Impact Area Groundwater Study Program

FINAL

J-1 Range Remedial Investigation/ Feasibility Study

Camp Edwards
Massachusetts Military Reservation
Cape Cod, Massachusetts

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LIST OF ACRONYMS AND ABBREVIATIONS

AFCEE	Air Force Center for Engineering and the Environment
AIRMAG	airborne magnetometer
AMEC	AMEC Earth & Environment, Inc.
ASTM	American Society for Testing and Materials
AT123D	Analytical Transient One-, Two-, and Three-Dimensional Model
bgs	below ground surface
BEHP	bis(2-ethylhexyl)phthalate
BIP	Blow in Place
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIA	Central Impact Area
COC(s)	Contaminant(s) of Concern
CSM	Conceptual Site Model
DO	dissolved oxygen
DWELs	drinking water equivalent levels
ECC	Environmental Chemical Corporation
EPA	U.S. Environmental Protection Agency
FS-12	Fuel Spill Number 12 (with an extraction, treatment and reinjection system in place and operating)
g	grams
GAC	Granular Activated Carbon
HA	health advisory
HE	high explosive
HLA	Harding Lawson Associates
HMX	Octahydro-1,3,5,7-Tetranitro-1,3,5,7-Tetrazocine
IAGWSP	Impact Area Groundwater Study Program
IX	ion-exchange resin
MAARNG	Massachusetts Army National Guard
MassDEP	Massachusetts Department of Environmental Protection
MCL	maximum contaminant level
MCP	Massachusetts Contingency Plan
MEC	munitions and explosives of concern
MMCL	Massachusetts maximum contaminant level
MMR	Massachusetts Military Reservation
msl	mean sea level
MSP	Munitions Survey Program
MTU	Mobile Treatment Unit
MW	monitoring well
NGB	National Guard Bureau
PCB	polychlorinated biphenyl
PCN	Polychlorinated naphthalene
RDX	Hexahydro-1,3,5-Trinitro-1,3,5-Triazine
RRA	Rapid Response Action
SE	Southeast Ranges
SSL	Soil Screening Level
SVOC	Semi Volatile Organic Compounds

LIST OF ACRONYMS AND ABBREVIATIONS

TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEQ	Toxic Equivalency
TIC	tentatively identified compounds
TNT	2,4,6-trinotrotoluene
USACE	United States Army Corps of Engineers
UXO	Unexploded Ordnance
VOC	Volatile Organic Compounds
2A-DNT	2-amino-4,6-dinitrotoluene
4A-DNT	4-amino-2,6-dinitrotoluene
2,4-DNT	2,4-dinitrotoluene
2,6-DNT	2,6-dinitrotoluene
3-NT	3-nitrotoluene
cm	centimeter
gpm	gallons per minute
kg	kilogram
mg	miligram
mg/Kg	milligrams per kilogram
mg/L	milligrams per liter
mm	milliliter
pCi/L	picocuries per liter
µg/Kg	microgram per kilogram
µg/L	microgram per liter

EXECUTIVE SUMMARY

This *J-1 Range Remedial Investigation/Feasibility Study (RI/FS)* presents the results of soil, UXO and groundwater characterization, geophysical investigations, and an evaluation of remedial alternatives for contaminated groundwater associated with the J-1 Range, located at the Massachusetts Military Reservation (MMR) on Cape Cod, Massachusetts.

The J-1 Range is located in the southeast portion of the MMR and is bounded to the north by the J-2 Range and to the south by the J-3 and L Ranges. From 1935 through the late 1980's, the J-1 Range was used for training and testing purposes. Activities associated with historical range uses, primarily munitions testing and disposal, have resulted in releases of explosive compounds to the soil which are the likely source of groundwater contamination beneath the site.

The groundwater underlying and downgradient of the J-1 Range is primarily contaminated by Hexahydro-1,3,5-Trinitro-1,3,5-Triazine (RDX) and perchlorate. For groundwater investigation and data presentation purposes, the J-1 Range has been divided into two sub-areas, J-1 Range northern plume and J-1 Range southern plume. This division between these two areas is based on the natural groundwater divide that is located beneath the J-1 Range. For the presentation of the source area characterization, the range was subdivided into nine sub-areas, based on the Conceptual Site Models (CSM) for each portion of the range.

J-1 Range Northern Plume

The J-1 Range northern plume is comprised of perchlorate and RDX in groundwater. The main lobe of the plume consists of perchlorate and RDX and the western lobe consists primarily of RDX with some isolated detections of perchlorate. The 2009 maximum perchlorate concentration is observed at MW-370M2 (54.5 µg/L, May 2009). The perchlorate plume has become detached from the suspected source area in the Interberm Area of the J-1 Range. Although the Main RDX plume is not fully detached from its sources, RDX concentrations in source area monitoring wells have decreased to levels that are below the health advisory (HA) of 2 µg/L. The highest 2009 detection of RDX in the plume was observed at MW-303M2 at 13.0 µg/L (May 2009). Both the perchlorate and RDX plume trajectories are north-northwest, and are associated with the Interberm Area of the J-1 Range.

The western lobe of the northern J-1 Range RDX plume has both a shallow (water table) and deeper area of contamination. Based on the CSM, the shallow portion emanates from tank targets in the Impact Area and is cross gradient of the main RDX plume. The source of the deeper contamination in the western RDX lobe has not been identified.

Soil and geophysical investigations began in 1997 and continued through 2009. The result of soil investigations in the Popper Kettle area, Cook-off Test location, the Steel-lined Pit, the Wastewater Disposal Area, Polygons 9, 10 and 16 and disposal areas in Grids J39, J36 and K36, shows soil contamination that is consistent with contamination found in downgradient groundwater. Of the known disposal areas identified during the investigation, these areas are among the source areas most responsible for development of the plumes. These features are located in the Interberm Area and the extent of the J-1 northern groundwater plume is consistent with a source area in these locations. Explosives and perchlorate soil contamination associated with these source areas has been removed. An area of elevated RDX contamination in surficial soils was identified northeast of the 1,000 meter berm. 2,4 DNT was also detected at elevated concentrations in the vicinity of Firing Point 3. Soils from these areas were excavated for on-site treatment in 2010.

A soil risk screen was conducted to evaluate the risk to human health and to evaluate the potential for detected analytes in soil to leach from the soil and migrate through the subsurface to the groundwater. The risk screen identified concentrations of RDX in the Interberm Area and at a tank target at the 2,000 meter berm exceeding the screening criteria. Contamination associated with tank targets is consistent with the development of the shallow component of the western RDX lobe downgradient of this area. 2,4-DNT was also detected in soils in the Interberm Area at concentrations exceeding screening criteria. These soils have been removed as part of ongoing response actions. All other detected analytes were at concentrations below the screening criteria, are associated with background concentrations or were detected infrequently.

A Human Health Risk Screening was conducted for the J-1 Range north groundwater. The screening identified RDX and perchlorate at concentrations exceeding the screening criteria, and were therefore recommended for further evaluation in the Feasibility Study. Several other compounds were also identified at concentrations exceeding the risk screening criteria, but these compounds were detected infrequently, are associated with naturally occurring background conditions, or are laboratory-related contaminants and therefore were not recommended for further consideration in the groundwater Feasibility Study.

Intrusive geophysical investigations identified multiple disposal pits in the Interberm Area. However, most of the finds consisted of munitions debris or other debris. The vast majority of MEC items encountered were considered small quantity energetic items. Other encountered MEC items were generally inert bodies with live fuzes or individual HE rounds. Based on the geophysical investigations, remaining geophysical anomalies in both the Interberm Area and the other portions of J-1 Range North, are likely munitions debris or other debris. However, there is the potential for residual MEC items, likely consisting of inert rounds with live fuzes or individual HE items.

Feasibility Study

A Feasibility Study was prepared to describe the development and evaluation of remedial action alternatives for the J-1 Range northern groundwater study area, based on the 2008 plume shell The Feasibility Study alternatives were developed to achieve the following response action objectives: to restore the useable groundwater to its beneficial use wherever practicable, within a timeframe that is reasonable given the particular circumstances of the site; to provide a level of protection in the aquifer that takes into account that the Cape Cod aquifer, including the Sagamore Lens, is a sole source aquifer that is susceptible to contamination; and to prevent ingestion and inhalation of groundwater containing contaminants of concern (COCs) in excess of federal maximum contaminant levels, Health Advisories, drinking water equivalent levels (DWELs), applicable State standards or an unacceptable excess lifetime cancer risk or non-cancer Hazard Index. Estimated cleanup times frames and costs for each alternative are summarized in Table 10-2. The following alternatives were evaluated:

<u>Alternative 1 – No Further Action.</u>

Monitoring wells would be abandoned and site close-out documentation would be completed. The source area soils have been removed. Perchlorate concentrations are predicted to decrease, through natural attenuation process, to below 2 µg/L by approximately 2080. RDX concentrations are predicted to decrease, through natural attenuation processes, to below 2 µg/L by approximately 2053 and to below 0.6 µg/L sometime after 2109. The response action would be complete when the existing groundwater-monitoring-well network is abandoned. The present value cost of this alternative is $144,127.

<u>Alternative 2 – Monitored Natural Attenuation and Land-Use Controls</u>

Alternative 2 includes long-term groundwater monitoring and land-use controls. The source area soils have been removed. Perchlorate concentrations are predicted to decrease, through natural attenuation processes, to below 2 µg/L by approximately 2080. RDX concentrations are predicted to decrease, through natural attenuation processes, to below 2 µg/L by approximately 2053 and to below 0.6 µg/L sometime after 2109. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $3,441,151.

<u>Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-Use Controls</u>

Alternative 3 includes construction of one extraction well, 2,100 feet of piping, a Mobile Treatment Unit (MTU), and an infiltration trench as well as land use controls. The flow rate of the system would be 125 gallons per minute (gpm). The source area soils have been removed. This alternative was evaluated using two different operational scenarios for the extraction well: Alternative 3a) the extraction well operates until the influent concentrations decrease below the method detection limit and Alternative 3b) the extraction well operates until 2030. The groundwater model indicates for Alternatives 3a, perchlorate concentrations would decrease below 2 µg/L by approximately 2042 and RDX concentrations would decrease below 2 µg/L by approximately 2038 and to below 0.6 µg/L by approximately 2048. It was estimated from groundwater modeling results, that if the extraction well was turned off in 2030 (which is predicted to be five years before influent concentrations decreased below the method detection limit), then perchlorate concentrations would decrease below 2 µg/L by approximately 2043 and RDX concentrations would decrease below 2 µg/L by approximately 2040 and to below

0.6 µg/L by approximately 2051. Alternative 3b was examined as a less expensive way to achieve cleanup levels prior to the end of the current lease in 2051. Ion-exchange resin (IX) and GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost for Alternative 3a is $12,439,320 and the present value cost for Alternative 3b is $11,763,660.

Alternative 4 – Focused Extraction with Two Wells (In-plume), Monitored Natural Attenuation and Land-Use Controls

Alternative 4 includes construction of two extraction wells, 3,500 feet of piping, two MTUs, and two infiltration trenches, as well as land use controls. The flow rate of the system would be 250 gpm. The source area soils have been removed. This alternative was evaluated using two different operational scenarios for the extraction wells: Alternative 4a) the extraction wells operate until the influent concentrations decrease below the method detection limit, which is predicted to occur in 2024, and Alternative 4b) the upgradient extraction well (J1NA5EW1) was turned off in 2015 and the downgradient extraction well (J1NA5EW2) turned off in 2023. The groundwater model indicates for Alternative 4a, perchlorate concentrations would decrease below 2 µg/L by approximately 2037 and RDX concentrations would decrease below 2 µg/L by approximately 2027 and to below 0.6 µg/L by approximately 2035. It was estimated, from groundwater modeling results that with the shortened operation scenario described above (Alternative 4b), perchlorate concentrations would decrease below 2 µg/L by approximately 2045 and RDX concentrations would decrease below 2 µg/L by approximately 2031 and to below 0.6 µg/L by approximately 2050 before the end of current lease. IX and GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of Alternative 4a is $13,057,684 and the present value cost of Alternative 4b is $11,623,876.

Alternative 5 – Focused Extraction with Two Wells (In-plume and leading edge), Monitored Natural Attenuation and Land-Use Controls

Alternative 5 includes construction of two extraction wells, 6,900 feet of piping, two MTUs located next to the J-2 Range northern plume treatment plant, and two infiltration trenches located near the J-2 Range northern plume infiltration trenches along Wood Road, as well as land-use controls. The flow rate of the system would be 250 gpm. The source area soils have been removed. The groundwater model indicates for Alternative 5, perchlorate concentrations would decrease below 2 µg/L by approximately 2035 and RDX concentrations would decrease below 2 µg/L by approximately 2037 and to below 0.6 µg/L by approximately 2047. IX and GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $14,935,898.

Alternative 6 – Focused Extraction with Five Wells, Monitored Natural Attenuation and Land-Use Controls

- Alternative 6 includes construction of five extraction wells, 4,305 feet of piping, five MTUs, and infiltration trenches, as well as land-use controls. The flow rate of the system would be 625 gpm. The source area soils have been removed. Perchlorate concentrations are estimated to decrease below 2 µg/L by approximately 2020 and RDX concentrations are estimated to decrease below 2 µg/L by approximately 2018 and to below 0.6 µg/L by approximately 2020. IX and GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $19,752,815.

J-1 Range Southern Plume

The primary site-related contaminant in the J-1 Range southern groundwater study area is RDX. In general, the plume flow trajectory is southeasterly in the area immediately downgradient of the source and more southerly toward the downgradient portion of the plume. The 2009 maximum RDX concentration is 20 µg/L (MW-481M2, May 2009)) located in the off-base portion of the plume. More than half of the plumes spatial extent is off-base. Recent groundwater characterization activities conducted in January 2010 have identified unanticipated concentrations of RDX contamination near the currently mapped boundary of the downgradient plume. Therefore, additional groundwater characterization efforts are underway to further delineate the extent of the RDX contamination. The discussion of groundwater contamination for the J-1 southern plume contained in this report is based on monitoring well data and profile data collected through 2009.

Disposal areas in the southern portion of the J-1 Range include a munitions disposal area consisting of three pits located near the former Loading and Assembly building, and Polygons 2, 3, and 4, and the suspected water saw operation. The target area consists of a 100 meter Range target. Intrusive geophysical investigations identified multiple disposal pits in the southern portion of the range. However, most of the finds consisted of munitions debris or other debris. Encountered MEC items were generally inert rounds with live fuzes or individual HE rounds. Based the geophysical investigations, remaining geophysical anomalies are likely munitions debris or other range related debris. However, there is the potential for residual MEC items, likely consisting of inert rounds with live fuzes and individual HE items.

Soil investigations began in 1997 and continued through 2009. Elevated concentrations of explosives compounds were also detected in surface soils in the vicinity of Polygons 2, 3 and 4. A soil risk screen was conducted to evaluate the risk to human health and to evaluate the potential for detected analytes in soil to leach from the soil and migrate through the subsurface to the groundwater. The risk screen identified concentrations of RDX and HMX in the vicinity of Polygons 2, 3 and 4 exceeding the screening criteria. These soils have been removed as part of ongoing response actions. All other detected analytes were at concentrations below the screening criteria, are associated with background concentrations or were detected infrequently.

A Human Health Risk Screening was conducted for the J-1 Range southern groundwater using the same screening approach as discussed for the J-1 Range northern area. RDX was identified during the screening evaluation at concentrations exceeding the screening criteria, and was therefore recommended for further evaluation in the Feasibility Study. Chloroform and arsenic also exceeded the screening criteria, but were attributable to naturally occurring background conditions and therefore were not recommended for further consideration in the Feasibility Study.

Feasibility Study

A Feasibility Study was prepared to describe the development and evaluation of remedial action alternatives for the J-1 Range southern groundwater plume, based on the January 2010 plume shell. The Feasibility Study alternatives were developed in the same manner as the J-1 northern plume. Estimated cleanup times frames and costs for each alternative are summarized in Table 10-4. The following alternatives were evaluated:

Alternative 1 – No Further Action

Monitoring wells would be abandoned and site close-out documentation would be completed. The source area soils have been removed. RDX concentrations are predicted to decrease through natural attenuation processes to below 2 µg/L by 2032 and to below 0.6 µg/L by approximately 2050. The response action would be complete when the existing groundwater monitoring well network is abandoned. The present value cost of this alternative is $111,209.

Alternative 2 –Monitored Natural Attenuation with Land-Use Controls

Alternative 2 includes long-term groundwater monitoring and land-use controls. The source area soils have been removed. RDX concentrations are predicted to decrease through natural attenuation processes to below 2 µg/L by 2032 and to below 0.6 µg/L by approximately 2050. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $1,555,596.

Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-Use Controls

Alternative 3 includes operation of the existing J-1 Range southern ETI system and land-use controls. The ETI system would operate at 45 gpm. The source area soils have been removed. RDX concentrations are predicted to decrease through treatment and natural attenuation processes to below 2 µg/L by approximately 2032 and to below 0.6 µg/L by approximately 2048. GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $2,601,620.

Alternative 4 – Focused Extraction with Two Wells, Monitored Natural Attenuation and Land-Use Controls

Alternative 4 includes operation of the existing J-1 Range southern area ETI system and supplementing it with an additional extraction well, and associated piping (2,634 feet) at locations where these can be feasibly implemented as well as land-use controls. The extracted water would be treated at the existing MTU and returned to the aquifer through the existing infiltration trench. The total flow of the ETI system would be 125 gpm. The source area soils have been removed. RDX concentrations are predicted to decrease through treatment and natural attenuation processes to below 2 µg/L by 2019 and to below 0.6 µg/L by approximately 2024. GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $4,889,422.

Alternative 5 – Focused Extraction with Three Wells, Monitored Natural Attenuation and Land-Use Controls

- Alternative 5 includes operation of the existing J-1 Range southern area ETI system, and supplementing it with two additional extraction wells and associated piping (TBD) at locations where these can be feasibly implemented as well as land-use controls. The extracted water would be treated at the existing MTU and additional MTU. The treated water would be returned to the aquifer through the existing infiltration trench and a new infiltration trench. The total flow of the ETI system would be 250 gpm. The source area soils have been removed. RDX concentrations are predicted to decrease through treatment and natural attenuation processes to below 2 µg/L by approximately 2018 and to below 0.6 µg/L by approximately 2022. GAC media would be used to treat the extracted water. The response action would be complete when two years of monitoring have shown that goals have been achieved. The present value cost of this alternative is $5,729,427.

1.0 INTRODUCTION

This *J-1 Range Remedial Investigation/Feasibility Study Report* provides a summary of activities conducted and data gathered for characterization of soil, UXO and groundwater contamination at the J-1 Range. The J-1 Range is among several training areas, ranges, and other sites evaluated by the IAGWSP for potential groundwater impacts. The investigation at the J-1 Range and a groundwater rapid response action are conducted under the authority of the United States Environmental Protection Agency 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).

1.1 Purpose of Report

The purpose of this report is to present the scope of soil and groundwater characterization activities conducted for the J-1 Range. This report presents the results of the J-1 Range investigations, remedial actions completed to date, the nature and extent of soil and groundwater contamination, and potential impacts to groundwater quality and the risks associated with the contamination. This report also includes a Feasibility Study, which evaluates remedial actions for groundwater contaminants.

1.2 Report Organization

Section 2.0 of this report provides a site description of the J-1 Range and its subcomponent areas and presents the history of past military and testing activities conducted at the range and describes the physical characteristics of the site. A summary of groundwater characterization activities, nature and extent of groundwater contamination and groundwater modeling is presented in Section 3.0. Section 4.0 presents a summary of geophysical and soil investigations and findings including an evaluation of the potential for remaining unexploded ordnance. The conceptual site model is presented in Section 5.0. The soil and groundwater risk screening is presented in Section 6.0. Section 7.0 presents the remedial investigation findings. Section 8.0 introduces the groundwater feasibility study. Section 9.0 discusses the development of alternatives. Detailed analysis of the alternatives is presented in Section 10.0, while Section 11.0 provides the comparative analysis of alternatives. Section 12.0 summarizes the feasibility study findings.

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2.0 SITE BACKGROUND

The Massachusetts Military Reservation (MMR) includes Camp Edwards, Otis Air National Guard Base, United States Coast Guard Air Station Cape Cod, Cape Cod Air Force Station, and the Veteran's Affairs Cemetery. It is located on the western side of Cape Cod, Massachusetts (Figure 2-1). The J-1 Range Investigation Area is located southeast of the Impact Area between the J-2, J-3 and L Ranges. A depiction of investigation areas for both soil and groundwater are shown in Figures 2-2 through 2-4.

2.1 Site Description

The J-1 Range is located adjacent to (and partially within) the Impact Area and is one of four former training ranges that comprise the Southeast Ranges (SE Ranges) (Figure 2-1). The SE Ranges are former military training and defense contractor test ranges that operated from the 1930s until the 1990s (AMEC 2004). The J-1 Range is approximately 2,000 meters long and between 50- and 250-meters wide. The range is oriented southeast to northwest, with the southeastern "uprange" end near Greenway Road and the northwestern "downrange" end extending several hundred meters beyond Chadwick Road into the impact area. A dirt road runs down the entire length of the range. The terrain is undulating with natural and man-made depressions but no surface water bodies of any kind. There are five large man-made berms located at various distances along the length of the range. Two "tunnel" barriers, located toward the southeastern end of the range, have eight foot diameter concrete culverts buried within them. These were designed to constrain the trajectory of fired artillery rounds, which would pass through the tunnels in their flight toward targets placed in front of impact berms located 1,000 and 2,000 meters downrange. Off-target rounds would be stopped by the tunnel barriers, preventing untargeted downrange flight. A fifth "150 meter" berm is located near the 1,000 meter berm. The current layout and features of the J-1 Range is depicted in Figure 2-5.

The only structure remaining on the Range is a concrete bunker located near the 1,000 meter berm. Access to the J-1 Range is currently restricted by a locked gate located at Greenway Road.

2.2 Site History

The following presents a general summary of the historical uses of the area, with more detailed descriptions following. Available aerial photographs are presented in Figures 2-6 through 2-9)

- <u>1935 to 1950s</u> – **I Range**; used as an estimation range, rifle range and anti-tank range;
- <u>1940s to 1950s</u> – **J-1 Transition Range**; used as a small arms range;
- <u>1957 to late 1980s</u> – **J-1 DoD Contractor Test Range**; used for munitions testing.

I Range (1935 to 1950s)

The I Range was developed in 1935 along the west side of Greenway Road as an estimation range (Figure 2-6). The estimation range consisted of a series of markers at known distances that were used for training in distance estimation. No firing was reportedly conducted on this range. Through the 1950s, the I Range was used as an anti-tank range where moving targets were mounted on sleds and controlled by cables and pulleys from the rear of the firing positions. There is no further documentation of the purpose of the range or the ammunition used.

J-1 Transition Range (1940s to 1950s)

The J-1 Range was initially established in the 1940s as a transition range and used until the 1950s (Figure 2-6). The 1955 aerial photograph (Figure 2-6), shows that this area has been further developed and includes what appears to be a firing line and accompanying targets. The range consisted of nine firing lanes, each lane with pop-up targets originating in target control pits spaced 25- to 50-yards apart, up to 500 yards out from the firing positions. Available documentation does not include the types of weaponry used on the range.

J-1 DoD Contractor Test Range (1957 to the late 1980s)

From 1957 to 1986, the J-1 Range area was utilized as a test range by the following DoD contractors; American Potash and Chemical Corporation (1957-1960), Atlantic Research Corporation (1960 to 1975), Norris Industries/Hesse-Eastern Division (1975 to 1980) and AVCO, (1980 to 1986) (later known as Textron).

The expansion of the J-1 range to support Contractor activities is evident in the 1966 and 1977 aerial photographs (Figures 2-7 and 2-8).

The following activities were conducted on the J-1 Range by the DoD contractors:

Testing Activities

Munitions Testing - Testing on the range in the 1950s and 1960s included 60mm, 81mm and 4.2-inch mortars, 105mm, 155mm howitzers, 20mm, and eight-inch guns and 0.50 caliber machine guns. The majority of rounds fired were inert; the explosives used were primarily associated with the propellant and the fuze primers (HLA 2000).

105 mm Tank Barrel Testing – Over-pressure testing on the 105mm tank barrels using 105mm High Explosives Anti-Tank munitions and sabot rounds was conducted from 1975 through 1986. Typically, these munitions were fired at cloth targets located downrange, passing through the tunnel barriers in flight. The 105mm M456 High Explosives Anti-Tank Tracer rounds and 105mm M490 TP-T (target practice, inert) rounds were fired to evaluate warhead dispersion at various distances; the interior

ballistics and velocity of the projectile; and fuze and warhead performance (HLA 2000). An estimated 39,000 105mm rounds were fired at the J-1 Range (USACE 1999a), the majority of which were reportedly inert.

40mm Practice Grenade Testing – A two-day test was conducted with 40mm practice grenades to determine the effects of firing plastic-nosed rounds at extremely cold temperatures.

Cook-off Tests - 5.56mm, 7.6mm, and 0.45 caliber small arms ammunition were reportedly placed in a large steel pan (approximately 4 feet by 5 feet) along with fuel and waste oil; the mixture was ignited and observed to determine the detonation temperature of the munitions. This testing was used to determine the hazard classification of the munitions. MW-191 was installed at the suspected location. Another source suggests that the cook-off tests were completed at J-3 Range, not J-1 Range (HLA 2000).

Disposal Activities

Propellant Burning – Excess propellant for the 105mm High Explosives Anti-Tank munitions was reportedly burned in the middle of the range road; however, the specific location of the burning is not known (USACE 1999a).

Explosive Debris Burning – Excess propellant, unexploded ordnance (UXO) and other miscellaneous explosive debris were burned on the J-1 Range in two areas:

- Steel-lined Pit: Excess propellant, UXO and other miscellaneous debris were burned in a former steel-lined pit. This pit had a steel floor with a hole in the middle, three steel-lined walls, and was open on the east side. An investigation of the pit was conducted in 1999 (Ogden 2000).
- Explosives were reportedly burned in an area northeast of the 2,000 meter berm. This disposal area was reportedly used by the U.S. Air Force Explosive Ordnance Disposal unit (HLA 2000). This statement has never been substantiated.
- Excess propellant bags were reportedly burned in an area around the berms at the beginning of the range. (USACE 1999a).

Wastewater Disposal - Approximately 1,200 gallons of process wastewater were released into a depression between the two telephone poles at the 1,000 meter range target area. The process wastewater was generated from the milling of explosives at the J-3 Range melt/pour building and from cleaning the melt/pour bay after each casting. This was reportedly a one-time disposal in the 1980s, prior to 1987 (HLA 2000).

Miscellaneous Disposal – Additional suspected disposal areas were noted in interviews with a former range employee (USACE 1999b, Cullity Interview). Suspected disposal areas were described in two locations; one on the north side of 150 meter Berm and another in a depression off of Barlow Road, south of 150 meter Berm and the range road. Burned 20mm rounds and steel plates were observed in the depression. It was also reported that drums of carbon disulfide were observed at the J-1 Range; however, no locations were specified (USACE 1999b, Cullity Interview). Atlantic Research Corporation, in their Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) 104(e) response, indicated that the following excess or scrap explosives were disposed of by open detonation: Octahydro-1,3,5,7-Tetranitro-1,3,5,7-Tetrazocine (HMX), Comp-B, 2,4,6-trinotrotoluene (TNT), dynamite, and lead azide. Their information was inconclusive as to whether all of these compounds were disposed of specifically at the J-1 Range. However, it can be presumed that disposals occurred at the J-1 Range since this is the range on MMR on which Atlantic Research conducted testing activities.

Based on witness interviews, excess explosives from the button bomblet anti-personnel mine were also burned near the 1,000 meter range, in an unknown location (USACE 2001). The excess explosives consisted of a slurry of lead azide, Hexahydro-1,3,5-Trinitro-1,3,5-Triazine (RDX), and ground glass.

Propellant was reportedly cut with a water saw in front of the instrumental building.

Late 1980s to the Present

In the late 1980s, the former I Range and the J-1 Range were combined under the designation M Range; however, no specific activity is documented to have occurred under that designation and available aerial photography indicates significant revegetation has occurred (Figure 2-9).

Previous investigations have identified several features on the J-1 Range; the locations of these are depicted on Figure 2-5. Most investigation activities, as further described in Section 4.0, focused on these site features. A description of each feature follows:

- Firing Position 1 - the suspected firing point for the 1,000 meter range located on an earthen mound, south of the range road. Equipment pads and a mortar position are located in the same vicinity.
- Firing Position 2 - the suspected firing position for the 100 meter and 2,000 meter ranges located on an earthen mound on the northern side of the range road, northeast of Firing Point 1.
- Former Buildings and Storage Area - the buildings at the southeast end of the range included three storage buildings for gun barrels and jeeps, a loading and assembly building, an instrumentation building, three steel magazines, a semi-trailer, and a wooden range tower.
- Tunnel Barrier 1 - a 135-foot by 75-foot, 60-foot high earthen mound tunnel barrier. An eight-foot diameter concrete pipe passes through the middle of the mound. Steel plates surround the entrance to the tunnel.
- Steel Plate Target for 100 meter Range - located on the same earthen mound as Tunnel Barrier 1. The steel plates were reported placed to surround the entrance to the Tunnel Barrier.

- Tunnel Barrier 2 - a 100 foot by 70 foot, 40-foot high earthen mound tunnel barrier. An eight-foot diameter concrete pipe passes through the middle of the mound. Steel plates surround the entrance to the tunnel.
- Firing Position 3 - the suspected firing point for the 150 meter range near the 1,000 meter berm.
- 1,000 meter berm - a 100 foot by 100 foot, 45-foot high earthen backstop mound with steel plates at the end of the 1,000 meter range. A depression in front of the mound near the former popper kettle is believed to be the location where wastewater generated at the J-3 Range was discharged.
- 150 meter berm - a 130 foot by 70 foot, 30-foot high earthen backstop mound at the end of the 150 meter range.
- 2,000 meter(a) berm - a 120 foot by 70 foot earthen backstop mound at the end of the 2,000 meter range within the Impact Area.
- 2,000 meter(b) berm - a 270 foot by 100 foot earthen backstop mound at the end of the 2,000 meter range.
- Depression – a topographic depression located southwest of 2,000 meter berm on the south side of the Range Road.
- Popper Kettle (a.k.a. Burn Kettle) - a metal kettle formerly located near Firing Position 3 at the 150 meter range. The contents of the Kettle were drummed and the kettle was removed in 2001.
- Steel-lined Pit - an eight foot by eight foot, steel-lined pit that contained munitions. The steel-lined pit had a hole in the bottom of the pit. The steel lining was removed, the underlying soils were excavated, and the area was backfilled to allow for the installation of a water table monitoring well (MW-58S).
- Burial Trench – a burial trench approximately 108-foot long and 4-foot deep, located on the west side of Tank Range Road, opposite the 150 meter berm, at Polygon 16.
- Mortar Disposal Area - a disposal area (near MW-127) that contained over 1,000 rounds of predominately inert 81mm mortar rounds, 60mm mortars, 105mm anti-tank training rounds, 105mm artillery projectiles, and illumination rounds. These rounds were removed in December 1997 and March 1998 and were disposed of off-site.

2.3 Inter-Relationship with Adjacent Study Areas

Several past and present studies in the region have provided information that has helped develop the current understanding of the fate and transport of groundwater contamination in the SE Ranges area. Several of these investigations have helped refine aquifer hydraulic characteristics, while others have formed the basis for evaluation of source characteristics.

The Central Impact Area (CIA) occupies the central portion of Camp Edwards. The northwest portion of the J-1 Range extends into the Impact Area and partially into the CIA. Soil and groundwater contamination have been documented in the *Draft UXO/Source Investigation Report for the Central Impact Area* (AMEC 2008). The trailing edge of the CIA plume is located west-northwest and slightly crossgradient to the J-1 North plume and has been found not to be co-mingled with the contamination from the J-1 Range (Refer to Figure 4-1 of AMEC 2008). Due to the location of the J-1 Range near the top of the groundwater mound (further discussed in Section 2.4.6), groundwater from this area generally flows beneath (i.e. deeper than) the CIA plume, and contamination has yet to be detected in the deeper well screens in the CIA downgradient of the J-1 Range. Soil and groundwater contamination associated with the CIA are currently managed as a separate site and are not expected to impact or influence the J-1 Range investigations. The L Range, J-3 Range and J-2 Range are located adjacent to portions of the J-1 Range (Figures 2-1 and 2-2). The following documents present assessments of the nature and extent and fate and transport of contamination at these sites:

- *Final L Range Groundwater Characterization Report (ECC 2005b)*
- *Draft L Range Soil and Groundwater Remedial Investigation and Feasibility* Study (ECC 2009).
- *Draft J-3 Range Soil Remedial Investigation Report* (ECC 2006)
- *Draft J-3 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2006c)
- *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007)

2.4 Environmental Setting

2.4.1 Geographic Setting

The MMR includes Camp Edwards, Otis Air National Guard Base, United States Coast Guard Air Station Cape Cod, Cape Cod Air Force Station, and the Veteran's 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 the MMR is residential or commercial development. The MMR is situated adjacent to the towns of Bourne, Sandwich, Falmouth, and Mashpee. The J-1 Study Area is located in the southeastern portion of Camp Edwards between Greenway Road and the Impact Area.

A restricted area surrounded by fencing and guarded gates; the land is controlled by the US 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 to protect the water supply and wildlife habitat. Therefore, the potential for human exposure to on-site soil contaminants is limited to occasional trespassers, site workers, and military personnel. It is anticipated that the land use at the J-1 Range will not significantly change over time. An Upper Cape Regional Water Co-op operates three water supply wells. (WS-3) is located approximately 8,700 feet cross gradient and downgradient of the most downgradient extent of the J-1 Range northern plume.

2.4.2 Cultural Setting

Land use near MMR is primarily residential and recreational, and secondarily agricultural and industrial. Portions of the MMR are opened for deer and turkey hunting by permit from the Massachusetts Division of Fisheries and Wildlife. The major agricultural land use near the 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 which 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 the 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 in which the J-1 Range is located is used for military training. As such, it is a restricted area surrounded by fencing and guarded gates. The land is controlled by the U.S. Army under a lease from the Commonwealth of Massachusetts running 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, site workers, and military personnel. It is anticipated that the land use at the J-1 Range will not significantly change over time. An Upper Cape Regional Water Supply Co-operative water supply well (WS-3) is located approximately 8,700 feet cross gradient and downgradient of the most downgradient extent of the J-1 Range northern plume.

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.

2.4.3 Ecological Setting

The northern two-thirds of the 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 the 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 the 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 the 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 the 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 the MMR; however, the 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).

2.4.4 Climate

The climate for Barnstable County, where the 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^{o} F 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).

2.4.5 Geology

The J-1 Range groundwater study area is situated within the Mashpee Pitted Plain, a thick wedge-shaped deposit of unconsolidated Late Pleistocene outwash sands and gravels. The Mashpee Pitted Plain is bounded to the west and north by the Buzzards Bay and Sandwich moraines, respectively. The Mashpee Pitted Plain is an outwash plain formed by streams that drained the Buzzards Bay and Cape Cod Bay lobes of retreating glaciers. Depositional environments of the Mashpee Pitted Plain range from glaciofluvial for the coarser deposits to glaciolacustrine for the finer deposits. In the Mashpee Pitted Plain, the glaciolacustrine deposits are discontinuous and commonly overlie basal till or bedrock. Coarse textured basal till, consisting of poorly sorted sands and gravels, occurs sporadically across the top of the bedrock surface. Coarser grained sands and gravels, deposited in glaciofluvial environments, usually overlie the glaciolacustrine deposits and are more continuous across the plain. Overlying these glaciofluvial deposits is a thin veneer of eolian silt (Fletcher 1993). A general description of the geology of Cape Cod, the geology of the Southeast Ranges, and the soils in the Southeast Ranges is provided in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007).

The J-1 Range northern area stratigraphy is shown on three cross sections (plan view Figure 2-10, cross sections Figures 2-11 through 2-13) and the J-1 Range southern area stratigraphy is shown on three cross sections (plan view Figure 2-14, cross sections Figures 2-15 through 2-16).

2.4.6 Hydrogeology

The J-1 Range groundwater study area is ocated within the Sagamore Lens of the Western Cape Cod aquifer. Numerous groundwater investigations have been conducted for the SE Range plumes. These investigations have addressed many aspects of the hydrogeologic conditions pertinent to the J-1 Range. A general description of the hydrogeologic setting for the Southeast Ranges is provided in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007). This section summarizes the water table and top of mound characteristics, hydraulic gradients and groundwater flow velocities.

2.4.6.1 Water Level Elevations

Water level elevation data in the Southeast Ranges collected in 2000, 2003, and 2004, along with water level contours and top of mound positions are presented in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007). The 2003 water level contours are also provided on Figure 2-10 for the J-1 Range North groundwater study area and on Figure 2-14 for the J-1 Range South groundwater study area.

Water levels in the upgradient portions of the J-1 Range plumes generally vary from 68- to 70-feet msl with unusually high water levels (71- and 72-feet msl) in 2007 and 2008. Groundwater elevations in the downgradient portions of the J-1 Range northern groundwater study area (e.g., MW-430, MW-401, MW-479) are typically three feet lower than for upgradient areas. Groundwater elevations in the downgradient portions of the J-1 Range southern groundwater study area (e.g., MW-400, MW-402, MW-403) are typically one foot lower than for upgradient areas.

2.4.6.2 Hydraulic Gradients

A synoptic groundwater elevation data set from May 17, 2004 was used to calculate horizontal hydraulic gradients for a series of triangular areas in the J-1 Range North groundwater study area as shown in Figure 2-17. The magnitude and direction of flow for these triangular areas are represented by the arrows and gradient table presented in Figure 2-17. The geometric mean for hydraulic gradients calculated from the data set shows 0.0003 feet/feet. The magnitude of the horizontal gradient is variable within the dataset, but generally increases with distance from the top of mound. The largest gradients were observed in the middle and downgradient portion of the plume. Results indicate that the dominant azimuth is to the northwest, although directions of gradients closer to the top of mound may vary considerably, as shown in triangles 1071 and 1072 pointing in a northwesterly direction, triangle 1069 pointing in a northerly direction, and triangle 1070 pointing in a northeasterly direction. In general, horizontal groundwater gradients calculated for the triangular areas are small, reflecting the relatively flat groundwater table proximal to the top of mound. Due to the flat gradients near the top of mound, small errors in field observations can have a large impact on calculated gradients. Thus, the large variability of flow direction near the top of mound presented in the triangular elements in Figure 2-17 may not be representative of actual conditions. It should be noted that although triangles 1083 and 1082 in Figure 2-17 show a northwesterly trajectory (315 degrees and 327 degrees, respectively), adjacent triangles just to the east (1078 and 1077) show a more north-northwesterly flow direction (339 degrees and 342 degrees, respectively). The water levels observed during the May 2009 sampling events indicate that the groundwater flow direction is similar to previous observations and model-predictions, indicating the core of the perchlorate plume is flowing toward MW-256.

A synoptic groundwater elevation data set from November 17, 2005 (the latest data set available) was used to calculate horizontal hydraulic gradients for a series of triangular areas in the J-1 Range southern groundwater study area as shown in Figure 2-18. The magnitude and direction of flow for these triangular areas are represented by the arrows and gradient table presented in Figure 2-18. The geometric mean for hydraulic gradients calculated from the November 2005 data is 0.0004 feet/feet. In general, the magnitude of the horizontal gradients is highly variable, although maximum value of 0.0009 feet/feet is located near the downgradient edge of the study area. This is in agreement with the conceptual model of groundwater flow. Results indicate that the dominant azimuth of the hydraulic gradients is to the south-southeast. The easterly oriented gradients in triangles 9 and 10 are likely a result of the FS-12 extraction, treatment, reinjection system. In general, horizontal groundwater gradients calculated for the triangular areas are small, reflecting the relatively flat groundwater table proximal to the top of mound.

For the J-1 Range groundwater study area, gradients near the top of mound are very flat and small errors in field observations can have a large impact on calculated gradients. Thus, the large variability of flow direction near the top of mound presented in the triangular elements in Figures 2-17 and 2-18 may not be representative of actual conditions.

Vertical hydraulic gradients were computed for nested well pairs in the J-1 Range groundwater study area. The chosen well pairs were within, or adjacent to, the J-1 Range plumes in upgradient, downgradient, and crossgradient locations (Table 2-1). Vertical gradients calculated from data collected from November 2003 to August 2007 and ranged from 0.0010 feet/feet to -0.011 feet/feet for J-1 Range northern area and 0.0006 feet/feet to -0.002 feet/feet for the J-1 Range southern groundwater study area. The resulting values indicate an essentially flat or slightly downward gradient as vertical gradient values less than +/- 0.01 are outside the limits of measurement precision.

2.4.6.3 Hydraulic Conductivity and Porosity

Hydraulic conductivity values were estimated from grain-size samples in selected borings using the Hazen and Beyer methods (Vukovic and Soro 1992) (Table 2-2). For nine of the samples, hydraulic conductivity could not be calculated, either because the sieve data lacked some values required for inputs, or because the data did not meet all of the criteria for use with the equations. This generally occurs when the sample is either too fine or too coarse to provide all of the sieve-size outputs. The following discussion of hydraulic conductivity for various lithologic units is based on the hydraulic conductivity (K) values that were successfully calculated from grain-size data.

As described in Section 2.4.5, the subsurface geology consists of a matrix of glaciofluvial stratified sand and gravel with a few laterally and vertically discontinuous glaciolacustrine lenses overlying glacial till. The K of sands (SP, SW) calculated from grain-size data range from 13 feet/day to 310 feet/day (Table 2-2). The poorly-graded medium and coarse sands comprise the largest volumetric percentage of the aquifer. The K of the gravels and most of the sands with higher percentages of gravel (greater than 10 percent) is slightly higher, ranging from 13 feet/day to 582 feet/day (Table 2-2). Anisotropy in sands is assumed to range from 3:1 to 10:1, depending on grain size (Masterson et al. 1997). The glaciolacustrine lenses and glacial tills within the study area were too fine grained to calculate K values. In general, these fine-grained units have hydraulic conductivities less than 10 feet/day with anisotropies up to 100:1 (Masterson et al. 1997).

Site-specific porosity data have not been collected from the study area; however, other studies on upper Cape Cod indicate that the effective porosity (ne) of the coarse sand and gravel likely ranges from 0.35 to 0.42 (Masterson et al. 1997). For groundwater modeling and plume shell-based estimates of mass, an effective porosity of 0.30 is assumed for the study area.

2.4.6.4 Groundwater Flow Velocities

Groundwater flow velocities (v) are dependent on hydraulic conductivity, gradients, and effective porosity and are a key factor for estimating travel times for groundwater plumes.

v = K (i/ne)

Where

K = hydraulic conductivity (feet/day)

i = horizontal gradient (feet/feet)

ne = effective porosity

- For this assessment, velocities were calculated for representative hydraulic conductivity values of 100 and 200 feet/day (based on grain size). For the evaluation of velocities, the average horizontal gradient of 0.0004 feet/feet and the maximum horizontal gradient of 0.0009 feet/feet were considered. Using an effective porosity of 0.30, the average linear velocities are 0.1 and 0.3 feet/day for the average gradient (0.0004 feet/feet). For the steepest gradient (0.0009 feet/feet), the average linear velocities increase to 0.3 and 0.6 feet/day for conductivity values of 100 and 200 feet/day, respectively.

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3.0 GROUNDWATER CHARACTERIZATION ACTIVITIES AND NATURE AND EXTENT

3.1 Groundwater Characterization Activities

Investigation of the J-1 Range was initiated in 1997 with groundwater and soil samples collected at areas identified as having the highest probability of contaminant releases. From 1997 to 2004, 24 monitoring well borings and two boreholes were advanced and 55 monitoring well screens were installed during the initial phases of work (AMEC 2004), as detailed in the *J-1, J-3, L Ranges Final Workplan* (Ogden 2000), *J-1, J-3, L Ranges Additional Delineation Workplan No. 1* (AMEC 2001a), and the *J-1, J-3, L Ranges Additional Delineation Workplan No. 2* (AMEC 2001b). The primary focus of the initial investigations was centered on RDX and HMX contamination, with the analysis of perchlorate added in 2000.

This section describes the investigative activities conducted from late 2004 through May 2008 to characterize the groundwater contamination associated with the northern portion of the J-1 Range, and the activities conducted from late 2004 through early November 2008 to characterize groundwater contamination associated with the southern portion of the J-1 Range. The scope and technical approach for this phase of the J-1 Range investigation was outlined in the *Final J-1 Range Supplemental Groundwater Workplan* (AMEC 2004) and the *J-1 Range Southeast Plume Investigation Project Note* (IAGWSP 2005), which included groundwater modeling activities, water level surveys, drilling, monitoring well installation, and groundwater sampling.

The synoptic water level surveys, drilling, monitoring well installation and groundwater sampling were conducted in accordance with the above mentioned plans, except for the minor deviations noted in Section 3.1.6. Activities conducted in support of the drilling program, such as surveying, are also described in this section. All field activities were conducted pursuant to agency-approved, MMR-specific procedures (AMEC 2001). The results of the field investigations, including interpretation of the hydrogeologic data and analytical results, are presented in Sections 2.3 and 5.0.

3.1.1 Groundwater Modeling

The SE Ranges flow and transport model was developed in 2004 to encompass all of the SE Ranges including the J-1 Range northern groundwater study area. This model was used to help site wells in the J-1 Range northern groundwater study area. In 2006, the J-1 South model was developed to simulate the J-1 Range South plume and was updated in 2009. Both the SE Ranges model and the J-1 southern model were used to assist in selection of drilling locations in the J-1 Range southern area. Data collected from drilling activities and water level surveys was used during model development. Specific issues addressed during calibration of these models included flow directions, groundwater travel times, and pond-aquifer interaction.

3.1.2 Synoptic Water Level Survey

A synoptic water level survey of 122 monitoring wells was performed in August 2003 to further refine the understanding of groundwater flow directions in the SE Ranges; especially in relation to the top of the mound and previous interpretations of top of the mound positions, to quantify vertical and horizontal gradients, and to help update both regional and subregional area-specific groundwater models used in the SE Ranges. This water level measurement event was accompanied by a resurveying of top of well casing location (x, y) and elevation (z) for all wells in the synoptic event. The updated models were then used to select appropriate locations for additional monitoring wells (in all of the SE Ranges), to provide insights on possible transient impacts on contaminant fate and transport, evaluate aquifer-pond interactions, and to test proposed remedial alternatives. Locations, survey coordinate data, and synoptic water level results are presented in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study Report* (ECC 2007a).

A second synoptic water level survey of 108 monitoring wells was performed in May 2004. This survey refined and updated the SE Ranges conceptual groundwater models. During scoping of the synoptic event, it was agreed to broaden the scope of the water level assessment to encompass the L Range, J-1 Range and J-2 Range plumes. Locations and synoptic water levels measured in this synoptic water survey are presented in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007a) report.

An additional focused synoptic survey consisting of 34 monitoring wells was performed on November 17, 2005 and was used to update and refine the groundwater model in the off-post area downgradient of the southern area of the J-1 Range. Locations and water levels measured in this synoptic water survey are presented in Table 3-1.

The Final J-1 Range Supplemental Groundwater Workplan (AMEC 2004) outlined a comprehensive water level survey and up to two limited extent water level surveys. During the investigation three synoptic events were conducted in August 2003, May 2004 and November 2005. Wells where water level measurements were collected are summarized in Table 3-1 and in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007a). Substitutions and/or additions were made based upon well availability and the need to expand the suite of wells monitored to characterize the entire SE Ranges area. The substitutions were made in areas that did not result in a significant change in the interpretation and mapping of the water table.

3.1.3 Drilling and Well Installation

Drilling and well installation activities outlined in the J-1 supplemental groundwater work plan were conducted according to the general parameters identified in the work plan (AMEC 2004); however, during the investigation, numerous drilling locations were revised and additional locations were added. The scope of the investigation grew based on groundwater profile results from predecessor wells and updated conceptual site models.

Unexploded ordnance clearance was performed at all well installation locations prior to initiation of drilling or sampling activities. Locations were drilled using dual rotary technology, rotosonic technology, hollow-stem auger technology and drivepoint technology. Groundwater profile samples (samples of groundwater collected from the bottom of the drill casing during borehole advancement) were collected every 10 feet from the water table to bedrock target depth or refusal. Profile samples were analyzed for explosives by EPA Method SW846/8330 and perchlorate by EPA Method E314.0. Profile samples from select locations were also analyzed for VOCs by EPA Method SW846/8260B. The chemical results are discussed in Section 3.2 and presented in Appendix D. These analyses were performed on an expedited basis, and the results were used to help determine well screen settings (i.e. the number of screens per location and the elevation of each screen) and the position of other planned wells. Drilling locations, monitoring wells, and piezometer locations are identified in Figure 2-3 and Figure 2-4 and are summarized in Table 3-2.

Lithologic characterization of all the borings included a description of the unconsolidated material and a description of bedrock where encountered. Grain-size analysis was conducted on soil samples collected from select borings. The soils were classified using the *American Society for Testing and Materials (ASTM) Unified Soil Classification System (USCS)* (ASTM-D2487). Lithologic data was recovered from boreholes advanced using sonic and dual-rotary methodology; no lithologic data was collected at auger or drivepoint locations. At borings drilled with sonic drilling methodology, continuous soil cores were collected from ground surface to bedrock and bedrock was cored for five feet to identify the bottom of the aquifer. At borings drilled with dual rotary technology, soil samples were collected every 10 feet. The boring logs are provided in Appendix A, and grain-size results are provided in Appendix B.

3.1.3.1 J-1 Range Northern Area Drilling and Well Installation

As part of the J-1 Range northern area Investigation, 18 boreholes were advanced, and 36 monitoring wells and one piezometer were installed. J1P-21 (MW-303), J1P-22 (MW-306) and J1P-27 (MW-315) were drilled at the locations identified in the work plan. Eight of the nine remaining locations (J1P-23 [MW-346], J1P-24 [MW-326], J1P-25 [MW-349], J1P-26 [MW-369], J1P-28 [MW-370], J1P-29 [MW-401], J1P-30 [MW-430], and J1P-32 [MW-479]) cited in the supplemental work plan were drilled downgradient of the Interberm Area using previous results and groundwater modeling to site the locations. Screens were set at each location based on profile data results and, in cases where there were no detects in the profile data, on groundwater modeling. Location information and screen elevation information is summarized in Table 3-2. These locations, along with previously installed IAGWSP monitoring well locations, helped define the main lobe of the J-1 Range North groundwater plume (Figure 2-3).

Location J1P-31 (MW-477) was installed on the downgradient side of the 2,000 meter Berm Area (Figure 2-3) due to detects of explosive compounds in soil samples suggesting that this area was a potential source of groundwater contamination. Detects of RDX at this location led to six additional locations (J1IA-P01 [MW-484], J1IA-P02 [MW-485], J1IA-P03 [MW-486], J1IA-P04 [MW-493], J1A-P05 [MW-494], and J1HUTA2T3-P01 [MW-487]) not included in the original work plan. These locations define the western lobe of the J-1 Range northern groundwater plume (Figure 2-3). As with other locations, profile results and modeling were used to set the monitoring well screens and to select well locations (Table 3-2). It should be noted that wells were not installed in the MW-493 and MW-494 boreholes.

3.1.3.2 J-1 Range Southern Area Drilling and Well Installation

As part of the J-1 Range southern area Investigation, 31 boreholes were advanced and 19 monitoring wells and six piezometers were installed. Only one of the boreholes, J1P-20 (MW-360), was included in the supplemental work plan (AMEC 2004) and it was installed at the location cited in the work plan. This location was drilled to bedrock. Since profile results at this location were non-detect for explosives and perchlorate, well screen placement was determined using groundwater modeling information (Table 3-2). Additional locations were drilled to the north, along Greenway Road, and the results are discussed in the *Draft J-2 Range Groundwater Remedial Investigation/Feasibility Study* (ECC 2007a).

Subsequent to the installation of J1P-20, a series of drive-point borings (DP-378, DP-379, DP-384, DP-385, DP-386 and DP-387) were installed along the MMR Boundary downgradient of the J-1 Range per the *J-1 Range Southeast Plume Investigation Project Note* (IAGWSP 2005). Detections of explosives (primarily RDX) in these borings lead to the installation of a monitoring well (J1P-33, MW-398) near the drive-point location with the highest detect of RDX (DP-384) and the installation of three upgradient drive-point locations (DP-389, DP-390 and DP-391) to define the upgradient portion of the RDX plume. In an attempt to define the leading edge of the plume, three additional monitoring well locations (J1P-34 [MW-403], J1P-35 [MW-400], and J1P-36 [MW-402]) were sited downgradient along Little Acorn Road. These locations, as seen at the base boundary, were selected based on groundwater modeling of the detects. Additionally, a drivepoint was advanced through the bottom of existing location 90WT0010 to determine if the RDX had advanced to Route 130. Profile results from the Little Acorn Road well-fence locations were non detect. Wells installed at these locations were also based on groundwater modeling information (Table 3-2).

In an attempt to define the core of the plume downgradient of the base boundary, three additional locations (J1P-37 [MW-480], J1P-38 [MW-481], and J1S-P02 [MW-482]) were sited along Windsong Road based on groundwater modeling results from upgradient and downgradient locations (Figure 2-4). An additional two locations (J1S-P01 [MW-483] and J1S-P03 [MW-488]) were installed along the base boundary to further define the core of the plume and for use as hydraulic control locations for the J-1 Range Groundwater Rapid Response Action (RRA) system that began operation in October 2007.

During routine groundwater monitoring activities in late 2007 and spring 2008, RDX was detected in the shallow screen at the southernmost location on the Little Acorn well-fence (MW-402M2). This well is located further downgradient and slightly south of the previously conceptualized leading edge of the J-1 Range southern RDX plume. These detections lead to the installation of ten additional drive-point locations (DP-498, DP-499, DP-500, DP-503, DP-504, DP-505, DP-508, DP-512, DP-513 and DP-514) to further define the downgradient portion of the plume, and one upgradient drive-point location (DP-507) to refine the RDX mass distribution upgradient of the extraction well (J1SEW0001) (Figure 2-4). Profile samples from these locations were analyzed for explosives by EPA Method SW846/8330. Additionally, profile sampling at several of these locations commenced approximately 30 feet into the water table rather than at the top of the water table. Unlike the drive-point locations installed earlier in the investigation, these drive-point casings were removed after groundwater profile samples were collected because they were not intended to be permanent monitoring locations. Follow-on work to the drive point program included the drilling of seven additional monitoring wells (MW-521, MW-522, MW-523, MW-524, MW-525, MW-526 and MW-527) to further refine the downgradient portion of the plume and the drilling of one additional location (MW-528) to define the remaining upgradient portion of the plume. As with the drive-point program, drilling at these locations commenced at approximately 30 feet into the water table.

3.1.4 Surveying

All monitoring well locations were surveyed by a professional land surveyor licensed by the Commonwealth of Massachusetts. Horizontal positioning was referenced to the North American Datum 1983, Universal Transverse Mercator (UTM) Zone 19 North in meters. The vertical datum was referenced with an accuracy of 0.005 feet of vertical/horizontal control to the North American Datum of 1927. Horizontal locations of additional polyvinyl chloride (PVC) well and piezometer casings in the same well boring were surveyed. Elevations were calculated using post-processing software and are referenced to the top of the PVC pipe at the designated mark.

3.1.5 Monitoring Well Sampling

Groundwater samples collected from monitoring wells in the J-1 study areas were historically collected as part of the *Draft Long-Term Groundwater Monitoring Plan* (AMEC 2005). The long-term groundwater monitoring (LTGM) program has since been superseded by site specific monitoring plans. The J-1 Range northern area plume monitoring is detailed in the *Final J-1 Range North Interim Groundwater Monitoring Plan* (ECC 2006) and further refined as part of the *Final J-1 Range North Interim Groundwater Monitoring Submittal* (ECC 2008). The J-1 Range southern area plume monitoring is detailed in the *Final J-1 South Rapid Response Action System Performance Monitoring Plan* (ECC 2007b). The analytical results of samples collected from monitoring wells are presented in Appendix E and the water quality parameters measured during groundwater sampling are presented in Appendix F. A discussion of previous results is included in the supplemental work plan (AMEC 2004).

3.1.5.1 Existing Monitoring Wells

As noted above, existing monitoring wells were sampled as part of the long-term monitoring program. Most of these monitoring wells have been included in the site specific monitoring plans for the J-1 Range groundwater study area.

3.1.5.2 Newly Installed Monitoring Wells

All of the monitoring wells installed as part of the J-1 supplemental groundwater investigation were sampled approximately every four months, for a total of three times within one year of installation. The analytical suite for these new wells varied by location and is listed in Table 3-2. The results of the first three sampling rounds, along with consideration of the conceptual model of the plume distribution and groundwater modeling were used to determine which new wells to include in the site-specific groundwater monitoring plans, listed above.

It should be noted that groundwater samples were not collected three times during the first year from the initial drive-point locations installed in the J-1 Range southern area (DP-378, DP-379, DP-384, DP-385, DP-386, DP-387, DP-389, DP-390 and DP-391) because the screens were driven below the plume during casing advancement, and sampling the locations would not provide useful chemical data results.

3.2 Nature and Extent of Groundwater Contamination

This section presents the analysis and interpretation of groundwater drilling profile results and groundwater monitoring well sampling results collected through 2009 within the J-1 northern and southern groundwater study areas in support of J-1 groundwater investigations and other monitoring programs (Section 3.1). The primary site-related contaminants in the northern groundwater study area are perchlorate and RDX and the primary site-related contaminant in the southern groundwater study area is RDX. Perchlorate, RDX, and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) concentrations in groundwater from monitoring well samples are presented in Table 3-3 and Table 3-4. All of the chemical data results are presented in Appendices D and E and the distribution of the primary site-related contaminants are shown on maps and cross sections. Refer to the Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study (ECC 2007) for a discussion of development of plume representations on maps and cross sections.

3.2.1 Northern Area

The northern plume depictions and following discussion utilizes validated results from wells sampled prior to May 2008. Analytical data available after this date is included in Appendix I, and has been presented in the *J-1 Environmental Monitoring Report - 2009* (ECC 2009). The northern plume is defined by perchlorate and RDX (primary site-related contaminants) detections in groundwater (Figures 3-1 and 2-10). The main lobe of the plume consists of perchlorate and RDX detections and the western lobe consists primarily of RDX detections with some isolated perchlorate detections (Figure 3-1). Vertical distribution of RDX is shown on cross sections A-A’, C-C’ and B-B’ (Figures 2-11 through 2-13). The vertical distribution of perchlorate is shown on cross sections A-A’ and C-C’ (Figures 3-2 and 3-3).

3.2.1.1 Perchlorate

The northern perchlorate plume, defined by detectable concentrations, is approximately 4,600-feet long and approximately 1,000-feet wide at its widest point (Figure 3-1). There are also three, small, isolated areas where perchlorate was detected just west of the main plume (Figure 3-1). The plume as defined by perchlorate above the Massachusetts maximum contaminant level (MMCL) (2 μg/L) is approximately 3,900 feet long and approximately 800-feet wide at the widest point. The plume trajectory is north to northwest. The perchlorate plume is no longer detected at the source area; MW-136S and M1, MW-189S, and MW-191S, M1, and M2 are non-detect for perchlorate. Just downgradient of the source area, the plume is detected from approximately 30 feet below the water table (40-feet msl) to 70 feet below the water table (negative 110-feet msl). The plume has a relatively flat trajectory with the center of the toe of the plume projected at approximately negative 30-feet msl (Figure 3-2).

The current upgradient portion of the perchlorate plume is characterized by low concentrations (maximum concentration less than 5 μg/L) from approximately 40-feet to negative 110-feet msl. There are no recent detections of perchlorate at monitoring wells MW-136, MW-191, MW-58, MW-166, and MW-188, which bound the upgradient extent of the perchlorate plume. Previously, perchlorate was detected once at MW-191S (0.83J μg/L, August 2002), but subsequent samples have been non-detect. Just downgradient of the source area, perchlorate has been detected from approximately 40-feet msl to negative 110-feet msl at MW-303. The historical maximum concentration of perchlorate, in this area of the plume, was 31 μg/L (MW-303M2, March 2004); the current maximum perchlorate concentration is 3.8 μg/L (MW-303M2, June 2008).

The core of the perchlorate plume, defined by concentrations above 24 μg/L, contains the highest concentration of perchlorate currently detected in the plume. The perchlorate plume in this area is the most vertically and horizontally extensive and shows a fairly flat trajectory (Figure 3-2). The plume is thicker (10-feet to negative 100-feet msl) and more heterogeneous upgradient of MW-265 compared to downgradient of this well (0-feet to negative 50-feet msl). The highest perchlorate concentration (66 μg/L) was observed during drilling at MW-346. Declining perchlorate concentrations have been observed at the shallower wells MW-346M3, and M4 while increasing perchlorate concentrations were observed at the deeper wells (MW-346M1 and M2) demonstrating vertical heterogeneity within the plume (Figure 3-4). The concentrations trends at MW-346M1, M2, M3, and M4 also indicate the shallow contamination is moving more rapidly downgradient than the deeper contamination. The current maximum perchlorate concentration is observed at the leading edge of the core of the plume (MW-370M2, 47.1 μg/L, May 2008). Perchlorate concentrations at MW-370M2 have been gradually increasing from 7.2 μg/L detected during drilling (May 2005) to 47.1 μg/L (May 2008).

The extent of the downgradient portion of the plume (downgradient of MW-370 and the 24 μg/L perchlorate isocontour) is estimated based on upgradient and downgradient observations; namely concentrations at MW-370 and MW-286 and non-detects at monitoring wells along Wood Road. The plume is predicted to taper slightly as it migrates downgradient of MW-370 and MW-286 (Figure 3-2).

3.2.1.2 RDX

The main RDX plume, defined by detectable concentrations, is approximately 4,900-feet long and approximately 1,300-feet wide at the widest point (Figure 2-10). The main RDX plume as defined by detections of RDX above 0.6 µg/L is approximately 4,100-feet long and 1,200-feet wide at the widest point. The western RDX plume, defined by detections of RDX above 0.6 µg/L is approximately 3,300-feet long and 470-feet wide at the widest point. The western RDX plume as defined by detections of RDX above 0.6 µg/L is approximately 3,800-feet long and 500-feet wide at the widest point. There is also an isolated detection of RDX downgradient of the main northern RDX plume.

The farthest upgradient detections of RDX are observed at MW-136. No detections of RDX were observed at MW-189, thus defining the upgradient extent of the plume (Figure 2-10). RDX concentrations in source area wells have been gradually decreasing from 2.1J (estimated value) µg/L (MW-191M2, January 2002) to 0.77 µg/L (M-191M2, April 2007) (Figure 3-5). The RDX plume is fairly thin at the source area (approximately 30-feet thick), but just downgradient of the source area the RDX plume thickens considerably to approximately 160 feet (MW-303, 50-feet to negative 110-feet msl). The area near MW-303 is the thickest portion of the plume, has the greatest heterogeneity, and is the area where the maximum RDX concentrations have been detected (36.5 µg/L, MW-303) (Figure 2-11).

In the area between MW-303 and MW-370 (the mid-portion of the plume) RDX is detected over a broader area (1,300-feet wide at MW-369) and gradually thins laterally and vertically to 700-feet wide and 50-feet thick at MW-370. The mid-portion of the RDX plume is characterized by lateral and vertical heterogeneity. The maximum RDX concentration in the mid-portion of the plume was detected during drilling at MW-306 (22 µg/L), but there are no other detections above 6 µg/L in the mid-portion of the plume. Subsequent monitoring well samples at MW-306 have gradually decreased to 0.61 µg/L (MW-306M2, April 2007). The current maximum RDX concentration in the mid-portion of the plume is 3.8 µg/L (MW-306M1) (Figure 2-11).

The extent of the downgradient portion of the plume (downgradient of MW-370) and the 2 µg/L RDX isocontour) is estimated based on upgradient and downgradient observations, namely concentrations at MW-370 and MW-286, and lack of recent detections at monitoring wells along Wood Road. The plume is predicted to taper slightly as it migrates downgradient of MW-370 and MW-286 (Figure 2-11). There have been isolated, low-concentration (below 1.7 µg/L), historic detections of RDX at MW-205.

Crossgradient of the main RDX plume is the western RDX plume. The most upgradient RDX detections in the western lobe were at MW-486 from 20-feet to negative 20-feet msl (more than 40 feet below the water table) indicating the source of RDX detections at MW-486 is farther upgradient. The western RDX lobe is defined by detections at MW-486, MW-485, MW-477, and MW-487. The MW-485, MW-477, and MW-487 detections are relatively thin and narrow at the source (approximately 10-feet thick and 200-feet wide) and broaden downgradient (approximately 50-feet thick and 450-feet wide). The historic maximum RDX detection was observed during drilling of MW-487 (14 µg/L, March 2007) with the current maximum RDX concentration of 7.6 µg/L (MW-487M2, December 2007).

3.2.1.3 Other Explosive Compounds

Other explosive compounds have been detected in the northern groundwater study area. Detects and maximum concentrations for all explosive compounds are summarized in Table 3-5 for monitoring well samples and Table 3-6 for profile samples.

Other than RDX, the following compounds have also been detected in groundwater: HMX, 1,3,5-trinitrobenzene, 2,4,6-trinitrotoluene (TNT), 2-amino-4,6-dinitro-toluene, 2,6-dinitrotoluene, 2,4-diamino-6-nitrotoluene, 2-nitrotoluene, 3-nitrotoluene (3-NT), 4-amino-2,6-dinitrotoluene (4A-DNT), nitrobenzene, picric acid, and tetryl. None of the detects have exceeded regulatory levels (i.e. maximum contaminant levels [MCLs], MMCLs, or HAs), except for one detection of TNT observed during drilling of MW-118 (4J µg/L, 120-feet bgs), which exceeded its health advisory. TNT was not detected during subsequent monitoring well sampling. Most of the detections of other explosives in monitoring well samples occurred in monitoring wells located near, or just downgradient of the source area of the main RDX plume.

None of the HMX detects within the J-1 Range North groundwater study area exceed the EPA HA of 400 µg/L or the MCP GW-1 standard of 200 µg/L (the maximum detected concentration is 110J µg/L). HMX detections in monitoring well samples are presented in Table 3-3. The HMX detections in monitoring well samples and profile samples are summarized in Tables 3-5 and 3-6, respectively. These low-level concentrations of HMX were detected at locations within the footprint of the J-1 Range North RDX plume.

3.2.1.4 Semi-Volatile Organic Compounds (SVOCs)

In the northern groundwater study area, over 300 samples collected from 75 monitoring wells were analyzed for SVOCs and sporadic detects were observed. The SVOC detects and maximum concentrations are summarized in Table 3-5. No detections of SVOCs exceeded the regulatory threshold with the exception of one detection of bis(2-ethylhexyl)phthalate (BEHP) in MW-477M2 at a concentration of 14 µg/L (MCL = 6 µg/L) in the January 2007 sample. The sporadic nature of the SVOC detections combined with BEHP being a common sampling artifact and/or laboratory contaminant suggests that SVOCs are likely not site-related.

SVOC groundwater tentatively identified compounds (TICs) have generally been laboratory artifacts (e.g., aldol condensation products or column bleed), or, in the case of the detects seen at MW-187 in the J-1 Range northern plume, compounds associated with fuels and fuel related products such as substituted benzene rings, higher molecular weight iso-alkanes and substituted low weight PAHs (dimethyl napththalene isomers), etc.

3.2.1.5 Volatile Organic Compounds (VOCs)

In the northern groundwater study area, over 290 samples collected from 76 monitoring wells were analyzed for VOCs. Table 3-5 summarizes the VOC detections and maximum concentrations in monitoring well samples. Groundwater profile samples from 30 locations were also analyzed for VOCs. Table 3-6 summarizes the compounds detected and maximum concentrations in profile samples.

Several of the VOCs detected are likely laboratory or sampling artifacts (e.g., acetone, bromomethane) and are not indicative of groundwater quality. Additionally, chloroform, which occurs naturally in the groundwater in the Sagamore Lens, was detected in several groundwater samples. Benzene, ethylbenzene, xylenes, and toluene were detected in the monitoring well samples collected from MW-187D. The maximum detected concentration of benzene was 1,300 µg/L, detected in February 2002, with concentrations decreasing to 42 µg/L in April 2007. Benzene has also been detected in profile samples (MW-136, MW-192, MW-303, MW-306, MW-401) and in monitoring wells (MW-192M3 and MW-245M1) at concentrations below 1 µg/L. Benzene was only detected at elevated concentrations at one location (MW-187D) and concentrations have been decreasing. No other benzene, ethylbenzene, xylenes, and toluene compounds were detected at elevated concentrations. Other VOCs (Tables 3-5 and 3-6) detected in the J-1 Range North groundwater study area occurred sporadically at low concentrations. There is no discernible pattern to the detections. Detections of VOCs are further evaluated in the Risk Screen (Section 6.0)

3.2.1.6 Pesticides, PCBs, and Herbicides

Monitoring well samples were analyzed for pesticides, PCBs, and herbicides.

Pesticides: Over 100 monitoring well samples were collected from 38 monitoring wells for pesticide analysis. Aldrin, beta hexachlorocyclohexane, dieldrin, and gamma-chlordane were detected – all below their respective Massachusetts Groundwater-1 standards. Table 3-5 summarizes the detections and maximum concentrations.

PCBs: Over 100 monitoring well samples were collected from 38 monitoring wells for PCB analysis. No PCBs were detected.

Herbicides: Over 100 monitoring well samples were collected from 38 monitoring wells for herbicide analysis. Chloramben and pentachlorophenol were detected below their Massachusetts Groundwater-1 standard.

The pesticide and herbicide detections are low concentration and sporadic and are not indicative of groundwater contamination in the J-1 Range North groundwater study area.

3.2.1.7 Metals

Over 100 monitoring well samples were collected from 38 monitoring wells for metals analysis. The detects and maximum concentrations of all the metals are summarized in Table 3-5.

Antimony was detected in three sample collected at MW-253M1 in 2003. The maximum detection was 6.6 µg/L. Thallium was detected in four samples with the maximum concentration of 7.3J µg/L (MW-58S, May 2000). Four subsequent samples from this well had no detections of thallium. Aluminum, iron, and manganese were also detected. There were 34 detections of aluminum with a maximum concentration of 5,750 µg/L. There were 45 detections of iron with a maximum concentration of 8,080 µg/L. There were 122 detections of manganese with a maximum concentration of 344 µg/L. There were six detections of sodium greater than 20,000 µg/L all of which were located at MW-187D, with a maximum concentration of 27,100 µg/L.

The highest detections of aluminum and manganese occur at MW-168M1. The last time this location was sampled, in September 2005, the dissolved oxygen was 1 mg/L. The low dissolved oxygen, indicative of reducing conditions, could account for the higher than average detects of aluminum, manganese and iron. The highest detection of Iron is seen at location MW-187D, which has historically had low dissolved oxygen and detections fuel related compounds. The low dissolved oxygen is likely related to the reducing conditions caused by the fuel-related compounds, and the higher Iron may be associated with the reducing conditions. Other high detects for iron occurred at location MW-168M1, where the highest detects of aluminum occurred. There is no discernable pattern, other than elevated detects at two locations, to the higher than average detections of aluminum, iron and manganese in the J-1 Range northern area. Metal detections are further evaluated in the risk screening (Section 6.0).

3.2.1.8 Radiological Parameters

Several radiological parameters were measured in samples from groundwater. Gross alpha had four measurable levels with the highest measurement of 3.2 picocuries per liter (pCi/L) at MW-168M1. This level was below the 15 pCi/L MCL for gross alpha. Gross beta had 51 measurable levels with a maximum level of 7.1 pCi/L in MW-188S. There are no regulatory criteria for gross beta.

3.2.1.9 Water Quality Parameters

Water quality parameters were measured at monitoring wells located within the study area during sampling events from 1997 to May 2008 (Appendix F). The range of groundwater water quality parameters was as follows: temperature ranged from 6.35 to 17.26 degrees Celsius with a mean of 10.69 degrees Celcius; dissolved oxygen (DO) ranged from 0.06 to 19.23 milligrams per liter (mg/L) with a mean of 10.81 mg/L; oxidation-reduction potential ranged from –227.3 to 496.3 millivolts (mV) with a mean of 215 mV; specific conductance ranged from 0.87 to 520 microsiemens per centimeters (µS/cm) with a mean of 59 µS/cm; and pH [scale for measuring aqueous hydrogen ion (H+) concentration] ranged from 4.28 to 8.26 standard units with a mean of 5.89 with one erroneous result (2.93) removed before the mean was calculated. The DO statistics were conducted after removal of five unreasonable values (21.19 mg/L, 21.86 mg/L, 43.56 mg/L, 88.3 mg/L, and 93.8 mg/L).

The DO concentrations below 1 mg/L were measured at locations MW-187D, MW-266M1, and MW-188S. The low DO measurements at MW-266M1 and MW-188S were single event results with other the other DO measurements indicating aquifer conditions in that area are aerobic. Low DO measurements have consistently been measured at MW-187D, which are likely due to the degradation of benzene, ethylbenzene, xylenes, and toluene and other hydrocarbons detected at the same location (Section 3.2.1.5).

3.2.1.10 Recent Groundwater Results

The J-1 Range northern RDX results showed little change between the 2008 and 2009 monitoring events, with most detected results remaining consistent between events. In general, RDX concentrations have remained similar to 2008 concentrations or decreased (Figure 3-6). The isolated area of RDX detections is no longer depicted at MW-205M1 because RDX has not been detected at this location for three consecutive sampling rounds in 2008 and 2009. The last RDX detection at MW-205M1 was 0.38 J µg/L in 2005.

The extent of the J-1 Range northern perchlorate plume did not change significantly between 2008 and 2009 (Figure 3-7). Within the plume, perchlorate concentrations have continued to increase in some wells (e.g., MW-346M1, M2), decrease in some wells (e.g., MW-303M2), and fluctuate in some wells (e.g., MW-265M2, MW-370M2) (Figure 3-6) supporting the conceptual model of a heterogeneous plume. The increase of perchlorate at MW-370M2 to 78 µg/L in November 2008 and trace level detections of perchlorate seen at MW-430 (0.048 J µg/L at MW-430M1 in October 2009 and 0.042 J µg/L and 0.058 J µg/L at MW-430M2 in May 2009 and October 2009, respectively), and MW-205M1 (0.056 J µg/L in October 2009) led to the installation of additional wells (MW-540 and MW-541) along Wood Road to monitor potential data gaps in the existing monitoring well network. Trace levels of perchlorate were detected in the profile results collected during borehole advancement at each location (which were drilled to bedrock), but perchlorate was not detected in the subsequent monitoring well samples. All perchlorate results in long term or system performance monitoring groundwater samples are currently being reported by the more definitive methods SW846/6850 or 6860, which have lower method detection limits and reporting limits. Therefore, there will likely be low-level results (<0.35 µg/L) reported for perchlorate in many groundwater samples. All of the results are presented in Appendix I.

3.2.2 Southern Area

The J-1 Range southern plume depictions and following discussion utilize the most recent validated results from wells sampled or boreholes advanced through 2009. The primary, site-related contaminant in the southern groundwater study area is RDX and the southern plume is defined by RDX detections in groundwater (Figure 2-14). Vertical distribution of RDX is shown on cross sections A-A’ and D-D’ (Figures 2-15 and 2-16).

3.2.2.1 RDX

The RDX plume, defined by detectable concentrations, consists of an upgradient portion that extends from the source area and terminates approximately 1,200 feet downgradient along the base boundary at extraction well J1SEW0001, and a downgradient portion, which has become detached from the upgradient portion due to the operation of the extraction well, extending from just beyond the base boundary approximately 2,100 feet to the vicinity of Grandwood Drive (Figure 2-14). The upgradient portion of the plume is approximately 400-feet wide at its widest point, and the downgradient portion of the plume is approximately 1,100-feet wide at its widest point. The upgradient portion of the plume, as defined by detections of RDX above the HA, is approximately 1,000-feet long and 300-feet wide at the widest point and the downgradient portion of the plume, as defined by detections of RDX above the HA is approximately 1,800-feet long and approximately 500-feet wide at its widest point. The upgradient portion of the plume is approximately 50-feet thick at its thickest point, near DP-507. The downgradient portion of the plume is approximately 40-feet thick at its thickest point, near MW-522 (Figure 2-15).

The trajectory of the southern RDX plume from the source to the extraction well at the base boundary is southeasterly, but the downgradient portion of the plume has a more southerly trajectory. The plume is present at the water table (approximately 68-feet msl) in the source area and generally decreases in elevation with distance from the source area to as deep as negative 50-feet msl in the downgradient portion of the plume (Figure 2-15). Prior to startup of the RRA system in 2007 the upgradient portion of the plume was mapped up to 70-feet thick and contained RDX concentrations in monitoring well samples up to 130 µg/L (MW-398). However, based on the 2008/2009 monitoring well sample results and profile data from DP-507 in 2008 and MW-528 in 2009, this portion of the plume appears to have thinned with RDX concentrations dropping below 15 µg/L within the plume and no longer detected along the base boundary (Figures 2-14 and 2-15).

The highest RDX concentrations observed in the downgradient portion of the southern RDX plume have consistently been detected at MW-481M2, located approximately 450 feet downgradient from MW-398/DP-384 where the highest historic RDX concentrations detected in the J-1 southern plume were detected in 2005/2006. RDX concentrations at MW-481M2 have fluctuated generally between approximately 10-20 µg/L, peaking at 22 µg/L in 2007 but dropping below 5 µg/L in October 2009 (Figure 3-8). RDX was detected in drive point profile samples collected in 2008 at concentrations up to 5.3 µg/L at DP-499, downgradient of MW-481M2, where the vertical extent of the plume gradually thins to 0- to 30-feet msl. Profile samples collected in the same area in 2009, during the installation of MW-522, detected a maximum concentration of 2.5 µg/L. There does appear to be areas of heterogeneity within this portion of the southern RDX plume, especially near MW-522, where the higher concentrations were detected deeper in the section, likely due to stratigraphic influences.

3.2.2.2 Perchlorate

Perchlorate has been detected in three samples collected within the southern groundwater study area; however, none of the concentrations exceeds the MMCL of 2 µg/L (the maximum detected concentration is 1.4 µg/L). Perchlorate detections in monitoring well samples are presented in Table 3-4 and detections in monitoring well samples and profile samples are summarized in Tables 3-7 and 3-8, respectively. Two of the low-level concentrations of perchlorate (0.42 J and 0.49 J µg/L) are located at MW-482 at 50 feet msl, approximately 30 feet above the RDX plume. The third perchlorate detection was at MW-403 (1.4 µg/L, 15 feet msl), which is outside the RDX plume. Detections of perchlorate are generally shallow and particle back tracks indicate that they do not track back to the base. Since perchlorate was not detected in profile samples or subsequent monitoring well samples for locations drilled on base (MW-360, MW-398, MW-488) or immediately downgradient of the core of the plume (MW-481), it is unlikely that these detects are related to base activity.

3.2.2.3 Other Explosive Compounds

HMX has been detected within the southern groundwater study area; however, none of the concentrations exceeds the EPA HA of 400 µg/L or the MCP GW-1 standard of 200 µg/L (maximum detected concentration is 29 µg/L). HMX detections in monitoring well samples are presented in Table 3-4. The monitoring well sample results are summarized in Table 3-7 and the profile sample results are summarized in Table 3-8. These low-level concentrations of HMX in the J-1 Range South plume are contained within the RDX plume geometry. HMX detects are co-located with RDX detections found in a shallow contiguous configuration located in the middle and along the northeastern edge of the plume at locations MW-360, DP-389, MW-228, DP-391, DP-384, MW-398, MW-488, DP-386, and MW-481. The maximum concentration (29 µg/L, June 2005) is located in the middle of the plume (DP-384, 28 feet msl) co-located with the highest RDX concentration.

Three other explosive compounds were detected in the study area. All of the detects occurred in groundwater profile samples, were low-level (below 1 µg/L), and did not exceed regulatory levels. The three explosive detections were TNT (0.36J µg/L), 2,6-dinitrotoluene (0.41J µg/L), and 4-nitrotoluene (0.33J µg/L). Detects and maximum concentrations for all explosive compounds are summarized in Table 3-7 for monitoring well samples and Table 3-8 for profile samples.

3.2.2.4 Semi-Volatile Organic Compounds (SVOCs)

In the southern study area, 21 monitoring well samples collected from seven monitoring wells were analyzed for SVOCs. The results are summarized in Table 3-7. The only SVOC detected was BEHP (MCL = 6 µg/L) in two monitoring well samples (0.27J to 0.36J µg/L) with the maximum at MW-131M1 (February 2001). The sporadic nature of the detections, combined with BEHP being a common sampling artifact and/or laboratory contaminant, suggests that BEHP is most likely not site-related. SVOC groundwater TICs have generally been laboratory artifacts (e.g., aldol condensation products or column bleed).

3.2.2.5 Volatile Organic Compounds (VOCs)

In the study area, 21 samples collected from seven monitoring wells were analyzed for VOCs. Table 3-7 summarizes the VOC detections and maximum concentrations in monitoring well samples. Groundwater profile samples from two locations were also analyzed for VOCs. Table 3-8 summarizes the compounds detected and maximum concentrations in profile samples.

The majority of the VOCs detected is likely laboratory or sampling artifacts (e.g., acetone, 2-butanone [MEK]) and are not indicative of groundwater quality. Additionally, chloroform, which occurs naturally in the groundwater in the Sagamore Lens, was detected in several groundwater samples. Methyl tert-butyl ether (MTBE) and toluene were detected at one location (MW-360M1, July 2005) at concentrations of 0.51J and 0.24J µg/L, respectively. Neither of these compounds was detected at concentrations exceeding regulatory levels or in subsequent monitoring well sampling events. Ethybenzene and total xylenes were detected in groundwater profile samples collected from MW-131. The maximum detected concentrations of ethylbenzene and total xylenes were 0.6J and 2 µg/L, respectively. Neither of these compounds was subsequently detected in monitoring well samples. Other VOCs (Tables 3-7 and 3-8) detected in the groundwater study area occurred sporadically at concentrations below drinking water standards. There is no discernible pattern to the detections.

3.2.2.6 Pesticides, PCBs, and Herbicides

Monitoring well samples were analyzed for pesticides, PCBs, and herbicides at the J-1 Range South groundwater study area. Refer to Table 3-7 for a summary of pesticide and herbicide detects and maximum concentrations in monitoring well samples.

Pesticides and PCBs: Nine monitoring well samples were collected from three monitoring wells for pesticide analysis. Heptachlor epoxide and p,p'-DDT were detected below their respective regulatory threshold. Both compounds were only detected in one sample from different wells. The pesticide detections are low concentration and sporadic, and are not indicative of groundwater contamination in the groundwater study area.

PCBs: Nine monitoring well samples were collected from three monitoring wells for PCB analysis. No PCBs were detected.

Herbicides: Nine monitoring well samples were collected from three monitoring wells for herbicide analysis. No herbicide compounds were detected.

3.2.2.7 Metals

Eleven monitoring well samples were collected from three monitoring wells for metals analysis. Various metal species have been detected at MW-131. High results for aluminum, iron and manganese all come from samples collected at the MW-131 well cluster (MW-131M1, M2 and S). A review of the associated field data shows no anomalous DO, turbidity or ORP readings. There is no discernable pattern of exceedences, other than they all came from groundwater collected at the MW-131 well cluster, located in the southern end of the J-1 range. The detects and maximum concentrations of all the metals are summarized in Table 3-7.

Aluminum, iron, and manganese were detected at concentrations above screening levels. There were six detections of aluminum with a maximum concentration of 5,120 µg/L. Iron was detected in seven samples with a maximum concentration of 5,790 µg/L. Manganese was detected in nine samples with a maximum concentration of 180 µg/L.

Metal detections are further evaluated in the risk screening (Section 6.0).

3.2.2.8 Six Radiological Parameters

Several radiological parameters were measured in samples from groundwater in the groundwater study area. Gross alpha had no measurable levels. Gross beta had eight measurable levels with a maximum level of 2 pCi/L (not validated) in MW-131M2. There are no regulatory criteria for gross beta. Tritium was detected in eight groundwater profile samples. The maximum detected concentration was 28.7J pCi/L in MW-131. There is no regulatory criterion for tritium.

3.2.2.9 Water Quality Parameters

Water quality parameters were measured at existing and newly installed monitoring wells located within the groundwater study area during sampling events from November 2000 through December 2009 (Appendix F). The range of groundwater water quality parameters was as follows: temperature ranged from 7 to 19.74 degrees Celsius with a mean of 11.03 degrees Celsius, DO ranged from 0.11 to 12.73 mg/L with a mean of 7.46 mg/L, Oxidation Reduction Potential ranged from -519.4 to 365.7 mV with a mean of 123.46 mV, specific conductance ranged from 22 to 285 µS/cm with a mean of 106 µS/cm, and pH ranged from 4.06 to 10.68 standard units with a mean of 6.41.

There are a few monitoring wells where DO concentrations less than 1.0 mg/L are measured consistently. All but two of the locations (MW-360M2, MW-482M1) are located outside the lateral and vertical extent of the southern plume. There is no indication of contaminant sources, such as fuels, that may have resulted in the low DO concentrations. Fuel degradation often leads to low DO and anaerobic aquifer conditions. There is no significant evidence of fuel contaminants across the J-1 Range southern groundwater study area.

3.2.2.10 Recent Groundwater Results

Additional monitoring wells were installed in the J-1 Range southern area (MW-521M1, MW-522M1, MW-522M2, MW-523M1, MW-524M1, MW-525M1, MW-525M2, MW-526M1, MW-527M1 and MW-528M1) in the fall of 2009 in order to more definitively define the footprint of the J-1 Range southern RDX plume. These wells were sampled in January and February 2010. The groundwater results agreed in general with the profile results collected during well installation, with the exception of the samples collected at MW-524M1 and MW-522M1. The RDX concentration at MW-524M1 was higher (11 µg/L, January 2010) than the profile result at the same elevation (1.6 µg/L, +4 to -6 feet msl interval). A subsequent sample, collected at MW-524M1 in February 2010, had an RDX concentration of 12 µg/L. The RDX concentration at MW-522M1 was lower (non-detect, January 2010) than the profile result at the same elevation (2.4 µg/L, -49 to -59 feet msl).

Until these monitoring well results were obtained, the MW-524 location was conceptualized as being the bounding well on the eastern edge of the J-1 Range southern RDX plume. Based on these higher detects at MW-524M1, it was decided to advance an additional eight drivepoints (DP-543 through DP-550) to further delineate the high-concentration core and the eastern, downgradient, and upgradient of extent of the J-1 Range southern plume in the area of MW-524 (Figure 3-9). All locations were drilled from ground surface to refusal, and profile water samples were collected at 10-foot intervals from approximately 20 feet below the water table to refusal and analyzed for RDX by EPA method SW846/8330 (location DP-550 was also analyzed for perchlorate by EPA method SW846/6850). All of the results are presented in Appendix I.

The results indicate the high concentration core of the J-1 Range southern RDX plume has a more easterly trajectory and the plume is slightly wider to the east than previously conceptualized (Figure 3-9). The shape of the core was revised based on the RDX concentrations detected at DP-549 (maximum of 74 µg/L). The eastern side of the plume has been delineated by bounding non-detect results at DP-547, DP-500, and DP-543. A non-contiguous zone of concentrations greater than 2 µg/L (2.4 µg/L, DP-546) was detected crossgradient, east-northeast of MW-482 at the same elevation of RDX detections seen at MW-482M2 including the most recent monitoring well result of 0.442 µg/L (October 2009). While this zone is conceptualized as an isolated zone, it is possible, given the elevations of the RDX detects, that this is associated with the main body of the J-1 Range southern RDX plume.

3.3 Groundwater Modeling

Groundwater modeling was performed for the northern and southern areas of investigation. This evaluation is intended to provide further understanding of the J-1 Range groundwater plumes fate and transport. A general discussion of uncertainty in groundwater modeling is presented in the *Draft J-2 Range Groundwater Remedial Investigation and Feasibility Study* (ECC 2007).

Groundwater modeling of plumes at the MMR has been used extensively to support remedial investigations, the primary tool in the development of wellfield designs for plume remediation, and to evaluate performance of existing remedial systems. This section describes the use of the J-1 North Model and J-1 South Model for evaluating the potential fate and transport of the northern perchlorate and RDX plumes and the southern RDX plume. A detailed description of the development and calibration of the J-1 Range North and South models and the flow model parameters are presented in Appendix J. All of the flow and transport simulations were carried out utilizing

MODFLOW-SURFACT 2.1 (HydroGeoLogic 1999), an enhanced MODFLOW code with transport simulation capability.

3.3.1 Fate and Transport Model Input Parameters

The following is a summary of a more detailed description of the fate and transport model input parameters presented in the *Final J-2 Range North Groundwater Rapid Response Action (RRA) Plan* (ECC 2005c). To model solute transport for J-1 Range, input parameters were developed to describe hydrodynamic dispersion, and retardation processes. These parameters include dispersivity, Kd (partition coefficient), and contaminant half-life (zero for both RDX and perchlorate). Bulk density and porosity are physical parameters of the aquifer matrix that also influence contaminant transport. Values of longitudinal, lateral, and vertical dispersivity used in the J-1 Range North and J-1 Range South fate and transport models were 10, 0.3, and 0.03 feet, respectively. A retardation factor (Rf) of 1.05 was used for RDX transport; no retardation was used for perchlorate transport. Plume shells (Appendices K and L) served as initial conditions for the solute transport models.

3.3.1.1 J-1 Range North Transport Modeling

The J-1 Range North transport model is based on the calibrated J-1 North flow model. Contaminant shells for the northern perchlorate and RDX plumes were developed to provide initial conditions for transport simulations (Appendix K). The plume shells represent the June 2008 distribution of perchlorate and RDX (Figure 3-10). The J-1 Range North total perchlorate mass, accounting for all concentrations simulated within the model, is 21.63 lb. The J-1 Range North total RDX mass (dissolved = 8.00 lb and adsorbed = 0.40 lb), accounting for all concentrations simulated within the model, is 8.40 lb.

A J-1 Range northern perchlorate expanded mass plume shell was constructed after the November 2009 perchlorate detection of 78 µg/L at MW-370M2. The 2008 J-1 Range northern perchlorate expanded mass plume shell was constructed by adding control points upgradient of MW-370 to the 2008 J-1 Range northern perchlorate plume shell. The objective was to approximate an area of mass upgradient of MW-370 that would have contributed to the perchlorate detection of 78 µg/L at MW-370M2. No other changes were made to the 2008 perchlorate shell. The maximum perchlorate concentration in the expanded mass plume shell is 131 µg/L, in 27.5x106 ft^3 of water with perchlorate above 2 µg/L, and a total mass in the model of 12.1 Kg. The expanded mass plume shell has approximately 24 percent more mass and approximately 13 percent more volume above 2 µg/L than the 2008 J-1 Range northern perchlorate plume shell. The overall extent of perchlorate in the expanded mass plume shell (Figure 3-11) was not significantly different from the 2008 perchlorate plume shell.

3.3.1.1.1 <u>Fate and Transport Simulations</u>

The fate and transport of the northern perchlorate and RDX plume were simulated under ambient conditions. The model runs incorporate hydraulic stresses from other nearby operating remedial system components (i.e. J-2 North, J-2 East, J-3, J-1 South, and

FS-12) and water supply wells that are within the model domain. The model runs also assumed no continuing mass flux from the source area, based on source removal actions and decreasing groundwater concentrations in the source area. The Upper Cape Water Supply wells WS-2 and WS-3 are within the J-1 North model domain (ECC 2007) and are simulated in the model at average operating conditions, 297 and 148 gpm, respectively.

The northern plume migrates in a north-northwesterly direction towards the Cape Cod Canal. Perchlorate concentrations above 2 µg/L are not predicted to migrate as far downgradient as Gibbs Road and are predicted to decrease below 2 µg/L by approximately 2080 and below detection limits past 2109.

The main northern RDX plume migrates north-northwesterly along a similar path as the perchlorate plume (Animation 3-2). The main RDX plume lobe, defined by concentrations above 0.6 µg/L, is not predicted to migrate as far downgradient as Gibbs Road and is predicted to decrease below 2 µg/L by approximately 2053, and below 0.6 µg/L and detection limits past 2109.

The western RDX lobe migrates north-northwesterly and is not predicted to cross Wood Road at concentrations above 0.6 µg/L (Animation 3-2). The RDX concentrations in the western lobe are predicted to decrease below 2 µg/L by approximately 2013, below 0.6 µg/L by approximately 2022, and below detection limits by approximately 2035.

3.3.1.2 J-1 Range South Transport Modeling

The J-1 Range south transport model is based on the calibrated J-1 south flow model. Contaminant shells for the J-1 southern RDX plume were developed, both prior and subsequent to the startup of the J-1 RRA system in 2007, to enable plume transport simulations and support the development and evaluation of remedial alternatives. However, based on monitoring well sampling and aquifer profile data obtained through 2009, it has become apparent that the plume shells currently available contain far more contaminant mass than is being detected, particularly within the off-post portion of the plume and, therefore, do not represent the characteristics of the plume with enough accuracy to enable reasonable simulations of future plume behavior. In addition, sampling data obtained in January 2010 from newly installed off-post monitoring wells suggest that additional delineation of the northern edge of the plume is needed. Therefore, a contaminant shell for the J-1 Range Southern RDX plume was developed to provide initial conditions for transport simulations (Appendix L). The plume shell represents the January 1, 2010 distribution of RDX (Figure 3-12). The J-1 Range Southern plume total RDX mass (dissolved = 0.726 Kg and adsorbed = 0.036 Kg) accounting for all concentrations simulated within the model is 0.76 Kg.

3.3.1.2.1 <u>Fate and Transport Simulation</u>

The fate and transport of the J-1 Range Southern RDX plume was simulated under ambient conditions. The model run incorporates hydraulic stresses from other nearby operating remedial system components (i.e. J-3, J-1 Southern, FS-12, J. Braden Thompson system) and water supply wells that are within the model domain. The

Sandwich water supply wells GP Well No. 4, GP Well No. 6, and GP Well No. 10, the MMR water supply Well J, and the Upper Cape Water Supply Cooperative Well No. 1 are within the J-1 Range model domain and are simulated in the model at average operating conditions (i.e. 89.6 gpm, 136.6 gpm, 230.2 gpm, 90 gpm, and 147.6 gpm, respectively) (Jacobs 2005).

After initializing the RDX concentrations at year 2010 in the transport model, J-1 Range Southern RDX plume migration was simulated with no active pumping from the J-1 Range Southern ETI system for 100 years with the exception of the first half year (2010 to 2010.5), when the ETI system was modeled as operating at the current operating rate. For this simulation, the end of active pumping corresponds to the expected final site decision. Approximately 0.006 Kg of RDX is predicted to be removed by the J-1 Range Southern ETI system from 2010 to 2010.5.

The J-1 Range Southern RDX plume migrates in a southeasterly direction (Animation 3-3). The animation indicates that some RDX concentrations are located within, or migrate into, low-hydraulic-conductivity units (less than 10 feet/day), and very slowly disperse without migrating appreciably downgradient. Field data indicate that the J-1 Southern RDX plume is primarily located within the sandy portion of the aquifer (i.e., high-hydraulic-conductivity units) and not within the low-hydraulic-conductivity units. Based on the distance the plume has traveled, and the general lack of contamination within the low-hydraulic-conductivity units (as evidenced in profile results), it appears that the bulk of the contaminant transport occurs through high-hydraulic-conductivity units and around low-hydraulic-conductivity unit. The low-hydraulic-conductivity units are carefully mapped into the model, but the extent of the units is approximated based on available data and the conceptual understanding of the aquifer matrix within the study area. The extent of the low-hydraulic-conductivity units within the model is also partially determined by the discretization of layers within the model. The plume shells are carefully constructed to match observed concentrations and migrated data. However, kriging (geostatical interpolation) of the data to construct the plume shell can result in an increase of concentration in areas where no data is mapped, such as a low-hydraulic-conductivity units. When the plume shell is imported into the model a small amount of mass can be initialized in low-hydraulic-conductivity units. Based on this information, the discussion of time frames to various thresholds in the following subsections below will refer to the useable (high conductivity) portions of the aquifer.

4.0 SOURCE CHARACTERIZATION

Initial investigations of the J-1 Range focused on those features identified during a historical aerial photograph analysis of Camp Edwards. Additional range features were included in the investigation as range records became available. Significant information regarding range activities has also been obtained through interviews of current and former base employees and range workers and observations noted during site reconnaissance, as previously discussed in Section 2.2. However, available records generally lacked sufficient detail to allow focused soil characterization activities.

4.1 Source Characterization Activities

Since 1997 a variety of field investigation methods have been employed to help locate and characterize site features that have caused, or have the potential to cause, groundwater contamination. As discussed below, multiple lines of evidence have been developed, including geophysical and soil sampling data, to characterize the J-1 Range. The following sections describe geophysical and soil sampling activities that have been conducted at the J-1 Range.

4.1.1 Soil

Soil characterization investigations in the J-1 Range commenced in 1997. During the period from August 1997 to July 2007, 1,675 soil samples were collected at various depths from 410 locations within the J-1 Range Study Area.

Samples were collected in accordance with the following work plans and project notes:

- *Final Field Sampling Plan for Area 5 (J-1 Range)* [FSP05] (Ogden, 1998 January).
- *Final J-1, J-3 and L Range Work Plan* [JLWP] (Ogden, 2000a), August
- *Final Field Sampling Plan for Turpentine Road and Tank Alley Targets* (Ogden, 2000b)
- *Final J-1, J-3 and L Ranges Additional Delineation Workplan No 1* [ADWP1] (AMEC 2001)
- *Final J-1, J-3 and L Ranges Additional Delineation Workplan No. 2* [ADWP2] (AMEC, 2002a), April
- *Munitions Survey Program (MSP) Phase 3, J-1 Range Site Work Plans* [MSP3] (Tetra Tech, 2001) November
- *Final J-1 Range Supplemental Soil Work Plan* [J1SWP] (AMEC, 2004), April
- *Final J-1 Range Supplemental Geophysical Investigation Work Plan* (ECC, 2005) August
- *J-1 Range Supplemental Geophysical Investigation-Additional Priority 1 Area of Investigation Project Note* (ECC 2005)
- *Final J-1 Range Priority 1 Grids Supplemental Geophysical Anomaly Investigation Report – Technical Memorandum* (ECC 2006)
- *J-1 Range Detailed Reconnaissance, EM-61 Survey and Aerial Photo Assessment – Summary and Recommendations* (ECC 2007)

- *Revised Draft J-1 Range Interberm Area RDX Delineation Sampling Project Note, (ECC 2009x), July*
- *Revised Final J-1 Range 2,4-Dinitrotoluene Delineation Project Note, (ECC 2009X), March*
- *Final J-1 Range Soil Removal Activities, (ECC, 2009x), August*

Results from many of these investigations are summarized in the following reports.

- *Final J-1, J-3 and L Ranges Interim Results Report*, TM 01-9 (AMEC, 2001b). March. This report includes analytical data collected from the beginning of the J-1 Range investigation in August 2000, through March 02, 2001
- *Technical Team Memorandum 01-3, Tank Alley And Turpentine Road Targets Investigation* (AMEC, 2001)
- *Draft J-1, J-3 and L Ranges Interim Results Report No. 2, TM 01-16* (AMEC, 2001c), September. This report includes analytical data collected from the beginning of the J-1 Range Investigation in August 2000 through July 27, 2001
- *Draft J-1, J-3 and L Ranges Additional Delineation Report No. 1 [*ADR1] (AMEC, 2002b), April. This report presents analytical results from the beginning of the J-1 Range investigation in August 2000 through April 14, 2002
- *Final J-1 Range Polygon Investigation Report,* Military Reservation, Camp Edwards, Massachusetts Munitions Survey Project Phase 3. September 2003 (Tetra Tech)
- *Final J-1 Range Priority 1 Grids Supplemental Geophysical Anomaly Investigation Report – Technical Memorandum* (ECC 2006)

Soils data collected pursuant to work plans and project notes dated after 2006 are presented for the first time in this remedial investigation report.

Types of soil samples collected include soil boring samples, discrete soil samples, composite soil samples, and multi-increment soil (MIS) samples. Soil samples associated with BIP activities have also been collected.

The majority of the samples at J-1 Range were composite samples collected from five-point sample grids designed to represent a 22 feet x 22 feet area. Sampling points within the grid were placed equidistant from each other; one point in the center and four points offset from each of the grid corners to form an “X” pattern. Sampling depths were typically 0- to 0.25-feet, 0.25- to 0.5-feet, and 0.5- to 1-feet below ground surface (bgs). Deeper depth samples or different grid dimensions may have been used depending on site features. Variations in grid dimensions, depths and/or number of composite points were defined in respective work plans. Soil samples were collected at magnetic anomalies, proposed excavation areas, from the base of excavations, at specific features noted in site records, aerial photographs and site reconnaissance, and in support of BIP activities. Samples were also collected using systematic random sampling (using MIS) to characterize large geographic areas within the range. Typically, 100-increment soil samples were collected from a predetermined area called a decision unit following an approach outlined in CRREL TR-07-10. These decision units corresponded with the grids established for the geophysical survey of the range (see Section 4.1.2). Post excavation 100-point composite soil samples were collected from the 0- to 0.25-feet depth from each decision unit following soil removal. The number, location and depth of MIS samples were specified in various Project Notes. Discrete samples were typically collected at locations with visible explosives, propellant and/or burn residue for explosives and perchlorate analysis only. The number, location and depth of discrete samples were designated in respective work plans.

Pre-BIP samples were collected from 0- to 0.25-feet depth around the UXO item combined as one sample and submitted for analysis. Post-BIP samples were collected following detonation from the bottom and sides of the BIP crater, combined and submitted for analysis.

Soil boring samples, obtained using a drill rig, were collected using stainless steel, split spoon samplers. The split spoon samplers were driven in accordance with the Standard Penetration Test (ASTM Method D1586-99) at designated sampling intervals. If required, a portion of the sample was collected for VOC analysis prior to homogenization of the soil. Sampling depths and analyses were specified at each sampling location and samples were typically collected every five to 10 feet from the ground surface to the top of the water table. In general, soil borings were used to characterize the vertical extent of contamination in those areas where surface soils were contaminated or where disposal activities were believed to have occurred. All soil samples were field screened with a photoionization detector to detect VOCs as the borings were advanced.

4.1.2 Geophysical

UXO discoveries have primarily been made in conjunction with ordnance clearance conducted in support of intrusive drilling, surface and subsurface soil sampling, and ground-based geophysical surveys. The initial ground-based geophysical survey conducted in the J-1 Range was in 2001 over an area of 60 acres approximating the historic maximum extent of vegetation clearance on the range.

The goal of the geophysical investigation was to produce a digital geophysical record of the subsurface that might indicate the locations of potential munitions disposal pits, as well as individual UXO items and other anomalies, including munitions debris to identify where sources of contamination to the aquifer might exist.

Site preparation included clearing the area of vegetation, conducting a UXO sweep, and mapping the site. After the surveyed corners of the range were determined in the field, a 30-meter by 30-meter reference grid was established throughout the investigation area. All UXO, UXO related materials, and debris encountered during the surface sweep were flagged and recorded on incident report forms. Following the surface sweep of the study area, EM-61 geophysical systems were used to survey the J-1 Range.

The geophysical investigations proceeded in a sequential manner; each of which used information collected during previous investigations to guide the next step of the process. The investigations typically focused on the anomalies with the highest potential to contain burial or disposal pits based on geophysical signals, field observations, witness interviews and program site knowledge. Generally, the largest and/or most densely distributed anomalies were investigated during each phase, which resulted in smaller anomalies being investigated as the phases of the investigation progressed and, ultimately, a thorough evaluation of potential source areas.

Geophysical surveys and investigations were conducted at the J-1 Range as indicated in the table below.

Investigation Phase	Scope	Work Plan/Report
Air Magnetometer (AIRMAG) Surveys	Helicopter-mounted magnetometers of four large areas o MMR , including the J-1 Range	*Draft AirMag Technology Evaluation Report* (Tetra Tech 2002)
Munitions Survey Programs (MSP) Phase I	Ground- based geophysical survey (EM-61) of AIRMAG findings	*MSP1 Final Report* (Tetra Tech 2003)
MSP Phase III	Intrusive investigation of “polygons” identified in MSP Phase I as having the potential to contain burial pits or UXO items	*Final J-1 Range Polygon Investigation Report* (Tetra Tech 2003)
Supplemental Geophysical Anomaly Investigations	Detailed reconnaissance and Intrusive investigation of additional polygons/grids.	*J-1 Range Supplemental Geophysical Anomaly Investigation Workplan* (ECC 2005) *J-1 Range Priority 1 Grids, Supplemental Geophysical Anomaly Investigation Report-Technical Memorandum* (ECC 2006) *J-1 Range Supplemental Geophysical Investigation-Additional Priority Area of Investigation Project Note* (ECC 2005)
Disposal Pit Discrimination Analysis Investigation	Intrusive investigation of potential pit targets	*Draft J-2 Range Supplemental Geophysical Anomaly Investigation Report*

Investigation Phase	Scope	Work Plan/Report
	based upon a statistical analysis of the geophysical data	*- J-2 Range Priority 1 Grids Technical Memorandum* (ECC 2005)
Data Gap Assessment, QC Grid Investigations	EM-61 survey of previously cleared areas and intrusive investigations of select anomalies	*J-1 Range Detailed Reconnaissance, EM-61 Survey and Aerial Photo Assessment - Summary and Recommendations* (ECC 2007)
Data Gap Assessment, Detailed Reconnaissance Investigation	Detailed reconnaissance of areas of the range, and intrusive investigation of selected anomalies	*J-1 Range Detailed Reconnaissance, EM-61 Survey and Aerial Photo Assessment - Summary and Recommendations* (ECC 2007) *Revised Reconnaissance for Assessment of Potential Data Gaps at the J-1 and J-2 Ranges (IAGWSO; Jan 2007)* *Standard Operating Procedure for Detector–Aided Reconnaissance and Spatial Data Collection* (ECC, 22 May 2006)
Data Gap Assessment, Aerial Photo Assessment	Intrusive investigations of areas identified in aerial photos as being disturbed in the past	*J-1 Range Detailed Reconnaissance, EM-61 Survey and Aerial Photo Assessment - Summary and Recommendations* (ECC 2007) *Revised Reconnaissance for Assessment of Potential Data Gaps at the J-1 and J-2 Ranges (IAGWSO; Jan 2007)* *Standard Operating Procedure for Detector–Aided Reconnaissance and Spatial Data Collection* (ECC, 22 May 2006)
Robotics Technology Demonstration	Soils were removed and sifted from the	*J-1 Range Berms AFRL Technology Demonstration*

Investigation Phase	Scope	Work Plan/Report
	uprange faces of the 1,000 meter berm, 150 meter berm and 2000 (a and b) meter berms using remote robotic technology	*(IAGWSP, 2 April 2008)*

Geophysical data and areas intrusively investigated are depicted graphically in characterization figures for each sub-area and summarized by phase in Table 4-1.

4.2 Source Characterization Findings

This section describes the various geophysical and soil characterization activities and results, lists the various removal actions that were conducted at the Range and finally presents a summary of the nature and extent of contamination/UXO at the Range. To simplify the discussion, the Range has been divided into sub-areas based largely on range features and the grid layout shown in Figure 4-1. These sub-areas will be discussed as follows: Firing Point Area (Rows 0 to 6), Southern Flyover Area (Rows 7 to 29), Interberm Area (Rows 30 to 44), Northern Flyover Area (Rows 45 to 64) and the 2000 Meter Berm Area (Rows 65 to 72). These sub-areas were chosen based on historical range use, range features and the conceptual site model of the range.

Tentatively identified compounds (TICs) detected in soil samples included the SVOCs TNT, RDX, acetophenone, benzaldehyde and benzo(e)pyrene. Acetophenone and benzaldehyde are common laboratory artifacts of the SVOC extraction process. TNT and RDX were reported as TICs in post-BIP samples. These TIC results confirm the detected results that were reported by explosives compounds method SW846/8330 for respective samples. Benzo(e)pyrene was detected at low levels in a few samples which had reportable detections of other PAH compounds. TICs were considered only for the confirmation of detected compounds and, therefore, are not discussed specifically in the source area subsections.

4.2.1 Firing Point Area (Rows 0 to 6)

The firing point area is situated in the southeastern portion of the J-1 Range (Figure 4-1). The Archives Search Report documents that this area of the range was used as the firing, staging and administrative area for the munitions testing that occurred at the range. The two berms located in this vicinity on either side of the range road were reportedly used as barriers between firing points and buildings and as a location for firing. Section 2.2 discusses, in greater detail, the historical range uses and potential disposal activities in this portion of the range.

The following specific site features are or were formerly located within this sub-area:

- Suspected Water Saw Area
- Firing Point 1
- Firing Point 2
- Mortar Position
- Range Tower
- Tunnel Barrier 1
- Steel Plate Target for 100-Meter Range
- Former Buildings and Storage Areas

In addition, the following significant features were identified as a result of intrusive investigation of geophysical anomalies:

- Munitions Disposal Area – The Munitions Disposal Area was discovered in September 2000 during well pad clearance for MW-131. Ordnance items, including munitions, munitions debris, and other debris were recovered from a pit.
- MSP Polygon 1 – An area containing several large geophysical anomalies, designated as Polygon 1, was located on the north side of the range road near the entrance of the J-1 Range, and adjacent to the Munitions Disposal Area. Two burial pits and two burn pits were found in Polygon 1.

Soil sampling activities were generally focused on the features listed above. A description of each of these features was previously presented in Section 2.2. The J-1 Range Rows 0 to 6 soil data set represents site investigations conducted from December 1997 through September 2009. A total of 260 soil samples were collected from 84 locations within this portion of the range. In most cases samples were collected from multiple depths at each location, resulting in a larger number of samples than actual sample locations. Additional details about soil samples collected around each feature within this sub-area are discussed below and presented in Table 4-2. Table 4-3 summarizes analytical detections in soil that has already been excavated during various intrusive investigations, removal actions, or in conjunction with BIP activities. Table 4-4 summarizes analytical detections for all soil samples which represent current in-situ site conditions. The complete data-base for all soil analytical results collected through 2007 is included in Appendix G. Table 4-5 summarizes the results of recent multi-increment soil sampling. Soil sample locations as well as locations and descriptions of MEC items identified in the field are depicted on Figure 4-2. Figure 4-3 depicts current site conditions, and includes chemical results boxes for samples with explosives or perchlorate detections. Munitions items were categorized based on their explosive characteristics. The categories developed include: high explosive (HE), possible HE, Propellant/Energetic, Small Quantity Energetic, and Inert. Munitions items that were classified as HE were required to have positive identification for their main charges, (e.g., lot number or Post-BIP results indicative of High Explosives). Items that were classified as "possible HE" were munitions items that were assumed to contain HE on initial discovery and were either transported to the CDC for detonation or BIP, where the actual presence of the HE was not conclusively established or was not recorded. Items classified as Propellant/Energetic include raw propellant, chunk explosives or bulk explosives. Items classified as Small Quantity Energetic were MEC items that contained small amounts of energetic materials in one or more components (fuzes, detonator spotting charges). Items classified as inert were munitions items that were considered to be HE as a safety precaution but post BIP or CDC results indicated that the item was inert.

4.2.1.1 Grids H0 to J2 and K2

A total of 11 samples were collected from four locations at and around Firing Point 1. Soil samples were collected at the base of the firing point (CP05A), and on top of the earthen mound (SS05A1, SS05A2, and SS05A3). There were no explosives detected in these samples (see Table 4-2 for a complete list of analytes).

A total of eight samples were collected from three locations at and around Firing Point 2. One sample was collected from on the top of the berm (SS05PA) and two were collected behind the firing point (CP05P and SS05PB). There were no explosives detected in these samples.

Three samples were located at SS15147-A, up-range of the instrumentation building, where a water saw was reportedly used to cut explosives. The water saw location was based on a witness interview (AMEC 2004). No explosives were detected at this location.

Three soil samples were collected from sample location SS15137-A. RDX was detected in this sample at 3,400 µg/Kg and HMX was detected at 520 µg/Kg (Table 4-3). This contaminated soil has been removed for treatment.

A total of four soil samples were collected from two locations (CP05F and CP05G) associated with former building locations (Table 4-2, Figure 4-2). There were no explosives detected at location CP05F. Sample CP05G was only analyzed for VOCs.

Soil samples were collected in grids H-0, I-0, J-0 and J-1 (locations SSJ1H001, SSJ1001, SSJ1J001, and SSJ1J101) prior to intrusive investigation of geophysical anomalies. These samples were analyzed for explosives and perchlorate and were non-detect for both analytes. Another sample was collected adjacent to a steel plate at the boundary of grids I-2 and J-2 (SSJ1I201). This sample had an RDX detection of 250 µg/Kg (Table 4-3). This soil has been removed for treatment.

Intrusive investigation of geophysical anomalies within these grids resulted in the discovery of primarily debris (steel bars, and other miscellaneous metal debris). However, one of the large anomalies, located along the edge of grid I2, was identified as a munitions burial pit (J1I2-BLP-001). Recovered items during the excavation of this pit were munitions debris and metallic debris. Items recovered included: expended M54 LAW rocket motors, inert 81mm mortars, LAW rocket parts, other debris, and 0.5 lbs of propellant associated with a 2.75 inch rocket motor (this was the only MEC item recovered). A discrete sample, J1I2-BLP-001, was collected from the soil beneath the propellant. A sample was also collected from the soil excavated from the burial pit, J1I2-BLP-001 (stp), and from the base of the excavation, J1I2-BLP-001 (post). There were no explosives or perchlorate detected in any of these samples (see Table 4-1 for a complete list of analytes and Table 4-3 for analytical detections). However, eight cubic yards of excavated soil were disposed off-site due to the presence of the semi-volatile compound 2-nitrodiphenylamine (this compound was detected at 140 µg/Kg). Munitions recovered during the intrusive investigation are described in Table 1 of Appendix H.

A quality control geophysical survey was conducted in grid I2 to assess thoroughness of the initial geophysical survey and intrusive investigation. Numerous small anomalies were subsequently investigated and the majority of items recovered were munitions debris and other debris. Intrusive finds are described in Table 1 of Appendix H.

A corroded 55-gallon drum with an attached pipe was discovered in grid J2 (identified as location J1-21). A discrete sample was collected from the soil under the 55-gallon drum [J1J1001 (under drum)]. A separate grab sample from soil located within the drum was also collected [J1J1001 (soil in drum)]. There were no explosives or perchlorate detected in these samples (see Table 4-2 for a complete list of analyses and Table 4-4 for analytical results).

4.2.1.2 Grids K1, L1 through M2 and Location 59

Prior to the initial geophysical survey conducted in grids K1, L1 through M2 and Location 59, a Munitions Disposal Area was found in grid K1 during the construction of the drilling pad for well MW-131. Items recovered from this pit were 81mm and 60mm mortars, 105mm projectiles and fuzes. All of these munitions were inert. One soil sample (SSJ1DP1S) was collected from the soil pile excavated from the pit, and one composite soil sample (SSJ1DP1) was collected at the base of the excavation. Both of these samples were non-detect for explosives and the excavated soils were backfilled. Soil boring samples were also collected during the drilling and installation of MW-131 in the vicinity of the disposal area. There were no explosives detected in the soil boring samples. In addition, water was collected from a 105mm cartridge case and analyzed for petroleum hydrocarbons (J1DP1RW). Concentrations of C10-C22 range aromatic compounds exceeding MassDEP standards were reported by the laboratory. The remaining sample volume was disposed by the laboratory. All of the volume of water in the cartridge casing was consumed during the sampling process.

Additional intrusive investigation of geophysical anomalies within these grids resulted in the discovery of numerous disposal pits. Munitions burial pits found in grid L2 (polygon 1) contained the following items: M374 81mm mortars, M302 60mm mortars, M1 105mm projectiles, and M524 fuzes. Three presumed HE M374 81mm mortars were the only items potentially containing high explosives in grid L2. The majority of anomalies were determined to be either munitions debris or other debris. A total of 46 samples (J1.A.T1, J1.F.T1.MT1, J1.A.T1, SS15146-A), including BIP samples associated with this feature, were collected. Post-excavation samples were non-detect for explosives and perchlorate.

Also identified in Polygon 1 were two burn pits, both of which contained layers of ash material. Three soil samples were collected from Burn Pit Number 1 including: a sample from the ash layer (J1.F.T1.BP1.3.0); a sample of excavated soil (J1.F.T1.BP1.1.0); and a sample from the pit bottom. No explosive compounds were detected in any of the three samples. However, low levels of metals, SVOCs, VOCs and dioxin congeners were detected. A total of three soil samples were collected from Burn Pit Number 2 including: a sample of the ash layer (J1.F.T1.001.3.0); a sample of excavated soil (J1.F.T1.001.1.0); and a pit bottom sample (J1.F.T1.001.2.0). All three samples were non-detect for explosives. These samples also had detections of metals, SVOCs, and dioxin congeners. Soils excavated from Burn Pits 1 and 2 (7 cubic yards) were disposed of off-site. See Table 4-3 for a complete list of analytical detections in the excavated soils. Table 4-4 contains analytical results for soils that represent current conditions.

In Burn Pit number 2, a deformed and rusted 5-gallon metal bucket containing clear liquid (with a “solvent-like odor”) and tar-like material was also identified. The bucket was over packed and disposed of as a lab-pack item. The waste characterization screening of this material identified the items as a flammable solid waste. The tar-like substance was sampled for perchlorate and had a low concentration of 3.8J µg/Kg.

Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The QC geophysical survey was conducted in grids L1, L2, M1 and M0. A burn pit (J1L1-BNP-001) containing two hundred thirty-six M524 live fuzes, munitions debris, and miscellaneous other debris was found in grid L1. The post-excavation sample (SSJ1L1BNP001) was non-detect for explosives and perchlorate. Waste characterization samples from the excavated soil indicated that it did not contain detectable concentrations of explosives or perchlorate, but cadmium was present at levels exceeding MassDEP standards. Approximately 59 cubic yards of soil was removed from this pit for off-site disposal. Items recovered during the intrusive investigations are listed in Table 1 in Appendix H.

Another disposal pit was discovered in grid M1 (J1M1-BLP-001) that contained munitions components, munitions debris and other debris. One inert 105mm M1 item was destroyed and found to be inert (with a live fuze). A post-excavation sample was collected (SSJ1M1BLP001), which was non-detect for explosives and perchlorate. No explosives or perchlorate were detected in the waste characterization samples from the excavated soil. However, the soil was disposed off-site due to the presence of benzo(a)pyrene (51 µg/Kg). Items recovered from the excavation are listed in Table 1 in Appendix H. In addition, thirty-two M51 fuzes, classified as small quantity energetic, were also found in grid M1, and were taken to the CDC for disposal.

Location 59 is located in the woods, southeast of grid L1. Four items with live fuzing, and scattered munitions debris and other debris were found at this location. (Three inert M374 81mm mortars and one inert M456 104mm HEAT round, all with live fuzing).

As discussed above, numerous munitions disposal pits were identified within this portion of the range. The majority of munitions items were inert. Live fuzes were the only items identified as MEC. Three M374 81mm mortars were found in grid L2 and presumed to be HE and taken to the CDC.

4.2.1.3 Rows 3 through 6

Geophysical anomalies identified as Polygons 2, 3, 4 and 5 are located on the south side of the range road near the entrance of the J-1 Range. A total of 15 surface soil samples were collected from five locations prior to excavation of these geophysical anomalies. Soil samples were collected from one location each at Polygons 2, 3 and 4 (SS05AB, SS05AC, and SS05AD, respectively) and from two locations at Polygon 5 (SS05AE and SS05AF). Samples collected from Polygon 5 had no detections of explosives or perchlorate, but had detections of pesticides, SVOC and VOC compounds (Table 4-4). During a second phase of sampling, four additional samples were collected in the vicinity of Polygons 2, 3 and 4 (SS15134-A, SS-15136-A and SS15137) to further define the extent of explosive contamination in this area. RDX was detected in samples collected from locations SS05AD, SS05AC, SS05AB and SS15137, ranging from 140 µg/kg to 3600 µg/kg (Table 4-3). In 2009, multi-increment soil sampling was conducted in grids I1, I2, I3, I4, I5, I6, J1, J2, J3, J4, J5, J6, K2 and K3. The results of the sampling identified RDX contamination in grids I1, I2, I3, J1, J2, J3, and K3 ranging from 130 µg/Kg to 34,000 µg/Kg. HMX was detected in grids I1, I2, J2 and J3 at concentrations ranging from 1,200 µg/Kg to 3,700 µg/Kg (Figure 4-4, Table 4-5)). Contaminated soil in grids I1, I2, I3, J2 and J3 likely is a contributing source for the J-1 South RDX plume and has been removed for treatment (ECC 2009) (IAGWSP 2009). Approximately 1,665 cubic yards of soil was removed from the J-1 south area. During soil excavation activities one T324 37mm HE projectile was found in grid I3 and is documented in Table 1 of Appendix H.

The target for the 100-meter range was a steel box located on the side of Tunnel Barrier 1. One discrete grab soil sample was collected from the berm, below the base of the target (SS05A). In 2009, a sample was collected from soil removed from the interior of the box-shaped target. There were no explosives detected in these samples (see Tables 4-2 and 4-4 for a list of analyses and analytical detections).

A total of 19 samples were collected from six locations on and around Tunnel Barrier 1. One sample was collected at the top of the mound (CP05B) and one was located at the base of the mound on the slope facing the firing position (CP05C). Samples were collected from three locations near the tunnel entrance at Tunnel Barrier 1 (SS05TA, SS05TB, and SS05TC). One sample was also collected on the uprange side of the projectile trap near the tunnel barrier (SS15145-A/SS05V). There were no explosives or perchlorate detected in these samples. (see Tables 4-2 and 4-4 for a complete list of analyses and analytical detections).

One disposal pit, containing MEC, munitions debris and other debris, was identified in this portion of the range in Area 1 of grid K4 (J1K4-BLP-001). This pit, discovered along the north side of grid K4, contained inert 81mm mortars, inert 105mm projectiles, two M374 81mm mortars (presumed HE), a partial drum, cable, tank parts, concrete, and various scrap. The items within the pit were accompanied by odors, discolored soils, and unknown bottled liquids and solids. These unknown materials were characterized for off-site disposal. The soil was disposed of off-site due to the presence of PCBs (12 µg/Kg – Aroclor 1254) (Table 4-3). None of the unknown liquids/solids contained explosives or perchlorate. Approximately 20 cubic yards of soil was removed from the pit for off-site disposal. A post-excavation soil sample (SSJ1K4001) was collected. No explosives or perchlorate were detected in this sample (Table 4-4).

Several munitions items discovered during various field investigations in Rows 3 through 6 were blown-in-place (BIP). Two M374 81mm mortars found during a surface sweep in grid J4 and BIP, were determined to be HE. Two M374 81mm mortars found during the access road clearance in grids K5 and J6 and BIP were also determined to be HE. One additional M374 81mm mortar was found during a surface sweep in grid K6 and presumed to be HE. One M49 60mm mortar found in grid J3 was determined to be HE. Two M49 60mm mortars were found in grid K6 and presumed to be HE.

Most of the large aerial extent anomalies investigated in Rows 3 through 6 were identified as concrete pads and large steel plates. These features are visible on historical photographs from the period when testing activities were conducted in this area. Other debris identified within these grids included railroad ties, a 55-gallon steel drum, sheet metal, metal siding, vehicle doors and steel pipes. One disposal pit containing unknown liquids and solids and associated excavated soils were managed for off-site disposal. It is likely that additional M374 81mm HE mortars and M49 60mm HE mortars are present within rows 3 through 6. It is also likely that the quantity is low as a result of clearance activities conducted in this area in support of investigations (roads, well pads, and select anomalies).

RDX and HMX contaminated soil identified in the vicinity of Polygons 2, 3 and 4 has been removed for treatment.

4.2.1.4 Firing Point Area BIP-Related Sampling

A total of 126 samples were collected from 29 locations associated with BIP activities in this portion of the range. BIP sample locations, sample identification, collection date, sample depths, and laboratory analyses associated with this sub-area of the range are listed in Table 4-2. Most of the BIP samples were associated with Polygon 1. Contaminated soils generated as a result of BIP activities were excavated as required in the BIP management program. Table 4-3 contains analytical detections for those soils excavated under the BIP management program.

Three BIP-related soil samples for soil that remains in place have detections of RDX or HMX. Remaining locations with RDX detections are J1.A.T1.PR05.1.0 and SS08526-A. The RDX concentrations in these samples were 54 µg/Kg and 145 µg/Kg. HMX at 130 µg/Kg remains at BIP location SS15231-A (Table 4-3 and Figure 4-3).

4.2.1.5 Firing Point Area Source Characterization Conclusions

Grids H0 to J2 and K2

Aside from a burial pit with .5 lbs of propellant in grid I2, the majority of items identified in this area during intrusive investigations consisted of range related debris. All of the large anomalies identified as possible burials based on the geophysical survey were intrusively investigated and none showed evidence of MEC burials. Field observations indicate that large anomalies that remain on the range are primarily metallic range features (Figure 4-3). Clearance conducted in support of other site investigation activities (road and well pad clearance) also did not suggest the presence of burials or widely distributed MEC items as only range related debris was recovered during these efforts. Based on the significant amount of intrusive investigations conducted in this area, the remaining small isolated anomalies in the area have a high probability of being metallic debris (Figure 4-3). While there is a potential for residual single MEC items, the investigation findings suggest there is a low likelihood of the presence of uninvestigated MEC burials or the potential for widespread distribution of MEC items.

Soil analytical results indicated that explosives contamination was present in surface soils in the vicinity of the former water saw, as well as the area within grids I1, I2, I3, J2 and J3. The significant detections of explosives compounds in this portion of the range indicate that this area was likely the most significant source for the J-1 South RDX plume. These soils have been removed for treatment.

Grids K1, L1 to M2 and Location 59

The findings of investigations in grids K1, L1, L2, M0 to M2 and location 59 suggest that this part of the range was used as a disposal area; numerous munitions disposal pits were identified in this portion of the range. Three munitions disposal pits were identified in grid K1, three burn pits were identified in grid L1, one burial pit was identified in grid M1, and two burial pits were discovered in grid L2. However, the majority of items identified in this area during intrusive investigations consisted of munitions debris and other debris. Munitions debris was identified in each of the grids and consisted of over one thousand inert 81mm and 60mm mortars and 105mm projectiles, hundreds of expended fuzes, thousands of fuze parts, and other miscellaneous munitions debris.

Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The QC geophysical survey was conducted in grids L1, L2, M1 and M0. MEC items containing small quantities of energetics are 235 M524 fuzes that were discovered within a burn pit in grid L1 and 32 M51 fuzes discovered within a burial pit in grid M1. Three N374 81mm mortars and one M567 adapter booster found in grid L2 were also presumed to be HE and transported to the CDC.

Categories of findings from intrusive investigations in the range are listed in Table 4-1 and specific finds are shown in Table 1 of Appendix H.

There were no detections of explosive compounds in soil associated with the intrusive investigations in this portion of the range (Tables 4-3 and 4-4). Soil samples were analyzed for the parameters identified in Table 4-2. Based on findings of investigations, this portion of the range is unlikely to have contributed significantly to the J-1 South RDX plume.

<u>Rows 3 to 6</u>

Finds from the investigation of this portion of the range suggest that this area was used as the 100 meter range target, as a flyover area and a disposal area. Elevated detections of RDX in this portion of the range have been removed for treatment (370 cy from grids I3 and J3).

All of the large anomalies identified as possible burial pits were intrusively investigated. One disposal pit, containing MEC, munitions debris and other debris, was identified in Area 1 of Grid K4 (J1K4-BLP-001). The excavated soil (20 cy) was disposed off-site due to the presence of PCBs. Additional geophysical investigations of anomalies in Grid K4 will be performed in accordance with the "*Final J-1 Range Targets 22 and 35 Soil Sample Collection and Grid K4 Anomaly Investigation*" Project Note dated July 7, 2010 (ECC 2010).

The majority of the large geophysical anomalies investigated were concrete pads and steel plates. Single impacted UXO were documented but not in the context of an impact area. Munitions items identified as HE included M374 81mm mortars and M49 60mm mortars. However, the quantity of these items was low and the investigation suggests there is a low likelihood for the presence of uninvestigated MEC burials or the potential for widespread distribution of MEC items.

4.2.2 Southern Flyover Area (Rows 7 to 29)

The Southern Flyover Area (Rows 7 to 29) is situated in the southeastern portion of J-1 Range (Figure 4-1). The archive search report indicates that this area of the range was primarily a munitions flyover area for munitions fired downrange. Section 2.2 discusses, in greater detail, historical uses in this portion of the range. Tunnel Barrier 2 is the only visible significant physical site feature located within this portion of the range.

In addition, two significant features were identified during intrusive clearance activities along the J-1 Range Road:

- Mortar Disposal Area - The Mortar Disposal Area was discovered in 1998 during the investigation of a topographical depression, based on witness accounts, on the southwest side of the Range Road within grid J24 (Figure 4-6).
- Polygon 6 - Polygon 6 is located northwest of the Mortar Disposal Area as indicated on Figure 4-6. Munitions debris and other debris materials were discovered.

Soil sampling activities in this portion of the range were generally focused on the features mentioned above. A description of these features was previously presented in Section 2.2. The J-1 Range Rows 7 to 29 soil data set represents site investigations conducted from December 1997 through July 2007. A total of 137 soil samples were collected from 45 locations within this portion of the range. In most cases, samples were collected from multiple depths at each location, resulting in a larger number of samples than actual sample locations. Additional details about soil samples collected around each feature within this sub-area are discussed below and presented in Table 4-2. Table 4-3 summarizes analytical detections in soil that has already been excavated during various BIP soil removal actions. Table 4-4 summarizes analytical detections for all soil samples that represent current in-situ site conditions. The complete data-base for all soil analytical results (through 2007) is included in Appendix G. Soil sample locations as well as location and description of MEC items are depicted on Figure 4-6. Figure 4-7 represents the existing site conditions, and includes chemical result boxes for samples with explosive or perchlorate detections. Munitions items were categorized based on their explosive characteristics, as defined in previous sections. Categories of findings from intrusive investigations in the range are listed in Table 4-1 and specific finds are located in Table 1 of Appendix H.

4.2.2.1 Rows 7 to 29 Findings

Based on the site history and munitions finds, this portion of the range was predominantly used as a flyover area for munitions testing. As indicated on Figure 4-6, site investigations have been conducted throughout this portion of the range. Soil sampling was focused on physical site features, geophysical investigation areas, and other areas of interest identified from the review of historic photographs, range records or witness accounts. In addition to the focused intrusive investigations of geophysical anomalies other investigative activities including monitoring well pad construction and access road maintenance often involved intrusive clearance work. The findings from all of these activities helped characterize this portion of the range. A summary of notable investigation results in this area is provided below.

The dominant feature within this portion of the range is Tunnel Barrier 2 located in grid J10. A surface sweep was performed in this area prior to the range-wide geophysical survey and no MEC items were reported. The large remaining geophysical signatures in the vicinity of Tunnel Barrier 2 are associated with steel plates. A total of five samples were collected from two locations on and around Tunnel Barrier 2 (Figure 4-6). Soil samples were collected from the top of the mound (CP05D) and from the base of the mound adjacent to the uprange slope (CP05E). There were no explosives detected in these samples.

Prior to the EM-61 geophysical survey, a large Mortar Disposal Area was discovered in December 1997 during the investigation of a topographical depression on the southwest side of the range road within grid J24 (Figure 4-6). Approximately 1067 M374 81mm inert mortars were recovered from this disposal area. In addition, 60mm inert mortars, fuzes and other munitions debris were discovered within the pit. Two 105MM HE/M51 PD Fuzes were BIP and determined to be HE. Soil samples were collected from the bottom of the excavation (sample location SS05EF, sample ID BG5EAA) and from the excavated soil (sample location SS05EF, sample ID BG5FAA). There were no explosives detected in either soil sample. Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The follow up geophysical survey was conducted in grid J24 in order to determine the thoroughness of the munition clearance activities at the Mortar Disposal Area. Findings from subsequent intrusive investigations included inert 81mm and 60mm mortars and munitions debris. Two inert M374 81mm mortars were identified with live M524 fuzes.

Intrusive investigation of a large subsurface anomaly in grid J12 identified a burial pit containing 154 inert M374 81mm mortars (J12-BLP-001). Additional inert items found within the excavation included nine M72 66mm warheads, two 3.5 inch rocket fin assemblies and two 2.75 inch rocket assemblies. Since all the projectiles were determined to be inert, no soil samples were collected from this burial pit. An additional anomaly, J1J12 Area1, was determined to contain metallic debris (Figure 4-6).

A large geophysical anomaly was detected in grid K27 and designated as Polygon 6. Seven soil samples were collected from two sample locations (SS05OA and SS05OB) prior to the initiation of intrusive activities. There were no explosives detected in these samples. Only munitions debris and other debris were recovered from this area, and therefore, no soil samples were collected during or after the excavation (Table 4-1). A follow-on geophysical survey was conducted in grids K27 following the intrusive investigation of Polygon 6. Subsequent intrusive finds included one MEC item and residual munitions debris and other debris. The MEC item was an inert M374 81mm mortar with live M524 fuze. Two additional aerial photo feature grids in the vicinity of Polygon 6, designated Locations 53 and 51, were investigated. These features were selected based on aerial photo and site reconnaissance indications of past surface disturbances. A geophysical survey was conducted at Location 53 but no investigation was performed due to the presence of only very small anomalies. Location 51 was investigated with handheld magnetometers and munitions debris and other debris was identified.

During various investigation support activities, three HE, M9 Rifle grenades were found within grids J11, J17 and L16. These items are likely associated with historic training activities. Based on these finds additional investigations were conducted northeast of the J-1 Range Access Road in grids J11-17 and K11-17. During these investigations, six additional M9 Rifle Grenades were discovered that were determined to be HE. Additional items found during the investigation are documented in Appendix H Table 1.

A detailed reconnaissance was performed in grids I8 and I9 (J1I8 Areas 1-3, J1I9 Area 1) because of indications of past surface disturbances. Numerous small anomalies were detected and identified as fragmentation debris. A large geophysical anomaly, J1I8 Area 1, was investigated in grid I8 within the berm that bounds the edge of the range. Findings within the anomaly included munitions debris and other debris. Additional areas on the southwest side of the range berm in grids I8 and I9 were also investigated; however, only munitions debris and other debris were identified. Grid I8 contained two M374 81mm inert mortars with live M524 fuzing.

One presumed HE M374 81mm mortar was found in grid K7. It is not clear from site records if this item was inert or HE but it is likely associated with historic testing activities.

Geophysical investigations of Location 9 (grid J22), Location 6 (grid K26), Location 15 and 35 (grid J7) identified only munitions debris and other debris. Four 105mm HEAT rounds were found in grid J15 and were BIP and determined to be inert. Three, M374 81mm mortars, found in grid J16, were determined to be inert with live M524 fuzing.

A single M760 105mm HE projectile was found within grid J8, blown-in-place and reported as HE. A 155mm projectile with exposed filler was found and removed in grid J8.

4.2.2.2 Southern Flyover Area BIP Samples

Some potential unexploded ordnance items discovered during intrusive field investigations, and road and well pad clearance activities, were BIP. A total of 118 samples were collected from 44 locations associated with BIP activities in the J-1 Southern Flyover Area South. BIP sample locations, sample identification, collection date, sample depths, and laboratory analyses associated with this sub-area are identified in Table 4-2. 2,4 DNT was detected in the pre-BIP sample SSJ1RD022 at 29 µg/Kg, however, the soil at this location was excavated under the BIP management program (Table 4-3).

Four explosive compounds (RDX, nitroglycerin, tetryl and perchlorate) were detected in four BIP soil samples that were not excavated. Two post-BIP sample locations had RDX detections (SS287-A, and SSJ1I18001) at 14 µg/Kg and 22 µg/Kg, respectively. Tetryl was detected in two post-BIP samples (SSJ1I18001 and SSJRANGED) at 28 µg/Kg and 680 µg/Kg, respectively. Perchlorate was also detected in two pre-BIP samples at locations SS287-A and SS288-A at 2.4 and 2.2 µg/Kg respectively (Figure 4-7, Table 4-4). The significance of these detections is further evaluated in the risk screen (Section 6). There were no other explosive compounds detected in pre-BIP samples.

4.2.2.3 Southern Flyover Area Characterization Conclusions

All of the large geophysical anomalies identified in this portion of the range were investigated and where appropriate, the contents excavated; large anomalies that still remain are associated with observed steel plates. Most of the anomalies were related to munitions debris and other debris; however, a few were representative of inert munitions in disposal pits. No MEC burials were identified in this portion of the range nor were any significant soil contamination identified.

Some small to medium size anomalies remain in this portion of the range (Figure 4-7). It is possible that single 60mm or 81mm mortars may remain on the range. Based on the types of rounds recovered, there is a high likelihood that any residual rounds would be inert or inert with live fuzing. It is also possible that additional M9 HE Rifle Grenades exist within grids Columns J, K and M, Rows 11 to 17. While there is a potential for residual single MEC items, the investigation findings suggest there is a very low likelihood of the presence of MEC burials or the potential for widespread distribution of MEC items. The geophysical data for this area shows a lesser density of anomalies compared to other areas at the J-1 Range. In addition, clearance activities conducted in this area in support of investigations (roads, well pads, and select anomalies) indicated a relative lack of significant finds. No groundwater contamination is known to exist in this portion of the J-1 Range.

4.2.3 Interberm Area (Rows 30 to 44)

The Interberm Area (IBA) is situated in the mid-range portion of the J-1 range (Figure 4-1). The Archives Search Report documents that this area of the range was used as the firing, testing and disposal area for the munitions testing that occurred at the range. Section 2.2 discusses in greater detail historical range uses and potential disposal activities in this portion of the range.

The following specific physical site features are or were formerly located within this sub-area:

- Firing Point 3
- 1,000 Meter Berm
- 150 Meter Berm
- Popper Kettle/J-3 Waste Water Discharge Area
- Cook-Off Test Location
- Steel Lined Pit
- Magnetic Anomalies/Partially Buried Tanks and Tank Parts
- Potential Burn Area

In addition, disposal areas were identified as a result of the initial intrusive investigation of geophysical anomalies. These disposal areas include the following:

- Burial Trench - A burial trench approximately 108-feet long by 4-feet wide by 4-feet deep, was uncovered adjacent to Polygon 16 on the west side of the road opposite the 150 meter berm (Figure 4-8), during well pad clearance activities. Approximately 30 five-gallon metal containers, filled with what appeared to be solid paint-related materials, were found placed end-to-end along the length of the trench.
- Polygon 16 - A shallow burn pit in grid H40 and I40 which contained a deteriorated drum with burn material, a five-gallon bucket of tar-like substance and munitions and other debris.
- Polygons 7 through 15 – Numerous large geophysical anomalies, designated as Polygons 7 through 15 (Figure 4-8). Polygons 9 (grid H35) and 10 (grid H38) contained disposal and burn pits and Polygons 14 and 15 (grid J40) contained three disposal pits. Polygon 8 (grid I33), Polygon 11-13 (grids I39 and I40)] were not classified as disposal pits.
- Disposal pits were identified in grids K38 (K38-BLP-001), grid J39 (J39-BNP-001), grid K34 (K34-BLP-001), Location 44/grid H 37 (J1APA-BLP-001), grid H39 (H39-

BLP-001), grid K36 (K36-BLP-001 and K36-BLP-002) and grid J36 (J36-BNP-001), grid K38 (K38-BLP-001), grid J39, and grid K34 (K34-BLP-001)

Soil sampling activities were generally focused on the physical site features and disposal pits identified above. A description of each of the physical site features was previously presented in Section 2.2. The soil data set for the IBA represents site investigations conducted from December 1997 through September 2009. A total of 637 soil samples were collected from 164 locations within this portion of the range. In most cases samples were collected from multiple depths at the same location, resulting in a larger number of samples than sample locations. Additional details about soil samples collected around each feature within this sub-area are described below. Table 4-2 contains details on sample depths and analytes. Figure 4-8 depicts all sample locations as well the location and description of identified MEC items. Figure 4-9 depicts multi-incremental sampling decision units. Figure 4-10 depicts excavation areas. Table 4-3 summarizes analytical detections in soil samples representing soil that has already been excavated (pre-2009) during intrusive investigations, removal actions or under the BIP Program. Table 4-4 summarizes detections for soil samples that represent current site conditions. Sample locations and geophysical data representing current conditions are depicted on Figure 4-11.

The results of geophysical investigations and soil sampling are discussed below. Due to the significant amount of data generated during the extensive geophysical investigations in the IBA, the discussion for the geophysical investigation is focused primarily on MEC discoveries. Figure 4-8 identifies each investigation area and Table 4-1 lists each investigation and provides a general description of the types of anomalies that were identified (i.e. MEC, munitions debris or other debris). Table 1 of Appendix H provides a detailed listing of finds from each geophysical investigation. Munitions constituents are presented in Table 4 of Appendix H.

For data presentation purposes, the IBA is divided into three sub-areas, based on the conceptual site model presented in the Munitions Source Assessment (Appendix H). The area within Rows 30 to 33 was used as an impact area, Rows 34 through 42 was primarily related to disposal activities and Rows 43 through 44 was primarily a flyover area.

The discussion below first presents the investigative results of the major range features and surface soil sampling results, followed by a more focused discussion of disposal pits discovered during intrusive investigations of geophysical anomalies. Individual MEC items found during the various investigations are discussed last.

4.2.3.1 Rows 30H to 33M

The conceptual site model of munitions use in this portion of the IBA was developed from range characteristics, range records, review of aerial photographs, and intrusive investigation finds. The development of the conceptual site model is presented in Appendix H. The available information suggests that this area, between Rows 30 and 33, was used as an impact area during the testing of mortar fuzing.

Soil samples were collected from three locations prior to intrusive investigations in grids I30 and I31 (SSJ1I31, SSJ1I30, and SSJ1J31). Most of the soil sampling conducted in this portion of the range was associated with BIPs. All pre-BIP sampling results were non-detect for explosives and perchlorate. Post-BIP contaminated soils were removed in accordance with the BIP protocols. No explosives or perchlorate were detected in these sample locations (Figure 4-8). Inert mortar discoveries from intrusive investigations occurred in grids I30, I31 and J31.

The munitions discovered during intrusive investigations in this area primarily consisted of inert M374 81mm and M720 60mm mortars with suspect fuzes. The only Items identified as MEC were one M524 fuze that was taken to the CDC and one inert M374 81mm mortar (with a live fuze). It should be noted that the M374 81mm and M720 60 mm mortars that were BIP had suspect fuzing.

Two large anomalies, Polygon 7 in grid K33 and Polygon 8 in grid H33 were intrusively investigated. Polygon 7 contained steel plates and Polygon 8 contained heavy gauge sheet metal and minor munitions fragmentation debris. Based on the types of items found no soil samples were collected at Polygons 7 and 8. The geophysical data for this area shows a lower density of anomalies compared to the interberm area. The lack of large geophysical anomalies suggests that the use of this area was different from that of the interberm area and was not used for munitions burial

Based on indications of past surface disturbances, a detailed reconnaissance was conducted along the southwestern side of the IBA to identify potential burials. (Figure 4-9). UXO Technicians using hand-held magnetometers (Schonstedts) walked the area and categorized audible responses according to response size. Anomalies with an audible response greater than six-feet in size (Type E or larger) were intrusively investigated since anomalies of this size or larger could be indicative of burial pits. During this reconnaissance, an inert M456 105mm HEAT round with live fuze was discovered in grid H33. No E-size anomalies were encountered during this reconnaissance. Aerial assessment Location 58 in grid H31 was investigated and only munitions debris was recovered.

4.2.3.2 Rows 34 through 44

The conceptual site model for this portion of the IBA was developed from observed range characteristics, range records, review of aerial photographs, and intrusive investigation finds. This information was used to refine the understanding of historical range activities and to map the munitions use and disposal conceptual site models. The conceptual site model suggests that the area between Rows 34 and 42 of the IBA is a general disposal area that also includes munitions testing. Within the central portion of the IBA, range features, including a former Popper Kettle/Wastewater discharge area and steel-lined pit, were discovered. These features are considered the primary contributors to the northern J-1 plume as discussed further below. In this portion of the IBA a MEC disposal area has also been mapped based on MEC finds (Appendix H).

Two large earthen berms are the dominant features within this area of the IBA. They are designated the 1,000 meter berm and the 150 meter berm. Both berms were used as backstops during historic munitions testing. Munitions were fired from the firing line in the southern portion of the range into the 1,000 meter berm. Firing Point 3 was primarily used for firing into the 150 meter berm.

A total of 20 samples were collected from six locations from a suspected burn area located on the south side of the Range Road (SS15152-A through SS15157-A) (Figure 4-8). The suspected burn area was identified based on witness interviews – a precise location could not be identified due to the absence of visible burn residue. Details regarding sample depths and analyses are presented in Table 4-2 and the results of detected analytes are listed in Table 4-3 and Table 4-4. 2,4-DNT was detected in sample SS15156-A at a concentration of 220 µg/kg (Table 4-4, Figure 4-11). Two 5-point composite soil samples were collected from one sample location (CP05J) near Firing Point 3 in grid K35 (Figure 4-8). No explosives were detected in these samples.

Samples were collected in grids N38, M38 and M39 above three geophysical anomalies located in the IBA (SS05BA, SS05BB, SS05BC, SS05BD, SS05BD, SS05BE, SS05BF, and SS05CA). Additional soil samples were collected from general locations in the vicinity of these anomalies (SS05CB through SS05CI). A borehole (BH-31) was also advanced in this investigation area (Figure 4-8). Details regarding sample depths and analytes are presented in Table 4-2 and analytical detections are included in Table 4-4. Tetryl was detected at sample location SS05CC at 590 µg/kg in the 0- to 0.25-feet bgs sample, and at 48,000 µg/kg in the 0.5- to 1.0-feet bgs sample (Table 4-4 and Figure 4-11). 2,4-DNT was detected at sample location SS05CF at 470 µg/kg, and 2-amino-4,6-dinitrotoluene was detected at sample location SS05BA at 140 µg/kg. There were no explosives or perchlorate detected in any other samples. One M43 81mm mortar was found in grid N39 during a reconnaissance; the item was BIP and determined to be HE.

Firing Point 3 was a firing position used during various munitions testing activities. The 150 meter berm generally acted as a target/backstop for items fired in this area. Two 5-point composite soil samples were collected from one sample location (CP05J) at Firing Point 3 (Figure 4-8). No explosives were detected in these samples.

Multi-increment sampling conducted more recently (2009) identified additional soil contamination (Figure 4-9). Samples were analyzed for explosives compounds and perchlorate from the grids identified on Figure 4-9. 2,4-DNT was detected at concentrations ranging from 890 µg/Kg to 4,200 µg/Kg. RDX was detected in one grid (J37) at 2,200 µg/Kg. HMX was detected in this same grid at 390 µg/Kg. This RDX contaminated soil, and 2,4 DNT contaminated soil at concentrations greater than 2,000 µg/Kg were removed for treatment (ECC 2009). The excavation boundary is presented on Figure 4-10.

Grids 34H through 38J

Intrusive investigations of geophysical anomalies within these grids resulted in the discovery of numerous subsurface disposal areas.

Three disposal areas were identified in the treeline along the southern range boundary. A location identified as Polygon 9 contained a burn pit. MEC items encountered included: one M524 fuze, two 105mm cartridge case with live primers, and residual propellant (approximately 2 ounces) from a 105mm cartridge case. Additional munitions debris and other debris were also discovered. Soil samples were collected from the burn pit (sample location SS08525-A), within the observed ash layer (sample ID J1.F.T9.001.2.0), from excavated soil (sample ID J1.F.T9.001.1.0), and from the pit bottom (sample ID J1.F.T9.001.3.0). Approximately 3 cubic yards of soil were removed from this pit. HMX was detected in the ash layer at 460 µg/Kg (Table 4-3). There were no explosives detected in the excavated soil or the pit bottom. The ash layer was disposed off-site at an approved facility. A follow-on geophysical survey was conducted in grids H35 and H36 after the intrusive investigation of Polygon 9. Findings from this survey indicate that residual anomalies, J1H35 Area 1 through J1H35 Area 10 and J1H36 Area 1 and J1H36 Area 2, were various munitions debris and other debris, consistent with materials recovered during the previous investigation. There were no explosives or perchlorate detected in the pre-investigation sample collected from grid H36 (sample location SS15144-A).

Two areas and seven individual targets were investigated at aerial assessment Location 44. A disposal pit, J1APA-BLP-001, was found in Location 44, Area 1 containing MEC, munitions debris and other debris. MEC items consisted of 176 37mm projectiles with inert bodies and live fuzes, and 307 14.5mm trainer-spotters. Three additional items, an M374 81mm mortar, M49 60mm mortar, and M456 105mm HEAT all with inert bodies and live fuzes, were discovered in the pit. Approximately 150 cubic yards of soil was removed during intrusive investigation and disposed at a permitted off-site facility. While the waste characterization sample did not have any detections of explosive or perchlorate, the soil was disposed off-site due to the presence of benzo(a) pyrene at 280 µg/Kg (Table 4-3). Soil samples were collected from the bottom of the excavation (sample location SSJ1L44BLP01). There were no explosives or perchlorate identified in this sample. Location 44 Area 2 contained one inert M49 60mm mortar with live fuze, 60mm mortar fins, and miscellaneous other debris. The remaining anomalies investigated at Location 44 contained various munitions debris items.

In December 2000, a disposal pit was discovered around grid H37, partially overlapping Location 44. This pit was identified during the surface sweep conducted at the J-1 range prior to the geophysical survey. Within the pit, 424 inert M49 60mm mortars, 208 inert M374 81mm mortars, and one inert M43 81mm mortar were discovered. In addition, eight MEC items consisting of M557 PD fuzes were taken to the CDC for disposal. No soil samples were collected during the investigation of this disposal pit.

Polygon 10 included a burn pit that contained MEC, munitions debris and other debris (including asbestos sheets). MEC items encountered were twelve 105mm cartridge casings with live primers. A three-inch ash layer was observed in the burn pit at a depth of 21-inches below ground surface. The ash layer was segregated from the soil during excavation. Approximately three cubic yards of ash and soil were excavated from the burn pit. Soil samples were collected from the ash layer (sample ID J1.F.T10.XC1.3.0), excavated soil (J1.F.T10.XC1.1.0) and from the pit bottom (J1.F.T10.XC1.2.0). 4-Nitroaniline was detected in the ash, soil and post excavation samples at 95 µg/Kg;

100 µg/Kg and 110 µg/Kg, respectively. Perchlorate was not detected in this sample. The excavated soil, including the ash layer, was disposed off-site at an approved facility. Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The follow-on geophysical survey was conducted in grids H38 and H39 after the intrusive investigation of Polygon 10. Findings from these intrusive investigations indicate that residual anomalies, J1H38 Area 1 and J1H39 Area1, consisted of various munitions debris and other debris consistent with the initial Polygon 10 investigation.

A disposal pit was also discovered in grid J-36 (J36-BNP-001). This disposal pit contained five pieces of M30 propellant (<0.1 lbs), four ignition cartridges, and .50 caliber ball small arms. The pre-investigation soil sample [sample location SSJ1J36001, sample ID J36-BNP-001 (pre)] contained HMX at 300 µg/Kg, RDX at 760 µg/Kg, TNT at 140 µg/Kg, 4-Amino-2,6-Dinitrotoluene at 250 µg/Kg, 2,4-DNT at 910 µg/Kg, 2-Amino-4,6-Dinitrotoluene at 280 µg/Kg (Table 4-3). The sample was not analyzed for perchlorate because the items identified do not contain perchlorate. The pre-BIP sample from this location (SSJ1I37001) contained TNT at 32 µg/Kg. Approximately 29 cubic yards of soil was removed and disposed at a permitted off-site facility. A soil sample collected from the pit bottom [sample ID. J36-BNP-001 (post)] contains RDX at 160 µg/Kg, TNT at 560 µg/Kg, 2-Amino-4,6-Dinitrotoluene at 130 µg/Kg, and 4-Amino-2,6-Dinitrotoluene at 140 µg/Kg (Table 4-4, Figure 4-11). The sample was not analyzed for perchlorate. The significance of these detections is further evaluated in the risk screen (Section 6). A follow-on geophysical survey was conducted in grid J37 and J38. Only small scattered anomalies were detected and no further investigation was conducted.

BIP location SSJ1RD016, located in grid J34 had HMX at 60 µg/Kg in the pre-BIP sample. There were no explosives detected in the post-BIP sample, therefore, this soil sample remains in place (Figure 4-11).

Grids 34K through 38N

Five locations on the 1,000 meter berm were sampled (Figure 4-8). There were no explosives or perchlorate detected in these samples. Soils in the vicinity of the steel plates formerly located on the face of the berm were also evaluated for the presence of depleted uranium. Depleted uranium was not detected in these soils (AMEC 2004). Samples were also collected from a topographical high area north of the 1,000 meter berm (SS05CK, SS05CJ) and from soil boring BH-32, which was drilled west of the berm. Perchlorate was detected in the soil sample collected from SS05CK at a concentration of 4.8 µg/Kg in the 0- to 0.25-feet. bgs sample interval (Figure 4-11 and Table 4-4). No explosives were detected in the soil sampled in this portion of the range. Soils from the uprange face of the 1,000 meter berm were removed during a robotics demonstration in 2008 (as discussed in more detail later in this section). There were no MEC items recovered from the face of the berm.

Two pre-investigation soil samples, SSJ1K34-NW and SSJ1K34-SE, were collected to gather a general understanding of the soil contaminant characteristics of this area prior to intrusive investigation in grid K34. No explosives were detected in soil sampled in this portion of the range. A disposal pit, K34-BLP-001, was identified in grid K34. Only munitions debris and other debris were recovered. No MEC items were encountered within this disposal pit. A follow-on geophysical survey was conducted in grid K34. Based on the results of the survey, three additional anomalies were investigated. These anomalies, Target 2, Target 3, and Target 4, consisted of munitions debris and other debris. Nearby anomaly Location 25 in grid L35 was determined to be other debris.

A total of 111 samples were collected from 16 locations associated with the Popper Kettle/wastewater discharge area in grid K35 (Table 4-2), including soil boring samples associated with monitoring well MW-136. There were no explosives detected in these samples. During the excavation and removal of the former Popper Kettle, samples for waste characterization were collected from the ash within the Kettle and from a mixture of soil and ash removed from beneath the former Popper Kettle (SS05S). This sample contained elevated concentrations of explosive compounds (RDX at 10,000 µg/Kg, HMX at 2,800 µg/Kg, picric acid at 1,100 µg/Kg, 2-amino-4,6-dinitrotoluene at 230,000 µg/Kg, 2,4-dinitrotoluene at 4,800 µg/Kg, 2,6-DNT at 26,000 µg/Kg, trinitrotoluene at 17,000,000 µg/Kg, 1,3,5 trinitrobenzene at 31,000 µg/Kg) and lead at 14,800 mg/Kg (Table 4-3). These samples were not analyzed for perchlorate. This material was disposed of off-site.

Approximately 544, 14.5mm subcal cartridges were recovered from the Popper Kettle. The contents of the kettle were drummed and the kettle was removed in June 2001.

A post-excavation soil sample (location SS05AA) was collected from the location of the former Popper Kettle subsequent to its removal. There were no explosives detected in this sample. However, the sample had elevated concentrations of lead ranging from 343 mg/kg to 701 mg/Kg (Table 4-3). Adjacent sample location SS05P also had elevated lead concentrations (35,600 mg/Kg). Soil from this area of high lead concentrations was excavated to a depth of one-foot bgs resulting in approximately 60 cubic yards of lead-contaminated soil being removed and disposed off-site. Three discrete, post-excavation samples were collected from the base of the excavation and analyzed for lead. The samples were collected from locations SS05P, SS05Q, and SS05R. Results confirmed that the lead hotspot was adequately removed, with remaining lead results ranging from 12 mg/Kg to 56.8 mg/Kg. Details regarding sample depths and analytical suite are presented in Tables 4-2 and analytical detections are included in Tables 4-3 (current conditions) and Table 4-4 (results from excavated soil). Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The follow-on geophysical survey was conducted in grid K35, in the vicinity of the former Popper Kettle. One area, J1K35 Area 1, was selected for intrusive investigation. No MEC items were found.

Two disposal pits, K36-BLP-001 and K36-BLP-002, were identified in the immediate vicinity of Firing Point 3. A burn kettle was discovered in burial pit K36-BLP-001 in which MEC items were discovered consisting of 154 electro-explosive devices and an indeterminate quantity of stab detonators. The electro-explosive devices and stab detonators range contain less than 1 gram of energetic material. The kettle and associated soils were removed in June 2001. Approximately six cubic yards of soil was excavated from this burial pit. The stab detonators and electro-explosive devices could not be safely segregated from the soil. Therefore, this material was sent to a permitted off-site disposal facility. A sample collected from the bottom of the excavation [SSJ1K36001(post)] was non-detect for explosive compounds, but had a trace of perchlorate (2.5 µg/kg) (Figure 4-11, Table 4-4).

MEC items recovered in burial pit K36-BLP-002 consisted of eight 14.5mm trainer-spotters, five explosive boosters, and 24 lbs of M30 propellant. One inert M374 81mm mortar was also found. A sample collected from the bottom of the burial pit excavation [SSJ1K36002(post)] was non-detect for explosive compounds and perchlorate. A total of 144 cubic yards of soil was removed from burial pits K36-BLP-001 and K36-BLP-002. A waste characterization sample (K36-BLP-002) collected from the excavated soil identified 2,4 DNT at 150 µg/Kg (Table 4-3). This soil was disposed off-site at an approved facility. One additional polygon, J1-41, was investigated in grid J36. The polygon contained assorted munitions debris and other debris. A follow-on geophysical survey was conducted in grid K36 and one anomaly, J1K36 Area 1, was selected for investigation. The investigation identified only munitions debris.

A total of 28 soil samples were collected from six locations associated with the Cook-off Test Location (Figure 4-8) and the surrounding area in grid L37. Sample SS05DA was collected from the inferred location of the cook-off tests, and soil samples were collected during the installation of MW-191 (J1P-15) at the same location. Additional samples (SS15139-A, SS15140-A, SS15141-A) were collected in the general vicinity of this area to fill data gaps. No explosives or perchlorate were identified in these samples (Figure 4-11).

Pre-investigation sample [J1K38-BLP-001 (pre)] collected from grid K38 identified Tetryl at a concentration of 150 µg/Kg (Table 4-3). Intrusive investigation in this grid resulted in the discovery of a burial pit (K38-BLP-001). MEC items discovered in this pit consisted of twenty-four high explosive pellets. This material was taken to the CDC for final disposition. Other debris was found in the excavation. Approximately 16 cubic yards of soil was excavated from this pit. There were no explosives or perchlorate detected in a soil sample collected from the pit bottom [J1K38-BLP-001 (post)]. The soil was disposed off-site at an approved facility. A follow-on geophysical study was conducted in grid K38. Five anomalies were investigated, J1K38 Area 1 through J1K38 Area 5, and the findings consisted of various debris.

Two additional anomalies were investigated in grid I37. Anomaly 6859 consisted of assorted munitions debris and other debris. Anomaly 6860 consisted of assorted munitions debris and an M1 105mm projectile that was BIP and determined to contain HE.

Grids 39H through 44J

A detailed reconnaissance was conducted along the southwestern side of J-1 Range from Rows 31 to 43 (Figure 4-8). UXO Technicians walked the area using hand-held magnetometers (Schonstedts) and categorized audible responses according to response size. Anomalies with an audible response greater than six-feet in size (Type E or larger) were intrusively investigated under the presumptions that an anomaly of this size or larger could represent a burial pit.

A disposal pit with MEC items was found in grid H39, at J1H39 Area 2. The pit, designated as H39-BLP-01, contained 17 60mm illumination Candles with presumed pyrotechnics. These MEC items were taken to the CDC for disposal. Munitions debris and other debris were also found at this location. Approximately 13 cubic yards of soil was removed during intrusive investigation and characterized concurrently with the soils from Location 44. The soils were disposed at a permitted off-site facility. A soil sample collected from the base of excavation (SSJ1H39BLP001) was non-detect for explosives and perchlorate.

Propellant bags were discovered in grid H40 at J1H40 Area 2. Samples were collected from the soil beneath the propellant bag sample location, SSJ1H40002, sample ID SSJ1H40002PE). This sample had perchlorate at 1.8 µg/Kg and 2,4-DNT at 1300 µg/kg. Approximately 2 cubic yards of soil was excavated for off-site disposal. The sample collected from the excavation bottom (sample location, SSJ1H40002, sample ID SSJ1H40002PE_2) was non-detect for explosives. An inert M374 81mm mortar with a live fuze was also found along with munitions debris and other debris.

Nine additional large anomalies, J1H36 Area 3, J1H38 Area 2, J1G39 Area 1, J1H39 Area 3, J1H40 Area 1, J1G40 Area 1, J1G41 Area 1, J1H41 Area 2 and J1H43 Area 1, were investigated during the reconnaissance. With the exception of Locations J1H38 Area 2 and Location J1H40 Area 1, none of the areas contained MEC items; only munitions debris and other debris. A M43 81mm mortar was found adjacent to J1H38 Area 2 in grid G38 and determined to be HE based on the observations of the BIP event. Location J1H40 Area 1 contained munitions debris and other debris as well as a low order M1 105mm projectile with residual HE. This item was taken to the CDC.

Polygons 11, 12, and 13 located between grids I39 and I40 were investigated concurrently. Only munitions debris and other debris were identified at this location. Surface soil samples were collected prior to intrusive activities (SS05NA). This sample was non-detect for explosives compounds. No additional soil samples were collected. One additional nearby anomaly in grid I39 was investigated at Location 12 that also contained other debris. A follow-on geophysical survey was conducted in grids I39 and I40 after the intrusive investigation of Polygons 11, 12, and 13. Only small, scattered anomalies were detected and no further investigation was conducted.

The steel-lined pit located in the Interberm Area, was situated on the west side of the range road, southwest of the 150 meter berm, as shown in Figure 4-8. Excess propellant, UXO and other miscellaneous debris were burned in the former steel-lined pit, as discussed in Section 2.2. The steel-lined pit was a three-sided open topped steel structure imbedded in the ground with a drainage hole in the bottom. One composite sample was collected from the soil surrounding the pit (sample location CP05CP), one grab sample was collected from the soil in the pit (sample location CP05N, sample ID BG5DAA), and one grab sample was collected from soil beneath the hole at the bottom of the pit (sample location CP05N, sample ID BG5CAA). The soil inside the pit had detectable concentrations of explosives (HMX at 9,300 µg/Kg and 2,4 DNT at 200 µg/Kg) (Table 4-3). These soils and associated debris were placed in 55-gallon drums and disposed off-site. The sample collected from beneath the hole in the pit did not have detectable explosives compounds. The sample (CP05CP) collected from the surface soils surrounding the pit had a detection of 2,4 DNT of 550 µg/Kg. Additional soil samples (sample location CP05N, sample IDs B05NAA, B05NBA,) were collected from the open side of the pit before the steel lining was removed in October 1999. These samples did not have any detections of explosives or elevated metals concentrations. None of the samples were analyzed for perchlorate. The area was subsequently backfilled to allow for the installation of a water table monitoring well MW-58. Additional information regarding the steel-lined pit removal is available in the *Draft Rapid Response Action Work Plan* for Camp Edwards (Ogden 2000).

A geophysical survey was conducted in grid J39. A burn pit was discovered in J1J39 Area 10. Munitions debris, other debris and MEC items were identified in this pit. MEC items encountered consisted of one thousand two hundred nine 14.5mm trainer-spotters three M953 fuzes, and 37mm cartridge casings with live primers. The 14.5mm trainer-spotter contained a smoke agent composed of zinc chloride (6.48g). Live primers contain less than 1 gram of energetic material. The 14.5mm trainer spotter contained The fuzes and cartridge casings were taken to the CDC for disposal. The energetic state of the 14.5 mm rounds with melted aluminum casing could not be verified and were unable to go the CDC for disposal. Therefore, this material was sent to a permitted off-site disposal facility. A soil sample was collected from the pit bottom after the initial excavation [sample ID J1J39BNP_PE]. This sample contained RDX at 500 µg/Kg and TNT at 440 µg/Kg. This sample also had elevated lead concentrations (420 mg/Kg). Additional soil was removed from the excavation and another pit bottom sample was collected (sample location SSJ1BNP001, sample ID J1J39BNP_PE2). The pit bottom sample contained TNT at 300 µg/Kg, 2-Amino 4,6-dinitrotoluene at 160 µg/Kg, and 2-Amino 4,6-dinitrotoluene at 170 µg/Kg (Table 4-4, Figure 4-11). A total of 88 cubic yards of soil was removed during intrusive investigations and disposed of at a permitted off-site facility. Only munitions debris and other debris were recovered from the remaining 10 anomalies that were investigated, J1J39 Area 1 through J1J39 Area 9 and J1J39 Area 11. Two additional nearby geophysical anomalies in grid J39, Location 14 and Location 19, were investigated and determined to be other debris. Therefore, no soil samples were collected.

Polygons 14 and 15 were addressed concurrently and consisted of three burial pits that contained MEC items, munitions debris and other debris. MEC items discovered included 316 105mm cartridge casings with live primers. One surface soil sample was collected prior to intrusive activities (SS05NB). There were no explosives detected in this sample. Soil samples were collected from the excavated soil (J1.F.T14.XC1.1.0) and from the pit bottom (J1.F.T14.XC1.2.0). There were no detections of explosives or perchlorate in either sample and the soils were backfilled. One additional nearby geophysical anomaly in grid J40, Location 31, was also investigated and consisted of various non-munitions debris. Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The follow-on geophysical survey was conducted in grid J40 after the intrusive investigation of Polygons 14 and 15. The four anomalies in this geophysical survey were investigated (J1H40 Area 1 through J1H40 Area 4) and were determined to be related to various munitions debris and other debris consistent with previous investigations.

A burial trench, approximately 108-feet long by 4-feet wide by 4-feet deep, was discovered adjacent to Polygon 16 on the west side of the range road opposite the 150 meter Berm (Figure 4-8). Approximately 30 five-gallon metal containers, filled with what appeared to be solid paint-related materials, were found placed end-to-end along the length of the trench. The containers were excavated and placed into 55-gallon drums for off-site disposal. Initial post excavation soil sample results identified elevated concentrations of bis(2-chloroethyl ether) (2,500 µg/kg). Additional soil was excavated to remove this detection. Composite post-excavation samples (SS05FA1 - SS05FA5, SS05FAA3) were collected from the base and walls of the excavation at five locations spaced evenly along the length of the trench. There were no explosives detected in these samples. Details regarding sample depths and analytes are presented in Table 4-2 and analytical detections are listed in Table 4-4.

The investigation of Polygon 16 (grids H41/I41) identified a burn pit and a burial pit. The burn pit contained 60mm mortar fins, a metal rod, and a 5 gallon can containing tar-like material. In addition, stained soil was identified in the pit. A sample was collected from the stained soil (J1.F.T16.003.1.0) which had a detection of 4-Nitroaniline at 77 µg/Kg. A sample collected from the base of the burn pit excavation (sample location SS08524-A, sample ID J1.FT16.003.2.0) was non-detect for explosives and perchlorate. Waste characterization of the tar-like material (sample location SS03217-A, sample ID J1.T16.001.0) indicated that the material was not considered a hazardous waste and was disposed off-site. The burial pit contained a deteriorated 55-gallon drum partially filled with burnt material and three inert M49 60mm mortars. A sample collected from the burnt material within the drum (sample location SS08523, sample ID J1.F.T16.002.1.0) had detections of RDX (8,300 µg/Kg), 2,4-DNT (580 µg/Kg) and nitrobenzene (11,000 µg/Kg) (Table 4-3). The burn material from the drum was disposed off-site at an approved facility. A sample collected from the bottom of the excavation (sample location SS08523-A, sample ID J1.F.T16.002.2.0) was non-detect for explosives and perchlorate (Figure 4-14). One additional geophysical anomaly was investigated in grid H42, Location 26, and contained fragmentation debris and various scrap. A follow-on geophysical survey was conducted in portions of grids H42, I42, H41 and H41 following the intrusive investigation of Polygon 16. Findings from this survey did not indicate the potential for disposal pits, and residual anomalies were therefore not investigated.

Grids 39K through 44N

This area is primarily defined by the 150 meter berm. Samples collected from the top and uprange face of the 150-m berm identified no detections of explosive compounds. A technology demonstration was conducted by the Air Force Research Laboratory using remote-controlled robotic equipment at the 150-m berm. A remotely operated excavator equipped with a rotating, 2-inch slot screen bucket attachment was used to separate rocks and any munitions from finer soil materials. These materials (“overs”) were placed into a separate stockpile for further inspection. Munitions items recovered from the 150 meter berm consisted of three 81mm Illumination mortars, 28 M1 105mm projectiles, 50 105mm HEAT projectiles, seven M107 155mm projectiles, one 3-inch Rocket, and two 8-inch projectiles. Each item was moved by remotely operated equipment to a consolidated shot area located in grid J37 for disposition. Items determined to be MEC were two 81mm Illumination mortars, two M107 155mm projectiles, two M374 81mm mortars and two PD fuzes. A confirmatory EM-61 survey was conducted over the face and base of the 150-m berm. The remaining large anomaly in the vicinity of the 150 meter berm in Grid L39 will be further investigated. Soil samples collected from the screened soil stockpile indicated concentrations of 2,4,6-Trinitrotoluene (690 µg/Kg), 2-Amino-4,6-Dinitrotoluene (160 µg/Kg), and 4-Amino-2,6-Dinitrotoluene (230 µg/Kg). Approximately 150 cubic yards of soil was disposed of off-site.

Additional polygons J1-44 and J1-45 in grid K40 were intrusively investigated. Items recovered from J1-44 were assorted munitions debris and other debris. Additional polygon J1-45 consisted primarily of assorted munitions debris and other debris. Two items, a M374 81mm mortar and a M1 105mm projectile, were BIP and determined to be inert. A follow-on geophysical survey was conducted in grid K40 and two areas, J1K40 Area 1 and J1K40 Area 2, were selected for intrusive investigation. Items identified in J1K40 Area 1 were munitions debris and other debris. In J1K40 Area 2, MEC items consisting of seven M557 PD Fuze and six cartridge-actuated devices, were discovered and taken to the CDC for disposition. Additional munitions debris and other debris were also removed from this location.

Aerial Assessment Location 63 was located along the edge of the range marked by an earthen berm. This location partially overlapped grid N39. A geophysical survey was conducted at this location and five anomalies were selected for investigation based on the signal strength (Figure 4-8). Findings for J1LOC63 Area 1 through J1LOC 63 Area 5 included munitions debris and other debris including tank and target debris.

An EM-31 investigation was conducted to determine if propellant disposal was conducted as inferred from witness interviews. Four exploratory trenches (Trenches 1 though 4) were investigated in grids K42 and K43. No propellant disposal areas were identified and the exploratory trenches were backfilled. No munitions debris or other debris were encountered.

Pre-BIP samples collected from SS0277-A, SSK40002 and SSK41001 (grids N39, K40 and K41) had low concentrations of explosives contamination. RDX concentrations ranged from 15 µg/Kg to 70 µg/Kg. TNT was detected at 96 µg/Kg, 2,4-DNT was detected at 19 µg/Kg, and 2-Amino-4,6-Dinitrotoluene was detected at 14 µg/Kg. The soil at these sampling locations was removed under the BIP Program. Text from Section 4.2.3.2, pages 4-19 through 4-29 was deleted.

4.2.3.3 Interberm Area BIP samples

Some potential MEC items discovered during intrusive field investigations were BIP. A total of 280 samples were collected from 75 locations associated with BIP activities in the IBA. BIP sample locations, sample identification, collection date, sample depths, and laboratory analyses associated with this sub-area of the range are identified in Table 4-2. Contaminated soils generated as a result of BIP activities were excavated in accordance with the BIP management program. Table 4-3 contains analytical detections for those soils excavated under the BIP program. Pre-BIP samples with detections of explosives compounds were discussed in the previous subsection, based on the grid location. Post BIP sample SSJ1I30003 had an HMX detection of 14 µg/Kg. This detection was below the BIP program excavation threshold, and therefore, was not excavated (Figure 4-11). Post BIP sample SSJ1H33001 had RDX, HMX, TNT, Tetryl, 2-Nitrotoluene, 2,4 Dinitrotoluene, 2-Amino-4,6-Dinitroltoluene and 4-Amino-2,6-Dinitroltoluene. This sample is a post- BIP sample that is being removed under the BIP management program.

Post BIP sample SSJ1I30003 had an HMX detection of 14 µg/Kg. This detection was below the BIP program excavation threshold and, therefore, was not excavated (Figure 4-11).

4.2.3.4 Interberm Area Source Characterization Conclusion

A significant amount of intrusive investigation has been conducted to support the development of the conceptual site model, as discussed in Section 4.2.3.2. A quality control geophysical survey along with an intrusive investigation of residual anomalies has been conducted over most of the IBA. It is unlikely that any subsurface burials still remain in the IBA. Remaining geophysical anomalies are small and scattered and are likely to be residual munitions debris and other debris from contractor activities on the range. Individual MEC items, both High Explosive versions and inert with live fuzes could still remain. Intact HE ordnance items identified during site investigations consisted of M107 155mm (2 items), M1 105mm projectiles (2 items), M43 81mm mortars (2 items), and M374 81MM (4 items). Inert rounds with live fuzing were likely to be M374 81mm mortars with the M524 fuze.

MEC items discovered in disposal pits that were classified as small quantity energetic or propellant/energetic were taken to the CDC. The largest quantities of items found were the 14.5mm trainer-spotter and the 105mm cartridge cases with live primers. The 14.5mm trainer-spotter contained a smoke agent composed of zinc chloride. Live primers contain less than 1 gram of energetic material. Other items that contained small quantities of energetic material included: electro-explosive devices, stab detonators, ignition cartridges, and fuzes. These items range from less than one gram to 18 grams of energetic material.

Raw M30 propellant in the form of small pellets was discovered in two locations. A total of approximately 10.89 kg of M30 propellant from these investigations was transported to the CDC for disposal.

It is possible that some individual M43 81mm mortars, M1 105mm projectiles, and inert bodied mortars with live fuzes still remain within the IBA. The technology demonstration at the 1,000 meter and 150 meter berms has likely eliminated the potential for residual munitions at these areas.

Soils contaminated with explosive compounds were identified in the Popper Kettle, Steel Lined Pit and several burn pits (J1J39 Area 10, J36-BNP-002, J36-BNP-001). These contaminated soils and associated structures have been removed. RDX was also detected during the MIS sampling in Grid L37 at 2,200 µg/Kg. This soil has been removed for on-site treatment. MIS sampling was also conducted in the IBA to delineate 2,4-DNT contamination. In addition, low concentrations of other explosive compounds still exist in the site soils (Figure 4-11). The significance of these detections will be evaluated in the risk screen (Section 6).

Grids 30H through 33M

This area of the range was a presumed impact area for the fuze testing on inert mortars. The munitions discovered are consistent with the conceptual site model of this portion of the range. No explosives or perchlorate were detected in any of the samples collected from this portion of the range. No large geophysical anomalies remain, and of the remaining small, scattered anomalies exhibiting elevated signal response, none are expected to be a source of groundwater contamination because of the nature of the items already uncovered.

Grids 34H through 38J

This area of the range appears to have been used primarily for the disposal of munitions, munitions debris, and range residue debris. Two burial pits and three burn pits were identified in this area. Explosives compounds were detected from two of the burn pits, Polygon 9 and J36-BNP-001. These presumed source areas should be considered the more significant potential contributors to the J-1 northern plume in this area of the range. The residual explosives detections remaining at the J36-BNP-001 location do not warrant removal as the detections are not significantly elevated above the detection limits. Additional intrusive investigations following post excavation geophysical surveys did not result in any significant findings. The remaining uninvestigated anomalies are not expected to be disposal areas based upon the nature of the remaining geophysical response. Individual items may remain.

Grids 34K to 38N

This area of the ranges appears to have been used primarily for the firing of munitions, surface disposal, and subsurface burial of munitions, munitions debris, and range residue debris. Three burial pits and three burn areas were identified in this area. The most significant potential contributor to the J-1 northern plume in this area is presumed to be the popper kettle/wastewater discharge area based upon the concentrations of explosives compounds detected from the popper kettle, and the adjacent burn pit in grid K36. Historical photographs obtained during the archive search show the process of hazard classification tests at the cook-off test location, which likely also served as a contributor to the known plumes and the benzene detections at MW-187D. The residual explosives detections remaining at locations SSJ1K36001, SS05CK, SS05BN, SSJ1K36CSL01, SSJ1K3701 and SSJ1L3801 do not warrant removal as the detections are not significantly elevated above the detection limits. Additional intrusive investigations following post excavation geophysical surveys did not result in any significant findings. The remaining uninvestigated anomalies are not expected to be disposal areas based upon the findings to date. Individual items may remain.

Grids 39H to 44J

This area of the range appears to have been used primarily for the disposal of munitions. Five burial pits and three burn pits were identified in this area. The most significant potential contributors to the J-1 northern plume in this area were likely the steel-lined pit and adjacent J36-BNP-001 burn pit. The residual explosives detections remaining at locations SSJ1H39BLP001, J1A200128, CP05CP, SSJ1G38001 and SSJ1BNP001 do not warrant removal as the detections are not significantly elevated above the detection limits. Additional intrusive investigations following post excavation geophysical surveys did not result in any significant findings. The remaining uninvestigated anomalies are not expected to be disposal areas based upon the findings to date. Individual items may remain.

Grids 39K to 44N

This area consists primarily of the 150-m berm. Soil samples were collected from four locations in the vicinity of the 150 meter berm (Figure 4-8). No explosives were detected in these samples. Munitions were removed from this mound, and residual explosives detected at SS05CF and SSJ1K40BLP001 do not warrant removal as the detections are not significantly elevated above the detection limits.

Location 7 in grid M38 and Locations 20 and 30 in grid M39 were investigated and found to be other debris. Location 38 in grid N39 and Location 34 in grid N40 were investigated, items found were various pieces of scrap and track vehicle wheel, respectively.

Supplemental geophysical surveys were performed as quality control measures within selected grids to determine the effectiveness of previous munitions investigations and removals. The follow-on geophysical survey was conducted in grids M38, M39, N38 and N39. No anomalies were investigated in grids M38 and M39 based on the results of the survey. Intrusive investigation was conducted on anomalies in grids N38 (J1N38 Areas 1 through 5) and N39 (J1N39 Areas 1 through 4). In general, these areas consisted of scrap metal, target debris and tank parts, consistent with previous findings in these grids.

The remaining uninvestigated anomalies are not expected to be disposal areas based upon the nature of the geophysical response. Individual items may remain.

Soils with significant explosives contamination were found to be associated with the steel lined pit, the Popper Kettle, Cook Off Test location, the steel Lined Pit, wastewater discharge area, and Polygons 9,10 and 16 and disposal areas in Grids J39, J36 and K 36. These areas were previously addressed during soil removal actions and no significant soil contamination remains. An area of RDX contamination was identified in the Interberm Area, northeast of the 1,000 meter berm. 2,4 DNT was also detected in the vicinity of Firing Point 3. As previously discussed, this soil has been removed and treated in conjunction with an on-going soil treatment project.

Geophysical investigations in the IBA identified multiple disposal pits. The majority of the disposal pits contained munitions debris and other debris. Some pits also contained small quantities of energetic materials, a majority of which were inert rounds with live primers. Soil excavated from many of the disposal pits had concentrations of explosives compounds. However, these concentrations of explosives associated with disposal pits were generally low in comparison to those detected at the steel lined pit, Popper Kettle, waste water discharge area and Polygon 16. Based on the quality control geophysical survey conducted in the Interberm Area and the significant intrusive investigations to date, it is unlikely that any subsurface burial pits still remain.

Individual MEC items identified in the IBA included both HE munitions and inert munitions with live fuzes. It is possible that individual 81MM mortars, 105mm projectiles, and inert bodied mortars with live fuzing may still remain within the IBA.

4.2.3.5 Potential Interberm Source Areas

Munitions items, along with excess propellant and other debris, were presumably disposed of in the Steel-lined Pit over a long period of time. There was a drainage hole in the bottom of this structure through which fire suppression and rain water contaminated with explosives and propellant compounds were transferred to the subsurface. Explosive compounds detected in soils from the Steel-lined pit include RDX, HMX, 2,4-DNT, di-n-octyl phthalate, and di-n-butyl phthalate. Perchlorate was not analyzed for in these samples. This soil now removed likely contributed to the development of the northern plume. The steel-lined pit was located near the trailing edge of the plume .

Cook-off tests were conducted in the J-1 IBA . During these tests, items were placed in a large steel pan with fuel and waste oil and ignited to determine the detonation temperature of the items. Explosive compounds found in the soils at the Cook-off Test Location include 2,4-DNT, and di-n-butyl phthalate. Perchlorate was analyzed for and not detected.

The Popper Kettle was located near the 1,000 meter berm and was used for burning of items for testing and/or disposal. Sampling of the ash from the Popper Kettle showed detections of HMX, RDX, 2,4-DNT, 1,3,5-TNB, TNT, 2,6-DNT, 2A-DNT, picric acid and di-n-butyl phthalate. Explosive compounds in the soils around the Popper Kettle included HMX, RDX, 2,4-DNT, ethyl centralite, and di-n-butyl phthalate. Perchlorate was analyzed for and not detected. This contamination would have likely been available for leaching. Ash remaining in the kettle could also have been a source for groundwater contamination if the kettle leaked during rainfall events. The ash in the Popper Kettle and the surrounding soil was removed and disposed. The Popper Kettle was located near the trailing edge of the RDX and perchlorate plumes and could have been a contributing source of the plume.

The Burial Trench was found on the west side of Tank Alley opposite the 150 meter berm. Approximately 30 5-gallon metal containers were uncovered that were filled with paint-related compounds. Contamination from these cans could have leaked. However, no explosives were found in the soils of the trench and the containers and trench soils were removed eliminating this area as a potential future source of contamination to groundwater. Perchlorate was not analyzed for in these samples.

A series of polygons (Polygons 7 through 16) were investigated within the IBA based on the results of the geophysical surveys of the area. Polygon 9 consisted of a burn pit containing MEC, munitions debris, and other debris and a 3-inch thick ash layer. HMX was detected in the ash layer. Polygon 10 included a burn pit containing MEC, munitions debris, and other debris plus a three-inch thick ash layer. No explosive compounds were detected in soils at this location. Polygon 16 contained a shallow burn pit and burial pit (Figure 3-9). The burial pit contained a 55-gallon drum partially filled with burned material. The material in the drum contained RDX, nitrobenzene and 2,4-DNT. Residual soils collected following drum removal contained no explosive compounds. Perchlorate was analyzed for and not detected.

A burn pit was discovered in J1J39 Area 10. Munitions debris, other debris and MEC items were identified in this pit. The excavated soil had detections of RDX and TNT. A disposal pit was also discovered in grid J-36 (J36-BNP-001). This disposal pit contained propellant and munitions debris. The pit soil contained HMX, RDX, TNT, 4-Amino-2,6-Dinitrotoluene, 2,4-DNT and 2-Amino-4,6-Dinitrotoluene. A burn kettle was discovered in burial pit K36-BLP-001. The burn kettle contained MEC items (electro-explosive devices and stab detonators). These items were mixed in with the soil, and therefore soil samples could not be collected.

Approximately 1,200 gallons of wastewater generated at the J-3 Range Melt/Pour building during the processing of octol were released near the 1,000 meter berm. Soil samples collected from the berm area contained RDX, HMX, 2,4-DNT, ethyl centralite, and di-n-butyl phthalate. Perchlorate was not analyzed for in these samples. The constituents of the wastewater would have likely been in a dissolved phase, and therefore, components such as RDX and HMX would migrate relatively quickly from the wastewater into the vadose zone.

The potential source of groundwater contamination in the IBA are primarily related to the disposal and/or burning of items that would have introduced dissolved explosives and/or perchlorate directly to the subsurface (waste water discharge) or left contamination in area soils. The extent of the plume is consistent with source areas in the Interberm Area.

4.2.4 Northern Flyover Area (Rows 45 to 64)

The northern flyover area is situated in the northwestern portion of the J-1 Range and lies mostly within the impact area (Figure 4-1). This portion of the range is primarily a flyover area, with no other documented uses, based on the Archives Search Report. There are no visual site features on this portion of the range, and no significant features were identified as a result of intrusive investigation of geophysical anomalies.

The dataset for Rows 45 to 65 soil represents site investigations conducted from December 1997 through July 2007. A total of 208 soil samples were collected from 36 locations within this portion of the range. In most cases, samples were collected from multiple depths at each location resulting in a larger number of samples than actual sample locations. Most of the samples collected in this portion of the range were related to BIP activities. Additional details about soil samples collected within this sub-area are discussed below and presented in Table 4-2. Table 4-3 summarizes analytical detections in soil that has already been excavated during various removal actions conducted in accordance with the BIP program. Table 4-4 summarizes analytical detections for all soil samples which represent current in-situ site conditions. The complete database for all soil analytical results (through 2007) is included in Appendix G. Soil sample locations as well as location and description of recovered MEC items are depicted on Figure 4-12. Figure 4-13 represents the existing site conditions, and includes analytical results for samples with explosive or perchlorate detections. Munitions items were categorized based on their explosive characteristics, as defined in previous sections. Categories of findings from intrusive investigations in the range are listed in Table 4-1 and specific finds are located in Table 1 of Appendix H.

4.2.4.1 Northern Flyover Area Findings

In addition to the intrusive investigation of geophysical anomalies, other intrusive activities included monitoring well pad clearance and access road clearance. Findings from these activities helped characterize this portion of the range.

Geophysical investigations conducted at Polygon 17, Location 23 and Location 11 consisted of munitions debris and other debris (Figure 4-12). Based on these findings, no soil samples were collected from these three investigation areas.

Location 55, an aerial assessment location, had 10 anomalies that were investigated. Three of these anomalies contained MEC items; two inert 105mm HEAT projectiles with a live M509 fuze and one inert M374 81mm mortar with a live M524 fuze. These are characterized as small quantity energetic items (fuzes only) on Figures 4-14.

Monitoring well MW-306 was installed in grid L52. During construction of this well pad, six M49 60mm mortars were discovered. These items were BIP and all were determined to be HE. Another M49 60mm mortar was found in grid J55 and transported to the CDC; demolition results determined this item to be HE. Two additional M49 60mm mortars were discovered in grid K57 and determined to be HE; one fuzed item was BIP and the other (unfuzed) was taken to the CDC. One unfuzed M49 60mm mortar was also found in grid K60, taken to the CDC and determined to contain HE.

During range and road maintenance activities in this part of the J-1 Range, two M374 81mm mortars were discovered in grid J48. One fuzed item was BIP and the other (unfuzed) was taken to the CDC. Both items were determined to be HE. Inert M374 81mm mortars with a live M524 fuzes were also found in grids K57 and K59 (one in each grid) and BIP. One 81mm flare was discovered in grid K60 and was taken to the CDC for disposal. One 30mm HEI projectile was found in grid J57, BIP, and was determined to be energetic. Another 30mm HEI projectile [MOX-2B filler found in grid K61 was determined to be energetic and was BIP. Also, during the construction of well pad MW-306, one M1 105mm projectile was taken to the CDC and determined to be HE.

With the exception of soil samples collected during the installation of monitoring wells, all soil samples collected in this portion of the range were associated with BIP sampling. Soil samples collected during the installation of MW-06 and MW-126 did not have any detections of explosives or perchlorate.

Pre-BIP soil samples identified only one area with elevated concentrations of explosives compounds. HMX was detected at 7,400 µg/Kg at BIP location J120034 (sample ID J1.A.2.00034.1.0). This soil was excavated under the BIP Program. Other low concentration pre-BIP explosives detections included HMX at 110 µg/Kg at sample location SS15227-A [sample ID ECC041404J101 (pre)], RDX at 14 µg/Kg and TNT at 54 µg/Kg at sample location SSRDST0613 (sample ID TT062906-01RDS-C-PRE). These locations were all excavated under the BIP program.

RDX was detected at 42 µg/Kg and 2-nitrotoluene at 13 µg/Kg in the pre-BIP sample collected from sample location SS15112-A [sample ID ECC102303J1P2204 (pre)] (Figure 4-13). The post-BIP sample had no explosive detections. Therefore, this location was not excavated under the BIP program and these very low RDX concentrations remain in-situ. Likewise, a post-BIP sample collected from location SSJ1P26007 had an RDX concentration of 17 µg/Kg (sample ID ECC031405J102 (post)]. This level is below the excavation threshold established under the BIP program, and therefore, was not excavated.

4.2.4.2 Northern Flyover Area Conclusions

Energetic items identified in this area during intrusive investigations consist of individual impacted rounds, inert bodies with live fuze, and HE rounds. Geophysical anomaly density in Rows 45 to 64 can be seen to as low, progressively increasing towards the middle of the impact area. A majority of small residual anomalies are likely associated with fragmentation from ordnance that functioned as designed. Medium-sized anomalies may represent intact ordnance items (either inert or HE). All large anomalies in this portion of the range were investigated and found to be munitions debris and other debris. Energetic items and constituents identified consist of the M524 fuze, M509 fuze, M49 60mm mortar, M374 81mm mortar, and the 30mm HEI MOX-2B.

Based on the concentration of M49 60mm mortars in the area of grid L51 and L52, it is likely that additional M49 60mm mortars would be present in grids L50 through L54 as well as in areas outside the gridded portion of the J-1 Range, as the entire portion of the range beyond Row 49 lies within an impact area for these munitions.

One pre-BIP sample collected in the grid K61 area had a significant detection of explosives (HMX at 7,400 µg/Kg). This soil was excavated under the BIP program. There were other low-level detections of explosives; however, all were associated with BIPs. The significance of the detections that were not excavated will be further evaluated in the risk screen (Section 6.0).

4.2.5 2,000 Meter Berm Area (Rows 65 to 72)

The 2,000 meter berm area is situated in the northwest portion of the J-1 Range (Figure 4-1). This portion of the range is primarily a target area and lies entirely within the Impact Area. The targets in this area were likely used both for training and for munitions testing. Section 2.2 discusses in greater detail the historical range uses and potential disposal activities in this portion of the range. No disposal areas were found during intrusive investigations of geophysical anomalies.

The following specific site features are or were formerly located within this portion of the range:

- 2,000 meter (a and b) berms
- Topographical depression
- Tank Targets

The J-1 Range Rows 65 to 72 soil dataset represents site investigations conducted from December 1997 through September 2009. A total of 433 soil samples were collected from 81 locations within this portion of the range (Figure 4-14). In most cases, samples were collected from multiple depths at the same location resulting in a larger number of samples than sample locations. Additional details about soil samples collected around each feature within this portion of the range are discussed below and presented in Table 4-2. This table contains details on sample depths and analytes. Table 4-3 summarizes analytical detections in soil samples from soil that was excavated under the BIP program. Table 4-4 summarizes analytical detections for soil samples that represent current conditions (Figure 4-15). Figure 4-15 also presents the most recent geophysical data for this study area. The complete database for all soil samples collected through 2007 is included in Appendix G. The location and description of all MEC items identified during field investigation are depicted on Figure 4-14. Munitions items were categorized based on their explosive characteristics, as defined in previous sections.

4.2.5.1 2,000 Meter Berm Area Findings

Soil samples were collected from four areas of interest within the J-1 Range 2,000 meter Berm Area: the 2,000 meter(a) Berm, the 2,000 meter(b) Berm, a topographical depression southwest of the two berms, and six tank targets.

Location 1 in grid K66 consisted of tank parts associated with adjacent tank target 22. Location 8 in grid I66 contained munitions debris and other debris. Location 4 in grid K66 contained miscellaneous tank parts, munitions debris, and MEC. The MEC items consisted of one, inert M1 105mm projectile with live fuzing and one inert M456 105mm HEAT projectile with live fuzing. Location 10 in grid I67 contained munitions debris and other debris. Location 2 in grid K67 contained munitions debris, other debris, and MEC. The MEC item consisted of one M456 105mm HEAT projectile. The item was BIP and determined to be an inert body with live fuze. Locations 18 and 33, also located in grid K67, consisted of munitions debris and other debris. Location 39 in grid L69 contained only munitions debris. Location 17 in grid J68 contained munitions debris. Location 32 in grid I68 contained munitions debris and MEC. The MEC item consisted of one M456 105mm HEAT projectile. The item was BIP and determined to be inert with a possible live fuze. Locations 21 in grid I69, 22 in grid J70, 24 in grid J71, and 37 in grid K72 contained munitions debris.

In addition to the investigation of geophysical anomalies, other intrusive activities including monitoring well pad clearance and access road maintenance/clearance were conducted in the 2,000 meter berm area. MEC items were identified during this clearance work. Two, M329 4.2 inch mortars were discovered. One mortar was found in grid J69 and the other mortar was identified in grid L71. Both items were determined to be HE. Two, M1 105mm projectiles were also discovered. One of these projectiles was discovered in grid L72, and the other was found in grid N70. Both items were determined to be HE. Lastly, two M49 60mm mortars were discovered. One mortar was found in grid K71 and the other mortar was in grid K72. Both mortars had inert bodies and live fuzes.

<u>Technology Demonstration</u>

In 2008, a technology demonstration of remote-controlled robotic technology was conducted at several ranges using crews and equipment from the Air Force Research Laboratory. The technology demonstration at the J-1 Range involved the removal of soil and munitions from the uprange faces of the 1,000 meter, 150 meter and 2,000 meter berms (a and b). A remotely operated excavator equipped with a rotating, two inch slot-screen bucket attachment was used to separate rocks and any munitions from finer soil materials. These materials ("overs") were placed into stockpiles for further inspection. An EM-61 geophysical survey was conducted on the berm face to evaluate the completeness of the removal. A small number of discrete items that remained in each berm were intrusively investigated by UXO Technicians.

The "overs" were spread out for UXO Technicians to inspect and catalogue as MEC, munitions debris, or other debris (Table 4-1). All suspect MEC items were moved by robotic equipment to a consolidated shot area located in grid J37 for disposal. The MEC items recovered during the technology demonstration, along with soil sample results, are discussed below.

<u>2,000 meter(a) Berm</u> – MEC items recovered from the technology demonstration and subsequent inspection of "overs" from the 2,000 meter(a) berm consisted of nine inert

M456 105mm projectiles with live fuzes, and two suspect M107 155mm projectiles. A total of 14 samples were collected from five locations associated with the 2,000 meter(a) Berm, as depicted on Figure 4-14 and summarized in Table 4-2. One sample location (CP04D) was located at the top of the berm. Two sample locations (CP04C and CP04E) were at the base of the berm on the northwest and southeast sides, respectively. Samples were also collected from the southwestern slope (SS04H) and from the base of the southwestern slope (SS04M). A pre-BIP sample was also collected from BIP location J1A200106. There were no explosives or perchlorate detected in any of these samples.

<u>2,000 meter(b) Berm</u> – MEC items recovered from the technology demonstration during the 2,000 meter(b) berm consisted of seventeen inert M456 105mm projectiles with live fuzes, one suspect M374 81mm mortar and one suspect 81mm Illumination mortar. A total of 33 samples were collected from six locations associated with the 2,000 meter(b) Berm, as summarized in Table 4-2 and depicted on Figure 4-14. One sample (CP04A) was located at the top of the berm and one sample location (CP04B) was located at the base of the berm on the southeast side (see Figure 4-14). Samples were collected from locations on the south and southwestern slopes (SS04J and SS04L respectively) and from locations at the base of the south and southwestern slopes (04I and 04K, respectively). Soil samples were also collected during the advancement of a soil boring (MW-27) to the northwest of the Berm. There were no explosives or perchlorate detected in any of these samples.

<u>Depression</u> – Two soil samples were collected from one location (CP04F) located within a topographic depression south of the 2,000 meter berm (b), which appears to periodically accumulate surface water runoff (Figure 4-14). There were no explosives or perchlorate detected in these samples.

<u>Tank Targets</u>

A total of 179 samples were collected from 16 locations associated with six tank targets (Targets 20, 22, 32, 33, 34 and 35) (Figure 4-14) in the vicinity of the 2,000 meter (a and b) berms. Both composite and discrete samples were collected from these investigation areas (Table 4-2). Explosive compounds were detected at all the tank target locations except for Target 20 (SS112A, SS112B) (Figure 4-14 and Tables 4-3 and 4-4). RDX was detected at concentrations ranging from 160 µg/Kg to 3,500 µg/Kg. HMX was detected at concentrations ranging from 130 µg/Kg to 2,000 µg/Kg. The highest concentrations of both RDX and HMX were detected at Tank Target 34 (SS118A) in grid H69. Perchlorate was also detected at a concentration of 60 µg/Kg at sample location SS118A. Other detected explosive compounds include 2,6-DNT, 3-Nitrotoluene, and 2A-DNT, and 4A-DNT (Figure 4-15 and Table 4-4). The contaminated soils surrounding Tank Target 34 (SS118) have been removed for treatment as part of a soil treatment project (ECC 2009, IAGWSP 2009). The excavation boundary is presented on Figure 4-16. The remaining explosive detections (Figure 4-15) will be evaluated during the risk screening process (Section 6).

4.2.5.2 2,000 Meter Berm Area BIP Samples

A total of 136 samples were collected from 60 locations associated with BIP activities in the 2,000 meter berm area. Sample locations, sample identification, collection date, sample depths, and laboratory analyses associated with BIPs on this sub-area of the range are summarized in Table 4-2. Contaminated soils generated from BIP activities were excavated according to protocols established under the BIP management program. Table 4-3 contains analytical detections for soils excavated under the BIP program.

Pre-BIP samples collected at two locations had low concentrations of explosives contamination prior to BIP activities (sample locations SSRDST0064 and SSJ1IAP001). RDX was detected at 30 µg/Kg and 43 µg/Kg. The post-BIP samples for both locations were non-detect for explosives compounds. Therefore, the soils associated with these pre-BIP detections were not excavated. (Figure 4-15). In addition, the post-BIP sample at location J1200182R had a detection of 2,4-DNT of 255 µg/Kg. No other explosives were detected at this location and, therefore, the soil at this sample location was not excavated (Figure 4-15).

4.2.5.3 2,000 Meter Berm Area Summary

The majority of items recovered from this portion of the range during intrusive investigations consist of munitions debris and other debris. Two M329 HE 4.2 inch mortars and two M1 HE 105mm projectiles were discovered. Three inert M456 105mm HEAT projectiles with suspect M509 fuzes, one inert M1 105mm projectile with suspect M51 fuze and two inert M49 60mm mortars with live M525 fuzing were discovered.

Soil sample results identified explosive contaminants primarily associated with tank targets. There were no explosives associated with either of the 2,000 meter berms. Tank target 34 (SS118A) with the highest levels of explosive contamination (SS118) has been removed for treatment. Additional soil sampling will be performed at Tank Targets 22 and 35 in accordance with the "*Final J-1 Range Targets 22 and 35 Soil Sample Collection and Grid K4 Anomaly Investigation*" Project Note dated July 7, 2010 (ECC 2010).

The downrange portion of J-1 Range located within Rows 65 to 72 lie completely within the impact area and was impacted from base-wide training activities as well as activities associated solely with the J-1 Range. Geophysical data indicates that this area is heavily saturated with metallic items. Individual MEC items, both HE and inert with live fuzes could still remain in this portion of the range. It is likely that the HE round types would include: the M374 81mm mortar, the M329 4.2-inch mortar, the M1 105mm projectile, and the M107 155mm projectile.

4.3 Source Removal

Geophysical investigations, including anomaly and associated soils removals were conducted from 1997 through 2009. These activities resulted in the investigation of over 150 geophysical anomalies. These investigations resulted in the excavation and off-site disposal of approximately 1,000 cy of soil (Table 4-1) from 19 investigation locations. In addition to the soil removals, these investigations also removed MEC from 39 locations (Table 4-1).

As previously discussed in Section 4.2, MIS sampling results identified soils with elevated concentrations of explosives compounds in three areas of the range (J-1 south grids I1-3 and J2-3, J-1 IBA grids L38, J37/38 and K39/40, and J-1 north target 34). Soil from decision units (Figures 4-5, 4-12 and 4-18) with explosives detections were excavated to depths ranging from of 0.5- to 1.5-feet below ground surface and mechanically screened to remove any remaining munitions. Excavation activities were conducted between September 2009 and April 2010.

Approximately 2,754 cubic yards of contaminated soil was excavated (Table 4-1). Post-excavation, 100-pt multi-increment soil samples were collected in each of the excavation areas units from 0 to 3 inches below the excavation floor. All samples were processed in accordance with ERDC/CRREL TR-07-10 and analyzed for explosives by method SW 846/8330B. Results from post-excavation sampling indicated no detections of explosives or perchlorate

The soils are being treated at the L Range using alkaline hydrolysis which involves raising the pH of the soil by blending it with treatment cell water and hydrolyzed lime to mineralize the explosive compounds to more elemental compounds of inorganic nitrogen and carbon dioxide. After blending, the soils are staged in a lined treatment cell at the L Range then sampled to determine the effectiveness of treatment. The total costs for the UXO clearance, soil excavation, screening, sampling and treatment (anticipated treatment costs) are estimated to be approximately $830,000.

A completion of work report detailing all excavation, confirmatory sampling and soil treatment activities will be prepared after soil treatment is complete.

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5.0 CONCEPTUAL SITE MODEL

The conceptual site model is the depiction of site conditions that relate to contaminant source, environmental pathways for contaminants, and potential for contact with human receptors.

5.1 Source

The J-1 Range has primarily been used as a defense contractor testing range where functional and ballistic testing of various mortar and artillery munitions was conducted. Munitions assembly and disposal activities are also known to have occurred at various locations on the range. Residues from the firing activities have been found to be concentrated around firing positions and target areas. Residues from munitions assembly and disposal practices have been found at various locations on the range. In addition, several old battle tanks that served as targets for artillery training are also located on a portion of the J-1 range that lies within an impact area. Groundwater contaminated with perchlorate and/or RDX has been found in areas downgradient from the J-1 Range North and South areas that appears to be associated primarily with the targets and disposal areas on the range.

5.1.1 Northern Area

The conceptual site model (Figure 5-1), based on known activities and presence of soil contaminants, recognizes two major source components in J-1 Range northern area. (1) The first is the disposal and/or burning of munitions that would have led to soil contamination. Results of investigations in the Popper Kettle area, the Steel-lined Pit, the Wastewater Disposal Area, and Polygon 16 show soil contamination that are consistent with explosives and perchlorate found in downgradient groundwater. These areas are located in the Interberm Area and the extent of the plume is consistent with source areas in these locations. (2) The second would be soil contamination from the dispersal of explosive particles near artillery targets in the impact area, several of which are located in areas that overlap the J-1 Range. These artillery or tank targets show elevated levels of RDX that are consistent with the development of a nearby RDX plume. It is, therefore, likely that particles dispersed as a result of low-order detonation have accumulated in soils around these tank targets in sufficient quantities to result in groundwater contamination.

5.1.2 Southern Area

The conceptual site model (Figure 5-2), based on known activities and presence of soil contaminants, recognizes one major source component in J-1 Range southern area. That is the disposal and/or burning of munitions that would have led to soil contamination. Surface soil sample results in the vicinity of Polygons 2, 3, and 4 show contaminants detected in soil that are consistent with explosives and perchlorate found in downgradient groundwater. These polygons are located in the J-1 Range southern area between the firing points and the 100 meter target. The extent of the plume is consistent with a source area in this location.

5.2 Pathway

Following deposition onto the soil, precipitation will dissolve a fraction of the contaminant mass and then migrate toward the water table. Dissolution is a function of the temperature, intensity, and duration of the precipitation, soil characteristics, drainage patterns, solubility, surface area, and kinetics. Although dissolution of the solid compounds is relatively slow, once dissolved, compounds such as RDX, HMX, and perchlorate move through the soil column with minimal sorption to the soil surfaces. Other contaminants such as metals, pesticides, and PAHs move more slowly based on their chemical properties. It is, therefore, reasonable to assume that contaminants that are more easily mobilized, such as RDX and perchlorate, pose a more immediate threat to groundwater than many other potential COCs from the J-1 Range. However, all detected analytes were evaluated for their potential to leach to groundwater in the risk screen (Section 6.0).

For the northern area, releases of explosive-related contaminants in the environment have occurred, ultimately causing infiltration of these contaminants to groundwater. All indications are that the primary contaminants, perchlorate and RDX, entered the groundwater with little retardation, and migrated in the direction of groundwater flow. Flow trajectories are influenced by the position of the top of the groundwater mound that is located southeast of the J-1 Range northern area. Based on the amount of recharge during a particular period, the groundwater mound can move and increase hydrodynamic dispersion (flow field tends to splay/disperse contaminants). In general, the flow trajectories are northwesterly in the area of the J-1 Range northern plume.

For J-1 Range southern area, releases of explosive contaminants to the environment have occurred, ultimately causing infiltration of these contaminants to groundwater. All indications are that RDX entered the groundwater with little retardation and migrated in the direction of groundwater flow. Flow trajectories are influenced by the position of the top of the groundwater mound that is located just north of the J-1 Range southern area. Based on the amount of recharge during a particular period, the groundwater mound can move and increase hydrodynamic dispersion (flow field tends to splay/disperse contaminants). In general, the flow trajectories are southeasterly just downgradient of the source and in the downgradient portion of the plume flow trajectories are more southerly.

5.3 Receptors

Analysis of the potential for contaminants reaching receptors is based on hypothetical exposures to groundwater if it were drawn from monitoring wells downgradient of the J-1 Range. No one is using the groundwater in these areas and the areas downgradient are closely managed. The J-1 northern plume remains in the Impact/Firing Area so access is severely limited. There is, however, a public water supply well (WS3) located approximately two and a half miles north / northeast of the J-1 Range. Residences in the vicinity of the J-1 southern plume are connected to the municipal water system and all future residents are required to use the municipal system as well. There is one irrigation well located on Little Acorn Lane.

Although residential use is not likely future land use within MMR, hypothetical residents are identified as potential receptors to determine the need for institutional controls and to provide information for evaluating all future-use options in the Feasibility Study. Therefore, hypothetical residents (on- and off-site) were identified as future receptors and the use of groundwater from the J-1 Range as a source of potable water was considered a potential exposure pathway.

Ongoing soil removal actions at the J-1 Range have removed all of the explosives-contaminated soil in the southern, mid-range and target areas and thereby eliminated any further leaching as well as the potential for contact with contaminated soils.

Contaminated groundwater from the northern J-1 plume flows in a north-northwest direction. Groundwater modeling indicates that the plume will dissipate to below risk based concentrations through advection/dispersion processes before that water reaches Gibbs Road. Contaminated groundwater from southern J-1 plume flows in a south-southwesterly direction and crosses the base boundary downgradient of Greenway Road into a residential neighborhood. The soil removal actions conducted in the southern IBA and target areas will reduce contaminant mass in the source areas.

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6.0 RISK SCREENING

6.1 Introduction

Risk screening evaluations were conducted for the J-1 Range. The objectives of the risk screening were to identify any contaminant of concern (COC) detected in the J-1 Range groundwater and soil that requires further evaluation. The groundwater was evaluated for J-1 Range northern and southern plumes separately. The risk screening for soil included an evaluation of the potential for analytes detected in the soils to leach from the soil and migrate through the subsurface to the groundwater.

6.2 Groundwater Screening

Table 6-1 provides the summary for analytes detected in the northern J-1 Range groundwater. Table 6-2 presents similar information for southern J-1 Range groundwater. As shown on Tables 6-1 and 6-2, the maximum detected concentration of each analyte was compared against various screening levels. The screening values included Federal Maximum Contaminant Levels (MCLs), Health Advisory Levels (HAs), EPA Regional Screening Levels for Tap water (RSL), and the Massachusetts Contingency Plan (MCP) Method 1 GW-1 cleanup standards.

In addition to the comparisons to the various screening levels, other factors such as an analyte's detection frequency, the temporal trends of the concentrations, the magnitude of screening criteria exceedences, comparisons with site-specific background levels, and ubiquity in the groundwater were considered when determining if further evaluation is required.

A discussion of the significant findings of the groundwater screening process is provided in the following sections.

6.2.1 Northern Plume

6.2.1.1 Explosive Compounds and Perchlorate

As presented on Table 6-1, a number of explosive compounds and perchlorate were detected in the groundwater. The maximum detected concentrations for a few of the explosive compounds (2,6-DNT, nitrobenzene, 2-NT, RDX, and TNT) and perchlorate exceeded at least one of their respective screening levels, as summarized below:

- 2,6-DNT exceeded its tap water RSL and was detected in 22 of 1545 samples (frequency of detection [FOD] rate equals 1.4%).
- Nitrobenzene exceeded its tap water RSL and was detected in 2 of 1545 samples (FOD rate <1%).
- 2-NT exceeded its tap water RSL and was detected in 3 of 1541 samples (FOD rate <1%).

- Perchlorate exceeded its tap water RSL, and MCP GW-1 Standard. It was detected in 152 of 947 samples (FOD rate equals 16%).
- RDX exceeded its HA, tap water RSL, and MCP GW-1 Standard. It was detected in 384 of 1539 samples (FOD rate equals 25%).
- TNT exceeded its HA and tap water RSL and was detected in 5 of 1541 samples (FOD rate <1%).

The maximum concentrations for the remaining explosive compounds (4-amino-2,6-DNT, 2-amino-4,6-DNT, 2,4-diamino-6-NT, HMX, 3-NT, tetryl, and 1,3,5-trinitrobenzene) that were detected in J-1 Range northern groundwater were less than the screening criteria and had low FOD rates. Screening levels were not available for picric acid but this explosive compound had a low FOD rate (<0.1%).

Based on these findings, it was determined that perchlorate and RDX will be retained as COCs for the Feasibility Study. Any future actions taken for perchlorate and RDX would also address the other co-located explosives compounds.

6.2.1.2 Inorganics

A number of inorganic constituents were detected in the J-1 Range northern groundwater. The maximum concentrations of antimony, arsenic, manganese, nitrogen (nitrate-nitrite), and thallium exceeded at least one of their respective screening levels.

- Antimony exceeded its MCL, HA, and MCP GW-1 Standard. It was detected in three of 140 samples (FOD rate equals 2%).
- Arsenic exceeded its HA and tap water RSL. It was detected in 4 of 135 samples (FOD rate equals 3%).
- Manganese exceeded its HA. It was detected in 122 of 135 samples (FOD rate equals 90%).
- Nitrogen exceeded its MCL (FOD rate equals 70%).
- Thallium exceeded its MCL, HA, tap water RSL, and MCP GW-1 Standard. It was detected in four of 141 samples (FOD rate equals 3%).

The table below presents a comparison of site-specific background levels to site concentrations for the inorganics that exceeded a screening value.

Analyte	Background Mean (µg/L)	Background Maximum (µg/L)	Site Maximum (µg/L)
Antimony	0.13	48.6	6.6
Arsenic	0.58	34.5	5.3
Manganese	210	11500	344

Analyte	Background Mean (µg/L)	Background Maximum (µg/L)	Site Maximum (µg/L)
Nitrogen	Not available	Not available	5200
Thallium	0.23	13.3	7.3

As presented in the table above, four of the five site concentrations were less than the maximum background levels. The exception to this was nitrogen, which was not sampled for in the background sampling program. However, only 10% of the samples exceeded the MCL. The maximum concentration of manganese is below the RSL of 880 µg/L. Therefore, inorganic compounds/metals will not be evaluated in the Feasibility Study.

6.2.1.3 SVOCs, Pesticides and Herbicides

Several SVOCs, pesticides, and herbicides, were detected in the groundwater. The SVOCs were detected sporadically throughout the site. The list below presents the SVOCs that exceeded the screening criteria:

- Aldrin exceeded its tap water RSL and was detected in one of 123 samples (FOD rate equals <1%).
- Benzo(a)anthracene exceeded its MCL and tap water RSL and was detected in one of 316 samples (FOD rate <1%).
- Bis(2-ethylhexyl)phthalate (BEHP) exceeded its MCL, tap water RSL, and MCP GW-1 Standard. It was detected in 60 of 316 samples (FOD rate equals 19%). The presence of BEHP in the groundwater samples appears to be an artifact of the investigation methods, introduced to the samples from plastic equipment used during collection and analysis. This conclusion is supported by the results of historic sampling on MMR that show much lower levels of the chemical after additional precautions were taken to prevent cross-contamination during sample collection and analysis.
- Dieldrin exceeded its tap water RSL and was detected in three of 123 samples (FOD rate equals 2.4%).

None of the other SVOCs exceeded a screening value. Based on the low levels, the low FOD rates, and the historic investigation methods issue, none of the SVOCs will be carried forward into the Feasibility Study.

6.2.1.4 VOCs

A number of VOCs were detected in the groundwater. The VOCs were detected sporadically throughout the site. The list below presents the VOCs that exceeded the screening criteria:

- Bromodichloromethane exceeded its tap water RSL and was detected in one of 869 samples (FOD rate <1%).
- Chloroform exceeded its tap water RSL. It was detected in 447 of 869 samples (FOD rate equals 51%). Chloroform is ubiquitous in the groundwater at MMR and it is, therefore, not considered a site COC.
- Chloromethane exceeded its HA and was detected in 61 of 869 samples (FOD rate equals 7%).
- Dibromochloromethane exceeded its tap water RSL and was detected in seven of 869 samples (FOD rate <1%).

In general, the detection frequency was low for these VOCs. Based on these findings, none of the VOCs will be evaluated in the Feasibility Study.

6.2.1.5 Fuel Related Compounds

One well, MW-187D, had detections of fuel related compounds that included aliphatic and aromatic hydrocarbons, benzene, dichloroethane, chloroethane, 2-methyl-naphthalene, naphthalene, and potentially others. The maximum detected concentrations of the C5-C8 aliphatic hydrocarbons, the C9-C10 aromatic hydrocarbons, benzene, dichloroethane, 2-methylnaphthalene, and naphthalene were greater than their respective screening criteria.

The concentrations of the fuel related compounds have been decreasing over time and were only detected in the deepest sampling interval (306- to 311-feet bgs). To date, the fuel-related contaminants found in MW-187D have not been detected in any downgradient wells at levels greater than the screening standards. It appears that these compounds are limited to a small localized area and are likely related to a depleted source area in the vicinity of the IBA.

6.2.1.6 Radionuclides

The maximum concentrations of gross alpha and gross beta were compared to the screening criteria. The concentrations were less than the available screening levels. Therefore, the radionuclides will not be evaluated in the Feasibility Study.

6.2.2 Southern Plume

6.2.2.1 Explosive Compounds and Perchlorate

As presented on Table 6-2, a number of explosive compounds and perchlorate were detected in the groundwater. The maximum detected concentration of RDX exceeded its HA, tap water RSL, and MCP GW-1 Standard. RDX was detected in 38 of 343 samples (FOD rate equals 11%). The maximum concentrations for the remaining detected explosive compounds (2,6-DNT, HMX, 4-NT, and TNT) and perchlorate were less than the screening criteria and had low FOD rates. Based on these findings, it was determined that only RDX will be retained as a COC for the Feasibility Study.

6.2.2.2 Inorganics

A number of inorganic constituents were detected in the J-1 Range southern groundwater. The maximum concentration of arsenic exceeded its HA and tap water RSL. The maximum concentrations for the remaining metals that were detected in J-1 Range South groundwater were less than the available screening criteria.

It is likely that the arsenic levels in the groundwater are naturally occurring. The table below presents a comparison of site-specific background levels to the site concentration for arsenic.

Background Mean (µg/L)	Background Maximum (µg/L)	Site Maximum (µg/L)
0.58	34.5	5

As presented in the table above, the site arsenic concentration is less than the site-specific maximum background level. Based on these findings, none of the inorganics will be evaluated in the Feasibility Study.

6.2.2.3 SVOCs and Pesticides

Some SVOCs, and pesticides were detected in the groundwater. None of the SVOCs or pesticides exceeded a screening value. Based on these results, none of these compounds will be carried forward into the Feasibility Study.

6.2.2.4 VOCs

A number of VOCs were detected in the groundwater. Chloroform exceeded its tap water RSL. It was detected in 33 of 61 samples (FOD rate equals 54%). Chloroform is ubiquitous in the groundwater at MMR and it is not considered a site COC. None of the other VOCs exceeded a screening value. Based on these findings, none of the VOCs will be evaluated in the Feasibility Study.

6.2.2.5 Radionuclides

The maximum concentration of gross beta was compared to the screening criteria. The concentration was less than the available screening levels, therefore, the radionuclides will not be evaluated in the Feasibility Study.

6.2.3 Groundwater Evaluation Summary

Based on the screening analysis performed for the J-1 Range northern groundwater, perchlorate and RDX were identified as COCs in groundwater and will be further evaluated in the Feasibility Study. RDX was identified as a COC in the J-1 Range southern groundwater and will also be evaluated in the Feasibility Study.

6.3 Soil Screening

For purposes of the soil screening evaluation, the J-1 Range was divided into the following nine discrete sub-areas based on the range use:

- Firing Point Area (Grid Rows 0 to 2, Columns H, I, J, and K)
- Firing Point Area (Grid Rows 0 to 2, Columns L and M)
- Firing Point Area (Grid Rows 3 to 6)
- Southern Flyover Area (Grid Rows 7 to 29)
- Interberm Area – (Grid Rows 30 to 33)
- Interberm Area – (Grid Rows 34 to 42)
- Interberm Area – (Grid Rows 43 and 44)
- Northern Flyover Area (Grid Rows 45 to 64)
- 2,000 Meter Berm (Grid Rows 65 to 72)

Tables 6-3 through 6-11 present comparisons of the maximum detected concentrations in surface soil (0- to 2-feet bgs) to a series of screening values for the J-1 Range soil sub-areas. The screening values include the MCP Method 1 S-1/GW-1 Standards, the MassDEP leaching based soil concentrations, the MMR SSLs, and the EPA Region 3 risk-based SSLs. It is noted that the MCP S-1/GW-1 Method 1 standards were used as a screening criteria only for those compounds for which a value has been published in 310 CFR 40.0975(6)(a). Other considerations evaluated in the screening evaluation included whether an analyte was a human nutrient, the discrete subarea average in comparison to standards, the detection frequency of that analyte, and background levels.

6.3.1 Firing Point Area (Grid Rows 0 to 2, Columns H, I, J, and K)

Table 6-3 presents the comparisons of the maximum detection concentrations to a series of screening values.

6.3.1.1 Explosive Compounds and Perchlorate

HMX and RDX were the only explosives related compounds detected (see Table 6-3). The maximum detected concentrations for HMX and RDX exceeded at least one the screening values. HMX was detected in one of 51 samples and RDX was detected two of 51 samples. HMX marginally exceeded its MassDEP leaching concentration and the MMR SSL. RDX exceeded its MCP S-1/GW-1 Standard, the MassDEP leaching concentration, the MMR SSL, and the EPA risk-based SSL. These elevated detections were removed for treatment.

6.3.1.2 Inorganics

As presented on Table 6-3, a number of inorganics were detected. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the average concentrations within each sub-area were similar to or were less than background levels. Based on these findings, none of the inorganics will be evaluated in the Feasibility Study.

6.3.1.3 SVOCs, Pesticides, Herbicides and PCBs

Several SVOCs, pesticides, herbicides, and PCBs, were detected in the soil. The SVOCs were detected sporadically throughout the site.

- PAHs – The maximum detected concentrations of three PAHs exceeded at least one of their respective screening values. The maximum detected concentrations of the PAHs were less than or similar to background levels for the State of Massachusetts and none exceeded the S-1/GW-1 standards.
- Pesticides and Herbicides – The maximum detected MCPA concentration exceeded its MMR SSL and EPA risk-based SSL. None of the other pesticides or herbicides exceeded the screening criteria. MCPA was detected in one of eight samples. The pesticides and herbicides were applied in accordance with manufacturing guidelines.
- PCBs – PCB-1254 exceeded two of its screening values and was detected in one of nine samples. However, the S-1/GW-1 standard was not exceeded.
- Other SVOCs – None of the other SVOCs exceeded the screening criteria.

Based on these findings, the SVOCs will not be further evaluated in the Feasibility Study.

6.3.1.4 VOCs

Acetone and methyl ethyl ketone were the only VOCs detected. The concentrations of these analytes were less than the screening criteria. Based on these findings, the VOCs will not be evaluated in the Feasibility Study.

6.3.2 Firing Point Area (Grid Rows 0 to 2, Columns L and M)

Table 6-4 presents the comparisons to the screening criteria for this area.

6.3.2.1 Explosive Compounds and Perchlorate

RDX was the only explosives related compound detected. The RDX detection was in grid L2 in BIP location SS028526-A. The maximum detected RDX concentration exceeded its MassDEP leaching concentration, the MMR SSL, and the EPA risk-based

SSL. However, it did not exceed the S-1/GW-1 standard. It was detected in one of 25 samples. This remaining RDX detection is associated with a BIP activity and the concentration is below the established BIP excavation criteria. Therefore, RDX will not be further evaluated in the Feasibility Study.

6.3.2.2 Inorganics

As presented on Table 6-4, a number of inorganics were detected. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the average site concentrations were similar to or were less than background levels. The exception to this is copper. While the maximum copper concentration is above the MMR SSL and EPA SSL, the average concentration is well below these levels, but exceeds background levels. However, copper is not expected to be mobile in the environment and has not been detected in the groundwater above screening criteria. Based on these findings, none of the inorganics will be evaluated in the Feasibility Study.

6.3.2.3 SVOCs, Pesticides and Herbicides

Several SVOCs, pesticides and herbicides were detected in the soil.

- PAHs – The maximum detected concentrations of two PAHs exceeded at least one of their respective screening values. The maximum detected concentrations of the PAHs were less than or similar to background levels for the State of Massachusetts.
- Pesticides and Herbicides – None of the pesticides or herbicides detected in the soil exceeded the available screening criteria.
- BEHP was the only other SVOC that exceeded at least one of the available screening criteria. It marginally exceeded its risk-based SSL. The presence of BEHP appears to be an artifact of the investigation methods, introduced to the samples from plastic equipment used during collection and analysis.

Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.2.4 VOCs

Four VOCs were detected in the soil. The concentrations of these analytes were less than the screening criteria. Based on these findings, the VOCs will not be evaluated in the Feasibility Study.

6.3.3 Firing Point Area (Grid Rows 3 to 6)

Table 6-5 presents the comparisons of the maximum detected concentrations to a series of screening values.

6.3.3.1 Explosive Compounds and Perchlorate

HMX and RDX were the only explosives related compounds detected (see Table 6-5). The maximum detected concentrations for HMX and RDX exceeded at least one the screening values. HMX was detected in three of 53 samples and RDX was detected five of 53 samples. HMX marginally exceeded its MassDEP leaching concentration and MMR SSL. RDX exceeded its MCP S-1/GW-1 Standard, the MassDEP leaching concentration, the MMR SSL, and the EPA risk-based SSL. The RDX and co-located HMX detections have been removed for treatment, as previously discussed in Section 4.2.1.

6.3.3.2 Inorganics

As presented on Table 6-5, a number of inorganics were detected in the soil. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the maximum or average site concentrations were similar to or were less than background levels. The exception to this is copper and nickel, for which the average exceeded background, but was below the screening criteria. None of these metals are expected to be mobile in the environment and only one, arsenic which is naturally occurring in the area, was detected in groundwater above screening levels. Due to their low mobility and lack of significant groundwater detections none of these metals were further evaluated.

6.3.3.3 SVOCs, Pesticides and Herbicides

Several SVOCs, pesticides and herbicides were detected in the soil. The SVOCs were detected sporadically throughout the site. In general, the detection frequency for a number of the SVOCs was low and similar to background levels.

- PAHs – The maximum detected concentrations of several PAHs exceeded at least one of their respective screening values. The maximum detected concentrations of the PAHs were less than or similar to background levels for the State of Massachusetts.
- Pesticides and Herbicides – The maximum detected concentrations of a few pesticides and herbicides exceeded at least one of their respective screening values. The pesticides and herbicides were applied site-wide in accordance with manufacturing guidelines.
- Other SVOCs – Other SVOCs including carbazole and n-nitrosodiphenylamine exceeded at least one of the available screening criteria but as presented on Table 6-5, the frequency of detection rate for these analytes was low and none exceeded the S-1/GW-1 standards.

Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.3.4 VOCs

Four VOCs were detected in the soil. The concentrations of these analytes were less than the screening criteria. Based on these findings, the VOCs will not be evaluated in the Feasibility Study.

6.3.4 Southern Flyover Area (Rows 7 to 29)

Table 6-6 presents the comparisons to the soil screening criteria for the Southern Flyover Area.

6.3.4.1 Explosive Compounds and Perchlorate

Two explosive compounds (RDX and tetryl) and perchlorate were detected in soil (see Table 6-6). The maximum detected concentrations for these compounds exceeded at least one the screening values. RDX and tetryl were detected in two of 64 samples. Perchlorate was detected in two of 20 samples. RDX exceeded its MassDEP leaching concentration, the MMR SSL, and the EPA risk-based SSL. The maximum tetryl concentration exceeded its MMR SSL and EPA SSL but the average concentration was less than all criteria. The maximum perchlorate concentration (0.0024 mg/kg) was essentially equal to its MassDEP leaching concentration (0.002 mg/kg). These detections are in small areas associated with BIP activities and were allowed to remain in-place under the BIP protocols. Therefore, they will not be further evaluated.

6.3.4.2 Inorganics

As presented on Table 6-6, a number of inorganics were detected. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the average site concentrations were similar to or were less than background levels. The exception to this is copper, for which the average exceeded background. None of these metals are expected to be mobile in the environment and only one, arsenic which is naturally occurring in the area, was detected in groundwater above screening levels. Due to their low mobility and lack of significant groundwater detections none of these metals were further evaluated.

6.3.4.3 SVOCs

Several SVOCs were detected in soil. The SVOCs were detected sporadically throughout the site. In general, the detection frequency for a number of the SVOCs was low.

- PAHs – The maximum detected concentrations of four PAHs exceeded at least one of their respective screening values. The maximum detected concentrations of the PAHs were less than or similar to background levels for the State of Massachusetts.

- Other SVOCs – None of the other SVOCs exceeded the screening criteria.

Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.4.4 VOCs

Several VOCs were detected in the soil. The maximum detected concentrations of benzene, bromomethane, chloroform, chloromethane, ethylbenzene, methylene chloride, tetrachloroethene, and trichloroethene exceeded at least one of their respective screening values. However, none of the VOCs exceeded the S-1/GW-1 standards. The detection frequency for these VOCs was low, and they were only detected sporadically throughout the site. Based on these findings, the VOCs will not be evaluated further.

6.3.4.5 Polychlorinated Naphthalenes

Polychlorinated naphthalenes (PCNs) were detected in the soil. The PCNs were analyzed for in four samples all associated with BIP activities. Dichloronaphthalene, trichloronaphthalene, tetrachloronaphthalene, and pentachloronaphthalene were detected in one sample. The presence of the PCNs is associated with their use as inert fillers. As a result, they are not expected to be widely present on-site. The PCN detections are evaluated and removed, as appropriate, under the BIP program. Based on this, the PCNs will not be evaluated further.

6.3.5 Interberm Area (Grid Rows 30 to 33)

Table 6-7 presents the comparisons to the screening criteria for this part of the IBA.

6.3.5.1 Explosive Compounds and Perchlorate

HMX was the only explosives related compound detected in soil (see Table 6-7). HMX (14 µg/Kg) was detected in grid I30 at Sample Location SSJ1I30003. The maximum detected concentration was less than all the available screening criteria. Based on these findings, explosives compounds were not further evaluated.

6.3.5.2 Inorganics

As presented on Table 6-7, a number of inorganics were detected in soil at various FOD rates. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the average site concentrations were similar to or were less than background levels and were all less than the S-1/GW-1 standards, if available. The exception to this is copper, for which the average exceeded background, but was less than the screening criteria. Copper is not expected to be mobile in the environment and was not detected in groundwater above screening levels. Based on these findings, the inorganics will not be evaluated in the Feasibility Study.

6.3.5.3 SVOCs

Four SVOCs were detected in the soil. The concentrations of these analytes were less than the screening criteria. Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.5.4 VOCs

Three VOCs were detected in the soil. The maximum benzene concentration exceeded its MMR SSL and EPA risk-based SSL in one sample. All other samples analyzed for benzene and all other VOCs were either non-detect or were less than the available screening criteria. This isolated benzene detection is associated with BIP activities and was allowed to remain in-place under the BIP protocols. Therefore, benzene will not be further evaluated.

6.3.6 Interberm Area (Grid Rows 34 to 42)

Table 6-8 presents the comparisons of the maximum detection concentrations to a series of screening values for this portion of the IBA.

6.3.6.1 Explosive Compounds and Perchlorate

Four explosive compounds (2,4-DNT, 2-amino-4,6-DNT, HMX, and tetryl) and perchlorate were detected (see Table 6-8). The maximum detected concentrations for 2,4-DNT, 2-amino-4,6-DNT, perchlorate, and tetryl exceeded at least one of the screening values. However, the FOD rates for these four compounds were low (less than 3%) with a large number of samples. The portion of the IBA where these detections were identified was re-sampled using MIS sampling approach as previously discussed in Section 4.2.3. Based on the MIS sampling results, soils with elevated concentrations of RDX and 2,4 DNT were removed for treatment. Based on the removal action, these compounds will not be further evaluated. The locations of any remaining detections are presented on Figure 4-11.

6.3.6.2 Inorganics

As presented on Table 6-8, a number of inorganics were detected in the soil. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the maximum or average site concentrations were similar to or were less than background levels. The exception to this is copper and nickel. However, the average nickel concentrations were below all screening criteria, and nickel has not been detected in groundwater above screening levels. Copper is not expected to be mobile in the environment and was not detected in groundwater above screening levels. Based on these findings, none of the inorganics will be evaluated in the Feasibility Study.

6.3.6.3 SVOCs, Pesticides and Herbicides

Several SVOCs, pesticides and herbicides were detected in the soil. The SVOCs were detected sporadically throughout the site. In general, the detection frequency for a number of the SVOCs was low.

- PAHs – The maximum detected concentrations of several PAHs exceeded at least one of their respective screening values. The frequency of detection rates for the PAHs was low (approximately 7%). The maximum detected concentrations of the PAHs were less than or similar to background levels for the State of Massachusetts and none exceeded the S-1/GW-1 standards.
- Pesticides and Herbicides – The maximum detected concentrations of several pesticides and herbicides exceeded at least one of their respective screening values. The frequency of detection rates for the pesticides and herbicides were low (less than 10%). Pesticides and herbicides were historically used at MMR, and were applied in accordance with the manufacturer's guidelines.
- PCBs – PCB-1254 exceeded two of its screening values but it was detected in only one of 95 samples (frequency of detection rate equals 1%) and was below the S-1/GW-1 standards.
- Other SVOCs – Other SVOCs including bis(2-chloroethyl)ether, carbazole, n-nitrosodiphenylamine, and pentachlorophenol exceeded at least one of the available screening criteria but as presented on Table 6-8, the frequency of detection rate for these analytes was low and none exceeded the S-1/GW-1 standards.

Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.6.4 VOCs

Several VOCs were detected in the soil. The maximum detected concentrations of benzene, bromoform, bromomethane, chloroform, chloromethane, 1,4-dichlorobenzene, tetrachloroethene, 1,2,4-trichlorobenzene, and trichloroethene exceeded at least one of their respective screening values. The detection frequency for the majority of the VOCs was low. The VOCs were detected sporadically throughout the site. . Bromoform and bromomethane were detected at higher frequencies; however, neither compound exceeded the S-1/GW-1 standards and these compounds have not been detected in groundwater at concentrations exceeding the screening levels. Based on these findings, the VOCs will not be evaluated in the Feasibility Study.

6.3.6.5 Dioxins and Furans

Dioxins and furans were detected and remain in three samples collected from this area; sample locations SSJ1K40BLP-001 (grid K40), J1P-15 (grid K37), and SSJ1J36001 (grid J37). Evaluated as 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (2,3,7,8-TCDD TEQ), the dioxins and furans exceeded the MMR SSL and the EPA risk-based SSL. The TEQ however, is below the S-1/GW-1 standard. The presence of the dioxins and furans is associated with isolated burn/burial pits. All identified burn/burial pits have been removed, and based on the findings of the munitions source assessment (Appendix H), additional burn/burial pits are unlikely in this portion of the range. Therefore, dioxins and furans are not expected to be widely present at the J-1 Range. Based on these findings, the dioxins and furans will not be evaluated in the Feasibility Study.

6.3.6.6 Aliphatic and Aromatic Hydrocarbons

Aliphatic and aromatic hydrocarbons were detected. The maximum detected concentrations were less than the available screening standards. As a result, the aliphatic and aromatic hydrocarbons will not be evaluated in the Feasibility Study.

6.3.7 Interberm Area (Rows 43 and 44)

Table 6-9 presents the comparisons to the screening criteria for this part of the IBA.

6.3.7.1 Explosive Compounds and Perchlorate

There we no explosive compounds or perchlorate detected in the soil. Based on these findings, no explosive compounds will be evaluated in the Feasibility Study.

6.3.7.2 Inorganics

As presented on Table 6-9, a number of inorganics were detected in the soil. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the site concentrations for these metals were similar to or were less than background levels and none exceeded the S-1/GW-1 standards. Based on these findings, none of the inorganics will be evaluated in the Feasibility Study.

6.3.7.3 SVOCs

Three SVOCs (benzo(a)pyrene, BEHP and chrysene) were detected in the soil. The benzo(a)pyrene concentration exceeded its EPA SSL but it was less than the State of Massachusetts background level. The concentrations for the other analytes were less than the screening criteria. Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.8 Northern Flyover Area (Grid Rows 45 to 64)

Table 6-10 presents the comparisons to the screening criteria for the Northern Flyover Area.

6.3.8.1 Explosive Compounds and Perchlorate

RDX and 4-Nitrotolouene were the only explosives compounds detected in Northern Flyover Area soils (see Table 6-10). The maximum detected concentrations for RDX and 4-NT exceeded at least one the screening values. RDX was detected in only two of 80 samples and 4-NT was detected one of 80 samples. RDX exceeded its MassDEP leaching concentration, the MMR SSL, and the EPA risk-based SSL. 4-Nitrotouene exceeded its EPA risk-based SSL. These isolated detections are associated with BIP activities and were allowed to remain in-place under the BIP protocols. Therefore, no explosives or perchlorate will be evaluated in the Feasibility Study.

6.3.8.2 Inorganics

As presented on Table 6-10, a number of inorganics were detected in the soil. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the maximum or average site concentrations were similar to or were less than background levels. The exception to this is cadmium and copper. The maximum cadmium detection was associated with a post-BIP sample that was below the excavation criteria established by the BIP protocol, sot the soil was left in place. Copper is not expected to be mobile in the environment and was not detected in groundwater above screening levels. Based on these findings, none of the inorganics will be evaluated in the Feasibility Study.

6.3.8.3 SVOCs, and Pesticides

Several SVOCs and pesticides were detected in the soil. The SVOCs were detected sporadically throughout the site. In general, the detection frequency for a number of the SVOCs and pesticides was low. Naphthalene was the only SVOC that exceeded at least one of its respective screening values; however, the maximum detected naphthalene concentration was less than the background level for the State of Massachusetts and below the S-1/GW-1 standard. None of the detected pesticides exceeded screening values. Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.8.4 VOCs

Several VOCs were detected in the soil. The maximum detected concentrations of benzene, bromomethane, and chloromethane exceeded at least one of their respective screening values. However, there were no exceedences of the S-1/GW-1 standards, and detections in groundwater are infrequent. Based on these findings, the VOCs will not be evaluated in the Feasibility Study.

6.3.8.5 Polychlorinated Naphthalenes

PCNs were detected in the soil. The PCNs were analyzed for in 33 BIP related samples. The presence of the PCNs is associated with their use as inert fillers. As a result, they are not expected to be widely present on-site. The PCN detections are evaluated and removed as appropriate under the BIP program. Based on this, the PCNs will not be evaluated in the Feasibility Study.

6.3.9 2,000 Meter Berm (Grid Rows 65 to 72)

Table 6-11 presents the comparisons of the maximum detection concentrations to a series of screening values for the 2,000 Meter Berm Area.

6.3.9.1 Explosive Compounds and Perchlorate

Eight explosive compounds (2,4-DNT, 2,6-DNT, 2-amino-4,6-DNT, 4-amino-2,6-DNT, HMX, 2-NT, 3-NT, and RDX) and perchlorate were detected in the 2,000 Meter Berm soil (see Table 6-11 and Figure 4-21)). The maximum detected concentrations for the majority of these compounds exceeded at least one the screening values. The frequency of detection rates for the explosives compounds were 5% or lower. Only one compound (RDX) exceeded the S-1/GW-1 standard. However, the contaminated soils associated with the maximum RDX and HMX detections (SS118, RDX at 3500 µg/Kg) have been removed for treatment, as previously discussed in Section 4.2.4. Based on this removal action, explosive compounds and perchlorate will not be further evaluated in the Feasibility Study.

6.3.9.2 Inorganics

As presented on Table 6-11, a number of inorganics were detected in the soil. The maximum detected concentrations of a number of inorganics exceeded at least one of their respective screening levels. However, the maximum or average site concentrations were similar to or were less than background levels. The exception to this is copper, for which the average exceeded background, but was less than the screening criteria. Copper is not expected to be mobile in the environment and was not detected in groundwater above screening levels. Based on these findings, none of the inorganics will be further evaluated.

6.3.9.3 SVOCs, Pesticides and Herbicides

Several SVOCs, pesticides and herbicides were detected in the soil. The SVOCs were detected sporadically throughout the site. In general, the detection frequency for a number of the SVOCs was low.

- PAHs – The maximum detected concentrations for all of the detected PAHs were less than the available screening values.
- Pesticides and Herbicides – The maximum detected concentrations of several pesticides and herbicides exceeded at least one of their respective screening values. The pesticides and herbicides were applied site-wide in accordance with manufacturing guidelines.
- Other SVOCs – Pentachlorophenol was the only other SVOC that exceeded at least one of the available screening criteria but as presented on Table 6-11, the FOD rate for pentachlorophenol is low and the maximum concentration did not exceed the S-1/GW-1 standard.

Based on these findings, the SVOCs will not be evaluated in the Feasibility Study.

6.3.9.4 VOCs

Several VOCs were detected in the soil. The maximum detected concentrations of benzene, chloroform, and trichloroethene exceeded at least one of their respective screening values. The detection frequency for these VOCs was low. The VOCs were detected sporadically throughout the site. Based on these findings, the VOCs will not be evaluated in the Feasibility Study.

6.3.9.5 Polychlorinated Naphthalenes

PCNs were detected in the soil. The PCNs were analyzed for in five samples. The presence of the PCNs is associated with their use as inert fillers. As a result, they are not expected to be widely present on-site. Screening values are not available for the PCNs at the current time. Based on this, the PCNs will not be evaluated in the Feasibility Study.

6.3.9.6 Soil Evaluation Summary

Elevated concentrations of explosives compounds have been removed from the 100 Meter Range (Rows 3 to 6), IBA (Rows 34 to 42) and from the 2,000 meter berm (Rows 64 to 72) for treatment. Based on these removal actions, explosive compounds and perchlorate in soils will not be further evaluated in the Feasibility Study. No other soil detections warrant further evaluation as part of the J-1 Range Feasibility Study.

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7.0 REMEDIAL INVESTIGATION FINDINGS

The following presents the summary and findings of the J-1 Range remedial investigation.

7.1 Groundwater Contamination

For the purposes of groundwater evaluation the J-1 southern and northern groundwater evaluations are discussed separately. This is due to the diverging flow directions of the two plumes emanating from the J-1 Range. The northern plume is flowing in a north-north- westerly direction and the J-1 southern plume is flowing in a southeast direction.

7.1.1 Northern Area

The main lobe of the plume consists of perchlorate and RDX and the western lobe consists primarily of RDX with some isolated detections of perchlorate (Figures 2-10 and 3-1). The main lobe of the perchlorate plume, as defined by perchlorate above the MMCL (2 µg/L), is approximately 3,900-feet long and approximately 800-feet wide at the widest point. The perchlorate contamination is detached from the suspected source area and the highest concentrations are located in the downgradient portion of the plume. The main RDX plume, as defined by concentrations above the HA (2 µg/L), is approximately 3,300-feet long and 1,100-feet wide at the widest point. RDX concentration in the source area have gradually decreased with time to levels that are below the HA. The highest RDX groundwater concentrations have not migrated as far downgradient as elevated perchlorate concentrations, and are located in the upgradient portion of the plume. The Conceptual Site Model, based on known range use activities and presence of soil contaminants, suggests disposal activities, including burning, in the IBA as the major source of the J-1 Range northern plume.

A human health risk screening was conducted for the J-1 Range northern groundwater. The objective of the risk screening was to identify any contaminant detected in the J-1 Range northern groundwater that requires further evaluation. The maximum detected concentration of each analyte was compared against its MCL, HA, RSL or GW-1 standard. The screening identified a widespread presence of RDX and perchlorate at concentrations exceeding the screening criteria. Therefore, RDX and perchlorate will be further evaluated in the Feasibility Study. Other compounds were identified at concentrations exceeding some risk screening criteria, but these compounds were detected infrequently, are associated with naturally occurring background conditions, or are laboratory-related contaminants and therefore were not carried forward to the feasibility study.

7.1.2 Southern Area

The primary site-related contaminant in the southern J-1 Range groundwater study area is RDX. The plume is defined by an upgradient portion which extends from the presumed source area and terminates along the base boundary at the extraction well (J1SEW0001), and a downgradient portion which extends from the base boundary, just beyond the extraction well (J1SEW0001) approximately 1,000 feet (Figure 2-14). The upgradient plume, as defined by detections of RDX above the HA, is approximately 1,000-feet long and 300-feet wide at the widest point and the downgradient plume, as defined by detections of RDX above the HA is approximately 1,900-feet long and approximately 700-feet wide at its widest point. The plume is approximately 50-feet thick (Figure 2-15). Further downgradient, past the extraction well, the plume thins (Figure 2-14).

The Conceptual Site Model, based on known range use activities and presence of soil contaminants, suggests munitions testing and disposal activities as the major source of the southern plume. In general, the plume flow trajectory is southeasterly in the area immediately downgradient of the source area and more southerly toward the downgradient portion of the plume.

A human health risk screening was conducted for the J-1 Range southern groundwater using the same screening approach as discussed for the J-1 Range northern groundwater. RDX was identified during the screening evaluation and will be further evaluated in the Feasibility Study. Other compounds were also exceeding some risk screening criteria, but these compounds were detected infrequently, are associated with naturally occurring background conditions, or are laboratory-related contaminants and therefore were not carried forward.

7.2 Source Characterization

During the period from 1997 through 2007, 1,732 soil samples were collected from 419 locations within the J-1 Range investigation area. In addition, numerous intrusive investigations of geophysical anomalies were conducted in the J-1 Range study area. Results of soil investigations in the Popper Kettle area, the Steel-lined Pit, the Wastewater Disposal Area, cook-off test location, Polygons 9,10 and 16 and disposal pits (Grids J39, J36 and K36) show soil contamination that are consistent with explosives found in downgradient groundwater. These areas are located in the Interberm Area and the extent of the northern groundwater plume is consistent with sources in these locations. Explosive and perchlorate soil contamination associated with these source areas has been removed as discussed in Section 4.0.

The primary sources of groundwater contamination in the southern area were testing and disposal areas including soils in the vicinity of Polygons 2, 3, and 4, disposal pits and the suspected water saw operation. Explosives contaminated soil associated with these sources has been removed as discussed in Section 4.

For the soil risk screen, J-1 Range soil data was divided into nine discrete subareas, based on the conceptual site model for the different portions of the range. The risk screen identified RDX and HMX detections exceeding the screening criteria. The locations of these exceedences were primarily in Firing Point Area (Rows 3 to 6), the IBA and 2,000 meter berm areas. These impacted soils were excavated during recent removal actions. Soils in the other subareas did not exceed the screening criteria, or were only detected at low frequencies. Based on the above findings, there is no further action warranted for soils at the J-1 Range.

Intrusive investigations identified multiple disposal pits in the southern portion of the range and in the IBA. However, the greatest number of finds consisted of munitions debris or other debris. The vast majority of MEC items encountered were small quantity energetic items. Other encountered MEC items were generally inert bodies with live fuzes or individual HE projectiles. Based on the geophysical investigations, remaining geophysical anomalies are likely munitions debris or other debris. However, there is the potential for residual MEC items, likely consisting of inert projectiles with live fuzes or isolated individual HE items.

Additional geophysical investigations of anomalies in Grid K4 and soil sampling at tank targets 22 and 35 will be performed in accordance with the "*Final J-1 Range Targets 22 and 35 Soil Sample Collection and Grid K4 Anomaly Investigation*" Project Note dated July 7, 2010 (ECC 2010).

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8.0 J-1 RANGE FEASIBILITY STUDY

The feasibility study portion of this report presents the evaluation of alternatives to remediate the RDX and perchlorate groundwater plumes at the J-1 Range areas. The sources of contamination have been removed during the investigation phase culminating in the removal and treatment of 2,754 cubic yards/tons of soil in May 2010.

The remedies evaluated in the J-1 Range groundwater feasibility study were monitored natural attenuation and focused extraction. These remedies include technologies implemented as part of the J-3 and J-2 rapid response actions (ECC 2005a, c), and evaluated in the feasibility study for the Demolition Area 1 (AMEC 2004). The technology selected for the active remediation alternative is groundwater extraction, treatment with granular activated carbon (GAC) (for RDX contaminated groundwater) and/or ion-exchange resin (IX) (for perchlorate contaminated groundwater) and return of treated water back into the aquifer. With a GAC adsorption process, groundwater contaminated with explosives is passed through a carbon medium and the explosives are adsorbed onto the surface of, or partition into, the carbon particles. GAC has also been shown to be an effective treatment for low levels of perchlorate (below 6 µg/L) (AMEC 2004). Once the capacity of the GAC has been exhausted, the GAC requires regeneration or disposal. IX is a physical-chemical process by which ions, such as perchlorate, are transferred from the liquid phase to the solid phase. Similar to GAC treatment, treatment with IX resin occurs via flow through a porous media. The IX resin removes perchlorate ions from the water and exchanges them for chloride ions bound to the resin. Perchlorate is an anion, which is attracted to the positively charged surface of the IX resins.

The return of treated water back to the aquifer can be accomplished by various methods (e.g., reinjection wells, infiltration trenches, surface water discharge). For the feasibility study, infiltration trenches were used to conceptually return water to the aquifer. The specific method will be determined during the wellfield design effort if the selected remedy involves treatment.

The following steps were taken to identify alternatives to address the contamination in the J-1 Range plumes: (1) response action objectives were developed, (2) alternatives were developed to address the objectives, and (3) alternatives were subjected to a detailed assessment based on nine criteria (protection of human health and the environment; compliance with regulations; long-term effectiveness and permanence; reduction of toxicity, mobility, or volume; short-term effectiveness; implementability; cost; state acceptance; and community acceptance).

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9.0 DEVELOPMENT OF ALTERNATIVES

9.1 Response Action Objectives

This section describes the response action objectives and potential response actions for J-1 Range groundwater. Based on preliminary information relating to types of contaminants, environmental media of concern, and potential exposure pathways, response action objectives were developed to aid in the development and screening of alternatives. The response action objectives for the selected response action for J-1 Range groundwater plumes are to restore the useable groundwater to its beneficial use, wherever practicable; with a timeframe that is reasonable given the particular circumstances of the site; to provide a level of protection in the aquifer that takes into account that the Cape Cod Aquifer (including the Sagamore Lens), is a sole source aquifer that is susceptible to contamination; and to prevent ingestion and inhalation of groundwater containing COCs (perchlorate and RDX for the northern J-1 plume and RDX for the southern J-1 plume) in excess of federal maximum contaminant levels, Health Advisories, drinking water equivalent levels (DWELs), applicable State standards or an unacceptable excess lifetime cancer risk or non-cancer Hazard Index.

RDX concentrations in groundwater between 6 and 0.6 µg/L, are currently equivalent to the 10^{-5} to 10^{-6} risk-based level. The EPA Lifetime Health Advisory for RDX is 2 µg/L. The MCP GW-1 Standard for RDX is 1 µg/L. The perchlorate MMCL is 2 µg/L and the EPA interim Lifetime Health Advisory for perchlorate is 15 µg/L.

9.2 Regulatory Considerations

Table 9-1 summarizes the federal and state regulatory considerations for the proposed J-1 Range groundwater remedial actions.

9.3 Remedial Alternatives

Remedial alternatives were developed that included:

- A no-action alternative to serve as a baseline for alternative comparisons.
- An alternative that, throughout the entire groundwater plume, reduces the contaminant concentrations to background conditions.
- An alternative that, throughout the entire groundwater plume, reduces the contaminant concentrations to levels that meet or exceed the MCLs, health advisories, DWELs, other relevant standards, results in a Hazard Index of 1 or less, and a cumulative 10^{-6} excess cancer risk and the non-cancer Hazard Risk of one as rapidly as possible and in less than 10 years and shall require no long-term maintenance.
- A limited number of remedial alternatives that attain site-specific remediation levels within different restoration time periods utilizing one or more different technologies if they offer the potential for comparable or superior performance or implementability; fewer or lesser adverse impacts than other available approaches; or lower costs for similar levels of performance than demonstrated treatment technologies.

A range of alternatives from no further action to focused extraction of the J-1 Range plumes are considered in this feasibility study. Contaminated soil has been removed and is being remediated concurrently with the development of groundwater remedies; therefore, the range of alternatives does not include any further source area remediation or control. The source area remediation can be considered a part of each alternative.

This section presents the remedial alternatives developed to address contamination at J-1 Range. The northern plume groundwater alternatives are:

- Alternative 1 – No Further Action;
- Alternative 2 – Monitored Natural Attenuation and Land-use Controls;
- Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-use Controls;
- Alternative 4 – Focused Extraction with Two Wells (in-plume), Monitored Natural Attenuation and Land-use Controls;
- Alternative 5 – Focused Extraction with Two Wells (In plume and leading edge), Monitored Natural Attenuation and Land-use Controls; and
- Alternative 6 – Focused Extraction with Five Wells, Monitored Natural Attenuation and Land-use Controls.

The J-1 Range southern groundwater alternatives are:

- Alternative 1 – No Further Action;
- Alternative 2 – Monitored Natural Attenuation and Land-use Controls;
- Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-use Controls;
- Alternative 4 – Focused Extraction with Two Wells, Monitored Natural Attenuation and Land-use Controls; and
- Alternative 5 – Focused Extraction with Three Wells, Monitored Natural Attenuation and Land-use Controls.

Alternative 1 for both the plumes only includes well abandonment and site closeout.

Monitoring and land-use controls are components of the J-1 Range northern plume Alternatives 2 through 6 and J-1 Range southern plume Alternatives 2 through 6 and J-1 Range southern plume Alternatives 2 through 5. Land-use controls consist of measures that would prevent human exposure to plume contaminants or interference with monitoring and/or treatment systems. Land-use controls can be considered in three categories: (i) those that relate to property that is under the control of the Army through the existing lease between the Commonwealth of Massachusetts and the US Army (i.e. on-post administrative controls), (ii) those that relate to property that is not under the control of the Army (i.e. off-post institutional controls), and (iii) those that relate to the Post after the lease with the Army has expired (i.e. post-lease institutional controls).

On-post land-use controls would be established by the Army, Massachusetts National Guard, and any other entity in control of the on-post areas. The program would include monitoring the effectiveness of the institutional controls.

For off-post land-use controls the Town of Sandwich has established regulations to protect human health. The Town of Sandwich Board of Health amended its private well regulations on 11 April 2005 to prohibit the construction of potable water supply wells for new buildings located in known and documented area of groundwater contamination if the Sandwich Water District Service is available. For existing buildings, the Board of Health will not approve any new well to be used for human consumption until its water has been tested and the Board of Health has determined that the water is potable. Additional water testing and special standards may be required by the Board of Health if the well is located in an area of potential contamination.

In addition to the Town of Sandwich Board of Health well regulations, the Army will also assess all private wells relative to potential exposure to the J-1 Range southern groundwater plume. If a potential exposure is identified the Army will take action to insure protectiveness. The actions may include well decommissioning, health warnings, supplemental water supply, or treatment. Monitoring of these restrictions and controls will be conducted annually.

If cleanup levels are not attained by the end of the lease with the selected alternative, the Army would develop land-use controls that would be implemented after the expiration of the Army's lease.

Monitoring would involve periodic analysis of groundwater for RDX and perchlorate (J-1 Range northern plume) or for RDX (J-1 Range southern plume) to measure the attenuation of the contaminated groundwater, and confirm that concentrations have decreased below risk-based concentrations. Prior to the termination of the proposed activities, a residual risk assessment will be conducted pursuant to a work plan approved by EPA, in consultation with MassDEP, to determine if RDX and perchlorate concentrations remaining in the aquifer pose unacceptable human health risks.

The extraction alternatives for the northern area (Figure 9-1) consist of: (1) extraction of groundwater through extraction well/s, (2) treatment of the groundwater through a modular treatment unit (MTU) [The MTU uses IX to remove perchlorate from the groundwater and GAC to remove explosives from groundwater], and (3) infiltration of treated water to the aquifer via infiltration trench(es).

The extraction alternatives for J-1 Range southern area (Figure 9-2) consist of: (1) extraction of groundwater through extraction well/s, (2) treatment of the groundwater through a MTU [The MTU uses GAC to remove explosives from groundwater], and (3) infiltration of treated water to the aquifer via infiltration trench(es).

Each of the alternatives reduces contaminant concentrations to background conditions. In addition, the J-1 Range northern area Alternative 6 and J-1 Range southern

Alternative 5 were designed to reduce the contaminant concentration to levels that meet or exceed regulatory and risk based standards in less than 10 years after the start of treatment.

10.0 DETAILED ANALYSIS OF ALTERNATIVES

10.1 Introduction

The following subsections describe the conceptual design the criteria for detailed analysis of each alternative. This section provides a description of the criteria for detailed analysis, groundwater modeling results, and the detailed analysis of the groundwater alternatives. Each alternative is evaluated against the same criteria established by the EPA and discussed below.

10.2 Criteria for Detailed Evaluation

Relative performance of each alternative is evaluated using the following nine criteria:

1. Overall protection of human health and the environment; this shall include prevention of the movement of contaminants into the aquifer and its preservation as a public drinking water supply.

2. Compliance with regulations, including:
   - Federal regulations; and
   - State regulations

3. Long-term effectiveness and permanence, considering:
   - The risks remaining after completion of the remedial action;
   - The adequacy and suitability of controls, if any, that are used to manage untreated contaminants remaining at the site.

4. Reduction of toxicity, mobility, and volume through treatment, including:
   - The expected reduction in toxicity, mobility or volume measured as a percentage or order of magnitude; and
   - The type and quantity of treatment residuals that will remain following treatment.

5. Short-term effectiveness, including:
   - Protection of the community during the remedial action;
   - Protection of workers during remedial action;
   - Environmental impacts to natural resources;
   - Time until remedial response objectives are achieved.

6. Implementability, considering:
   - Technical feasibility, including:
     - Construction and operation;
     - Reliability of technology;
     - Ease of undertaking additional remediation, if necessary;
     - Monitoring considerations, addressing the ability to adequately monitor the effectiveness of the remedy and the risks should monitoring be insufficient to detect a system failure.
   - Administrative feasibility;
   - Availability of services and materials, including:

- o Availability of adequate off site treatment, storage capacity, and disposal services;
- o Availability of necessary equipment and specialists, and any other necessary resources;
- o The potential for obtaining competitive bids (especially for innovative technologies); and
- o Availability of prospective technologies.

7. Cost, considering:
   - Source removal costs
   - Capital costs, both direct and indirect;
   - Annual O&M costs; and
   - Present worth analysis (or net present value) of costs.

The cost estimates for the alternatives include capital, annual and periodic costs associated with the anticipated scope of the alternative. These generally include construction costs, operations and maintenance (O&M) costs, system monitoring costs, and reporting costs. When possible, costs were based on actual costs for similar activities performed previously at the MMR. The general assumptions made for the present value calculation are that costs based on current (present day) information will escalate at a rate of five percent per year until year zero; after year zero, costs were discounted at a rate dependent on the length of the alternative (OMB 2008). A detailed presentation of the cost estimates and present value calculations are provided in Appendix M.

8. State Acceptance, considering the issues and concerns that the State may have regarding each alternative. This criterion will be evaluated throughout the development, screening and evaluation of alternatives based on comments and input received from MassDEP.

9. Community Acceptance which entails an evaluation of issues and concerns the public may have regarding each alternative. This criterion will be evaluated throughout the development, screening and evaluation of alternatives based on comments and input received from the MMRCT and the public.

10.3 Feasibility Study Groundwater Modeling

Groundwater modeling was used to predict the fate and transport of perchlorate and RDX in the J-1 Range northern plume and of RDX in the J-1 Range southern plume for each alternative. The assumptions and associated modeling output are conceptual in nature and are adequate for feasibility study-level evaluation.

Solute transport modeling was used to evaluate the feasibility study alternatives with respect to time required for RDX and/or perchlorate concentrations to decrease below specific concentrations, estimated remedial system operation time, and mass capture. The flow and transport simulations were performed with the same programs and transport parameters described in Section 3.3.

The hydraulic stresses simulated in the model were divided into numerous time periods to simulate ongoing remedial actions in nearby plumes and potential groundwater remedial actions at northern or sourthern J-1 Range. The impacts of operation of J-1 Range South treatment systems on the J-1 Range North plume, and vice versa, are anticipated to be minimal because the plumes are on opposite sides of the top of the mound. All model runs also incorporate other nearby operating remedial system components and water supply wells that are within the model domain. If active treatment is the selected remedy, a more thorough evaluation of the impacts of neighboring treatment systems will be conducted as part of wellfield design.

Both the J-1 Range northern and southern feasibility study modeling efforts were conducted assuming there were no continuing contaminant sources. The source areas are being addressed as separate actions (Section 4.0). Major insights into the J-1 North RDX plume are that the western plume contains consistent and decreasing concentrations, the trailing edge of the main plume has decreasing concentrations, the highest concentrations are in the mid-plume portion, and the plume is heterogeneous; there are areas of nondetects within detectable portions of the plume. Major insights into the J-1 North perchlorate plume are that there a low concentrations in the western plume, the trailing edge of the main plume has low concentrations, the highest concentrations are migrating downgradient from the center of the plume, and the plume is heterogeneous. The J-1 Range southern groundwater sampling data indicate decreasing RDX concentrations in upgradient monitoring wells. Major insights into the J-1 South RDX plume are that upgradient concentrations are decreasing, the highest concentrations are located within the core of the plume, and the portion of the plume downgradient of the base boundary continues to migrate downgradient. The data from both the northern and southern J-1 Range do not suggest a continuing source and the conceptual site models assume there is no remaining source material that would contribute significant mass to the groundwater. In the event that there are some remaining source contaminants that were not addressed by the various source removal activities, the modeling predictions presented herein may underestimate remedial time frames.

Animations that illustrate the future fate of the contaminant plumes were created and are presented in following sections. For feasibility study alternative presentation purposes, the animations show perchlorate above 2 µg/L and RDX above 0.6 µg/L. It is noted, however, that perchlorate concentrations below 2 µg/L and RDX concentrations below 0.6 µg/L contribute to mass capture and influent concentrations and are included in the transport model mass.

Infiltration trenches in the model are simulated as shallow wells with positive flow rates. The wells are located at the water table and therefore do not simulate infiltration of water through the vadose zone. Recharge into the model cells is not affected by their designation as wells. Infiltration trenches have been simulated in this same fashion for all IAGWSP and AFCEE modeling efforts.

For most of the modeling simulations, the remedial components of the alternative were assumed to operate unchanged for the duration of the simulation; however, in practice it is likely that the system operating parameters would be adjusted to optimize performance of the remediation system. Select modeling simulations conducted for J-1 Range northern plume alternatives did simulate extraction wells shutting off at specific times. The mass capture for each alternative was estimated by calculating the mass capture from each extraction well. The mass capture at extraction wells with specified operation times was only calculated for the specified operation time. Operation times for extraction wells simulated to operate for the duration of the simulation was estimated based on the influent concentrations; the estimated shutoff time was the year the influent concentrations decreased below 0.35 µg/L for perchlorate and 0.25 µg/L for RDX. If an active remedy was built, there may be differences between actual remedial system shutdown and the shutdown time estimated in the feasibility study.

The various plume volumes and mass capture for each alternative is shown in Figures 10-1 thru 10-3. Capture zones for the remedial action alternatives are presented in Appendix N.

10.4 Northern Area Feasibility Study

The following sections provide the J-1 Range northern groundwater modeling activities and results, a detailed description of each alternative, and a detailed analysis of the alternatives.

Note that the western lobe of the J-1 Range northern plume (Figure 2-10) will not be evaluated as part of the J-1 Range northern feasibility study; it will be addressed as part of the Central Impact Area plume.

The layout of designs for the active treatment components of Alternatives 3, 4, 5, and 6 are shown in Figure 9-1. The conceptual designs for the active treatment alternatives use extraction wells, modular treatment units (MTUs) with GAC and IX to treat the contaminated water and infiltration trenches to return the water to the aquifer. The conceptual designs for Alternatives 3, 4, and 6 consist of MTUs located on Chadwick Road and infiltration trenches located along Chadwick Road outside of the plume. For Alternative 5, the conceptual design consists of piping the contaminated water to MTUs located adjacent to the J-2 Range MTUs on Wood Road. The water would be returned to the aquifer through expansion of the J-2 infiltration trenches located on Wood Road (ECC 2007). The specific method and placement of returning treated water to the aquifer will be determined during the wellfield design effort if the selected remedy involves treatment.

10.4.1 Northern Area Feasibility Study Groundwater Modeling

Groundwater modeling was used to predict the fate and transport of perchlorate and RDX in the J-1 Range North plume for each alternative. The J-1 Range northern Model (Appendix J) and the J-1 Range northern 2008 perchlorate and RDX plume shells (Appendix K) were used. The J-1 Range northern total perchlorate mass accounting for all concentrations simulated within the model is 9.8 Kgs. The J-1 Range northern total

RDX mass (dissolved and adsorbed) accounting for all concentrations simulated within the model is 3.8 Kgs.

Even though the conceptual designs for returning treated water to the aquifer consist of infiltration trenches at J-2 Range and at the northern J-1 Range, for the J-1 Range northern modeling simulations, all of the water extracted from the J-1 Range northern plume was returned to the aquifer through expanded J-2 infiltration trenches located along Wood Road. This was conducted for ease of simulation and is expected to have no effect on the comparison of alternatives. The specific method and placement of returning treated water to the aquifer will be determined during the wellfield design effort if the selected remedy involves treatment.

All model runs also incorporate other nearby operating remedial system components (i.e. J-2 Range, J-3 Range, J-1 Range, FS-12) and water supply wells that are within the model domain. The Upper Cape Water Supply wells WS-2 and WS-3 are within the model domain and are simulated in the model at average operating conditions (i.e. 297 and 148 gpm, respectively) (Jacobs 2005).

The fate and transport of perchlorate and RDX under stressed conditions (active remediation) were simulated for Alternatives 3, 4, and 5. Alternatives 1 and 2 have the same pumping stress (i.e. only the influence of adjacent public water supply wells and remedial systems) and, thus, only Alternative 1 was simulated. Alternative 6 was not simulated in the groundwater fate and transport model. Estimates of the performance of Alternative 6 were made based on results of other similar wellfield scenarios that were modeled.

Each model simulation was initialized in June 2008 and ended in 2109. The start-up of the potential J-1 Range northern remedial system is simulated to begin in 2010. The extraction well locations, screen lengths, and flow rates used in each alternative are summarized in Table 10 -1.

Animations 10-1 through 10-8 illustrate the future fate of the perchlorate and RDX plumes under Alternatives 1 through 5 (as noted above, there are no animations for Alternative 6). The model-predicted mass capture was based on mass captured through the extraction wells during the estimated operation time. Even though the western RDX plume will be addressed in conjunction with the Central Impact Area plume, it is included in simulations of the J-1 Range northern RDX plume. Inclusion of the western plume does not affect comparison of the alternatives because it does not affect (1) the time RDX concentrations decrease below risk based concentration for the main RDX plume, or (2) the mass capture of each alternative. The modeling results are presented in the detailed analysis of each alternative.

The expanded mass sensitivity plume shell, with 24 percent more perchlorate, was simulated in the fate and transport model with Alternatives 1, 2, 3, 4, and 5 (Animations 10-9 through 10-12). The additional perchlorate mass did not have a significant effect on the overall (perchlorate and RDX) cleanup time, because the time for RDX concentrations to decrease to below 0.6 μg/L is greater and, therefore, there would be no significant impact on the estimated cost for Alternative 2. Due to the placement of the area of increased perchlorate mass downgradient of the conceptual extraction well for Alternative 3, the time to reach perchlorate cleanup levels was increased by approximately 17 years, and the overall (perchlorate and RDX) plume cleanup time was increased by approximately 11 years. There was no difference in the extraction well operation time. There would be only a small impact to the estimated cost for Alternative 3 because there would be no change in the extraction well operation time and the cost for the additional 11 years of monitoring at the end of an alternative is minimal. For Alternative 4, there was no difference in the estimated extraction well operation time. There was an increase in the perchlorate cleanup and the overall plume cleanup of approximately nine years. The cleanup time difference for Alternative 4 would not have a significant impact on the estimated cost for Alternative 4. For Alternative 5, there was no difference in the estimated extraction well operation time, the perchlorate cleanup time, or the overall plume cleanup time, and thus no impact on the estimated cost of the alternative. Alternative 6 was not simulated with the groundwater fate and transport model but an increase in perchlorate mass is unlikely to have an impact on the extraction well operation time, the perchlorate cleanup time, the overall plume cleanup time, or the estimated cost.

10.4.2 Detailed Analysis of Northern Area Alternatives

This section provides the detailed description and analysis of the remedial alternatives. Each alternative description includes assumptions made for planning and cost-estimating purposes.

10.4.2.1 Alternative 1 – No Further Action

Under the no further action alternative, treatment and/or monitoring would not be conducted and the monitoring wells, associated with the northern J-1 Range long-term chemical monitoring, would be abandoned. This alternative serves as a baseline for alternative comparisons.

<u>Overall Protection of Human Health and the Environment</u>

Alternative 1 would not prevent the migration of the plume or protect human health or the environment from the existing contamination. Although there is currently no exposure to the J-1 Range northern plume, Alternative 1 offers no monitoring or confirmation of existing land-use controls to ensure that future exposures do not occur. Perchlorate concentrations are predicted to decrease, through natural attenuation processes, below 2 µg/L by approximately 2080 and background concentrations (0.35 µg/L) could be achieved after year 2109. RDX concentrations are predicted to decrease, through natural attenuation processes, below the HA of 2 µg/L by approximately 2053, below the 10^{-6} risk-based level of 0.6 µg/L after year 2109, and background concentrations (0.25 µg/L) could be achieved after year 2109 (Table 10-2). However, without monitoring or land use controls, Alternative 1 would not ensure protectiveness or verify that cleanup levels were met.

Compliance with Applicable Regulations

Alternative 1 allows for continued migration of the plume. Because no action is taken, chemical-specific regulations would be met only if, and when, contaminant concentrations decreased below the cleanup standards by natural attenuation. Based on model predictions, Alternative 1 would be compliant with chemical-specific regulations across the entire plume by approximately 2080. Because this alternative takes no action, there are no location-specific or action-specific regulations to be met.

Long-Term Effectiveness and Permanence

In this Alternative, perchlorate and RDX concentrations in the plume will permanently decrease to below 2 µg/L and 0.6 µg/L through natural attenuation by 2080 and after year 2109, respectively. Because no further contribution from the source area is likely, this Alternative is expected to be permanent. However, as noted above, any natural attenuation that occurred under Alternative 1 would not be monitored or verified, and thus the degree of certainty that the natural attenuation would attain cleanup goals would be low. Since Alternative 1 does not include land use controls to prevent exposure, there is a potential threat to human health and the environment if the natural attenuation does not occur as predicted.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed from the site, there may be a potential for further groundwater contamination. This alternative does not include long-term groundwater monitoring to verify that any possible remaining sources will not pose a threat to groundwater. Therefore, this alternative is not expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment would occur; therefore, no reduction in toxicity, mobility, or volume would occur through treatment. However, the toxicity and volume of the contaminated groundwater would be reduced through natural processes.

Short-Term Effectiveness

There would be little to no effect on the community or natural resources from implementing Alternative 1 because no construction work would be involved other than well abandonment. There are risks to workers from unexploded ordnance within the Impact Area. A site-specific Health and Safety Plan (HASP) would be followed during well abandonment.

Implementability

Alternative 1 would require no technical implementation other than well abandonment which has been done successfully many times at MMR. Administratively, this alternative is feasible.

Cost

The costs are estimated for Alternative 1 as follows:

- Capital cost: $ 74,827
- O&M: $ 0
- Site closeout documentation: $ 69,300
- Total present worth: $ 144,127

Appendix M provides detailed calculations of the cost of Alternative 1.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.4.2.2 Alternative 2 – Monitored Natural Attenuation and Land-Use Controls

No extraction and treatment would occur with this alternative. This alternative would provide for long-term monitoring of the J-1 Range northern groundwater to ensure that natural attenuation was progressing toward cleanup levels and for land-use controls to prevent human exposure to contaminated groundwater.

On-base land-use controls would prevent exposure to contaminated groundwater or soil disturbance activities that might interfere with the remedy. The land-use controls would remain in place, and be monitored for compliance, until the concentrations of COCs in the groundwater attain cleanup levels.

Monitored natural attenuation would involve periodic analysis of groundwater for perchlorate and explosives to measure the natural attenuation of the contaminated groundwater, determining when concentrations have decreased below risk-based concentrations. Groundwater monitoring would continue after cleanup objectives are met for two additional years to ensure that plume concentrations remain below those levels. Additional monitoring wells would be necessary to monitor adequately the plume as it migrates downgradient of the current plume footprint into areas with less well coverage. The monitoring wells would be abandoned at the end of the project. A residual risk assessment would be performed, if necessary, and may include additional data collection and analysis.

Overall Protection of Human Health and the Environment

Alternative 2 would not prevent the migration of the plume. Monitoring and land-use controls would be implemented to prevent exposure to contamination. Perchlorate concentrations are predicted to decrease, through natural attenuation processes, below 15 μg/L by 2024, 2 μg/L by approximately 2080 and background concentrations (0.35 μg/L) after year 2109. RDX concentrations are predicted to decrease, through natural attenuation processes, below the 10^{-5} risk-based level of 6 μg/L by approximately 2027, the HA of 2 μg/L by approximately 2053, the 10^{-6} risk-based level of 0.6 μg/L after year 2109, and background concentrations (0.25 μg/L) after year 2109 (Table 10-2).

Compliance with Regulations

Alternative 2 would comply with applicable regulations. Because the plume is expected to naturally attenuate to below cleanup levels, Alternative 2 would eventually be expected to meet the response action objectives, including regulatory standards for COCs.

Long-Term Effectiveness and Permanence

In this Alternative, perchlorate and RDX concentrations would decrease to risk based concentrations through natural processes (dilution, dispersion, and sorption). Because no further contribution from the source area is likely, this alternative is expected to be permanent. Monitoring of the plume would continue for several years after the plume attenuates to ensure that all areas remain below remedial goals. In the meantime, the land-use controls would ensure that no use of the contaminated water occurs.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment would occur, therefore, no reduction in toxicity, mobility, or volume would occur through treatment. However, the toxicity and volume of the contaminated groundwater would be reduced through natural processes.

Short-Term Effectiveness

There would be little effect on the community because all short-term activity is on-post. There would be less effect on the workers because activities would be limited to monitoring well construction, sampling, and well abandonment. There are significant risks to workers from unexploded ordnance within the Impact Area. A HASP would be followed during construction and long-term groundwater monitoring. To date, health and safety precautions for unexploded ordnance clearance, groundwater sampling, and drilling have been adequate to protect workers.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells to minimize impact on cultural and natural resources. However, some disturbance of natural resources may be necessary to complete this alternative.

Implementability

Groundwater monitoring associated with the J-1 Range northern plume would continue, subject to periodic optimization, using the same sampling and analytical protocols currently in use. Administratively, this alternative is feasible. There are no implementability concerns anticipated with obtaining access for additional monitoring well installation because the locations would be on-post. There is a potential administrative implementability concern for monitoring well sampling and installation after the military's lease expires, because it is unknown what the administrative requirements will be necessary to perform those tasks.

Cost

The present worth costs were estimated for Alternative 2 as follows:

- Capital cost: $ 1,535,013
- O & M: $ 1,903,379
- Site Closeout Documentation: $ 2,759
- Total present worth: $ 3,441,151

Appendix M provides detailed calculations of the costs of Alternative 2.

State Acceptance

This criterion will be evaluated throughout the development, screening and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.4.2.3 Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-use Controls

Alternative 3 would provide for pumping and treatment of the plume, monitoring, and maintaining land-use controls. The design of the alternative consists of one new extraction well (125 gpm) located within the plume, treatment at a new MTU located on Chadwick Road, and infiltration of the treated water at a new infiltration trench located on Chadwick Road (Figure 10-1) (Table 10-1). Active treatment of the plume would remove perchlorate and RDX from the extracted groundwater and return the treated water to the aquifer. This alternative includes the option of modifying the system to optimize the system performance.

This alternative would include for chemical and hydraulic monitoring of the plume and treatment system as long as active remediation continues, and chemical monitoring of the aquifer after the system is turned off, to ensure that perchlorate and RDX concentrations have decreased below risk-based concentrations. Land-use controls would minimize potential future exposure. Groundwater monitoring would continue for two years after risk based concentrations were achieved to ensure that concentrations remain below those concentrations. The monitoring wells would be abandoned at the end of the project. A residual risk assessment would be performed, if necessary, and may include additional data collection and analysis.

This alternative was evaluated using two different operational scenarios for the extraction well: Alternative 3a) the extraction well operates until the influent concentrations decrease below the method detection limit and Alternative 3b) the extraction well operates until 2030. The variation of operational scenarios was conducted to assess the effect of the length of operating time on the time to reach cleanup goals and the costs associated with the variations. Specifically Alternative 3b was conducted to evaluate the shortest time the extraction well could operate in order to reach cleanup levels before the current Army lease on the property expires in 2051.

<u>Overall Protection of Human Health and the Environment</u>

The groundwater model indicates for Alternatives 3a, perchlorate concentrations would decrease below 15 µg/L by 2018, 2 µg/L by approximately 2042 and background concentrations (0.35 µg/L) later than year 2109. RDX concentrations would decrease below the 10^{-5} risk-based level of 6 µg/L by approximately 2025, the HA of 2 µg/L by approximately 2038, the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2048, and background concentrations (0.25 µg/L) by 2057 (Table 10-2). It was estimated, from groundwater modeling results, that if the extraction well was turned off five years before influent concentrations decreased below the method detection limit (Alternative 3b) then perchlorate concentrations would decrease below 2 µg/L by approximately 2043 (1 year later than Alternative 3a) (Table 10-2). RDX concentrations would decrease below the HA of 2 µg/L by approximately 2040 and below the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2051 (3 years later than Alternative 3a) (Table 10-2).

Compliance with Regulations

Alternative 3 would comply with applicable regulations.

Long-Term Effectiveness and Permanence

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the perchlorate and RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which would also be irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of perchlorate and RDX. The total perchlorate mass simulated within the model is 9.8 Kg and the total RDX mass simulated in the model is 3.8 Kg. Model-predicted mass capture for Alternative 3a from 2010 to 2035 (estimated operational time) is approximately 6.0 Kg of perchlorate and 2.1 Kg of RDX. If the extraction well was turned off in 2030 (Alternative 3b) the same amount of perchlorate would be captured and approximately 1.8 Kg of RDX would be captured.

Short-Term Effectiveness

There would be little effect other than transportation of construction materials and equipment on the community because most activity is on-post. There would be an effect on the workers from implementing Alternative 3 because of the construction work (i.e. ETI system construction, monitoring well construction, and decommissioning) and operation and maintenance activities. There are additional risks to workers from unexploded ordnance within the Impact Area particularly from installing underground pipelines and electrical lines.

A site-specific Health and Safety Plan would be followed during system construction where engineering controls and Personal Protective Equipment would be used as necessary to limit potential exposure to COCs. To date, health and safety precautions for unexploded ordnance clearance, groundwater sampling, and drilling have been adequate to protect workers although no treatment systems have been built in the Impact Area.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells, the infiltration trench, subsurface piping, power lines, and the MTU to minimize impact on cultural and natural resources. However, some temporary disturbance to the vegetation would be necessary during installation of the treatment system

Implementability

Administratively, this alternative would be feasible. IX has been shown to be effective in treating perchlorate. GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable. Maintenance of facilities downrange of a small arms firing range would require detailed coordination to ensure safe operation.

The Massachusetts Army National Guard's Revised Limited Authorization for Lead Ammunition Training (AO2, Appendix C) at Tango, Juliet, and Kilo Ranges, is conditioned on such coordination and specifically provides that investigation and cleanup take priority in the event of a conflict.

Cost

The present worth costs were estimated for Alternative 3a as follows:

- Capital cost: $ 2,988,445
- O & M: $ 9,427,002
- Site Closeout Documentation: $ 23,873
- Total present worth: $ 12,439,320

The present worth costs were estimated for Alternative 3b as follows:

- Capital cost: $ 2,985,450
- O & M: $ 8,756,170
- Site Closeout Documentation: $ 22,040
- Total present worth: $ 11,763,660

Appendix M provides detailed calculations of the cost of Alternative 3.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.4.2.4 Alternative 4 – Focused Extraction with Two Wells (In-Plume), Monitored Natural Attenuation and Land-Use Controls

Alternative 4 would provide for pumping and treatment of the plume, monitoring, and maintaining land-use controls. The concept for Alternative 4 is in-plume extraction, treatment at two new MTUs located along Chadwick Road, and infiltration of the treated water at two new infiltration trenches located along Chadwick Road. The simulated extraction wells include two new extraction wells, each pumping 125 gpm (Figure 10-1) (Table 10-1). Active treatment of the plume would remove perchlorate and RDX from the extracted groundwater and return the treated water to the aquifer. This alternative includes the option of modifying the system to optimize the ETI system performance.

This alternative would include for chemical and hydraulic monitoring of the plume and treatment system as long as active remediation continues and chemical monitoring of the aquifer after the system is turned off, to ensure that perchlorate and RDX concentrations have decreased below risk based concentrations. Land-use controls would minimize potential future exposure. Groundwater monitoring would continue for two years after risk based concentrations are achieved to ensure that plume concentrations remain below those levels. The monitoring wells and other subsurface infrastructure would be abandoned at the end of the project. A residual risk assessment would be performed if necessary, and may include additional data collection and analysis.

This alternative was evaluated using two different operational scenarios for the extraction wells: Alternative 4a) the extraction wells operate until the influent concentrations decrease below the method detection limit that is predicted to occur in 2024 and Alternative 4b) the upgradient extraction well (J1N5AEW1) was turned off in 2015 and the downgradient extraction well (J1NA5EW2) turned off in 2023. The variation of operational scenarios was conducted to assess the effect of the length of operating time on the time to reach cleanup goals and the costs associated with the variations. Specifically, Alternative 4b was conducted to evaluate the shortest time the extraction wells could operate in order to reach cleanup levels before the current Army lease on the property expires in 2051.

<u>Overall Protection of Human Health and the Environment</u>

The groundwater model indicates for Alternative 4a, perchlorate concentrations would decrease below 15 µg/L by approximately 2023, below 2 µg/L by approximately 2037 and background concentrations (0.35 µg/L) beyond year 2109. RDX concentrations would decrease below the 10^{-5} risk based level of 6 µg/L by approximately 2019, the HA of 2 µg/L by approximately 2027, the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2035, and background concentrations (0.25 µg/L) by 2048 (Table 10-2). It was estimated, from groundwater modeling results that with the shortened operation scenario described above (Alternative 4b), perchlorate concentrations would decrease below 2 µg/L by approximately 2045 (8 years later than Alternative 4a). RDX concentrations would decrease below the HA of 2 µg/L by approximately 2031 and below the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2050 (15 years later than Alternative 4a) (Table 10-2).

Compliance with Regulations

Alternative 4 would comply with applicable regulations.

Long-Term Effectiveness and Permanence

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the perchlorate and RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which are also irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of perchlorate and RDX. The total perchlorate mass simulated within the model is 9.8 Kg and the total RDX mass simulated in the model is 3.8 Kg. Model-predicted mass capture for Alternative 4a from 2010 to 2024 (estimated operational time) is approximately 7.1 Kg of perchlorate and 2.5 Kg of RDX. If the shortened, operational scenario was employed (Alternative 4b), then approximately 5.6 Kg of perchlorate and 2.2 Kg of RDX would be captured.

Short-Term Effectiveness

There would be little effect other than the transportation of construction materials and equipment on the community because most activity is on-post. There would be an effect on the workers from implementing Alternative 4 because of the construction work (i.e. ETI system construction, monitoring well construction, and decommissioning) and operation and maintenance activities. There are additional risks to workers from unexploded ordnance within the Impact Area particularly while installing underground pipeline and electrical lines.

A site-specific Health and Safety Plan would be followed during system construction where engineering controls and Personal Protective Equipment would be used as necessary. To date, health and safety precautions for unexploded ordnance clearance, groundwater sampling, and drilling have been adequate to protect workers, although no treatment systems have been built in the Impact Area.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells, infiltration trenches, subsurface piping, power lines, and the MTUs to minimize impact on cultural and natural resources. However, some temporary disturbance to the vegetation would be necessary during installation of the treatment system.

Implementability

Administratively, this alternative would be feasible. IX has been shown to be effective in treating perchlorate. GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable. Maintenance of facilities downrange of a small arms firing range would require detailed coordination to ensure safe operation.

The Massachusetts Army National Guard's Revised Limited Authorization for Lead Ammunition Training (AO2, Appendix C) at Tango, Juliet, and Kilo Ranges, is conditioned on such coordination and specifically provides that investigation and cleanup take priority in the event of a conflict.

Cost

The present worth costs were estimated for Alternative 4a as follows:

- Capital cost: $ 4,180,453
- O & M: $ 8,836,229
- Site Closeout Documentation: $ 32,003
- Total present worth: $ 13,057,684

The present worth costs were estimated for Alternative 4b as follows:

- Capital cost: $ 4,165,419
- O & M: $ 7,435,822
- Site Closeout Documentation: $ 22,635
- Total present worth: $ 11,623,876

Appendix M provides detailed calculations of the cost of Alternative 4.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.4.2.5 Alternative 5 – Focused Extraction with Two Wells (In-Plume & Leading Edge), Monitored Natural Attenuation and Land-Use Controls

Alternative 5 would provide for pumping and treatment of the plume, monitoring, and maintaining land-use controls. The concept for Alternative 5 is leading edge and in-plume extraction, treatment at new MTUs located near the existing J-2 North treatment facilities on Wood Road, and infiltration of the treated water at expanded J-2 North infiltration trenches. The simulated extraction wells include one new extraction well (125 gpm) located within the highest concentrations in plume and one new extraction well (125 gpm) located downgradient at the leading edge of the plume (Figure 10-1) (Table 10-1). The leading edge well (J1NA3EW1) would likely be installed and begin operation when the plume migrated to that position; approximately 2014, based on the modeling animations. Active treatment of the plume would remove perchlorate and RDX from the extracted groundwater and return the treated water to the aquifer. This alternative includes the option of modifying the system to optimize the ETI system performance.

This alternative would include chemical and hydraulic monitoring of the plume and treatment system as long as active remediation continues and chemical monitoring of the aquifer after the system is turned off to ensure that perchlorate and RDX concentrations have decreased below risk-based concentrations. Land-use controls would minimize potential future exposure. Groundwater monitoring would continue for two years after risk-based concentrations are achieved to ensure that plume concentrations remain below those levels. The monitoring wells and other subsequent infrastructure would be abandoned at the end of the project. A residual risk assessment would be performed if necessary, and may include additional data collection and analysis.

<u>Overall Protection of Human Health and the Environment</u>

The groundwater model indicates for Alternative 5, perchlorate concentrations would decrease below 15 µg/L by approximately 2017, below 2 µg/L by approximately 2035 and background concentrations (0.35 µg/L) by approximately 2048. RDX concentrations would decrease below the 10^{-5} risk based level of 6 µg/L by approximately 2024, the HA of 2 µg/L by approximately 2037, the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2047, and background concentrations (0.25 µg/L) by 2059 (Table 10-2).

<u>Compliance with Regulations</u>

Alternative 5 would comply with applicable regulations.

<u>Long-Term Effectiveness and Permanence</u>

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the perchlorate and RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which are also irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of perchlorate and RDX. The total perchlorate mass simulated within the model is 9.8 Kg and the total RDX mass simulated in the model is 3.8 Kg. Model-predicted mass capture for Alternative 5 from 2010 to 2034 (estimated operational time) is approximately 8.9 Kg of perchlorate and 2.3 Kg of RDX.

Short-Term Effectiveness

There would be little effect on the community other than transportation of construction materials and equipment because most activity is on-post. There would be an effect on the workers from implementing Alternative 5 because of the construction work (i.e. ETI system construction, monitoring well construction, and decommissioning) and operations and maintenance activities. There are additional risks to workers from unexploded ordnance within the Impact Area particularly while installing underground pipelines and electrical lines.

A site-specific Health and Safety Plan would be followed during system construction where engineering controls and Personal Protective Equipment would be used as necessary. To date, health and safety precautions for unexploded ordnance clearance, groundwater sampling, and drilling have been adequate to protect workers. Although no treatment systems have been built in the Impact Area.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells, infiltration trenches, subsurface piping, power lines, and the MTUs to minimize impact on cultural and natural resources. However, some temporary disturbance the vegetation would be necessary during installation of the treatment system.

Implementability

Administratively, this alternative would be feasible. IX has been shown to be effective in treating perchlorate. GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable. Maintenance of facilities downrange of a small arms firing range would require detailed coordination to ensure safe operation.

The Massachusetts Army National Guard's Revised Limited Authorization for Lead Ammunition Training (AO2, Appendix C) at Tango, Juliet, and Kilo Ranges, is conditioned on such coordination and specifically provides that investigation and cleanup take priority in the event of a conflict.

Cost

The present worth costs were estimated for Alternative 5 as follows:

- Capital cost: $ 4,029,838
- O & M: $ 10,618,541
- Site Closeout Documentation: $ 24,518
- Total present worth: $ 14,358,898

Appendix M provides detailed calculations of the cost of Alternative 5.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.4.2.6 Alternative 6 –Focused Extraction with Five Wells, Monitored Natural Attenuation and Land-Use Controls

Alternative 6 would provide for pumping and treatment of the J-1 Range North plume, monitoring, and maintaining land-use controls. The concept for Alternative 6 is in-plume extraction in order to reduce perchlorate concentrations below 2 µg/L and RDX concentrations below 0.6 µg/L within ten years, treatment at five MTUs located along Chadwick Road and infiltration trenches located along Chadwick Road. The conceptualized extraction wells include five new extraction wells, each pumping 125 gpm (Figure 10-1) (Table 10-1). Active treatment of the plume would remove perchlorate and RDX from the extracted groundwater and return the treated water to the aquifer. This alternative includes the option of modifying the system to optimize the ETI system performance.

This alternative would include for chemical and hydraulic monitoring of the plume and treatment system as long as active remediation continues (under the system performance monitoring plan), and chemical monitoring of the aquifer after the system is turned off to ensure that perchlorate concentrations have decreased below risk based concentrations. Land-use controls would minimize potential future exposure. Groundwater monitoring would continue for two years after risk-based concentrations are achieved to ensure that plume concentrations remain below those levels. The monitoring wells and other subsequent infrastructure would be abandoned at the end of the project. A residual risk assessment would be performed if necessary, and may include additional data collection and analysis.

Overall Protection of Human Health and the Environment

Perchlorate concentrations are estimated to decrease below 15 by approximately 2017, 2 µg/L by approximately 2020 and background concentration (0.35 µg/L) by approximately 2035. RDX concentrations are estimated to decrease below the 10^{-5} risk based level of 6 µg/L by approximately 2014, the HA of 2 µg/L by approximately 2018, the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2020, and background concentrations (0.25 µg/L) by 2026 (Table 10-2).

Compliance with Regulations

Alternative 6 would comply with applicable regulations.

Long-Term Effectiveness and Permanence

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the perchlorate and RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which are also irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of perchlorate and RDX. Alternative 6 was not simulated in the groundwater model and therefore the mass capture can only be estimated. Alternative 6 will likely provide greater initial mass capture than Alternative 3, 4, and 5 because of the greater initial hydraulic stress and extraction wells within the plume but the short operational time for Alternative 6 limits the amount of mass extracted from the plume.

Short-Term Effectiveness

There would be little effect on the community other than transportation of construction materials because all activity is on-post. There would be some effect on the workers from implementing Alternative 6 because of the construction work (i.e. ETI system construction, monitoring well construction, and decommissioning) and operation and maintenance activities. There are additional risks to workers from unexploded ordnance within the Impact Area particularly while installing underground pipelines and electrical lines.

A site-specific Health and Safety Plan would be followed during system construction where engineering controls and Personal Protective Equipment would be used as necessary. To date, health and safety precautions for unexploded ordnance clearance, groundwater sampling, and drilling have been adequate to protect workers. Although no treatment systems have been built in the Impact Area.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells, infiltration trenches, subsurface piping, power lines, and the MTUs to minimize impact on cultural and natural resources. However, more disturbance to the vegetation would be necessary during installation of the treatment system.

Implementability

Administratively, this alternative would be feasible. However, given the number of wells and pumping rates, there would be more technical implementability challenges to obtain the performance estimates for Alternative 6. IX has been shown to be effective in treating perchlorate. GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable. Maintenance of facilities downrange of a small arms firing range would require detailed coordination to ensure safe operation.

The Massachusetts Army National Guard's Revised Limited Authorization for Lead Ammunition Training (AO2, Appendix C) at Tango, Juliet, and Kilo Ranges, is conditioned on such coordination and specifically provides that investigation and cleanup take priority in the event of a conflict.

Cost

The present worth costs were estimated for Alternative 6 as follows:

- Capital cost: $ 7,031,958
- O & M: $ 12,669,328
- Site Closeout Documentation: $ 51,528
- Total present worth: $ 19,752,815

Appendix M provides detailed calculations of the cost of Alternative 6.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.5 Southern Area Feasibility Study

The following sections provide the J-1 Range southern groundwater modeling activities and results, a description of each alternative, and a detailed analysis of the alternatives.

The conceptual design for the pump and treat components of Alternatives 3, 4, and 5 is shown in Figure 9-2. All of the water extracted from the plume was anticipated to be treated at the location of the existing J-1 Range MTU. The treated water would then be returned to the aquifer either through the existing infiltration trench (Alternatives 3 and 4) or divided between an expansion to the existing infiltration trench and a new, conceptual infiltration trench located along the MMR boundary north of the existing MTU (Alternative 5). The specific method and placement of returning the treated water to the aquifer will be determined during the wellfield design effort if the selected remedy is Alternative 4 or 5.

10.5.1 Southern Area Feasibility Study Groundwater Modeling

Groundwater modeling was used to predict the fate and transport of RDX in the plume for each alternative. The 2009 J-1 Range southern groundwater model (Appendix J) and the J-1 Range southern 2010 RDX plume shell (Appendix L) was used. The J-1 Range south total RDX mass (dissolved and adsorbed) accounting for all concentrations simulated within the model is 0.76 Kg.

Each J-1 Range southern model simulation as initialized in 2010.75 (date of the plume shell) and ended in 2110. The estimated time of the site decision is 2010.5 and the estimated start-up of any additional remedial components is approximately one year later (2011.5). For all of the alternatives, the existing ETI system will be simulated at current operating conditions from 2010 to 2010.5 to continue current operation conditions until a final site decision is made. For Alternatives 1 and 2, no active treatment was simulated after 2010.5. Alternatives 1 and 2 have the same pumping stress (i.e. only the influence of adjacent public water supply wells and neighboring remedial systems) and, thus, only Alternative 1 was simulated. The extraction well locations, screen lengths, flow rates, and timing of the changing hydraulic stresses used in each alternative are summarized in Table 10-3. All model runs incorporate other nearby operating remedial system components (i.e. J-3, J-2, FS-12, J. Braden Thompson system) and water supply wells that are within the model domain. The Sandwich water supply wells GP Well No. 4, GP Well No. 6, and GP Well No. 10, the MMR water supply Well J, and the Upper Cape Water Supply Cooperative Well No. 1 are within the J-1 Range model domain and are simulated in the model at average operating conditions (i.e. 89.6 gpm, 136.6 gpm, 230.2 gpm, 90 gpm, and 147.6 gpm, respectively) (Jacobs 2005).

J-1 Range southern feasibility study animations illustrate the future fate of the RDX plume for each alternative (Animations 10-13 through 10-16). The estimated restoration time for each alternative was determined from model-predictions for restoration of the higher conductivity deposits (refer to Section 3.3).

The mass captured by operation of the existing system (0.84 Kg) from October 2007 through December 2009 and the model-predicted mass capture from January 2010 to June 2010 (0.006 Kg) will not be considered in evaluation of the alternatives because they occur prior to the final decision. The mass capture estimates considered for evaluation of the alternatives as based on mass captured through the extraction well during the estimated operation time. The estimated operation time is from 2010.5 (final site decision) to the estimated extraction well shutoff year. For the existing extraction well in the J-1 Range southern plume the estimated shutoff time is when the RDX concentrations immediately upgradient of the extraction well decrease below 2 µg/L. For the new extraction wells the estimated shutoff time is when extraction well influent RDX concentrations are predicted to fall below the method detection limit (0.25 µg/L).

10.5.2 Detailed Analysis of Southern Area Alternatives

This section provides the detailed description and analysis of the remedial alternatives. Each alternative description includes assumptions made for planning and cost-estimating purposes.

10.5.2.1 Alternative 1 – No Further Action

Under the no further action alternative, treatment and/or monitoring would not be conducted and the monitoring wells, associated with J-1 Range South plume would be abandoned

Overall Protection of Human Health and the Environment

Alternative 1 would not prevent the migration of the plume, and although residences in the area are believed to be on town water, Alternative 1 offers no monitoring or confirmation of existing land-use controls to ensure that future exposures do not occur. RDX concentrations are expected to drop below the HA of 2 µg/L by 2032 and the 10^{-6} risk-based level of 0.6 µg/L by 2050 due to natural processes (dilution, dispersion, and sorption). Background concentrations (0.25 µg/L) could be achieved by 2074. However, without monitoring or land-use controls, Alternative 1 would not ensure protectiveness or verify that cleanup levels were met.

Compliance with Regulations

Alternative 1 allows for continued migration of the plume. Because no action is taken, chemical-specific regulations would be met only if and when contaminant concentrations decreased below the cleanup standards by natural attenuation. Based on model predictions, Alternative 1 would be compliant with chemical-specific regulations across the entire plume by approximately 2050. Because this alternative takes no action, there are no location-specific or action-specific regulations to be met.

Long-Term Effectiveness and Permanence

In this Alternative, concentrations of RDX in the plume are expected to permanently decrease to below 2 µg/L and 0.6 µg/L through natural attenuation by 2032 and 2050 respectively. Because no further contribution from the source area is likely, this Alternative is expected to be permanent. However, as noted above, any natural attenuation that occurred under Alternative 1 would not be monitored or verified, and thus the degree of certainty that the natural attenuation would attain cleanup goals would be low. Since Alternative 1 does not include land use controls to prevent exposure, there is a potential threat to human health and the environment if the natural attenuation does not occur as predicted.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed from the site, there may be a potential for further groundwater contamination. This alternative does not include long-term groundwater monitoring to verify that any possible remaining sources will not pose a threat to groundwater. Therefore, this alternative is not expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment would occur; therefore, no reduction in toxicity, mobility, or volume would occur through treatment. However, the toxicity and volume of the contaminated groundwater would be reduced through natural processes.

Short-Term Effectiveness

There would be little to no effect on the community, workers or natural resources from implementing Alternative 1 because no construction work would be involved other than abandonment of wells and other infrastructure. A site-specific HASP would be followed during well abandonment.

Implementability

Alternative 1 would require no technical implementation other than discontinuation of treatment and infrastructure abandonment which has been done successfully many times at MMR. Administratively, this alternative is feasible.

Cost

The costs are estimated for Alternative 1 as follows:

- Capital cost: $ 38,444
- O&M: $ 0
- Site closeout documentation: $ 72,765
- Total present worth: $ 111,209

Appendix M provides detailed calculations of the cost of Alternative 1.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.5.2.2 Alternative 2 – Monitored Natural Attenuation with Land-Use controls

No extraction and treatment would occur with this alternative. This alternative would provide for long-term monitoring of the J-1 Range southern groundwater to ensure that natural attenuation was progressing toward cleanup levels and for land-use controls to minimize human exposure to groundwater.

Land-use controls would prevent exposure to contaminated groundwater or soil disturbance activities that might interfere with the remedy. The land-use controls would remain in place, and be monitored for compliance, until the concentrations of COCs in the groundwater attain cleanup levels.

The monitored natural attenuation would involve periodic analysis of groundwater for explosives to measure the natural attenuation of the contaminated groundwater, determining when RDX concentrations have decreased below risk based concentrations. Groundwater monitoring would continue after cleanup objectives are met for two additional years to ensure that plume concentrations remain below those levels. The current active treatment would be discontinued and infrastructure abandoned at the end of the project. A residual risk assessment would be performed if necessary, and may include additional data collection and analysis.

Overall Protection of Human Health and the Environment

Alternative 2 would not prevent the migration of the plume although the area of plume migration is unavailable as a public drinking water supply because of development. Monitoring and land-use controls would be implemented to prevent exposure to contamination. RDX concentrations would decrease below the 10^{-5} risk based level of 6 µg/L by approximately 2019 , the HA of 2 µg/L by approximately 2032, the 10^{-6} risk-based level of 0.6 µg/L by approximately 2050, and background concentrations (0.25 µg/L) by 2074 due to natural processes (Table 10-4).

Compliance with Regulations

Alternative 2 would comply with applicable regulations. Because the plume is expected to naturally attenuate to below cleanup levels, Alternative 2 would eventually be expected to meet the response action objectives, including regulatory standards for COCs.

Long-Term Effectiveness and Permanence

In this Alternative, concentrations of RDX in the plume are expected to permanently be reduced to risk based concentrations through natural processes by 2050. Because no further contribution from the source area is likely, this alternative is expected to be permanent. Monitoring of the plume would continue for several years after the plume attenuates to ensure that all areas remain below remedial goals. In the meantime, the land-use controls would ensure that no use of the contaminated water occurs.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

No treatment would occur, therefore, no reduction in toxicity, mobility, or volume would occur through treatment. However, the toxicity and volume of the contaminated groundwater would be reduced through natural processes.

Short-Term Effectiveness

There will be some impacts to the community through installation of monitoring wells and groundwater sampling activities. A site-specific HASP would be followed during long-term groundwater monitoring.

Implementability

Groundwater monitoring associated with the J-1 Range South plume would continue, subject to periodic optimization, using the same sampling and analytical protocols currently in use. Administratively, this alternative is feasible. Access agreements with private landowners may be necessary for future monitoring well installation and sampling.

Cost

The present worth costs were estimated for Alternative 2 as follows:

- Capital cost: $ 687,904
- O & M: $ 843,926
- Site Closeout Documentation: $ 23,766
- Total present worth: $ 1,555,596

Appendix M provides detailed calculations of the costs of Alternative 2.

State Acceptance

This criterion will be evaluated throughout the development, screening and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening and analysis of alternatives based on comments and input received from the MMRCT and the public..

10.5.2.3 Alternative 3 –Focused Extraction with One Well, Monitored Natural Attenuation and Land-Use Controls

Alternative 3 would provide for the continued treatment of the plume, and maintaining land-use controls. The existing ETI system would operate at an optimized rate of approximately 45 gpm. This alternative includes the option of modifying the system to optimize the ETI system performance.

Land-use controls would prevent exposure to contaminated groundwater or soil disturbance activities that might interfere with the remedy. The land-use controls would remain in place, and be monitored for compliance, until the concentrations of COCs in the groundwater attain cleanup levels.

This alternative would include chemical and hydraulic monitoring of plume and treatment system as long as active remediation continues and chemical monitoring of the aquifer after the system is turned off to ensure that RDX concentrations have decreased below risk based concentrations. Groundwater monitoring would continue after risk based concentrations are achieved to ensure that plume concentrations remain below those levels. The monitoring wells and other infrastructure would be abandoned when no longer needed. A residual risk assessment would be performed, if necessary, and may include additional data collection and analysis.

Overall Protection of Human Health and the Environment

The groundwater model indicates that RDX concentrations would decrease below the 10^{-5} risk-based level of 6 µg/L by approximately 2019, the HA of 2 µg/L by approximately 2032, the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2048 and background concentrations (0.25 µg/L) by 2071.

Compliance with Regulations

Alternative 3 would comply with applicable regulations.

Long-Term Effectiveness and Permanence

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which would also be irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of RDX. The total RDX mass simulated in the model is 0.76 Kg. Approximately, 0.08 Kg of RDX would be removed from estimated time from the site decision to the shutdown time.

Short-Term Effectiveness

There will be impacts to the community through installation of monitoring wells and groundwater sampling activities. There would be some effect on the workers during monitoring well construction, sampling, and decommissioning.

A site-specific Health and Safety Plan would be followed during system construction and monitoring where engineering controls and Personal Protective Equipment would be used as necessary. To date, health and safety precautions for construction activities, groundwater sampling, and drilling have been adequate to protect workers.

Implementability

Administratively, this alternative would be feasible. GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable.

Access agreements with private landowners may be necessary for future monitoring well installation and sampling.

Cost

The present worth costs were estimated for Alternative 3 as follows:

• Capital cost:	$	573,959
• O & M:	$	2.002,594
• Site Closeout Documentation:	$	25,067
• Total present worth:	$	2,601,620

Appendix M provides detailed calculations of the cost of Alternative 3.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.5.2.4 Alternative 4 – Focused Extraction with Two Wells, Monitored Natural Attenuation and Land-Use Controls

Alternative 4 would provide for the continued treatment of the plume at the installation boundary, additional downgradient treatment, monitored natural attenuation and land-use controls. The concept for Alternative 4 is treatment of the plume using the existing system at the MMR boundary and supplementing it with downgradient extraction at a location that can be feasibly implemented. The accompanying animations simulate an extraction well located near the intersection of Lady Slipper Lane and Lichen Lane (Figure 10-2) (Table 10-3). The total flow of the system is 125 gpm and would be treated at the existing J-1 Range MTU and returned to the aquifer through the existing infiltration trench. This alternative includes the option of modifying the system to optimize the J-1 Range ETI system performance.

Land-use controls would prevent exposure to contaminated groundwater or soil disturbance activities that might interfere with the remedy. The land-use controls would remain in place, and be monitored for compliance, until the concentrations of COCs in the groundwater attain cleanup levels.

This alternative would also include chemical and hydraulic monitoring of plume and treatment system as long as active remediation continues and chemical monitoring of the aquifer after the system is turned off to ensure that RDX concentrations have decreased below risk-based concentrations. Groundwater monitoring would continue for two years after risk-based concentrations are achieved to ensure that plume concentrations remain below those levels. The monitoring wells and other subsurface infrastructure would be abandoned when no longer needed. A residual risk assessment would be performed if necessary, and may include additional data collection and analysis.

Overall Protection of Human Health and the Environment

The groundwater model indicates for Alternative 4, RDX concentrations would decrease below the 10^{-5} risk based level of 6 µg/L by approximately 2016, the HA of 2 µg/L by approximately 2019, below the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2024, and background concentrations (0.25 µg/L) by 2030 (Table 10-4).

Compliance with Regulations

Alternative 4 would comply with applicable regulations.

Long-Term Effectiveness and Permanence

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which would also be irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of RDX. The total RDX mass simulated in the model is 0.76 Kg. Model-predicted mass capture for Alternative 4 from the estimated time for the site decision to the shutdown time is approximately 0.58 Kg of RDX.

Short-Term Effectiveness

There would be some effect on the community and workers from implementing Alternative 4 since construction would occur within a residential neighborhood. There would be short-term impacts during installation of the extraction well and piping. There will be long-term impacts from operation and maintenance of the system, and monitoring well sampling activities. Care will be taken to ensure safe operation particularly as it pertains to school bus routes and neighborhood children.

A site-specific Health and Safety Plan would be followed during system construction where engineering controls and personal protective equipment would be used as necessary. To date, health and safety precautions for construction activities, groundwater sampling, and drilling have been adequate to protect workers.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells and subsurface piping to minimize impact on cultural and natural resources. However, some temporary disturbance of natural resources would be necessary during installation of the subsurface piping.

Implementability

Administratively, this alternative would be feasible. Installation of the extraction well and piping would be technically feasible. However. construction in a residential neighborhood will require extra safety precautions, coordination with the community and school system, impact to roads and personal property and access agreements with private landowners and the Town of Sandwich.

GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable.

Cost

The present worth costs were estimated for Alternative 4 as follows:

- Capital cost: $ 1,226,760
- O & M: $ 3,613,646
- Site Closeout Documentation: $ 49,016
- Total present worth: $ 4,889,422

Appendix M provides detailed calculations of the cost of Alternative 4.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

10.5.2.5 Alternative 5 – Focused Extraction with Three Wells, Monitored Natural Attenuation and Land-Use Controls

Alternative 5 would provide for the continued treatment of the plume, additional mid-plume and downgradient treatment, monitoring and land-use controls. The concept for

Alternative 5 is extensive in-plume extraction, in order to reduce RDX concentrations below risk based levels within ten years (regardless of potential implementability challenges), treatment at MTUs located at the MMR boundary, and infiltration trenches located north and south of the plume along the MMR boundary. The simulated extraction wells include two new downgradient wells (Figure 10-2) (Table 10-3). The total flow of the simulated system is 250 gpm and would be treated at the existing J-1 Range MTU and an additional MTU with a 125 gpm capacity. This alternative includes the option of modifying the system to optimize the ETI system performance.

Land-use controls would prevent exposure to contaminated groundwater or soil disturbance activities that might interfere with the remedy. The land-use controls would remain in place, and be monitored for compliance, until the concentrations of COCs in the groundwater attain cleanup levels.

This alternative would also include chemical and hydraulic monitoring of the plume and treatment system as long as active remediation continues and chemical monitoring of the aquifer after the system is turned off to ensure that RDX concentrations have decreased below risk-based concentrations. Land-use controls would minimize potential future exposure. Groundwater monitoring would continue for two years after risk based concentrations are achieved to ensure that plume concentrations remain below those levels. The monitoring wells and other subsurface infrastructure would be abandoned when no longer needed. A residual risk assessment would be performed if necessary, and may include additional data collection and analysis.

<u>Overall Protection of Human Health and the Environment</u>

The groundwater model indicates for Alternative 5 RDX concentrations are predicted to decrease below the 10^{-5} risk based level of 6 µg/L by 2015, the HA of 2 µg/L by approximately 2018, below the 10^{-6} risk-based concentration of 0.6 µg/L by approximately 2022, and background concentrations (0.35 µg/L) by approximately 2028 (Table 10-4).

<u>Compliance with Regulations</u>

Alternative 5 would comply with applicable regulations.

<u>Long-Term Effectiveness and Permanence</u>

Both active treatment and natural attenuation components of the alternative would be permanent. Groundwater extraction and treatment would permanently remove some of the RDX from groundwater. The remaining contamination would continue to decrease due to natural attenuation processes, which would also be irreversible.

The source response actions already taken addressed the majority of source material, including unexploded ordnance, that may be acting as a current source. However, because not all potential source material has been removed, there may be a potential for further groundwater contamination. This alternative includes long-term groundwater monitoring to verify that any possible remaining source will not pose a threat to groundwater. Therefore, this alternative is expected to be effective over the long-term.

Reduction of Toxicity, Mobility, or Volume through Treatment

Extraction and treatment of groundwater would reduce the toxicity, mobility and volume of RDX. The total RDX mass simulated in the model is 0.76 Kg. Model-predicted mass capture from the estimated time from the site decision to the shutdown time is approximately 0.56 Kg of RDX.

Short-Term Effectiveness

There would be a significant effect on the community and workers from implementing Alternative 5 since construction would occur within a residential neighborhood. There would be short-term impacts during installation of the extraction wells, piping, infiltration trench, and the MTU. There will be long-term impacts from, operation and maintenance of the system and monitoring well sampling activities. Care will be taken to ensure safe operation particularly as it pertains to school bus routes and neighborhood children.

A site-specific Health and Safety Plan would be followed during system construction where engineering controls and Personal Protective Equipment would be used as necessary. To date, health and safety precautions for construction activities, groundwater sampling, and drilling have been adequate to protect workers.

To the extent feasible, previously disturbed areas would be utilized for the installation of wells, subsurface piping, and the MTU to minimize impact on cultural and natural resources. However, some disturbance of natural resources would be necessary during installation of the infiltration trench, subsurface piping, and MTU including some vegetation in the neighborhood.

Implementability

Installation of the extraction well and piping would be technically feasible. GAC has been shown to be effective in treating RDX. The treatment system would require regular maintenance and monitoring. Experience at other sites suggests that the components would be reliable.

There would be significant administrative implementability concerns for Alternative 5. Based on the density of existing development off-post, it is extremely unlikely that private property access, needed for optimal placement of J1SA5EW1, would be obtained. Attempts to obtain access to private property in this area have been repeatedly unsuccessful. Access agreements with private landowners may be necessary for future monitoring well installation and sampling.

Cost

The present worth costs were estimated for Alternative 5 as follows:

• Capital cost:	$ 2,180,213
• O & M:	$ 3,497,716
• Site Closeout Documentation:	$ 51,498
• Total present worth:	$ 5,729,427

Appendix M provides detailed calculations of the cost of Alternative 5.

State Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from MassDEP.

Community Acceptance

This criterion will be evaluated throughout the development, screening, and analysis of alternatives based on comments and input received from the MMRCT and the public.

11.0 COMPARISON OF ALTERNATIVES

A comparative analysis was conducted to evaluate the relative performance of each alternative in relation to each criterion. The presentation of the comparative analysis refers to each alternative by its number.

11.1 Northern Area

For reference, a brief description of each alternative follows:

- Alternative 1 – No Further Action. Monitoring wells would be abandoned and site closeout documentation would be completed.
- Alternative 2 – Monitored Natural Attenuation with Land-Use Controls. Alternative 2 includes source area removal, long-term groundwater monitoring and land-use controls.
- Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-Use Controls. Alternative 3 includes source area removal, construction of one extraction well, 2,100 feet of piping, an MTU, and an infiltration trench. The flow rate of the system would be 125 gpm. This alternative was evaluated using two different operational scenarios for the extraction well: Alternative 3a) the extraction well operates until the influent concentrations decrease below the method detection limit and Alternative 3b) the extraction well operates until 2030. IX and GAC media would be used to treat the extracted water.
- Alternative 4 – Focused Extraction with Two Wells (In-Plume), Monitored Natural Attenuation and Land-Use Controls. Alternative 4 includes source area removal, construction of two extraction wells, 3,500 feet of piping, two MTUs, and two infiltration trenches. The flow rate of the system would be 250 gpm. This alternative was evaluated using two different operational scenarios for the extraction wells: Alternative 4a) the extraction wells operate until the influent concentrations decrease below the method detection limit and Alternative 4b) the upgradient extraction well (J1N5AEW1) was turned off in 2015 and the downgradient extraction well (J1NA5EW2) turned off in 2023. IX and GAC media would be used to treat the extracted water.
- Alternative 5 – Focused Extraction with Two Wells, Monitored Natural Attenuation and Land-Use Controls. Alternative 5 includes source area removal, construction of two extraction wells, 6,900 feet of piping, two MTUs located next the J-2 treatment plant, and two infiltration trenches located near the J-2 infiltration trenches along Wood Road. The flow rate of the system would be 250 gpm IX and GAC media would be used to treat the extracted water.
- Alternative 6 – Focused Extraction Wells (In-Plume), Monitored Natural Attenuation and Land-Use Controls. Alternative 6 includes source area removal, construction of five extraction wells, 4,305 feet of piping, MTUs, and infiltration trenches. The flow rate of the system would be 625 gpm IX and GAC media would be used to treat the extracted water.

The strengths and weaknesses of each alternative are presented in a narrative that addresses each criterion.

11.1.1 Overall Protection of Human Health and the Environment

Alternatives 2 through 6 would be protective of human health and the environment. Alternative 1, however, offers no monitoring or confirmation of existing land-use controls to ensure that future exposures do not occur. Alternative 2 adds provisions for plume monitoring and land-use controls to help prevent future exposure to contaminated groundwater. Alternatives 3 through 6 add extraction and treatment components and achieve risk-based concentrations earlier than Alternatives 1 and 2.

Alternative	Estimated Year for RDX Cleanup Times (year)			Perchlorate Cleanup Times	
	6 µg/L	2 µg/L	0.6 µg/L	15 µg/L	2 µg/L
1	2027	2053	>2109	2024	2080
2	2027	2053	>2109	2024	2080
3a	2025	2038	2048	2018	2042
3b	2025	2040	2051	2018	2043
4a	2019	2027	2035	2023	2037
4b	2020	2031	2050	2024	2045
5	2024	2037	2047	2017	2035
6	2014	2018	2020	2017	2020

11.1.2 Compliance with Regulations

All alternatives are eventually expected to result in compliance with applicable regulations. Alternatives 1 and 2 allow for continued migration of the plume. Because these alternatives involve no active remediation, chemical-specific regulations would be met only when contaminant concentrations decrease below the cleanup standards by natural attenuation. Alternative 2 includes monitoring to confirm this occurs; Alternative 1 does not. Alternative 3, 4, 5, and 6 include active treatment to ensure that applicable standards are met.

11.1.3 Long-Term Effectiveness and Permanence

The source area has been removed so residual soil contamination is unlikely to compromise the permanence of the remedial alternatives once completed. All of the alternatives would all permanently achieve the cleanup goals; however, time to cleanup would vary. Moreover, Alternatives 3, 4, 5, and 6, which include active treatment of the plume, may result in fewer uncertainties over the long term regarding the fate and transport of the plume.

11.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 3, 4, 5, and 6 reduce the toxicity, mobility, and volume of contaminated groundwater through treatment. Alternative 3 through 6 would extract various amounts of perchlorate and RDX mass.

- Alternative 3a – 6.0 Kgs of perchlorate and 2.1 Kgs of RDX.

- Alternative 3b – 6.0 Kgs of perchlorate and 1.8 Kgs f RDX.
- Alternative 4a – 7.1 Kgs of perchlorate and 2.5 Kgs of RDX.
- Alternative 4b – 5.6 Kgs of perchlorate and 2.2 Kgs of RDX.
- Alternative 5 – 8.9 Kgs of perchlorate and 2.3 Kgs of RDX.
- Alternative 6 was not simulated in the model and thus there are no model-predicted mass capture values. Alternative 6 will likely provide greater initial mass capture than Alternative 3, 4, and 5 because of the greater initial hydraulic stress and extraction wells within the plume but the short operational time for Alternative 6 limits the amount of mass extracted from the plume.

11.1.5 Short-Term Effectiveness

Alternative 1 would have the least impact on workers because construction is minimal. Alternative 6 would have the greatest impact because of the large amount of construction involved. Alternative 3 through 6 would have the additional risks to workers associated with construction in an Impact Area containing unexploded ordnance.

Alternative 6 would cause the greatest environmental impact to natural resources and includes the installation of five extraction wells, piping, MTUs, and infiltration trenches. Alternatives 3, 4, and 5 would also have some environmental impacts due to construction. Alternative 2 through 6 would have environmental impacts from monitoring well installation, monitoring, and well abandonment. The only environmental impact of Alternative 1 would be from abandonment of the current monitoring-well system.

11.1.6 Implementability

None of the alternatives are limited by administrative feasibility. Alternative 1 is the most easily implemented alternative since it requires no further action other than abandoning groundwater monitoring wells and preparing close out documentation. Alternative 2 is the next most easily implemented alternative with groundwater monitoring and land-use controls implemented. Alternatives 3, 4, 5, and 6 are the most difficult alternatives to implement since they include the installation of extraction well(s), MTU(s), new piping/power lines, and infiltration trench(es) in an environment with the potential for munitions and maintenance of systems down range from small arms firing ranges. The Massachusetts Army National Guard's Revised Limited Authorization for Lead Ammunition Training (AO2, Appendix C) at Tango, Juliet, and Kilo Ranges is conditioned on such coordination and specifically provides that investigation and cleanup take priority in the event of a conflict. Alternative 6 would be the most difficult alternative to implement technically to obtain the cleanup in ten years. .

11.1.7 Cost

The costs of alternatives increase as the amount of treatment increases.

- Alternative 1 - total estimated cost of $ 144,127,
- Alternative 2 - total estimated cost of $ 3,441,151,
- Alternative 3a - total estimated cost of $12,439,320,
- Alternative 3b - total estimated cost of $11,763,660,

- Alternative 4a - total estimated cost of $13,057,684,
- Alternative 4b - total estimated cost of $11,623,876,
- Alternative 5 - total estimated cost of $14,935,898, and
- Alternative 6 – total estimated cost of $19,752,815.

11.1.8 State Acceptance

This criterion will be addressed in detail following comments on the Remedy Selection Plan.

11.1.9 Community Acceptance

This criterion will be addressed in detail following comments on the Remedy Selection Plan.

11.2 Southern Area

For reference, a brief description of each alternative follows:

- Alternative 1 – No Further Action. Treatment operations would be discontinued and monitoring wells and other infrastructure would be abandoned and site closeout documentation would be completed.
- Alternative 2 – Monitored Natural Attenuation with Land-Use Controls. Alternative 2 includes long-term groundwater monitoring until COC concentrations attain cleanup levels and land-use controls.
- Alternative 3 – Focused Extraction with One Well, Monitored Natural Attenuation and Land-Use Controls. Alternative 3 includes source area removal, operation of the existing J-1 Range ETI system. The ETI system would operate at 45 gpm. GAC media would be used to treat the extracted water.
- Alternative 4 – Focused Extraction with Two Wells, Monitored Natural Attenuation and Land-Use Controls. Alternative 4 includes source area removal, operation of the existing J-1 Range ETI system and supplementing it with downgradient extraction at a location that can be feasibly implemented. The extracted water would be treated at the existing J-1 Range MTU and returned to the aquifer through the existing J-1 Range South infiltration trench. The total flow of the ETI system would be 125 gpm.
- Alternative 5 – Focused Extraction with Three Wells, Monitored Natural Attenuation and Land-Use Controls. Alternative 5 includes source area removal, operation of the existing J-1 Range ETI system and supplementing it with mid-plume and downgradient extraction. The extracted water would be treated at the existing J-1 Range MTU and additional MTU. The treated water would be returned to the aquifer through the existing J-1 Range infiltration trench and a new infiltration trench. The total flow of the ETI system would be 250 gpm. GAC media would be used to treat the extracted water.

The strengths and weaknesses of each alternative are presented in a narrative that addresses each criterion.

11.2.1 Overall Protection of Human Health and the Environment

Alternatives 2 through 5 would be protective of human health and the environment. Alternative 1, however, offers no monitoring or confirmation of existing land-use controls to ensure that future exposures do not occur. Alternative 2 adds provisions for plume monitoring and land-use controls to help prevent future exposure to contaminated groundwater. Alternatives 3 through 5 add treatment and achieve risk-based concentrations earlier.

Alternative	Estimated Year for RDX Cleanup Times (year)		
	6 μg/L	2 μg/L	0.6 μg/L
1	2019	2032	2050
2	2019	2032	2050
3	2019	2032	2048
4	2016	2019	2024
5	2015	2018	2022

11.2.2 Compliance with Regulations

All three alternatives are eventually expected to result in compliance with applicable regulations. Alternatives 1 and 2 allow for continued migration of the plume. Because these alternatives involve no active remediation, chemical-specific regulations would be met only when contaminant concentrations decrease below the cleanup standards by natural attenuation. Alternative 2 includes monitoring to confirm this occurs; Alternative 1 does not. Alternatives 3, 4 and 5 include active treatment to ensure that applicable standards are met.

11.2.3 Long-Term Effectiveness and Permanence

The source area has been removed so residual soil contamination is unlikely to compromise the permanence of the remedial alternatives once completed. All of the alternatives would all permanently achieve the cleanup goals; however, time to cleanup would vary. Moreover, Alternatives 3, 4, and 5, which include active treatment of the plume, may result in fewer uncertainties over the long term regarding the fate and transport of the plume.

11.2.4 Reduction of Toxicity, Mobility, or Volume through Treatment

Alternatives 3, 4, and 5 reduce the toxicity, mobility, and volume of contaminated groundwater through treatment. Alternative 3 would extract 0.08 Kg, Alternative 4 would extract 0.58 Kg, and Alternative 5 would extract 0.56 Kg of RDX through use of the extraction wells

11.2.5 Short-Term Effectiveness

Alternative 5 would cause the greatest impact to the environment, community, and workers and includes the installation of two extraction wells, an MTU, and an infiltration trench. Alternative 4 would have a lesser impact but does include a new extraction well and pipeline through a residential community. Impacts to the environment, community, and workers for Alternatives 2 and 3 would be through the installation of monitoring wells. Alternative 1 would have the least impact on the community or workers because construction is minimal.

11.2.6 Implementability

Alternative 1 is the most easily implemented alternative since it requires no further action other than abandoning groundwater monitoring wells and preparing close out documentation. Alternatives 2 and 3 are the next most easily implemented alternatives with groundwater monitoring, O&M of the existing ETI system (for Alternative 3) and land-use controls. Alternative 4 would require installation of an extraction well in a residential neighborhood. Alternative 5 has significant administrative feasibility concerns since it may require access to private property in an area that already rejected previous attempts for access.

11.2.7 Cost

The costs of alternatives increase as the amount of treatment increases.

- Alternative 1 - total estimated cost of $ 111,209,
- Alternative 2 - total estimated cost of $ 1,555,596,
- Alternative 3 - total estimated cost of $ 2,601,620,
- Alternative 4 – total estimated cost of $ 4,889,422, and
- Alternative 5 - total estimated cost of $ 5,729,427.

11.2.8 State Acceptance

This criterion will be addressed in detail following comments on the Remedy Selection Plan.

11.2.9 Community Acceptance

This criterion will be addressed in detail following comments on the Remedy Selection Plan.

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