/Composite / 8330	0 / 16	0	Not Detected	Not Applicable	0.7	2.0
		101EK	Discrete/Composite / 8270	0 / 16	0	Not Detected	Not Applicable	0.7	2.0
		165ABC	Discrete/Composite / 8330	0 / 2	0	Not Detected	Not Applicable	0.7	2.0
		165ABC	Discrete/Composite / 8270	14 / 21	2	**1**	0.275	0.7	2.0
		165CDE	Discrete/Composite / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
		165CDE	Discrete/Composite / 8270	5 / 15	0	0.22	0.144	0.7	2.0
	LEAD	101EK	Discrete/Composite	3 / 3	0	8.4	6.00	300	300
		165ABC	Discrete/Composite	21 / 21	0	31.1	12.3	300	300
		165CDE	Discrete/Composite	15 / 15	0	21.2	7.49	300	300
		Area 1	MIS	1 / 1	1	**724**	**724**	300	300
		Area 2	MIS	1 / 1	1	**337**	**337**	300	300
FORMER N	LEAD	Area 1	MIS	1 / 1	1	**1670**	**1670**	300	300
O RANGE	NICKEL	166ABDE	Discrete/Composite	26 / 26	1	**30.2**	6.44	20	20
		166GH	Discrete/Composite	13 / 13	0	7.4	5.37	20	20
SE RANGE	2,4-DINITROTOLUENE	SE Area	Discrete/Composite / 8330	1 / 2	0	0.55	0.305	0.7	2.0
		SE Area	Discrete/Composite / 8270	2 7	1	**0.82**	0.278	0.7	2.0
		SE Area 1	Discrete/Composite / 8330	1 / 1	0	0.18	0.180	0.7	2.0
		SE Area 2	Discrete/Composite / 8270	8 / 18	0	0.51	0.158	0.7	2.0
		SE Area 2	MIS / 8330	1 / 3	0	0.35	0.156	0.7	2.0
		SE Area 2	MIS / 8270	1 / 3	0	0.21 J	0.180	0.7	2.0
		SE Area 3	Discrete/Composite / 8330	1 / 1	0	0.33	0.330	0.7	2.0
		SE Area 3	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
		SE Area 3	MIS / 8270	0 / 2	0	Not Detected	Not Applicable	0.7	2.0
		SE Area 4B	Discrete/Composite / 8330	0 / 2	0	Not Detected	Not Applicable	0.7	2.0
		SE Area 4B	Discrete/Composite / 8270	0 / 2	0	Not Detected	Not Applicable	0.7	2.0
		SE behind FL	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
		SE behind FL	MIS / 8270	0 / 1	0	Not Detected	Not Applicable	0.7	2.0
	LEAD	SE Area	Discrete/Composite	7 / 7	0	27.8	10.0	300	300
		SE Area 2	Discrete/Composite	18 / 18	0	18.6	9.06	300	300
		SE Area 2	MIS	3 / 3	0	13.1	9.37	300	300
		SE Area 3	MIS	4 / 4	0	74.7	26.5	300	300
		SE Area 4A	MIS	5 / 5	1	**710**	234	300	300
		SE Area 4B	Discrete/Composite	2 / 2	0	100	63	300	300
		SE Area 4B	MIS	2 / 2	1	**519**	273	300	300
		SE behind FL	MIS	1 / 1	0	10.2	10.2	300	300
		SW Area 2	MIS	1 / 1	0	14.5	14.5	300	300
	NICKEL	SE Area	Discrete/Composite	7 / 7	0	5.5	4.07	20	20
		SE Area 2	Discrete/Composite	18 / 18	1	**73.1**	8.47	20	20
		SE Area 4A	MIS	4 / 4	0	8.4	7.03	20	20
		SE Area 4B	Discrete/Composite	2 / 2	0	6.2	5.60	20	20
	NITROGLYCERIN	SE Area	Discrete/Composite / 8330	1 / 2	1	**41**	**21.125**	--	4.4
		SE Area 1	Discrete/Composite / 8330	1 / 1	1	**11**	**11**	--	4.4
		SE Area 2	MIS / 8330	2 / 3	1	**26**	**9.983**	--	4.4
		SE Area 2	MIS / 8270	1 / 1	0	1.1	1.1	--	4.4
		SE Area 3	Discrete/Composite / 8330	1 / 1	1	**32**	**32**	--	4.4
		SE Area 3	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	--	4.4
		SE Area 4B	Discrete/Composite / 8330	0 / 2	0	Not Detected	Not Applicable	--	4.4
		SE behind FL	MIS / 8330	1 / 1	1	**5.9**	**5.90**	--	4.4
SUCCONSETTE POND	CADMIUM	Area 1	Discrete/Composite	6 / 7	4	**30.9**	**8.49**	2	2
		Area 1	MIS	1 / 1	0	0.048	0.048	2	2
		Area 2	Discrete/Composite	0 / 3	0	Not Detected	Not Applicable	2	2
		Area 2	MIS	1 / 1	0	0.13	0.13	2	2
	PERCHLORATE	Area 1	Discrete/Composite	2 / 7	1	**0.101**	0.0265	0.1	0.1
		Area 1	MIS	0 / 1	0	Not Detected	Not Applicable	0.1	0.1
		Area 2	MIS	0 / 1	0	Not Detected	Not Applicable	0.1	0.1

Table E.1
Summary of Ranges with MCP Method 1* Exceedances

Range	Analyte	Area Descriptor	Sample Type	Frequency of Detection	Number of MCP Method 1 S-1/GW-1 Exceedances	Maximum Detected Concentration (mg/Kg)	Average Concentration (mg/Kg)	MCP Method 1 S-1/GW-1 Standard (mg/Kg)	MCP Method 2 S-1 Standard (mg/Kg)
SW RANGE	LEAD	SW Area 1	MIS	1 / 1	0	9.9	9.90	300	300
		SW Area 2	Discrete/Composite	20 / 20	0	24.3	8.5	300	300
		SW Area 2	MIS	6 / 6	0	39.6	19.4	300	300
		SW Area 3	MIS	12 / 12	1	**344**	127	300	300
		SW Area 4A	MIS	6 / 6	1	**624**	188	300	300
		SW Area 4B	MIS	18 / 18	1	**734**	95.4	300	300
	NICKEL	SW Area 2	Discrete/Composite	20 / 20	1	**23.1**	6.95	20	20
		SW Area 4A	MIS	1 / 1	0	12	12.0	20	20
	NITROGLYCERIN	SW Area 1	MIS / 8330	1 / 1	0	3.8	3.8	--	4.4
		SW Area 1	MIS / 8270	1 / 1	0	0.4 NJ	0.4	--	4.4
		SW Area 2	MIS / 8330	2 / 3	1	**16**	**7.05**	--	4.4
		SW Area 2	MIS / 8270	2 / 2	0	0.78	0.475	--	4.4
		SW Area 3	MIS / 8330	0 / 1	0	Not Detected	Not Applicable	--	4.4
T RANGE	ANTIMONY	Area 1	Discrete/Composite	15 / 18	1	**91.9**	7.58	20	20
		Area 1	MIS	59 / 91	0	17.9	1.86	20	20
		Area 2	MIS	6 / 12	0	0.49	1.11	20	20
		Area 3C	MIS	0 / 2	0	Not Detected	Not Applicable	20	20
		Area 3E	MIS	0 / 1	0	Not Detected	Not Applicable	20	20
		Area 3W	MIS	0 / 1	0	Not Detected	Not Applicable	20	20
	ARSENIC	Area 1	Discrete/Composite	15 / 18	1	**23.4**	4.25	20	20
		Area 1	MIS	6 / 6	0	3.7	2.8	20	20
		Area 2	MIS	4 / 4	0	3.9	3.33	20	20
		Area 3C	MIS	2 / 2	0	3.2	3.20	20	20
		Area 3E	MIS	1 / 1	0	3.9	3.90	20	20
		Area 3W	MIS	1 / 1	0	3.3	3.30	20	20
	CHROMIUM, TOTAL	Area 1	Discrete/Composite	18 / 18	0	21	13.0	30	30
		Area 1	MIS	6 / 6	6	**313**	**264.2**	30	30
		Area 2	MIS	4 / 4	4	**286**	**230**	30	30
		Area 3C	MIS	2 / 2	2	**190**	**183**	30	30
		Area 3E	MIS	1 / 1	1	**225**	**225**	30	30
		Area 3W	MIS	1 / 1	1	**226**	**226**	30	30
	LEAD	Area 1	Discrete/Composite	18 / 18	7	**5800**	**577**	300	300
		Area 1	MIS	91 / 91	35	**1990**	287	300	300
		Area 2	MIS	12 / 12	0	131	47.0	300	300
		Area 3C	MIS	2 / 2	0	97.1	81.7	300	300
		Area 3E	MIS	1 / 1	0	82.5	82.5	300	300
		Area 3W	MIS	1 / 1	0	41.4	41.4	300	300
	NITROGLYCERIN	2001 / 2003 Area	Discrete/Composite / 8330	0 / 16	0	Not Detected	Not Applicable	--	4.4
		Area 1	MIS	71 / 97	52	**29.7**	**8.04**	--	4.4
		Area 2	MIS	0 / 2	0	Not Detected	Not Applicable	--	4.4

NOTES:
MIS = multiple increment sample
Calculated average concentrations exceeding the applicable screening criterion are bolded and highlighted in yellow.
Maximum concentrations exceeding the applicable screening criterion are bolded.
* A calculated MCP Method 2 Standard was used to screen the sampling results for nitroglycerin.
The average was calculated using all detections and non-detections at 1/2 the sample-specific reporting limit.
The values shown for MCP Method 1 S-1/GW-1 and Method 2 S-1 standards for tungsten are an Interim Risk-Based Soil Concentration developed by the MassDEP Office of Research and Standards (MassDEP 2012)
The value shown for MCP Method 2 S-1 standard for nitroglycerin is a calculated value using the provisional oral reference dose (1E-4 mg/kg-day) and the default exposure parameters of the S-1 direct contact standards.

Appendix F
Additional Reports
(Available on CD)