S Range Alternatives Analysis and Proposed Best Management Practice/ Pollution Prevention Strategy Camp Edwards, Massachusetts

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ACRONYMS

AABC	Advanced Anti-Ballistic Composite
AO	Administrative Order
BMP	Best Management Practice
CBRN	Chemical, Biological, Radiological, and Nuclear
CRREL	U.S. Army Cold Regions Research and Engineering Laboratory
CSM	Conceptual Site Model
EMC	Environmental Management Commission
EPA	U.S. Environmental Protection Agency
EPS	Environmental Performance Standards
ERDC	Engineer Research and Development Center
ESTCP	Environmental Security Technology Certification Program
FM	Field Manual
GSL	Geotechnical and Structures Laboratory
HQDA	Headquarters Department of the Army
IAGWSP	Impact Area Groundwater Study Program
ITRC	Interstate Technology Regulatory Council
MAARNG	Massachusetts Army National Guard
MANG	Massachusetts National Guard
MGL	Massachusetts General Laws
MRF	Modified Record Fire
NGB	National Guard Bureau
O&M	Operation and Maintenance
OMMP	Operation and Maintenance and Monitoring Plan
P2	Pollution Prevention
RAMP	Range Adaptive Management Process
SACON	Shock Absorbing Concrete
SAR	Small Arms Range
SIT	Stationary Infantry Target
TCLP	Toxicity Characteristic Leaching Procedure
TSP	Triple Sodium Phosphate
USACE	U.S. Army Corps of Engineers
USAEC	U.S. Army Environmental Center

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EXECUTIVE SUMMARY

In accordance with Administrative Order 2 (AO2) issued by the U.S. Environmental Protection Agency (EPA), this document presents an analysis of alternative pollution prevention (P2) strategies and best management practices (BMPs) for implementation at Sierra Range on Camp Edwards, Massachusetts, in order to resume live fire small arms training using lead ammunition. This document also describes in depth the proposed Best Management Practice (BMP)/Pollution Prevention (P2) strategy that most effectively protects human health and the environment while still supporting military training objectives.

Small arms training conducted at Camp Edwards varies depending on the unit's mission and the training needed to acquire and maintain proficiency in mission essential tasks. Marksmanship proficiency is critical to soldiering and is advised for any unit deployed to a wartime theater [Headquarters Department of the Army (HQDA) 2008]. Specifically, soldiers must qualify on a Modified Record Fire (MRF) live fire range prior to mobilization or deployment. The use of 25-m Alternate Course (e.g., Tango, Juliette, Kilo ranges at Camp Edwards) or virtual training via computer simulation is not authorized for units that are mobilizing.

In February 1997, EPA Region 1 exercised its authority under the Safe Drinking Water Act to issue an AO concerning Camp Edwards. The Department of the Army, National Guard Bureau (NGB), and Massachusetts National Guard (MANG) received AO1, which advised the NGB to investigate the nature and extent of contamination at and emanating from the training ranges and Central Impact Area at Camp Edwards. AO2 was issued in April 1997 to the NGB and Massachusetts Army National Guard (MAARNG). It advised that Camp Edwards cease certain training activities (including firing lead small arms ammunition, artillery fire, and mortar fire) pending the completion of environmental investigations at the training ranges and Central Impact Area. To date, these activities are still prohibited at Camp Edwards.

Three significant legal drivers define the path forward for resuming effective small arms training at Camp Edwards, Massachusetts; they are:

- EPA Region 1 AO2 issued to MANG in 1997,
- Massachusetts Chapter 47 of the Acts of 2002, and
- Environmental Performance Standards (EPSs) for Camp Edwards, Massachusetts, dated 11 July 2007.

AO2 describes conditions and requirements for the resumption of prohibited training activities, to include resuming live fire training on Sierra Range. Specifically, Appendix A, Section II.E states "If…EPA approves resumption of Respondents' activities at the Training Range and Impact Area, Respondents shall ensure maximum feasible use at such time of pollution prevention technologies in any training activities." This document provides an alternatives analysis and a proposed BMP/P2 strategy in accordance with the requirements of AO2.

Chapter 47 of the Acts of 2002, Section 5 guides the Environmental Management Commission (EMC) to provide permanent protection of the drinking water supply and the wildlife habitat of the Upper Cape Water Supply Reserve, which comprises 15,000 acres of the northern training

area of Camp Edwards. EMC oversight, monitoring, and evaluation will assist in determining that military and other activities on the Reserve are consistent with the protection of the drinking water supply.

The EPS, as stated within Massachusetts General Laws (M.G.L.) Chapter 47, require MANG to develop small arms range-specific operations, maintenance, and monitoring plans and have those plans approved through the EMC. Once the plans are approved, the small arms ranges are operated in compliance with EPS 19.0 Range Performance Standard, other applicable EPSs, and an approved Operation and Maintenance and Monitoring Plan.

Proposed BMP and P2 technologies for Sierra Range are evaluated in this document on their effectiveness, implementability, adaptability, and cost. Process management, monitoring, process improvement, and regulatory oversight are advised for evaluating these strategies and technologies for promoting environmental protection.

As the largest National Guard Training Site in New England, Camp Edwards is a regional training platform and is well positioned to become a deployment point for MANG and other New England Nation Guard Soldiers. As such, a live fire MRF range on Camp Edwards is critical to meeting individual Soldier readiness and Army mobilization requirements.

1. INTRODUCTION

In accordance with Administrative Order 2 (AO2) issued by the U.S. Environmental Protection Agency (EPA), this document presents an analysis of alternative pollution prevention (P2) strategies and best management practices (BMPs) for implementation at Sierra Range on Camp Edwards, Massachusetts, in order to resume live fire small arms training utilizing lead ammunition. This document also describes, in depth, the proposed Best Management Practice (BMP)/ Pollution Prevention (P2) strategy that most effectively protects human health and the environment while still supporting military training objectives.

Extensive procedures, rules, regulations, and laws guide the Department of Army, National Guard Bureau (NGB), and Camp Edwards in the management of their ranges and training lands. Specifically, Camp Edwards Regulation 385-63 [Massachusetts Army National Guard (MAARNG) 2006] states that, “Users are to minimize environmental disturbance to protect the ecosystem as well as preserve the long-term value of our training site.” Complying with such regulations will protect human health and the environment as well as promote sustainable yet realistic training at Camp Edwards.

The following sections present the MAARNG training and environmental requirements, a detailed description of the Sierra Range facilities, and an overview of the environmental conditions of the site. The evaluation of the P2 alternatives, as advised by AO2, is discussed in Section 2.0 and presented in Appendix A.

1.1 MAARNG Requirements

1.1.1 Training

Small arms training conducted at Camp Edwards varies depending on the unit’s mission and the training needed to acquire and maintain proficiency in mission-essential tasks. Marksmanship proficiency is critical to soldiering and is advised for any unit deployed to a wartime theater [Headquarters Department of the Army (HQDA) 2008].

There are five phases in rifle marksmanship training:

- **Phase 1 - Basic Rifle Marksmanship Preliminary Marksmanship Instruction**. Soldiers master weapon maintenance, function checks, and firing fundamentals before progressing to advanced skills and firing exercises under tactical conditions.
- **Phase 2 – Basic Rifle Marksmanship Downrange Feedback Range Firing**. Soldiers fire at known distance targets and make sight adjustments while experiencing the effects of wind, gravity, and other environmental factors. Firing is conducted with a single, clearly visible target at a known distance.
- **Phase 3 – Basic Rifle Marksmanship Field Firing**. Soldiers begin a critical transition from unstressed firing at single, known distance targets to refined techniques for scanning the range for targets, estimating range, and firing quickly and accurately.
- **Phase 4 – Advance Rifle Marksmanship**. Soldiers master advanced techniques and procedures needed to participate in collective training during unit training exercises. Soldiers

learn advanced firing positions, combat firing techniques, unassisted night fire, moving target engagement, and short-range marksmanship.

- **Phase 5 – Advanced Optics, Lasers, and Iron Sights**. Soldiers learn to engage targets with their weapons using iron sights, and enhance marksmanship skills using the Army's newest optics and lasers to ensure that Soldiers can fight as well at night as they can during the day (HQDA 2008).

The Army specifies certain range types to conduct these rifle marksmanship tasks with different weapons systems. Sierra Range is a Modified Record Fire (MRF) Range (FCC Code 17806)[1], which is the Army standard for training and testing individual Soldiers on the skills necessary to identify, engage, and defeat stationary infantry targets (SITs) for day, night, and chemical, biological, radiological, and nuclear (CBRN) qualification requirements with the M16/M4 rifle series of weapons. Targets are automated and the event-specific target scenario is computer driven and scored from the range operations center. The range operating system is capable of providing immediate performance feedback to the participants. An MRF range combines the capabilities of field fire and record qualification fire for day, night, and CBRN to reduce land and maintenance requirements and increase efficiencies (HQDA 2004). Table 1-1 provides basic descriptions of small arms weapons training activities.

Table 1-1. Small Arms Weapons Training Terms

Term	Description
Zero	Zeroing aligns the weapon sights with the barrel so that the point of aim equals the point of impact for a given range for an individual Soldier.
Downrange Feedback	Soldiers fire tight shot groups at a known distance and make sight adjustments while experiencing the effects of wind, gravity, and other environmental factors. Firing is conducted with a single, clearly visible target at a known distance.
Marksmanship	Soldiers learn to accurately fire a given weapons system, allowing Soldiers to attain and maintain proficiency in engaging targets with the weapon.
Field Fire	As part of the continued progression in the development of combat shooting skills, this begins the Soldier's critical transition from unstressed firing at single, known distance targets to targets at various ranges for short exposures. It introduces techniques for scanning the range for targets, estimating range (distance), and firing quickly and accurately.
Record Fire (Qualification)	Record fire requires a Soldier to complete several phases of firing tasks to qualify to operate a particular weapon. Record fire is scored to provide the Solider with feedback and to record the Soldier's qualification.

Sierra Range will be used primarily for record qualification (also referred to as record fire) of the 5.56mm rifle (M16/M4) and field fire individual training. Firing requirements for Soldiers for these ranges are presented in Table 1-2. As an MRF range with 10 firing lanes, Sierra Range is capable of supporting downrange feedback, field fire, record fire, and transition exercises out to the Army standard of 300 m. Soldiers must have line of sight and be able to engage targets at 50 m, 100 m, 150 m, 200 m, 250 m, and 300 m to qualify with the M16/M4 weapon systems. Soldiers fire weapons in the prone, kneeling, and unsupported prone positions, although foxholes are optional. For night fire qualification, Soldiers fire at 50-m targets with a mix of ball and tracer ammunition. The range is equipped with interchangeable silhouettes at the 50-m line: F-type and E-type silhouettes (HQDA 2004). The F-type silhouette is a smaller silhouette of head

[1] TC 25-8 Army Ranges.

and shoulders only, the E-type is a larger silhouette of head to waistline. In addition to record fire for the M16/M4 weapon systems, an MRF range is designed to accommodate sustainment and advanced marksmanship courses of fire [i.e., field fire as described in Field Manual (FM) 3-22.9 (HQDA 2008)].

Table 1-2. Modified Record of Fire and Fields of Fire Firing Requirements

Target (m)	Record Day	CBRNE	Night	Field Fire	Field Fire II
50	3	10	10/5	—	—
50	3	10	10/5	—	—
75	0	—	—	20	20
100	8	—	—	—	—
150	11	—	—	—	—
175	0	—	—	19	20
200	7	—	—	—	—
250	5	—	—	—	—
300	3	—	—	—	14
Total Rounds	40	20	20 ball/10 tracer	54	54

Other 25-m small arms ranges (SARs) at Camp Edwards (T, J, and K Ranges) are designed to support basic weapons familiarization, zeroing, and short-range marksmanship training. Although these ranges can be used as alternate ranges for M16 series qualification using scaled targets, training conditions on these ranges are suboptimal for qualification and mobilization readiness. Scaled targets are placed at short range (25 m) to simulate firing at longer ranges by using reduced image size and perspective. This does not effectively replicate actual field condition affects on projectile flight characteristics (e.g., wind) or the advanced individual marksmanship skills for engaging multiple targets at various ranges out to 300 m.

It is a mobilization/deployment requirement to qualify on an MRF/Automated Record Fire live fire range. The use of 25-m Alternate Course or virtual training on a computer simulation is not authorized if the unit is mobilizing. As the largest National Guard Training Site in New England, Camp Edwards is a regional training platform and is well positioned to become a deployment point for Massachusetts National Guard (MANG) and other New England National Guard Soldiers. As such, an MRF live fire range on Camp Edwards is critical to meeting individual Soldier readiness and Army mobilization requirements.

1.1.2 Environmental Requirements

In 1997, EPA Region 1 issued AO2 [2] to MANG, advising Camp Edwards to cease certain training activities (e.g., firing lead small arms ammunition) due to potential environmental contamination from training ranges and the Central Impact Area. For MANG to resume effective small arms training, three significant legal drivers define the path forward; they are the AO2, Massachusetts General Laws (MGL) Chapter 47 of the Acts of 2002[3], and associated

[2] AO2 was issued in April 1997 following AO1, issued in February of that year. AO1 advised the NGB to investigate sources of contamination potentially originating from the training ranges and Central Impact Area.
[3] Chapter 47 of the Acts of 2002 codified a Memorandum of Agreement, ensuring permanent protection of the drinking water supply and wildlife habitats in the Upper Cape Water Supply Reserve/Training Area, while allowing compatible military training. It created the EMC to oversee compliance with and enforcement of EPS and environmental laws and regulations within the Reserve/Training Area.

Environmental Performance Standards (EPS) for Camp Edwards, Massachusetts, dated 11 July 2007[4].

AO2 has three key components as they relate to small arms training on Camp Edwards. The AO2:

- Assumes small arms training causes lead pollution and requires the amount and extent of pollution to be identified,
- Requires the remediation of the presumed pollution, and
- Requires MANG to develop P2 plans to protect the environment when they return to firing lead ammunition.

In accordance with AO2, MANG coordinated with the U.S. Army Cold Regions Research and Engineering Laboratory (CRREL) to research potential lead pollution of the groundwater at Camp Edwards. The CRREL findings concluded that there has been no lead contamination of the groundwater as a result of SAR activities over the more than 60 years of small arms training (Clausen et al. 1997).

MANG also initiated lead removal actions on Camp Edwards SARs in accordance with the AO2 requirement to remediate presumed pollution. Removal actions are ongoing and approximately 60 tons of lead have been removed from Camp Edwards SARs.

As also guided by AO2, this document provides an alternatives analysis and proposes a BMP/P2 strategy to resume live fire training on Sierra Range. Appendix A, Section II.E of AO2 states the following conditions and requirements for the resumption of prohibited training activities.

> "If…EPA approves resumption of Respondents' activities at the Training Range and Impact Area, Respondents shall ensure maximum feasible use at such time of pollution prevention technologies in any training activities. Specific measures to be evaluated by Respondents include the following:
>
> - Use of non-toxic lead-free combat ammunition;
> - Use of projectile traps at all small arms ranges;
> - Use of munitions-capturing material, such as 'SACON';
> - Use of non-exploding artillery and mortar rounds; and
> - Development of guidance for the operation and maintenance of the ranges consistent with the pollution prevention strategies."

This document only addresses the use of lead-free combat ammunition, projectile traps, and munitions-capturing material at Sierra Range; non-exploding artillery and mortar rounds are not applicable and operation and maintenance (O&M) guidance will be developed and reviewed as the process for returning to live fire on Sierra Range progresses.

[4] MANG, in collaboration with a multi-disciplinary team of local, state, and federal regulators, began compliance with EPSs for Camp Edwards in 2001 as a part of its obligations under a Memorandum of Agreement among the Commonwealth of Massachusetts, the U.S. Army, and the NGB.

Chapter 47 of the Acts of 2002, Section 5 creates and guides the Environmental Management Commission (EMC) to provide permanent protection of the drinking water supply and the wildlife habitat of the Upper Cape Water Supply Reserve. EMC oversight, monitoring, and evaluation assists in determining that military and other activities on the Reserve are consistent with this protection. The EMC oversees compliance with, and enforcement of, the EPS and facilitates an open and public review of activities on the Reserve.

The EPS require the MANG to develop SAR-specific operations, maintenance, and monitoring plans (OMMPs) and have those plans approved through the EMC. Once the plans are approved, the SARs will be operated in compliance with EPS 19.0 Range Performance Standard, other applicable EPSs, and an approved OMMP. The EPS require:

- Reduction of adverse impacts to the environment to the maximum extent feasible, including the design/redesign and/or relocation of the activity or allowing only those activities that result in meeting the goal of overall projectile and/or projectile constituent containment and
- Range management at each range that includes, to the maximum extent practicable, metal recovery and recycling, prevention of fragmentation and ricochets, and prevention of sub-surface percolation of residue associated with the range operations.

The P2 (projectile) management area for Sierra Range is defined by the existing bounds of the range—from the firing line to the 300-m target line to the east and west sides of the range. Proposed BMP and P2 technologies for Sierra Range will be evaluated on their effectiveness, implementability, adaptability, and cost. Process management, monitoring, process improvement, and regulatory oversight are advised to assist in determining that these strategies and technologies promote environmental protection.

1.2 Facility Description

The following sections present the historical use, site description, environmental setting, and conceptual site model (CSM) for Sierra Range at Camp Edwards.

1.2.1 Historical Use

Sierra East and Sierra West Ranges (hereinafter referred to as Sierra Range) were constructed between 1986 and 1989 at their current location for use as automatic rifle and machine gun transition ranges [Impact Area Groundwater Study Program (IAGWSP) 2003]. Each had five firing lanes to engage infantry pop-up targets. Mounded firing lines existed at both ranges: five lanes at Sierra East Range along the 280 ft long firing line and five lanes at Sierra West Range along the 200 ft long firing line. Targets were spaced between 100 and 800 m downrange from the firing points on both ranges. The target berms, which protect the pop-up mechanisms, were processed during the 1998 Berm Maintenance Project (IAGWSP 2003). During this project, metallic lead was removed and leachable lead was fixed in soil. Soils containing Toxicity Characteristic Leaching Procedure (TCLP) leachable lead concentrations greater than 5.0 mg/L were removed and/or treated in situ during the program. Figure 1-1 is an aerial photograph of the Sierra East and Sierra West Ranges.

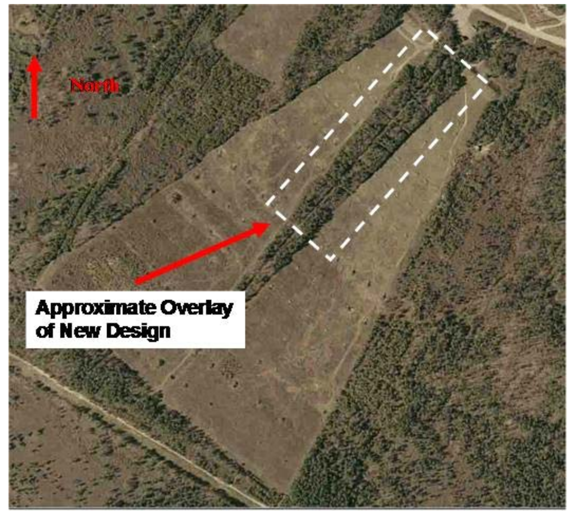

Figure 1-1. Former Sierra East and West Ranges and Overlay of Current Sierra Range

In 2006, Camp Edwards upgraded Sierra Complex to an Army MRF Range (FCC 17806) to meet doctrinal training requirements for M16-series qualification (see Figure 1-2). This upgrade aligns the range with current U.S. Army small arms training standards. The project included combining two formerly separate ranges (Sierra East and Sierra West) into a single 10-lane range with a new computer system, new targets, a new control tower, a set of bleachers, and a pavilion.

During the 2006 range upgrade project, the existing range soils were reconfigured to support the MRF range design. At that time there were no requirements to screen or remove surface rocks from these soils because projectile fragmentation was not an environmental concern. These rocks do not pose a safety issue from a surface danger zone consideration and would not affect normal range operations. It is proposed that, prior to resuming live fire on this range, surface rock be removed to minimize the impact/fragmentation of lead ammunition.

1.2.2 Sierra Range Site Description

Sierra Range covers approximately 16 acres south of Gibbs Road at Camp Edwards. It has generally flat topography with an elevation change of approximately 6 ft across the 300 m long range floor, with a slope from the firing line toward the back of the range (northeast to southwest). The range is surrounded by trees on the northeast, northwest, and southeast sides of the range floor. On the northwest and southeast sides of the range floor, the tree line is within 20 ft of the elevated firing line and gradually extends away from the range floor moving downrange. This is due to the previous configuration of the Sierra East and Sierra West Ranges in a V-shaped pattern emanating from the firing lines. On the southwest side (downrange boundary of the range, beyond the 300-m targets), trees are located in the four center lanes only. The other lanes on Sierra Range currently have no trees between 300 and 800 m. Figure 1-1 provides an aerial view of Sierra Range.

Distinct features of Sierra Range include an access road, a parking lot, a range tower, a range shed, a covered mess area, covered bleachers, the range floor, and soil berms that protect the 90 SITs.

The current range has 10 firing lanes and 90 automated pop-up targets arranged over approximately a 300 × 200-m area. The primary firing line is about 6 ft above the range floor and is used for most field fire and record fire (qualification) training events. The secondary firing line is located forward of the primary line on the range floor and may be used for night fire exercises.

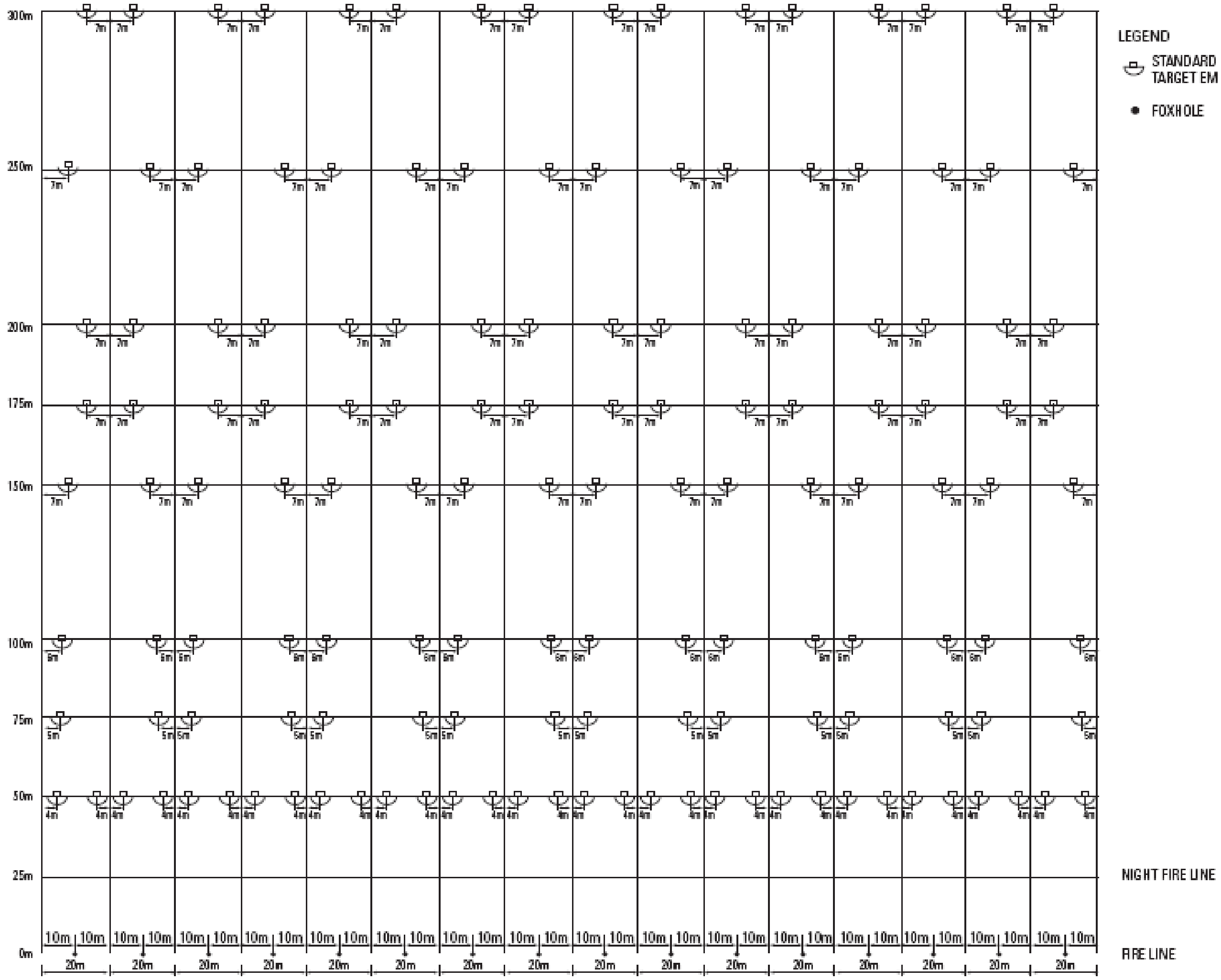

Figure 1-2. Standard Modified Record Fire Range

There are nine stationary, pop-up targets in each firing lane. The targets are located at 50 m, 75 m, 100 m, 150 m, 175 m, 200 m, 250 m, and 300 m. There are two targets in each lane at the 50 m distance and one target at the other distances. Figure 1-3 illustrates the firing line and typical line of sight on Sierra Range.

Figure 1-3. Basic Lateral View of Sierra Range, Primary, and Secondary Firing Lines

1.2.3 Environmental Setting

Camp Edwards is located on Cape Cod, an environmentally sensitive region, and contains threatened and endangered wildlife species and culturally sensitive areas. The Camp sits on top of the Sagamore lens of Cape Cod's aquifer, which is 30–76 m thick and supplies water to off-site as well as on-site populations. The aquifer is a sole source of drinking water for Cape Cod. The northern 15,000 acres of Camp Edwards, the Upper Cape Water Supply Reserve/Camp Edwards Training Area, are located within a recharge area of the aquifer. The nearest drinking water supply wells, WS-2 and WS-3 (see Figure 1-4) for the Upper Cape Water Cooperative, are approximately 1,524 m northeast of the Sierra Range boundary. Groundwater flows to the north and Sierra Range is hydraulically upgradient of these public water supply wells. The potential receptors of water supplied by these public wells include the populations of the Upper Cape towns of Bourne, Falmouth, Mashpee, and Sandwich, as well as the town of Barnstable, the Barnstable County Correctional Facility, and the Massachusetts Military Reservation.

In 2006, CRREL conducted a comprehensive Lead Assessment Study for the small arms training ranges at Camp Edwards. Relevant, readily available information on lead mobility was evaluated to assess steps MANG could take prior to resuming training with lead ammunition. After reviewing the CRREL lead study, the Small Arms Working Group concluded that lead from the SARs and Central Impact Area has not contaminated the groundwater. While lead contamination in soil has been found, the presence of lead in groundwater at Camp Edwards has not been identified; only 1 of 19 groundwater monitoring wells associated with the SARs has ever had a single, low detection of lead in the 15 ppb range. Groundwater models have predicted it will take anywhere from a few 100 to over a 1,000 years for lead to reach groundwater

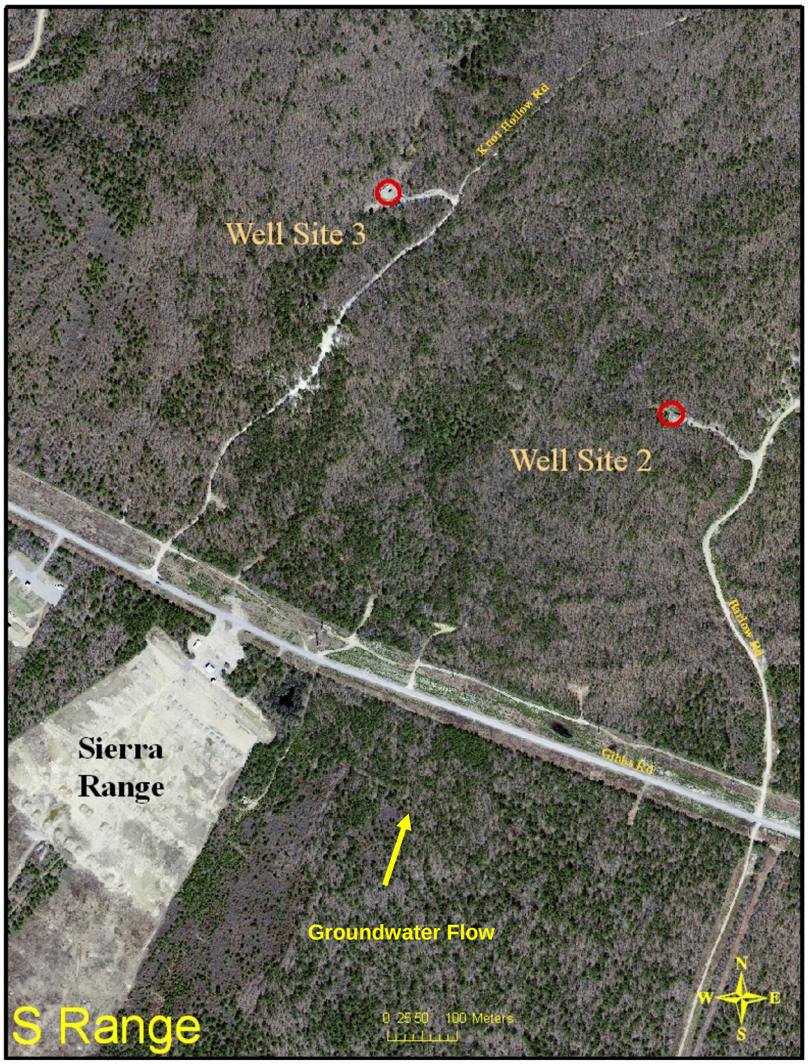

Figure 1-4. Well Sites 2 and 3

because the geochemistry of the soil at Camp Edwards serves to retard the migration of lead (Clausen et al. 2007). This model was based on the assumption that lead had accumulated on Camp Edwards SARs for more than 60 years and does not consider that lead on most of these ranges has been removed; in other words, it is conservative. Despite the findings from the CRREL study, P2 measures are still considered sensible for implementation at Camp Edwards due to the uncertainties in developing lead mobility models and because there is a finite capacity for the soils to act as a buffer. MANG, in accordance with AO1/AO2, is undertaking measures to mitigate the ultimate leaching of lead to groundwater.

As previously stated, MAARNG has undertaken several projects with the intent to reduce the existing lead load in the soils on Camp Edwards associated with SARs. To date, an estimated 60 tons of lead and other projectile constituents have been removed from 16 ranges. Additional lead and other projectile constituents will be removed from three former ranges and two active ranges in FY2009–2010. Additionally, three active SARs employ projectile containment systems, which effectively stop lead and other projectile constituents from ever entering the environment on Camp Edwards.

MAARNG understands the importance of not only protecting groundwater from future potential lead contamination, but also protecting the vadose zone soils above the water table and the soil-pore water contained in this zone from lead contamination. This proposed BMP/P2 strategy and alternative technology analysis is intended to meet the objectives of environmental protection and AO1/AO2 requirements.

1.3 Conceptual Site Model

A CSM is a description of a site and its environment based on existing knowledge. It is used to develop site-specific hypotheses regarding the location and movement of environmental pollutants and any potential interaction (exposures) with humans and other environmental resources. The basic components of a CSM are the source, the pathway, and the receptor.

The CRREL report found that the natural geochemistry of the soil at Camp Edwards serves to retard the migration of lead (MANG 2008). The coarse, permeable soils present on-site limit the time projectiles in the environment remain in contact with water, thus limiting the corrosion of lead fragments (MAARNG 2007b). “Several mitigating factors such as the lack of chloride and coarse soil texture limit corrosion of metallic lead and subsequent dissolution of lead oxides at Camp Edwards” (Clausen et al. 2007). Limited corrosion processes and the soil’s ability to adsorb metals limit the dissolution and migration of metals from surface soils to subsurface soils (MAARNG 2007b). With this, Figure 1-5 provides a pictorial representation of the general CSM for theoretical metals migration from Sierra Range with no BMPs in place. The pictorial CSM also depicts theoretical exposure via multiple media and mechanisms, as well as potential migration and exposure pathways. Brief descriptions of potential sources, pathways, and receptors are discussed in the following sections.

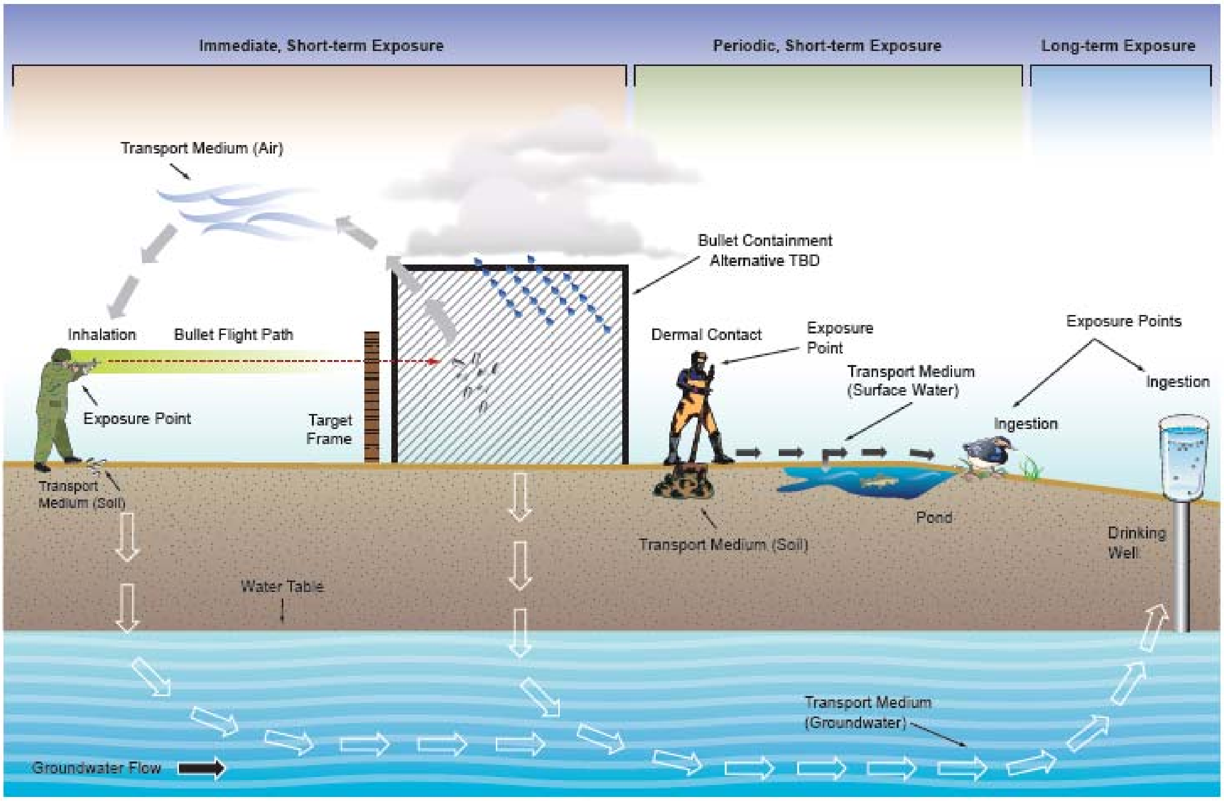

Figure 1-5. Pictorial Presentation of SAR CSM

1.3.1 Potential Sources

Metals (typically lead and copper) originate in the environment from small arms weapons fire and are deposited through muzzle blast or projectile deposition and projectile fragmentation. Fragmentation occurs when bullets strike rocks or previously deposited projectiles, causing the bullet to break into multiple fragments. Small metal particles are more susceptible to transport mechanisms than intact projectiles because of their lower mass and higher relative surface area exposed to weathering. On Sierra Range, without projectile containment, it is assumed that live fire will deposit projectiles far beyond each of the targets in a distribution around the trajectory point of impact and the frontal SIT berm as shown in Figure 1-6. These projectiles will fall to the ground intact with the lead core encased by the copper jacket, preventing extensive lead corrosion. In contrast, use of a projectile containment system will concentrate and contain projectile deposition immediately beyond each target. By containing the projectiles, potential lead bullet fragments will also be contained within the system and lead will be less mobile on the surface. The muzzle blast associated with small arms fire may also release residual energetic materials from primers and propellant and deposit them into the air and immediately in front of the firing line.

1.3.2 Potential Migration Pathways

Potential pathways where contaminants can travel include surface and subsurface soil, surface water, groundwater, and air. Metals and energetic materials deposited in surface soils may be transported through erosion or by soil disturbing activities. Typical activities of range users may disturb the soils, such as Soldiers walking on the range and crews conducting maintenance and repairs. The mobility and bioavailability of metals that corrode in these conditions will be limited by the formation of insoluble lead minerals and the adsorptive capacity of the soil at Camp Edwards (Clausen et al. 2007). Limited corrosion processes and the soil's ability to adsorb metals will reduce the dissolution and migration of metals as demonstrated over the more than 60 years of small arms training on Camp Edwards. Because air is not considered a viable migration pathway for lead to reach groundwater, it is not discussed further in this alternatives analysis.

1.3.3 Potential Receptors

Relatively controlled range access limits potential human receptors to range users, range maintenance workers, and trespassers in contact with soil and surface water on the range. Users of drinking water from drinking water wells WS-2 and WS-3 for the Upper Cape Water Cooperative are potential receptors via the groundwater pathway. Possible ecological receptors, such as birds, may be exposed to lead particles via surface water or soil on the range.

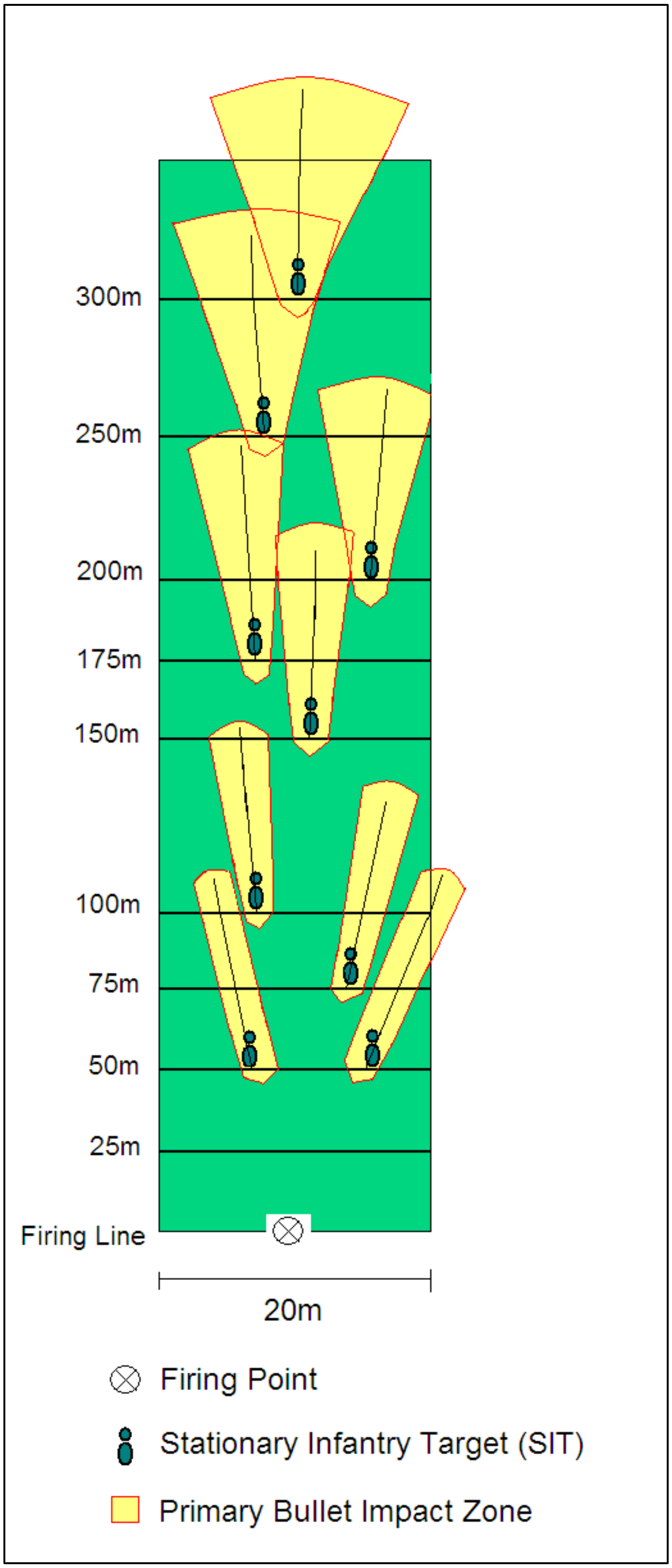

Figure 1-6. Sierra Range Primary Bullet Impact Zone

1.3.4 Potential Source-Receptor Interaction

Based on the CSM described in the T Range OMMP, there are four defined exposure pathways: ingestion and dermal contact of surface soil, and ingestion and dermal contact of surface water (MAARNG 2007b). Due to the limited corrosion processes and the soil's ability to adsorb metals, groundwater is not considered a complete short-term exposure pathway; however, it is considered a potentially complete long-term exposure pathway.

2. SIERRA RANGE ALTERNATIVES ANALYSIS

The following sections describe the methodology for evaluating alternative P2/BMP technologies as guided by EPA's AO2. Additionally, MGL Chapter 47 of the Acts of 2002; Army Regulation 350-19, *The Army Sustainable Range Program* (HQDA 2005); and other regulatory drivers mandate that the Army implement BMP/P2 planning while developing, improving, and operating SARs.

The development of effective BMP/P2 plans to return to live fire training on SARs, particularly Sierra Range, at Camp Edwards can be partially based upon the CRREL study. This study, which was developed as a requirement of AO1 and AO2, is a comprehensive understanding of the geological characteristics as they relate to lead mobility and some of the long-term effects of SAR training. Other sources used to develop possible BMP/P2 plans are U.S Army Environmental Center *Army Small Arms Range Environmental Best Management Practices (BMP) Manual* (AEC 2005), Interstate Technology Regulatory Council (ITRC) *Environmental Management at Operating Outdoor Small Arms Firing Ranges* (ITRC 2005), TC-25-8 (HQDA 2004), U.S. Army Corps of Engineers (USACE) Design Guide (USACE 2004), and FM 3-22.9 (HQDA 2008).

Each BMP/P2 alternative was evaluated with respect to protection of the environment (specifically protection of groundwater), lead containment and recovery, support of military training objectives, adaptability, and initial installation and maintenance costs. Information gathered on each alternative is summarized in Section 2.2 and presented in Appendix A. This information is organized by four main factors: effectiveness, implementability, adaptability, and cost. A literature search was conducted to identify the merits, advantages, and disadvantages of each alternative. Vendors were contacted with technical questions on system design, implementation, and cost. The factors used in the evaluation are discussed in Section 2.1.

2.1 <u>Evaluation Factors</u>

Each alternative was given a numerical rating between 1 and 5 based on the effectiveness, implementability, adaptability, and cost. A rating of 1 indicates low effectiveness, low implementability, low adaptability, or high cost. A rating of 5 indicates high effectiveness, high implementability, high adaptability, or low cost. These ratings serve as a comparison tool between alternatives. The ratings are presented in Appendix A.

2.1.1 Effectiveness

For the purposes of this document, effectiveness is defined as:

- Protection of human health and environment;
- Reduction of toxicity, mobility, and volume of contaminants;
- Compliance with EPA AO2; and
- Compliance with the EPS as provided by MGL Chapter 47 of the Acts of 2002.

As the alternatives were evaluated, three specific aspects of each system were considered to assess the alternative's effectiveness:

Lead Containment. Does the system contain projectiles and projectile fragments? Does the system effectively contain projectiles and fragments with respect to dissolved and particulate lead?

Recovery and Recycling. Is projectile recovery possible with this system? Is the recycling of projectiles possible?

Protection from Weather Conditions. Do weather conditions affect the system function? If this system is employed, is captured lead protected from interaction with precipitation? Will precipitation enable lead migration to groundwater?

2.1.2 Implementability

For the purposes of this document, implementability is defined as:

- Technical feasibility;
- Demonstrated performance;
- Availability of equipment, space, and services;
- Administrative feasibility (e.g., recordkeeping requirements);
- No potential adverse effect (short- or long-term) from implementation; and
- No constraints on the adoption of future P2 technologies.

As the alternatives were evaluated, four specific aspects of each system were considered to assess the alternative's implementability:

Training Capacity. Does system maintenance minimize range downtime? Does the operational throughput (i.e., number of rounds fired) change the frequency of maintenance?

Training Quality. Does the system support Army training doctrine? If this system is employed, will line of sight to downrange targets be affected? Can the system accept 5.56mm ammunition? Tracer fire (night fire)?

Availability of Method. Is the system widely available? Is specialized equipment advised? Is installation/construction by the manufacturer advised?

Environmental Monitoring Requirements. What are the potential environmental monitoring requirements? What is the monitoring requirement effort in relation to other evaluated systems?

2.1.3 Adaptability

For the purposes of this document, adaptability is defined as the ability of the selected system to incorporate new information and technologies as they relate to BMP/P2 strategies on SARs.

As the alternatives were evaluated, five specific aspects were considered to assess the alternative's functional adaptability.

Emerging Information. Would new scientific knowledge on lead mobility be compatible with a selected system? Can new processes on how to mitigate and/or inhibit lead mobility be integrated into the selected system? If new alternate service ammunition replaces lead-based ammunition would it be compatible with the selected system?

System Scalability. Can the selected system function at Sierra Range with 10 firing lanes and 90 SITs?

BMP/P2 Technology Pairing. Can more than one of the evaluated technologies be coupled together to form a more comprehensive solution? Can individual technologies be augmented after selection with additional technologies (e.g., building blocks)?

Unintended Consequences. Would a selected system mitigate the adaptation of additional known technologies as operational impacts are identified? Does the system create a single point of failure, such as liner failure or accumulation of water within the system, resulting in lane or range closures?

Technology Transfer. Is the selected system capable of transfer to other SARs on Camp Edwards, other military installations, or to civilian operated SARs?

2.1.4 Cost

As the alternatives were evaluated, two types of costs were considered to estimate the alternative's overall cost:

Capital Cost. What are the site preparation requirements? What are the site preparation, installation, labor, and material costs?

O&M Cost. What are the maintenance requirements? What are the maintenance, disposal, and environmental monitoring costs?

2.2 Alternatives Analysis

During the research of the available BMP/P2 technologies, two basic methodologies emerged, soil amendments and physical containment. Soil amendments are applied directly to the range soil and mitigate lead contamination in the environment by either limiting the ability of the lead to become physically mobile or by enhancing the soil's absorptive capability to fix/retain the lead in situ between recycling operations. Physical containment of projectiles requires hardware to be installed or constructed at each SIT location. Non-lead training rounds were also considered and are presented in this section.

Specific alternatives that are presented and discussed in this analysis are:

- Soil amendments
- Earthen berms
- Enhanced earthen berms
- Concrete block
- Rubber block
- Gel-COR™
- Granular rubber
- Deceleration
- Impact/Deflection traps
- Non-lead training rounds

The following alternatives are not presented as a course of action but rather as part of the overall strategy to return to live fire on Sierra Range. Alternatives may be utilized as part of a process improvement strategy that would support greater P2 on this range.

2.2.1 Soil Amendments

This section discusses the addition of amendments to the range soil to limit lead physical mobility or solubility or enhance the soil's absorptive capabilities.

Lime Addition
Monitoring and adjusting soil pH is an important BMP that can affect lead migration. Lead mobility increases in acidic conditions (soils with low pH values) because the acid in the soils contributes to the break-down of lead break fragments. Lime has a high pH value (i.e., is a base), therefore, spreading lime over the shot fall zone will help to raise the pH of the very top soil layer to a less acidic pH level and reduce the migration potential of lead.. The ideal soil pH value is between 6.5 and 8.5. If the soil pH is below 6, the pH may be raised by spreading lime. An annual check of the soil pH would be part of this option (EPA 2001).

Phosphate Addition
In addition to spreading lime, another way to manage lead migration is phosphate spreading. This method is often used when lead is widely dispersed in range soils, a range is closing, or there is a high potential for vertical lead transport to groundwater (e.g., low soil pH, shallow water table). Unlike lime spreading, the main purpose of phosphate spreading is not to adjust soil pH but to bind the lead particles. This process decreases the potential amount of lead that can migrate off-site or into the subsurface. Phosphate spreading can be done either separately or in conjunction with lime spreading. Generally, 15–20 lb of phosphate per 1,000 ft^2 of the range floor will effectively manage lead migration. Phosphate spreading is one option for ranges not easily accessible by reclamation equipment and may be repeated frequently during a range's lifetime (EPA 2001). However, phosphate addition may pose other environmental risks such as increased mobility of other contaminants due to a competitive displacement process for anionic binding sites in the soil. The unclear role of phosphate as a soil amendment for binding contaminants makes it questionable as an effective BMP (Chrysochoou et al. 2007).

Phosphate is commercially available in several forms: fertilizer, rock phosphate, and triple sodium phosphate (TSP).

Mulches and Compost

Mulches and composts applied to the range surface can reduce the amount of water that comes in contact with the lead fragments deposited on the range. In addition, mulches and compost contain hermic acid, which is a natural lead chelating agent that sorbs lead out of solution and reduces its mobility (Kennedy Krieger Institute 2008). These materials would be spread over any impacted area at a minimum thickness of 2 inches. Like vegetative covers, organic surface covers are not impermeable. The organic material needs periodic replacement to maintain effectiveness and aesthetic integrity. These materials tend to be acidic especially during decomposition, so, if low pH is a concern, this option may not be appropriate. Again, lime may be used for pH control (EPA 2001).

Apatite II

Apatite II is a waste product of the fish industry, made of clean and dried fish bone and fish hard parts. The major elements of bones are calcium, phosphorus, sulfur, and magnesium as well as several minor elements. As a soil amendment, Apatite II has low trace metal concentrations and is highly microporous, and thus provides a readily available and reactive source of soluble phosphates to bind lead particles. Previous leaching studies indicated that 5% by weight of Apatite II retains more than 90% of the lead in the soil matrix under TCLP conditions [Environmental Security Technology Certification Program (ESTCP) 2007].

Apatite II was used as a soil amendment in a PRBerm[5] treatability study and field demonstration at Barksdale Air Force Base in 2007. The treatability study used soil amendments that potentially bind with lead, creating insoluble minerals; the amendments selected for investigation were Apatite II, SulfiTech A/T, and Buffer Blocks. Initially, the Apatite II amendments did not perform as expected, but over time a reduction of lead was attributed to Apatite II as soil amendment. The organic matter present in the soils may have been a contributing factor to the initial inability of Apatite II to reduce lead in the soil (ESTCP 2007).

Ferric Oxide

Ferric oxide is one of several oxide compounds of iron. Iron (III) oxide is also known as hematite, red iron oxide, synthetic maghemite, colcothar, or simply rust.

Immobilizing lead as pyromorphite in soils has been studied extensively. It has been hypothesized that the addition of ferric oxide and phosphate to soils will cause lead in the soil to transform to pyromorphite; in this form, the lead is sequestered so that it is biologically inert and environmentally stable. In a field study performed in Joplin, Missouri, the supplemental addition of an iron amendment with phosphate in the form of TSP enhanced pyromorphite formation relative to independent TSP amendment of like concentrations (41% versus 29%). However, the amendment of biosolids and biosolids plus TSP observed little pyromorphite formation, but a significant increase of sorbed lead was observed (Sheckel and Ryan 2004).

In another laboratory study performed in Europe, backstop material from a German Army shooting range was treated with ferric oxide and phosphate to stabilize trace metals. Experiments

[5] Passive Reactive Berm (PRBerm) technology incorporates berm amendments with ballistic sand to immobilize soluble metals (e.g., lead) during the inevitable bullet corrosion process.

showed effective stabilization of target contaminants using ferric oxide as a soil amendment. Contrasting the ferric oxide additives, phosphate amendments effectively stabilized lead, but also mobilized copper and antimony possibly due to a competitive displacement process (Spuller et al. 2007).

If soil amendments are selected as a BMP/P2 strategy for Sierra Range, testing of the soil additives is advised to evaluate whether they cause cementing or hardening of the soil surface (Department of Air Force 2008).

2.2.2 Physical Containment

This section discusses two main types of physical containment systems; berms and bullet traps. Berms typically have an earthen material (e.g., soil) base and can be used in an end of range or end of lane application to capture small arms ammunition. Bullet traps also offer a means of limiting the amount of lead and other small arms metals released into the environment. Bullet traps have been used in indoor firing ranges for many years and are now commercially available for outdoor applications as a backstop on small arms ranges. Several types of bullet traps are available commercially. The predominant traps that may be applicable to U.S. Army small arms ranges are identified and discussed in this document and additional guidance on the selection of bullet trap systems on Army ranges is provided in the AEC Bullet Trap Performance Criteria decision-making tool brochure (AEC 2005). Both berms and bullet traps are discussed in this section as alternatives for use as physical containment systems behind each SIT.

Earthen Berms

This alternative consists of the following major components:

- Frontal berms consisting of native soils sifted to remove large rocks and treated with amendments to minimize migration of contaminants,
- Treatment of range floor with amendments to minimize migration of contaminants and sifted to remove large rocks,
- Backstop berms consisting of native soils sifted to remove large rocks and treated with amendments to minimize migration of contaminants, and
- Periodic removal of metals.

Figure 2-1. Earthen Berm

The soil berm is the oldest and most basic way to stop and contain projectiles. In its simplest form, this type of backstop is a properly sized and positioned soil mound placed behind the targets (see Figure 2-1). Projectiles pass through the target, strike the soil backstop, and remain embedded in the soil until removed. Ideal backstop slopes vary based on soil types but most are set at approximately 26 degrees to minimize erosion and projectile ricochet. Soils used in SAR berms may be vegetated and screened of rocks. Vegetation, mostly grasses, is also grown on the backstops and berms to reduce erosion (MAARNG 2007b).

At Sierra Range, the existing berms supporting each target emplacement would be extended behind each target by moving and contouring soil from on-site to form a new larger berm behind each target. Figure 2-2 is a conceptual design of the earthen berm. The berm face (i.e., the area designed to receive projectiles) would be sized based on distance from the firing line. The face of the berm exposed behind the target would be either 6 × 6 ft (50 m, 75 m, and 100 m), 9 × 9 ft (150 m, 175 m, 200 m, and 250 m), or 12 × 12 ft (300 m). The toe of the berm would be approximately 5 ft behind the target when in an upright position to allow the SIT room to function. The frontal berms would be constructed of on-site soil amended with organic matter. The frontal berms would be at least 1 ft deep and sized to protect the front of the SIT coffin and retain its shape.

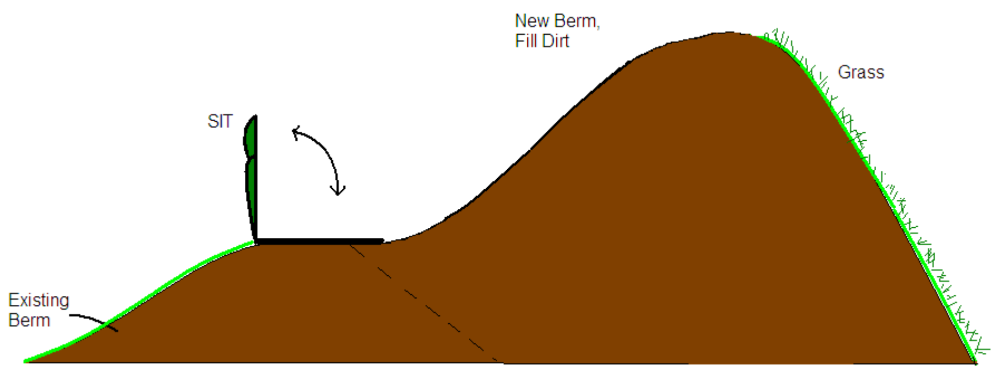

Figure 2-2. Earthen Berm Conceptual Design

Periodic removal of projectiles from the range would also help to remove the source of lead and other metals (ITRC 2005). If most bullets are deposited in the areas shown in Figure 1-6 then focused removal of lead from the primary bullet impact zones of the range in areas of the bullet trajectory will remove much of the source.

Lead and other metals may be removed by physical separation methods alone or by a combination of physical and chemical methods. There are five classes of physical separation techniques: size separation (screening), hydrodynamic separation (classification), density separation (gravity), froth floatation, and magnetic separation. After physical separation removes the course particulate metals, an acid leaching (soil washing) is advisable to remove the fine particulates or ions bound to the soil matrix (ITRC 2005). Periodic soil removal and lead screening/soil washing is advised to recover and recycle or dispose of lead bullets and fragments.

At Sierra Range, physical separation by soil screening is one option to remove large particulate metals, followed by soil washing to remove fine particulates and metals bound to the soil matrix. Lead removal/recovery in areas of concentrated bullet impact (along bullet flight paths in primary bullet impact zones) is assumed to occur every 5 years. Large-scale range recovery operations (across the entire range) are assumed every 20 years.

Enhanced Earthen Berm

As with the earthen berm discussed above, this type of backstop is also a properly sized and positioned soil mound located behind the targets. However, for this projectile containment alternative, enhancements to the soil berm design are presented to further reduce the transport of lead. Except as noted, this design is identical to the earthen berm design described above. Figure 2-3 presents a conceptual design of an enhanced earthen berm that incorporates multiple features to reduce metal transport. The features include:

- A wooden 8 × 8-ft roof over the front face of the berm to limit the interaction of precipitation with berm soil and projectiles;
- A sand berm face screened of large rocks to limit ricochet and projectile damage on impact, and to simplify lead reclamation activities;
- A 1 ft thick, concave clay layer placed beneath the sand portion of the berm to retard the migration of dissolved metals toward groundwater;
- Mixing soil amendments into the sand lens to limit corrosion and retard the migration of lead (see Section 2.2.1); and
- Periodic metals removal via physical sifting.

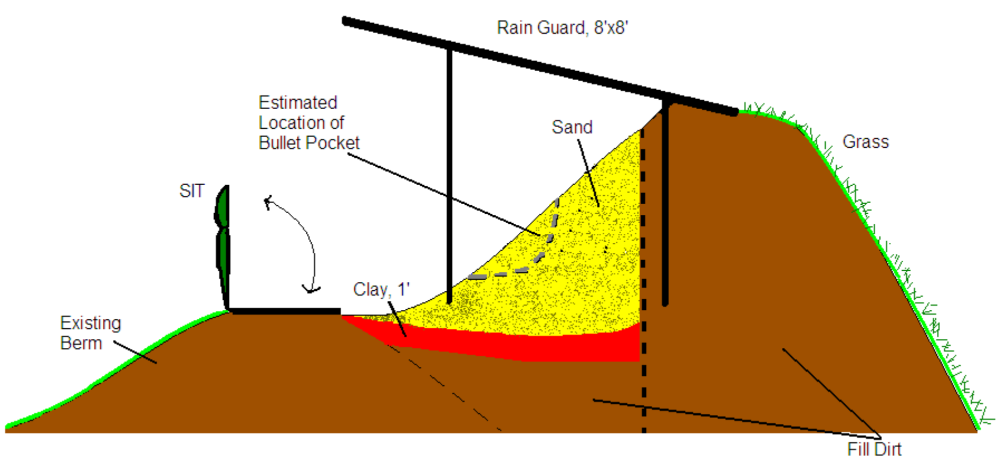

Figure 2-3. Enhanced Earthen Berm Conceptual Design

The frontal berms will be constructed of on-site soil screened of large rocks and amended with organic matter. The frontal berms will be at least 1 ft deep and sized to protect the front of the SIT coffin and retain its shape. The rain guard is composed of wood and supported by 6 × 6-in. posts set in 3-ft concrete footings within the berm. The posts support an 8 × 8-ft plywood roof with 2 × 6-in. rafters, set at an angle to protect the berm face from precipitation. Based on the prescribed angle of the roof, the rain guard will extend 2 ft above the maximum height of the berm. The soil amendments will be applied as discussed in Section 2.2.1. Additionally, periodic metals removal via physical sifting will occur as discussed under the earthen berm alternative.

Concrete Block

This alternative consists of the following major components:

- Modular system of shock absorbing concrete (SACON®) blocks stacked behind targets to contain bullets and fragments,
- Placement of one block as a frontal berm to capture undershot bullets,
- Enlargement and modification of existing soil berms to support both frontal and backstop berms,
- SACON® backstops sized based on distance from firing line to account for decreasing accuracy, and
- Maintenance of damaged SACON® blocks after approximately 10,000 rounds per block.

The most common manufacturer of concrete block projectile containment systems is SACON®, which was specifically named by EPA in AO2 issued to MAARNG (see Section 1.1.2). SACON® combines a low density material (steel fibers or polypropylene fibers) with concrete to achieve a density of 60–90 lb/ft^3 (compared to conventional concrete at 150 lb/ft^3) and allowing SACON® to absorb projectiles and shock waves. SACON® is poured into preformed molds according to the shape and color evaluated by the user and takes 28 days to cure. By applying SACON® in a modular or brick-like format as illustrated in Figure 2-4, only worn or projectile-filled blocks require replacement during maintenance activities [U.S. Army Environmental Center (USAEC) 1996].

Figure 2-4. Example of Modular SACON® Bullet Containment System (ESTCP 1999)

At Sierra Range, a modular system of stacked 3 × 3 × 3-ft SACON® blocks behind each target is one option, as this size of SACON® is readily available, satisfies the ballistic requirements, and can easily be configured to the sizes advised . Four blocks can be placed in a 2-by-2 block configuration to form a 6 × 6 × 3-ft backstop at the 50 m, 75 m, and 100 m distances. A 3-by-3 SACON® block configuration will form a 9 × 9 × 3-ft backstop at the 150 m, 175 m, 200 m, and 250 m distances. Finally, a 4-by-4 SACON® block configuration will form a 12 × 12 × 3-ft backstop at the 300 m distance. The SACON® blocks are placed on a level soil surface, and no concrete pad or steel framework is advised. Each SACON® block weighs 2,430 lb and would require heavy equipment to position. Using on-site soil, the existing berms supporting each target would be extended behind the target to support the SACON® blocks. The extended berm area will be at the same height as the SIT coffin. The SACON® backstop will be approximately 5 ft behind the target when in an upright position to allow the SIT room to function.

The frontal berms will be SACON® T blocks. T blocks are 2 × 4 × 2 ft in size; one T block will be placed in front of each SIT coffin. The frontal berms will be 2 × 2 × 4 ft in size to protect the front of the SIT coffin from undershot. Each SACON® T block weighs 1,440 lb, requiring heavy equipment to position.

In a pilot test conducted at Fort Knox and the U.S. Military Academy, the debris pile that accumulates in front of the SACON® projectile trap exhibits "leaching characteristics that would result in a hazardous waste classification based on lead toxicity" without exposure to time and weathering (ESTCP 1999). However, normal range use results in the formation of insoluble products containing oxidized lead, greatly reducing the amount of leachable contaminants in the debris pile. By the time SACON® debris is removed from the range during normal maintenance operations, it will likely pass a TCLP test and be classified as non-hazardous solid waste.

Rubber Block

This alternative consists of the following major components:

- Blocks of various rubber compounds stacked behind targets to contain projectiles,
- Rubber block placed in front of target to contain undershot bullets,
- Enlargement and modification of existing berms to support blocks,
- Rubber block backstops sized based on distance from firing line to account for decreasing accuracy, and
- Replacement of damaged blocks after approximately 3,500–5,000 rounds.

Blocks of various rubber compounds or recycled rubber material can be stacked to form a bullet barrier behind each target as illustrated in Figure 2-5. The blocks are molded from shredded rubber tires bound by an adhesive mixture. Blocks come in various sizes, but are generally 60–80 lb each and measure 30 × 12 × 12 in. When projectiles penetrate the rubber block, the friction of the rubber against the projectile surface causes the projectile to stop in a short distance. Blocks have the advantage of being modular, so that the worn or filled blocks require replacement, reducing the labor and cost associated with maintenance (USAEC 1996).

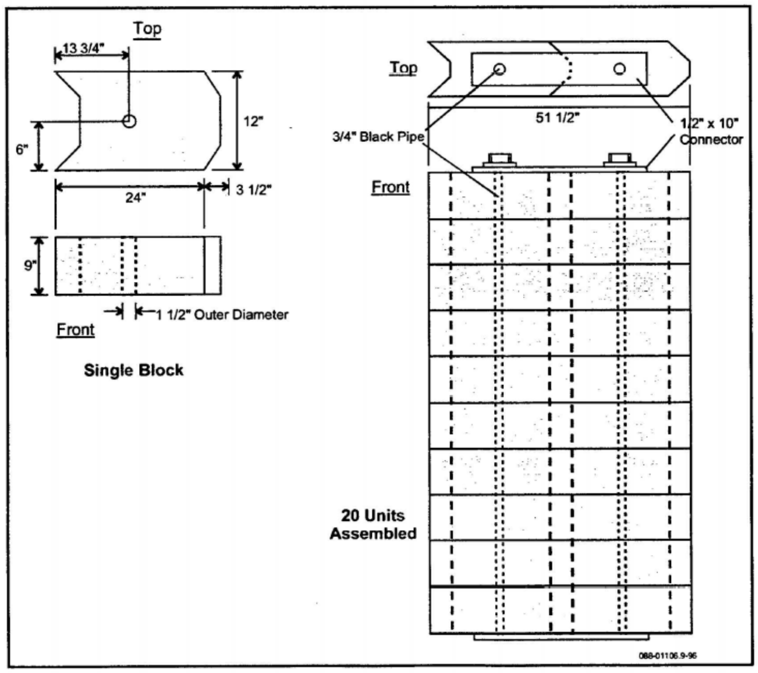

Figure 2-5. Example of Rubber Block Projectile Containment System (USAEC 1996)

Three types of rubber block systems were considered in this analysis:

- Vulcan Rubber by Advanced Training Systems, Inc.
- Advanced Anti-Ballistic Composite (AABC) by Ballistics Research, Inc.
- Dura-bloc by Range Systems

At Sierra Range, rubber blocks would be placed behind each target to form a 6 × 6-ft backstop at the 50 m, 75 m, and 100 m distances; a 9 × 9-ft backstop at the 150 m, 175 m, 200 m, and 250 m distances; and a 12 × 12-ft backstop at 300 m. The rubber blocks are placed on the soil surface with supporting framework. The existing berms will be enlarged to support the rubber block traps. On-site soil will be shaped to form a larger berm surface behind the target. The enlarged berm area will be at the same height as the SIT coffin. The rubber block backstop will be approximately 5 ft behind the target when in an upright position to allow the SIT room to function.

The frontal berms will also be constructed of rubber blocks and will be approximately 2 × 4 ft wide to protect the front of the SIT coffin from undershot. The depth of the frontal berm will vary from 8 in. to 1 ft deep, as individual rubber block sizes vary slightly by vendor.

GEL-COR™

This alternative consists of the following major components:

- Blocks of GEL-COR™ stacked behind targets to contain projectiles,
- A supporting frame (e.g., SACON®, existing berm) around the outside of the trap,

- GEL-COR™ placed in front of the target to contain undershot bullets,
- Enlargement and modification of existing berms to support GEL-COR™, and
- GEL-COR™ backstops sized based on distance from firing line to account for decreasing accuracy.

This product is a new, fireproof, bullet-trapping medium, developed by researchers from the Engineer Research and Development Center (ERDC) Geotechnical and Structures Laboratory (GSL) and Super Trap, Inc., that accepts bullets fired from most angles, producing little or no lead dust and reducing both fire risk and range noise.

It uses an engineered mixture of chunk rubber and hydrated potassium or sodium polyacrylate-polyamide gels consisting of approximately 60% rubber and 40% hydrated polyacrylate (by volume). The medium will resist ignition even when fired on with tracer rounds or when deliberately exposed to ignition sources that set fire to conventional rubber media. The addition of a phosphate-rich buffer material reduces the solubility of lead in any drainage water that might be produced in the trap. By combining a stable gel and a solid buffering material, it is possible to create a mixture that will maintain water-absorbing characteristics of the gel for years.

GEL-COR™ is the only bullet-trapping medium of its kind that has demonstrated fire resistance by passing the American Society for Testing and Materials E 108-00, Section 9, Burning Brand Test using Class A, Class B, and Class C burning brand ignition constructions.

By combining GEL-COR™ with another GSL-developed product (SACON®), GSL researchers developed a new, environmentally friendly, bullet-trapping system. GEL-COR™ is used as the interior bullet-trapping medium, and SACON® can create the frame around the outside of the trap.

Military and law enforcement training ranges and recreational shooting ranges face a number of serious safety, environmental, and cost issues. Bullet traps are finding increasing use on ranges as a method of preventing the loss of potentially toxic metals (especially lead) into the range soil and local groundwater. The chunk rubber-type media have been well accepted because they can capture many types of bullets intact, producing little or no lead dust. The resilient and porous surface reduces the amount of noise of the range and will accept bullets fired from any angle. GEL-COR™ improves the performance of these traps by removing the problem of fire in the medium and significantly reducing any chance of lead from spent bullets leaving the range in drainage from the trap or as dust.

The implementation cost of the GEL-COR™ firing range backstop depends on a number of factors, including square footage, foundation, location/access, SACON® perimeter, and whether the facility is to be indoors or outdoors. The bullet trap costs can range from as little as $450 to $2,200/linear foot of trap width. In certain cases, existing dirt berm, steel, and other rubber trap systems can be retrofitted with the GEL-COR™ bullet-trapping system to improve the range owner's training capabilities, safety, and environmental stewardship.

The combination of fireproofing, dust control, and immobilization of the lead in the trap solves many of the problems seen in earlier bullet-trapping media. The ERDC-developed bullet-trapping system provides both military and commercial shooting ranges the safest, most environmentally friendly and cost-effective system available. Furthermore, because of its design and heat-suppression capabilities, the GEL-COR™ range backstop can accommodate automatic small arms and calibers up through .50 caliber, unlike other traditional rubber trap systems.

Granular Rubber

This alternative consists of the following major components:

- A frame with a matrix of granular rubber between a rubber membrane cover and an impermeable liner placed behind each target;
- Depending on the system, matrix on either an earthen berm at a specific slope or supported by a metal frame;
- Frontal soil berms constructed of on-site soil;
- When advised, existing berms enlarged and modified to support the traps; and
- Bullet removal and maintenance after 40,000–60,000 rounds per trap.

Granular rubber containment systems are similar to typical earthen berms in design except instead of using soil to stop projectiles, recycled rubber material is used. Most granular rubber designs employ vehicle tires that have been chipped to the size of a large marble. These rubber chips are applied in a thick layer over a foundation or support structure. The depth of the granular rubber is 15–18 in. deep at the bottom and top of the angled support structure, and 28–30 in. deep in the center of the trap where most of the projectiles are fired. Some containment system designs include roofs that help keep water from infiltrating into the rubber matrix and potentially transporting lead into the environment. Some designs include a rubber membrane that covers the granular material (see Figure 2-6). The membrane further minimizes transport of dust or debris and minimizes infiltration of water or snow that may cause migration of metals into the environment. Some designs include a liquid collection system at the bottom of the trap to manage any water that may be collected in the trap.

Figure 2-6. Example of Granular Rubber Projectile Containment System (MAARNG 2007a)

Projectiles fired into the rubber are captured safely and are left virtually intact, with minimum deformation and almost no fragmentation. Rounds can be shot from any distance without ricochet or back splatter. Tracer ammunition is not an option for some granular rubber traps due to the potential fire hazard.

Three types of granular rubber systems were considered in this analysis:

- Reclining GranTrap by Meggitt Defense Systems-Caswell
- Environmental Projectile Catcher by STAPP
- Super Trap® Backstop System by SuperTrap

Deceleration

This alternative consists of the following major components:

- Steel plates that funnel bullets into a circular deceleration chamber,
- Collection chamber to concentrate bullets and fragments in one area,
- Size consistent across the range due to sizing of traps,
- Frontal berms constructed of on-site soil screened of large rocks, and
- Existing berms enlarged and modified to support traps and concrete pad.

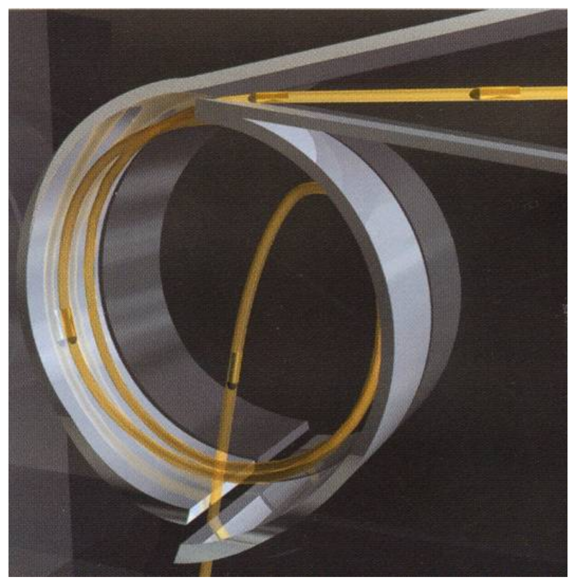

Figure 2-7. Cross-Section of Deceleration Chamber

This trap has steel plates on top and bottom to funnel projectiles into a circular deceleration chamber. The chamber resembles the shell of a snail and projectiles revolve in it until they lose energy and drop into the collection chamber below (see Figure 2-7). In some systems, an auger conveyer is placed beneath the deceleration chamber to collect and transport the projectiles to a bucket at the end of the system.

“Wet system” deceleration traps use a specially formulated biodegradable liquid lubricant that circulates through the trap, coating projectiles and virtually eliminating airborne metals dust. These wet systems can accept tracer fire. Use of tracer rounds requires that the collection bucket be lined with sand to mitigate potential fire hazards. The use of tracer ammunition may scorch the system and degrade the auger, requiring premature replacement. These systems can support oblique fire and ammunition up to and including .50 caliber.

Three types of deceleration systems were considered in this analysis:

- Projectile Trap Rifle Model R494 by Shooting Ranges International
- Total Containment Trap (T3) by Action Target International
- Colt Projectile Catcher by Rapid Range LLC

Impact/Deflection Traps

This alternative consists of the following major components:

- Steel plates behind targets that deflect bullets into sand or water-filled basin below,
- Frontal berms constructed of on-site soil screened of large rocks,
- Consistent plate size across the range, and
- Enlargement and modification of existing berms to support plates.

Several types of impact, or deflection, projectile containment systems are available. The general premise is that projectiles strike a steel plate, thereby stopping and often fragmenting the projectile. When projectiles strike the plate, set at an angle to the projectile trajectory, they are deposited into a sand or water-filled basin.

Some lead dust is generated as the projectiles impact the plate at high velocity. The lead dust can be managed with the installation of air pollution control equipment. Outdoor systems may also include an overhead roof structure to minimize the amount of precipitation collected in the sand/water basin. The type and thickness of plating depends on the ammunition used. Steel plates can be fabricated to support training with small arms ammunition up to and including .50 caliber.

Three types of impact systems were considered in this analysis:

- Escalator, LE4000 model by Meggitt Defense Systems
- Flat Trap by Action Trap International
- Steel Projectile Traps by MGM Targets

Non-lead Training Rounds
This alternative consists of the following major components:

- Use of copper or steel ammunition for training on SARs,
- No additional backstops needed to capture bullets, and
- Frontal berms made from on-site soil screened of large rocks.

Historically, Army small arms ammunition has been manufactured of lead. The majority of ammunition fired today in the U.S. military is manufactured with a lead core and copper jacket. Recently, the military has explored manufacturing and using ammunition that does not contain lead cores. Alternative materials for small arms ammunition include steel, copper, and tungsten-nylon (currently banned at Camp Edwards as a potential contaminant).

Copper. These projectiles are lethal and posses ballistic properties similar to those of lead-projectile ammunition. The Army ammunition inventory does not stock copper projectiles because there is no recognized Army requirement for all-copper projectiles and they have not undergone acceptance testing for ballistics, safety, and capability to train a soldier to mission standard[6]. A number of commercial sources (e.g., Barnes) have recently released 100% copper projectile ammunition primarily geared to the private civilian hunting/shooting market.

[6] The Army Training and Doctrine Command is responsible for testing alternative ammunition to ensure it meets these requirements. To meet these rigorous standards, the Army conducts a multi-year testing process for each new

Steel. These projectiles are lethal and posses ballistic properties similar to those of lead-projectile ammunition. Steel special armor piercing rounds for the .50 caliber M2 machine gun have undergone acceptance testing and are currently in the Army ammunition inventory. These rounds penetrate targets (as well as materials in front of and behind targets) much more efficiently and have a much larger effective range than lead-projectile counterparts.

Recently, at least one manufacturer (i.e., NAMMO) developed, tested, and released 5.56mm ammunition with non-lead projectiles and primers that meet NATO performance standards. As described for copper projectile ammunition above, the Army has no recognized requirement for such a round and it has not undergone acceptance testing for ballistics, safety, and capability to train a soldier to mission standard.

To conduct realistic training and qualification of marksmanship skills, soldiers must become proficient with a combination of weapon and ammunition that precisely matches what they will employ during combat. The Army conducts a strict and exhaustive acceptance testing and type classification process for projectiles of alternative compositions before they are procured and stocked in the Army ammunition inventory.

2.2.3 Alternatives Summary

Ten BMP/P2 alternative technologies were evaluated with respect to lead containment, support of military training objectives, initial installation and maintenance cost, and adaptability. The general analysis follows and the cost analysis is summarized in Table 2-1.

Table 2-1. Alternatives Summary

Alternative	Capital Cost	Maintenance Cost/Year
Earthen berms	$272,000	$147,000
Enhanced earthen berms	$378,000 to $826,000	$142,000
Concrete block	$478,000 to $506,000	$122,000
Rubber block	$882,000 to $1.7 million	$207,000
GEL-COR™	$405,000 and $2 million[a]	Currently not available
Granular rubber	$1.1 million to $3.4 million	$222,000
Deceleration	$1.1 million to $3.9 million	$197,000 to $710,000
Impact/deflection traps	$386,000 to $641,000	$131,000
Non-lead training rounds	$189,000 to $380,000	$33,000 to $183,000
Proposed BMP/P2 strategy[b]	$143,125[c]	Not available[d]

[a] Capital cost does not include cost for framework.
[b] Initial cost based on one earthen end berm, one earthen overshot berm, four earthen wing wall berms, and 80 earthen SITs.
[c] Line of sight analysis is advised for estimating the size of the geotextile wing walls before developing the cost for the geotextile covers for the overshot berm and wing walls.
[d] Cannot account for longer term adaptive technologies. No value or evaluation from this regard can be conducted.

alternative. If met, the alternative ammunition would undergo a procurement process, as outlined in Army Regulation 710-2-2 (HQDA 1998). As of Fiscal Year 2007, no other alternative met or exceeded standards and was not procured for the Army ammunition inventory.

Earthen Berms. Earthen berms contain lead projectiles and fragments, but may allow weathering and migration of dissolved lead. MAARNG can conduct Army training with this alternative, but it may have some line of sight impacts.

Enhanced Earthen Berms. Enhanced earthen berms contain lead projectiles and fragments; they also provide for containment of dissolved lead. MAARNG cannot conduct Army training with this alternative because it will have line of sight impacts.

Concrete Blocks. Concrete blocks contain lead projectiles and fragments; projectile interaction with the material inhibits the leaching of dissolved lead. MAARNG can conduct Army training with this alternative, but it will have some line of sight impacts, and creates hazardous/solid waste in addition to the lead projectiles.

Rubber Blocks. The rubber block alternative contains lead projectiles and fragments. Fired projectiles striking deposited projectiles can create some lead dust. Some vendor's blocks cannot accept tracer fire. MAARNG can conduct Army training with this alternative depending on the selected vendor, but it will have some line of sight impacts.

GEL-COR™. GEL-COR™ contains lead projectiles and fragments; projectile interaction with the material inhibits the leaching of dissolved lead. MAARNG can conduct Army training with this alternative, but it will have some line of sight impacts. GEL-COR™ also accepts bullets fired from any angle, producing little or no lead dust and reducing both fire risk and range noise.

Granular Rubber. Granular rubber projectile traps contain nearly all lead; there is little to no lead dust created upon impact with the projectile trap cover. Only one brand of this style trap can accept tracer rounds. MAARNG can conduct Army training with this alternative depending on the selected vendor, but it will have some line of sight impacts. With 90 traps on Sierra Range, maintenance of this alternative would be labor intensive.

Deceleration. The deceleration alternative captures lead projectiles and fragments in the chamber. Lead dust is generated upon impact, and is not captured by the system. The oil applied to minimize dust is not an option for cold weather climates; furthermore, the oil may ignite with tracer fire. There is also a chance of dissolved lead migration. The system requires significant range downtime for maintenance activities. Although MAARNG can conduct Army training, installation of this alternative is likely to affect line of sight for downrange targets.

Deflection/Impact. In deflection systems (e.g., impact traps), projectiles fragment when striking the steel plate and create lead dust upon impact. The system captures most of the lead fragments; however, lead dust and dissolved lead is not contained by the system, possibly resulting in a release to the environment. MAARNG can conduct Army training with this alternative, but the size of the trap will have a significant affect on line of sight for downrange targets. The three vendors did not advise their product in this situation as it is more suited for an end of lane application.

Non-lead Ammunition. The use of non-lead training rounds introduces no lead to the environment. In this alternative steel or copper is distributed over a relatively large area concentrated behind targets. This alternative would have no impact on line of sight. Training with the same ammunition used in combat provides the most realistic training for the Soldier. Substituting ammunition that does not provide the same stimuli to the Soldier during the firing process will not allow the Soldier to maintain proficiency. Furthermore, there could be a safety risk to the Soldier in substituting alternative ammunition because the Soldier would be unfamiliar with the use of lead ammunition in combat. As soon as a non-lead round is approved and available through normal ammunition channels for training it will be used. Moving forward with any BMP/P2 plan or strategy should be forward compatible with a potential alternative projectile. The following section provides a detailed description of the proposed BMP/P2 strategy for Sierra Range, which will be compatible both with emerging technologies and alternative projectiles, while protecting the environment from lead and other contaminants.

3. PROPOSED BMP/P2 STRATEGY FOR SIERRA RANGE

As advised by AO2, BMP/P2 technology alternatives, including those suggested by the EPA, were evaluated using the methodology presented in Section 2. The following is the proposed BMP/P2 strategy to return Sierra Range to live fire training using lead ammunition. The strategy takes into account the requirements of EPA AO1/AO2, MGL Chapter 47, and EPSs. The strategy is presented such that appropriate alternatives and emerging technologies can be applied to this range to further protect the environment from lead and other contaminants of concern by proposing a continuous process improvement strategy.

The proposed Sierra Range BMP/P2 strategy is comprised of three core elements: three dimensional, time phased, and process improvement. The three-dimensional element refers to the physical area of the range defined by the length x width x depth. Time phased refers to the actions advised before operations (e.g., soil conditioning, construction, etc.); near term operations (e.g., monitoring and maintenance, OMMP); and long term operations (e.g., projectile pocket remediation, review, modification, and implementation of OMMP based on observed and monitored conditions). The process improvement element is designed to be adaptable to the monitored conditions and applies previously reviewed complementary alternative P2 technologies as identified in an incremental process improvement strategy (ITRC EMP). An outline of the proposed BMP/P2 strategy, also known as the range adaptive management process (RAMP), is provided below.

I. Three Dimensional—Projectile management area for Sierra Range will be created to contain a majority of projectiles within the range footprint approximately 200 × 300 m (16 acres). Physical components of the projectile management area are:

   A. A continuous end berm at the 300-m firing line, connecting the existing 300-m target berms (width).
   B. An overshot barrier of geotextile, 2 m tall, on top of the 300-m continuous end berm.
   C. Berms (“wing walls”) at the east and west sides consisting of geotextile 2–3 m tall creating side baffles (length).
   D. Projectile management layers (depth).
      1. Berms (end, sides, and SITs) visual inspection, projectile pocket maintenance.
      2. Surface layer, visual inspection, and soil sampling.
      3. 18–36 in. layer, soil sampling.
      4. 36–60 in. layer, pore water sampling.
      5. 60 in. to groundwater (NO GO) layer, groundwater monitoring wells.

II. Time Phased—Before Operations, Near Term Operations, Long Term Operations.

   A. Before Operations complete range modifications to support proposed BMP/P2 strategy before resuming live fire training.
      1. Remove rock/debris range floor, rough grade, plant grass.
      2. Screen and replace SIT frontal berm soils.
      3. Construct 300-m end berm.
      4. Construct 300-m end berm overshot barrier.

5. Construct left/right wing wall/baffle.
6. Conduct comprehensive test live fire (n=5,000 rounds).
7. Establish soil monitoring plots for sampling.
8. Install lysimeters for pore water sampling.
9. Establish vegetation cover.

B. Near Term Operations.
1. Track target/lane/range usage.
2. Visually observe berms and barriers for impact zone development.
3. Repair berm wear.
4. Visually observe range floor and berms for impact zone development at 10,000, 50,000, and 100,000 rounds.
5. Repair range floor and berm wear.
6. Monitor soil conditions.
7. Conduct soil sampling.
8. Sample lysimeters.
9. Implement further alternatives as identified in need and functionality.

C. Long Term Operations.
1. Implement projectile pocket remediation.
2. Use tracked data (throughput), visual inspections, and monitoring results to implement complementary alternative P2 technologies to improve performance of the BMP/P2 strategy.
3. Develop timelines for range floor remediation efforts based on observed results and agreed upon standards.

III. Process Improvement—A focus to improve Sierra Range BMP/P2 Plan.

A. Incorporate known BMP/P2 technologies and systems from this alternatives analysis during the process improvement evaluations.
B. Evaluate emerging BMP/P2 technologies for inclusion in the current alternative P2 technology suite.

3.1 Three-Dimensional Range Concept

The Three-Dimensional Range Concept views the entire range footprint as a projectile management area with two main functions: projectile containment and projectile management. Projectile containment is accomplished by the construction of earthen berms based on known projectile flight characteristics, target locations, training plans, and observed (adaptive) range wear (projectile impacts). Projectile management uses current accepted range management and maintenance practices to protect the environment from long-term live fire effects.

The Sierra Range RAMP proposes that the range will be managed with the goal of preventing lead migration to groundwater. Projectiles will be largely contained within the range area, areas of primary projectile impact, and the associated berms (see Figure 3-1).

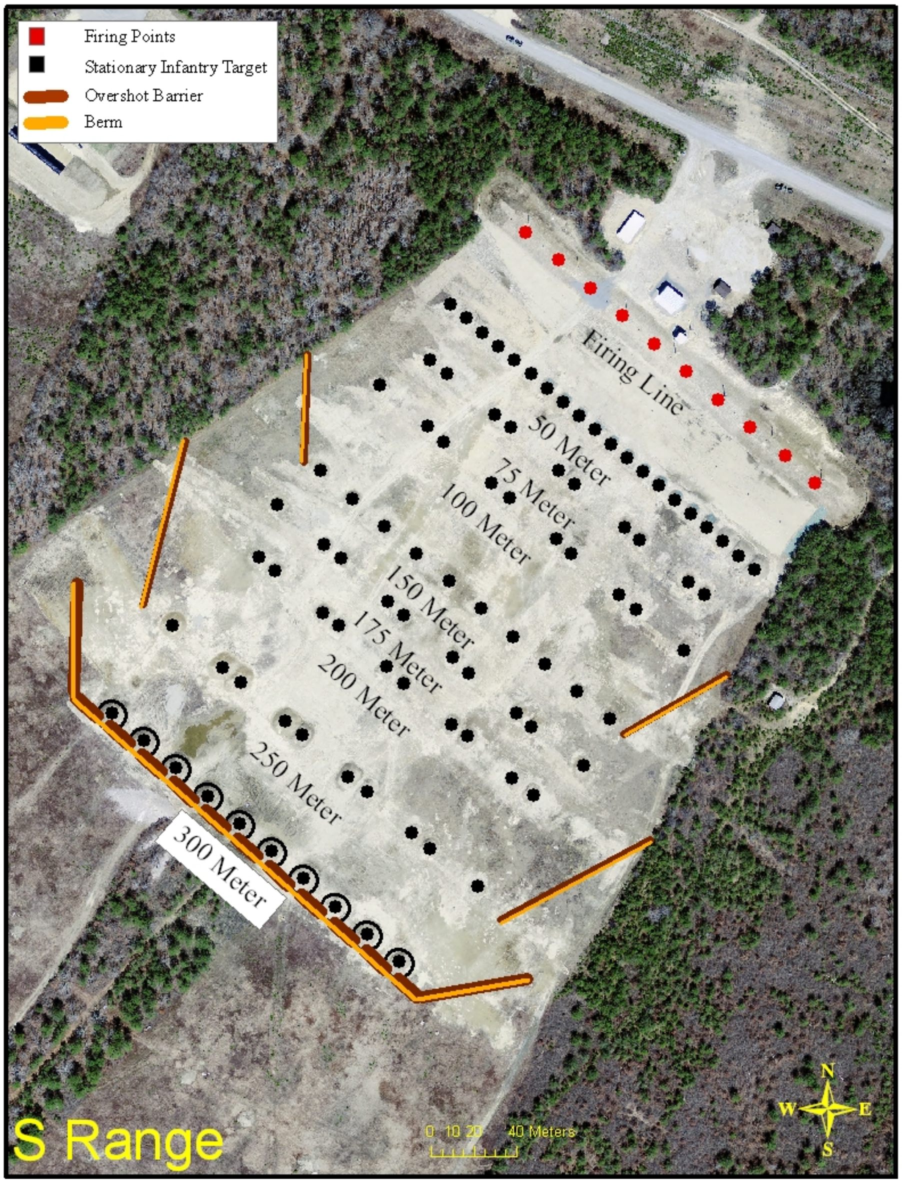

Figure 3-1. Sierra Range Projectile Management Area

3.1.1 Projectile Management Area

The construction of the projectile management area (see Figure 3-1) will use clean fill material. As part of an overall Camp Edwards P2 plan for SAR management, when practical, soils previously associated with SARs will be used in a coordinated way so as to reduce the creation of additional live fire impacted soils. This concept takes into consideration the environmental value of removing soils from former ranges where they are unmanaged and relocates them to active ranges where they can be managed under the P2 plan for that range. In general, berms constructed within the projectile management area (i.e., the range end berm at 300 m and the individual SIT frontal berms) will use a clean fill core and will be capped with 18 in. of ½ in. minus screened soil to support vegetation. The 300-m overshot wall and range wing walls will be constructed using geotextile products and screened soil as filler with geotextile caps to inhibit vegetation growth. The use of geotextiles for the construction of the overshot and wing wall berms supports the adaptability of the RAMP by allowing height adjustment of each berm if needed based on observed live fire operations. Line of sight analysis, drainage assessment, and berm design will be conducted prior to construction.

End Berm
The end berm is located at the 300-m target line and extends the width of the projectile management area. The existing 300-m SIT berms will be merged with fill to create a continuous berm approximately 4 m tall, 15 m wide at the base, and 5 m wide at the SIT elevation. Where appropriate, drainage structures will be installed to mitigate impounding of surface water due to the existing range floor topography and constructed berms.

SIT Frontal Berms (n=80)
Soils of the existing frontal berm at each target location will be screened and replaced. Because of the existing range topography, the line of sight analysis will be conducted to evaluate the extent of the soils at each frontal berm that need to be screened and replaced.

Overshot Berm
The overshot berm will be constructed behind the 300-m target line located on top of the 300-m end berm using geotextile barrier materials such as DefenCell®. The proposed dimensions are 2 m tall, 1 m wide at the base, and as wide as the proposed 300-m end berm.

Wing Wall Berms
Four geotextile berms will be constructed at an oblique angel to the far left and right side firing lanes. Due to the existing range floor topography, the constructed height of each individual wing wall will be evaluated by the line of sight analysis.

3.1.2 Projectile Management Layers

The projectile management layers component of RAMP consists of the following BMP/P2 strategies:

- Berms (end, wing wall, and SIT frontal berms) visual inspection, projectile pocket maintenance
- Surface layer, visual inspection and soil sampling
- 18–36 in. layer, soil sampling
- 36–60 in. layer, pore water sampling
- 60 in. to groundwater (NO GO) layer, groundwater monitoring wells

Throughout the training year, berms will be maintained to manage projectile pockets and encourage vegetation growth for berm stability and erosion prevention. The berms will be monitored by visual inspections throughout the training year to evaluate whether maintenance actions are advised. Materials will be kept on hand (loam, seed, mulch, straw, hydro seed, tackifier) to make repairs to projectile pockets. Berms will be mowed only to improve target visibility. Annually, soil condition will be evaluated (i.e., soil pH) to estimate the proper amounts of soil conditioners (e.g., lime, fertilizer, or compost) and the proper vegetative cover. Soil conditioners will be applied as evaluated. In the long term (i.e., every 5 years) projectile pocket harvesting will be initiated.

Surface soils will be actively monitored by visual inspections and sampled annually for metals and soil chemistry to maintain recommended soil conditions to retard lead mobility. This layer would have periodic removal of projectiles (long term maintenance) to decrease the potential sources of lead migration. Areas of action will be delineated by observed projectile impacts and reinforced by other sampling methods (i.e., XRF). Actions such as soil tilling and amending with lime or fertilizer will be used to maintain recommended soil conditions to further retard lead mobility.

The top 18–36 in. of range soil will be sampled annually for metals and soil chemistry to maintain recommended soil conditions to retard lead mobility. Sampling will be conducted along the target lines, which have the statistically largest number of projectiles based on qualification firing tables (see Table 1-2). Consistent with the approved action levels established for Juliette, Kilo, and Tango Ranges, acceptable operational, interim, and cease operation limits will be established for lead on Sierra Range.

In the top 36–60 in. the range floor, pore water sampling will be collected by lysimeter. This range is the lower end of the projectile management layer where MAARNG does not expect to find detectable lead (above natural background). Pore water sampling would be conducted annually unless more frequent sampling is advised. It is expected there may be some accumulation of lead, but detections above the accepted action levels would be an automatic trigger point to temporarily suspend training to estimate how widespread the migration of lead is and whether mitigation or changes to the RAMP are advised.

In range soil from 60 in. to groundwater (No Go), detection of lead is not expected. Existing groundwater monitoring wells will be sampled annually. Lead detections at groundwater wells would trigger immediate cessation of firing and resampling of Sierra Range lysimeters.

3.2 <u>Time Phase</u>

The second element of the RAMP for Sierra Range is time phased implementation of available BMP/P2 alternative technologies and current accepted live fire range BMPs. This approach allows for the approved BMP/P2 to be adapted according to observed impacts related to the return to live fire training. The following phases relate to the actions advised before operations (e.g., soil preparation, construction, etc.), near term operations (e.g., maintenance, OMMP), and long term operations (e.g., projectile pocket remediation, review of OMMP).

3.2.1 Before Operations

These are the actions advised to prepare the range for returning to live fire. Regardless of the containment process selected for Sierra Range, the range will require a major effort to remove the surface rock from the range floor and SIT frontal berms. The surface rock does not represent a safety hazard or diminish the effectiveness of the surface danger zone. The purpose is to increase the efficiency of the selected containment system by minimizing the fragmentation of projectiles. The construction of berms, overshot barriers, and wing walls comprising the projectile management area will comply with the analysis described in Section 3.1.1. A comprehensive live fire test period (n=5,000 rounds) will be conducted to identify preliminary locations for the sampling plots and whether additional construction (e.g., individual SIT berms) is advised prior to entering the near term phase. Soil monitoring plots will also be established and lysimeters will be installed for pore water sampling. Finally, the projectile management area will be loamed and seeded to support good vegetative cover.

3.2.2 Near Term Operations

Near term operations are those actions that will be taken to manage Sierra Range while being reactive to monitored range conditions. Actions here include tracking target, lane, and overall range throughput. This tracking along with visual inspections will indicate where projectile pockets develop at the end berms, wing walls, SIT frontal berms, and the overall range floor. During this near term phase the range management area will be maintained by regularly scheduled and as-needed maintenance based on the visual inspections. Soil conditions (e.g., pH) will be monitored and adjusted as needed and soil and pore water sampling for lead will be done per the OMMP when developed. The ongoing live test fire period will use benchmarks of 10,000, 50,000, and 100,000 projectiles fired to validate the established sampling plots and make adjustments as advised. The near term operations phase is critical to support the adaptive process element of the RAMP. It allows for a managed collection of actual data based on live fire training to validate the selection of appropriate BMP/P2 alternate technologies to improve the performance of this strategy. Additionally, the near term phase will develop planning information for the long term operations phase.

3.2.3 Long Term Operations

Long term operations are those actions undertaken 18 months, 36 months, and 60 months for the long term management of Sierra Range. Projectile pockets will be screened with the intent to reduce overall metal loading in the berms and the range as a whole (projectile management area). Pockets will be replaced with screened loam and seed to reestablish good vegetative cover. Using knowledge learned during the near term operations phase, an ongoing BMP/P2 review will be used to select appropriate BMP/P2 alternate technologies for incorporation into the Sierra Range RAMP. Emerging BMP/P2 technologies (i.e., soil amendments, projectile capturing technology, and/or replacement projectiles) will be added to the list of evaluated technologies and enhance the long-term effectiveness of the strategy. Timelines will be developed for projectile management area remediation efforts based on observed results and agreed upon standards. Timelines for remediation may be based on duration of operation (time) or cumulative operational throughput (total projectiles fired).

3.3 <u>Process Improvement</u>

The Process Improvement element of the RAMP relies on the foundation created by the three-dimensional projectile management area and the time phased operations and maintenance activities. These two elements form the RAMP strategy framework to return to live fire training using lead ammunition and they establish the mechanisms to accumulate knowledge based on actual training and observed sampling. Incremental changes to the BMP/P2 strategy are possible to adapt the strategy based on observed realities (e.g., projectile pocket locations, line of site, changes to training requirements), and to select P2 alternate technologies both known and emerging as appropriate. This process is the recommended method to allocate limited resources (i.e., time, financial, and environmental) without committing to a single BMP/P2 technology up front. This avoids selection of a plan that may not be as comprehensive and effective as originally presumed.

The BMP/P2 alternative technologies evaluations, as advised under AO2, have produced a suite of known BMP/P2 technologies and systems that may be incorporated during the process improvement evaluations. Benchmarks have been set during the before and near term operations (5,000, 10,000, 50,000, and 100,000 fired rounds) to reinforce the continuous assessment of the effectiveness of the plan and to incorporate advised adjustments.

Emerging BMP/P2 technologies will be evaluated for inclusion in the current alternative P2 technology suite. Examples of emerging technologies are the replacement of lead in the Army service ammunition, improvements in lead binding by use of soil amendments like Apatite II and ferric oxide, or the use of heavy metal extraction systems like Dynaphore sponge media for water.

Through comprehensive data and information collection and analysis, knowledge will be gained such that the strategy of process improvement will be ongoing.

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4. CONCLUSIONS AND RECOMMENDATIONS

The RAMP or BMP/P2 strategy and alternatives analysis represents MANG's earnest effort to use the knowledge gained under the requirements of the EPA issued AO2 and EPS 19 under MGL Chapter 47 to develop a comprehensive, actionable, and adaptive plan to return to live fire training on Sierra Range. The proposal creates a framework that is based on the science derived from years of study of the specific site characteristics found on Camp Edwards, the continuous evaluation of BMP/P2 technologies, and the incorporation of recommendations for SAR BMP/P2 development made by ITRC (2005).

The RAMP BMP/P2 strategy is not a simple return to live fire, known as "fire and forget," into earthen berms as was the practice prior to AO2 and Chapter 47. The strategy acknowledges the overall goal of AO2 and Chapter 47 to be protective of the groundwater and environment by establishing a clear and well-defined plan with measurable outcomes.

Based on the alternatives analysis (Section 2 and Appendix A), the evaluated BMP/P2 alternative technologies cannot be implemented as a stand-alone solution or coupled together to make a patchwork of solutions that is proven, easily managed, and cost effective. These alternative BMP/P2 solutions would require extensive preparatory site work (support berms). Each BMP/P2 alternative would require a commitment of time and resources to validate whether the technology actually performed as intended. Each of the projectile containment systems would need to be modified from its designed purpose, has the potential to create additional solid waste that would have to be managed into proper waste/recycling streams, and would not be advised if an alternative projectile is adopted by the Army. Additionally, each of these systems has some line of sight impact on training across the range, the degree of which cannot be fully assessed without full-scale testing.

The proposed Sierra Range BMP/P2 strategy is comprised of three core elements. They are three dimensional, time phased, and process improvement, which are designed to be adaptable to monitored conditions. Three-dimensional refers to the physical area of the range. Time phased refers to the actions advised before operations (e.g., construction, etc.), near term operations (e.g., monitoring and maintenance, OMMP implementation), and long term operations (e.g., projectile pocket remediation, implement modification of OMMP as advised). Process improvement phase refers to applying previously reviewed and emerging complementary alternative P2 technologies as identified in an incremental process improvement strategy (ITRC EMP).

A series of test firing before and during operations will provide knowledge to aid in adopting more environmentally protective methodologies that will allow for continuous improvement in the goal of eliminating lead projectiles from freely entering the surrounding environment and potentially threatening the groundwater supply.

Monitoring is advisable to assess the effectiveness of any BMP/P2 strategy. MAARNG will establish oversight and monitoring BMPs to evaluate whether the conditions on Sierra Range limit or mitigate lead mobility within the environment. To accomplish this on the Sierra Range, Camp Edwards will institute a monitoring program for soil, soil pore water, and groundwater as presented in Section 3.1.2. As on Juliet, Kilo, and T Range MARNG suggests the establishment of interim triggers for focused assessments, action levels, and maintenance actions. Based on monitoring results of soil, lysimeter, and groundwater sampling, Camp Edwards would initiate corrective and preventive actions and as part of the proposed process improvement strategy. This would in turn move toward the goal of preventing or eliminating lead from the environment at Cape Edwards and the Upper Cape Water Supply Reserve.

The RAMP BMP/P2 strategy is, by design, adaptable while providing an opportunity to react to observed/monitored conditions. It mitigates an accidental concentrated release of lead that is possible if other systems were used and failed (e.g., STAPP systems holding thousands of gallons of water that has to be managed) and would be in the end most protective of the environment.

Ten different bullet containment alternatives were evaluated with respect to lead containment, support of military training objectives, initial installation and maintenance cost, and adaptability; the general analysis is summarized in Section 2 and Appendix A. After consideration and analysis, none of these technologies were identified as a viable stand-alone BMP/P2 solution to return Sierra Range to live fire training.

MANG advises that Sierra Range return to live fire by implementing the proposed RAMP BMP/P2 strategy as presented in this document while adapting and adopting alternatives, the goal of which is the prevention and elimination of lead from the environment.

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Appendix A
Alternatives Analysis

EARTHEN BERMS			
	Backstop is a properly sized and positioned soil mound placed behind the targets to contain projectiles. This alternative involves moving and contouring on-site soil to form a new larger berm behind each of the targets. The backstop berm faces (area designed to receive projectiles) sized based on the distance from firing line. Berm faces are 6 × 6 ft (50 m x 2, 75 m, and 100 m), 9 × 9 ft (150 m, 175 m, 200 m, and 250 m), or 12 ×12 ft (300 m). Frontal soil berms installed to protect target mechanism. Proper slopes and vegetative cover are maintained on berms.		
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead projectiles and fragments will be largely contained in soil berms. Some lead dust and ricochets are created when fired projectiles impact rocks or other deposited projectiles. Limited dissolution/corrosion of lead in soils at Camp Edwards.	3
	Ease of Lead Recovery and Recycling	Periodic lead recovery is advised to "mine" the projectiles from the berm face for recycling and disposal. Remove/recover lead in areas of concentrated projectile impact (in projectile pockets behind targets) every 5 years. There are vendors and established processes to recycle lead from soil.	2
	Protection from Weather Conditions	Some protection from weather conditions. Regular maintenance of projectile pockets and annual re-seeding of the berms will reduce the erosion and exposure of embedded projectiles to weather conditions.	2
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Some range downtime when periodic lead recovery activities take place. Estimate the range will be closed for one month every 5 years to remove lead from the berms; projectile recycling activities will be performed outside of peak training times.	4
	Supports Necessary Training Quality (LOS, 5.56 ammo)	MAARNG can conduct Army doctrinal training. May affect line of sight for some downrange targets.	3
	Availability of Method	Widely available. Earth moving and survey equipment would be advised .	5
	Environmental Monitoring Requirements	Soil sampling, periodic soil removal, pH testing and maintenance, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
ADAPTABILITY	**Emerging Information**	Because earthen berms are made of just soil, they could be converted to support new projectile containment structures or removed entirely. They would also be effective at capturing non-lead ammunition	4
	System Scalability	An earthen berm at each SIT may cause line of sight issues. It would also be difficult to implement and prevent from eroding because it would be smaller in size than an end-of-range berm. However, an earthen berm could easily be placed at the end of the range but may not capture all projectiles	3
	BMP/P2 Technology Pairing	Could be paired as a supporting structure for other projectile containment systems or for overshot capture	4
	Unintended Consequences	Earthen berms have the ability to erode which would decrease their ability to effectively capture projectiles and would increase the possibility of projectile fragmentation. Also would expose ammunition to weathering and precipitation. However, vegetated berm slopes would help to prevent erosion.	2
	Technology Transfer	Soil from berms on Sierra could be transported with trucks or heavy equipment for use on other ranges or installations	3
COST	**Capital Cost**	**Frontal Soil Berms:** Per Target: Costs include labor, equipment rental, soil placement, transportation on-base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100	4

EARTHEN BERMS			
		(4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top). Range: $9,270 ($103 × 90) **Backstop Soil Berms:** Per Target: Costs would include labor, surface grading, earth moving, materials, transportation, and seeding to construct a backstop berm behind each of the 90 targets. The estimated cost per 6 × 6-ft berm is $1,300; per 9 × 9-ft berm is $3,600; and per 12 × 12-ft berm is $7,600, see Earthen Berm cost estimate sheet. Range: $272,000 (40 × $1,300 + 40 × $3,600 + 10 × $7,600) The Earthen Berm alternative would cost $272,000 to implement.	
	O&M Cost	**Soil Treatment:** 1,000 tons of soil cost $332,000 ($332/ton) to treat; 5,000 tons of soil cost $500,000 ($100/ton) to treat; and 10,000 tons of soils cost $700,000 ($70/ton) to treat.[a] Estimated amount of soil to be treated on Sierra Range is approximately 1,000 tons every 5 years. Therefore, lead removal/recovery in areas of concentrated projectile impact areas would cost $332,000 every 5 years (1,000 tons at $332/ton), or $66,400/year. **Berm Maintenance:** Erosion repair and resurfacing, mowing, and fertilizing of the earthen berms are advised for target visibility and to minimize soil erosion. Pockets in the surface created by repetitious fire need to be repaired to mitigate projectiles from impacting each other and pulverizing. Berm maintenance costs are estimated at $22,500 annually ($250/berm × 90 berms) to rake and re-seed areas of concentrated fire (Dudko 2008). **Environmental Monitoring:** Semiannual sampling/monitoring estimated at $58,500/year. The Earthen Berm alternative would cost $147,400/year to maintain.	5

[a] Data are from a Firing Range Maintenance Study conducted at Fort AP Hill in 2001 (HQDA 2002, App E page 22).

ENHANCED EARTHEN BERMS (soil additives, sand pocket, rain guard, clay layer)			
	Like an earthen berm, a backstop is a properly sized and positioned soil mound behind the targets to contain projectiles. Berm enhancements further reduce the transport of lead. A wooden rain guard limits interaction with precipitation. A sand berm face limits ricochet and projectile damage on impact and simplifies reclamation activities. A clay layer retards the migration of dissolved metals. Soil amendments in sand lens limit corrosion and retard lead migration. The backstop berm faces (area designed to receive projectiles) are sized based on the distance from the firing line. Berm faces are 6 × 6 ft (50 m x 2, 75 m, and 100 m), 9 × 9 ft (150 m, 175 m, 200 m, and 250 m) or 12 × 12 ft (300 m). Frontal soil berms are installed to protect target mechanism.		
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead projectiles and fragments will be largely contained in sand pocket within soil berms. Some lead dust is created when fired projectiles impact deposited projectiles. Dissolved lead is contained in the berm. A clay layer at the base of the sand pocket prevents the vertical migration of lead.	4
	Ease of Lead Recovery and Recycling	Periodic lead recovery is advised to "mine" the projectiles from the berm face for recycling and disposal. Remove/recover lead from projectile pockets each year. Sand lens makes projectile recovery and sifting relatively easy.	3
	Protection from Weather Conditions	A rain guard installed on the top of the berm protects the berm face from precipitation, inhibiting the interaction of water and lead.	4
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Minimal range downtime when periodic lead recovery activities take place. The enhanced berm design may reduce the frequency of maintenance activities and conducting maintenance during off-peak training times; will not interfere with training.	4
	Supports Necessary Training Quality (LOS, 5.56 ammo)	MAARNG can conduct Army doctrinal training. Will affect line of sight for some downrange targets.	2
	Availability of Method	Widely available. Earth moving, basic construction, and survey equipment would be advised .	5
	Environmental Monitoring Requirements	Soil sampling, periodic soil removal, pH testing and maintenance, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
ADAPTABILITY	**Emerging Information**	The elements (e.g., rain guard, clay liner, sand berm face) of an enhanced earthen berm would make it difficult to alter in response to new information on lead mobility. Enhanced earthen berms would effectively capture non-lead ammunition.	3
	System Scalability	An enhanced earthen berm at each SIT may cause line of sight issues. It would also be difficult to implement an enhanced earthen berm at each SIT because each berm would have to be constructed with several additional elements (e.g., rain guard, clay liner, sand berm face). However, an enhanced earthen berm could be easily placed at the end of the range but may not capture all projectiles	2
	BMP/P2 Technology Pairing	Would be difficult to pair with other technologies because of the structure and components of the berm. However, if implemented at the end of the range could be used to capture overshot if paired with other technologies.	3
	Unintended Consequences	The backslope of the earthen berm may erode and not be able to support the remaining enhanced earthen berm structure. Could prevent erosion with a vegetated back slope. The sand bullet capture pit may also erode.	2
	Technology Transfer	Would be difficult to transfer to other ranges or installations because of the rain guard, sand filer, and clay liner. These components would not be easily disassembled, transported, and reassembled	1

<table>
<tr><th colspan="4">ENHANCED EARTHEN BERMS (soil additives, sand pocket, rain guard, clay layer)</th></tr>
<tr><td rowspan="2">COST</td><td>Capital Cost</td><td>Frontal Soil Berms:
Per Target: Costs include labor, equipment rental, soil placement, transportation on-base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100 (4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top).
Range: $9,270 ($103 × 90)

Backstop Soil Berms:
Per Target: Costs would include labor, surface grading, earth moving, materials, transportation, rain guard, clay layer, and possible combinations of soil amendments to sand pocket. The estimated cost per enhanced sand berm sized 6 × 6 ft is $1,859–$3,193; 9 × 9 ft is $4,934–$8,755, and 12 × 12-ft berm is $9,748–$33,833, see Enhanced Earthen Berm cost estimate sheet.

Range: $369,200–$816,250
The following soil amendment combinations are recommended (see enhanced soil berm cost sheet):
Lime and phosphate: $582,263
Ferric oxide and phosphate: $588,081–$816,253
Apatite II: $369,187–$370,642

The Enhanced Earthen Berm alternative would cost between $378,470 and $825,520 to implement.</td><td>3</td></tr>
<tr><td>O&M Cost</td><td>Soil Treatment:
1,000 tons of soil cost $332,000 ($332/ton) to treat; 5,000 tons of soil cost $500,000 ($100/ton) to treat; and 10,000 tons of soil cost $700,000 ($70/ton) to treat.[a] Estimated amount of soil to be treated on Sierra Range is approximately 1,000 tons every 10 years.

Therefore, lead removal/recovery in areas of concentrated projectile impact areas would cost $332,000 every 10 years (1,000 tons at $332/ton), or $33,200/year.

Berm Maintenance:
Earthen berms require erosion repair and resurfacing and fertilizing to minimize soil erosion. Pockets in the surface created by repetitious fire need to be repaired to mitigate projectiles from impacting each other and pulverizing. Lime and phosphate reapplied at projectile pockets once a year with materials cost of $23,000.[b] Berm maintenance labor estimated at $25,000 annually ($275/berm x 90 berms) to repair erosion, resurface, seed, add soil amendments, and rake areas of concentrated fire (Dudko 2008).

Total replacement of rain guards every 25 years at $60,750 (90 rain guards at $675 each), or $2,430/year.

Berm maintenance estimated at $50,430/year.

Environmental Monitoring:
Semiannual sampling/monitoring estimated at $58,500.

Maintenance of the Enhanced Earthen Berm alternative would cost</td><td>4</td></tr>
</table>

ENHANCED EARTHEN BERMS (soil additives, sand pocket, rain guard, clay layer)			
		$142,130/year.	

[a] Data are from a Firing Range Maintenance Study conducted at Fort AP Hill in 2001 (HQDA 2002, App E page 22).
[b] The cost of soil amendments for construction is $113,168 for phosphate and lime. Assume 20% of the soil amendments will be replaced each year in the projectile pocket area (20% of $113,168 = $22,633).

CONCRETE BLOCKS (SACON®, Terran Corporation)			
	The most common concrete block is SACON®. EPA specifically named SACON® in the AO2 issued to MAARNG. This alternative is a modular system of stacked 3 × 3 × 3-ft SACON® blocks behind each target. Four blocks form a 6 × 6 × 3-ft backstop at the 50 m, 75 m, and 100 m distances. Nine blocks form a 9 × 9 × 3-ft backstop at the 150 m, 175 m, 200 m, and 250 m distances. Finally, 16 blocks form a 12 × 12 × 3-ft backstop at the 300 m distance. Using on-site soil, the existing berms supporting each target will be extended behind the target to support the SACON® blocks. Frontal berms will be SACON® T blocks. T blocks are 2 × 4 × 2 ft in size.		
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead projectiles and fragments will be contained in SACON® material. Minimal lead dust created when fired projectiles impact deposited projectiles (Huntsman 2008). A small debris pile forms in front of the trap. Projectile interaction with SACON® inhibits the leaching of lead (ITRC 2005, pg59).	5
	Ease of Lead Recovery and Recycling	Modular system, only worn or filled blocks require replacement. SACON can be disposed of as non-hazardous, solid waste (IRTC 2005, page 59). Recycling is not feasible for SACON®. In an ERDC Study, "Disposal of the used SACON® as a solid waste coupled with the purchase of new aggregate material would be approximately 75 percent cheaper than recovering the aggregate material, therefore, recycling was not proven to be economically feasible (USAEC 1999, page 6).	3
	Protection from Weather Conditions	Limited protection from weather conditions; however, interaction with SACON® prevents lead migration (ITRC 2005, page 59)	4
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Estimated capacity of 10,000 rounds per target before maintenance is advised (USAEC 1996). The manufacturer claims 30,000 round capacity (Huntsman 2008). Some effect on training capacity, range downtime during maintenance activities to rotate blocks. Maintenance would be advisable in 1–3 years (assuming traps are updated at the same time). If blocks are patched, it takes 28 days for the patch to cure causing range downtime (Huntsman 2008a). Conducting maintenance during off-peak training times reduces impacts.	2
	Supports Necessary Training Quality (LOS, 5.56 ammo)	Accepts ammunition up to 7.62mm. SACON® is not flammable (ITRC 2005, page 59) and can accept tracer fire. MAARNG can conduct Army doctrinal training. May affect line of sight for downrange targets.	4
	Availability of Method	Preformed 3 × 3 × 3-ft blocks are widely available. Can form SACON® in different shapes and colors; SACON® takes 28 days to cure.	5
	Environmental Monitoring Requirements	Soil sampling, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
ADAPTABILITY	**Emerging Information**	Concrete blocks could be compatible with new and emerging technologies as support structures for these technologies. However, they may need to be removed entirely in order to implement new technologies. Concrete blocks may be compatible with new ammunition depending on the projectile's penetration capabilities	3
	System Scalability	Concrete blocks at each SIT may cause line of sight issues. But because of their modular structure, they could be constructed with sizes compatible with the distance of the target to the firing line.	3
	BMP/P2 Technology Pairing	Could be used as a support structure for other projectile capture technologies, such as GEL-COR™. Could also be used in coordination with soil amendments or end of range berms	4
	Unintended Consequences	May create solid or hazardous waste debris in front of the projectile trap	1
	Technology Transfer	Could transport concrete blocks to other installations or ranges with ease due to their modular structure	5

CONCRETE BLOCKS (SACON®, Terran Corporation)			
COSTS	**Capital Cost**	A level surface is advised to support SACON®; by using 3-ft blocks no support framework is advised . SACON® blocks can be set on compacted soil and do not require a concrete or steel pad. **Site Preparation:** The construction cost for SACON® block installation, soil leveling, and compaction by Terran Corporation is \$60–100/yd^3 of SACON®, dependent on the amount of excavation and soil type (Huntsman 2008c). Enlarge existing soil berms to create a level surface behind the SIT to place the backstop blocks on. Backstop SACON® blocks are 1 yd^3 in size. 4 blocks × 40 locations, 9 blocks × 40, 16 blocks × 10 = 680 total SACON® blocks. Site preparation would cost between \$40,800 (\$60 × 680 blocks) and \$68,000 (\$100 × 680 blocks) for the backstop blocks. Modify existing soil berms to create a level surface in front of SIT to place SACON® T blocks as frontal berms. Each SACON® T block is 9 ft^2; therefore, 3 T blocks = 1 yd^3. 90 targets / 3 = 30 yd^3 of SACON® for the range. Site preparation would cost between \$1,800 (\$60 × 30 yd^3) and \$3,000 (\$100 × 30 yd^3) for the frontal berms. Total site preparation cost is between \$42,600 and \$71,000. **Frontal SACON® Berms:** Per Target: The cost of one T block (2 × 2 × 4 ft) is approximately \$247 (Huntsman 2009). Using one T block is an option for each frontal berm. Each SACON® frontal berm would cost \$247; shipping is an additional \$5,000. Range: \$27,200 (\$247 × 90 plus shipping) **Backstop SACON® Berms:** Per Target: The cost of each 3 ft^3 block is \$600, or about \$22/ft^3 (Huntsman 2008). A 2-by-2 block configuration, which forms a 6 × 6 × 3-ft SACON® berm behind each target, would be an option based on the SIT size. Each SACON® berm would cost \$2,400. The 9 × 9 × 3ft would cost \$5,400, and the 12 × 12 × 3 ft would cost \$9,600. Range: \$408,000 for SACON® material (\$2,400 × 40 + \$5,400 × 40 + \$9,600 × 10) A SACON® system would cost between \$477,800 and \$506,200, depending on the level of site preparation.	4
	O&M Cost	**Maintenance:** The cost for maintenance, including patching, is generally 10% of the cost of the structure per year (Huntsman 2008d); with a \$435,200 materials estimate, O&M would be \$43,500 annually. SACON® weighs 90 lb/ft^3 – one backstop block weighs 2,430 lb, one frontal berm block weighs 800 lb, which would require heavy equipment to move. Generally, any construction equipment can be used to move blocks except a bobcat. SACON® blocks come with straps to aid in moving them. Blocks may be rotated after 7,100 rounds; they can also be patched in	5

CONCRETE BLOCKS (SACON®, Terran Corporation)			
		place. A "hot-zone" damaged area can be drilled out and replaced with a SACON® core. SACON® blocks at the front of the range will be rotated and replaced more frequently than blocks at the end of the range.[a] Replacement blocks: $600 per backstop block, $247 per frontal berm block, or about $22/ft^3 (Huntsman 2008, 2009). **Disposal:** Filled blocks can be disposed of as solid waste (construction debris) at $100/ton[b]. Each 5.56mm projectile-filled backstop block weighs 2,696 lb[c], and costs $135 to dispose of. Assume annual disposal cost of $20,000[d]. The small debris piles of concrete dust in front of SACON® blocks can be collected when the blocks are removed for disposal and disposed of with the SACON® blocks as solid waste. **Environmental Monitoring:** Annual sampling/monitoring estimated at $58,500. A SACON® system would cost $122,000 a year to maintain.	

[a] The 50-m targets will take 52 rounds (12 plus an additional 50 for night fire and CBRN) per soldier per year, the 150-m targets will take 22 rounds per soldier per year, and the 300-m targets 6 rounds per soldier per year based on FM 3-22.9 qualification tables.
[b] Per a 2007 Massachusetts Construction and Demolition Debris Industry Study (DSM Environmental 2008, page 36).
[c] Each SACON® backstop block holds 30,000 rounds. A 5.56mm projectile weighs 4.02 grams. 30,000 × 4.02 g = 120,600 g or 266 lb. 1 gram = 0.00220462262. SACON weighs 90 lb/ft^2, so one 3 × 3 × 3-ft block weighs 2,430 lb (27 × 90 lb). 2,430 lb + 266 lb = 2,969 lb
[d] Assume 780,000 rounds fired on Sierra Range annually (6,000 soldiers firing 130 rounds each). Therefore, 110 backstop blocks would be disposed of per year (780,000 total rounds/7,100 rounds per block) at a cost of $14,850 (110 × $135 per block), plus $5,000 for labor to move the blocks.

RUBBER BLOCKS

- Vulcan Rubber, Advanced Training Systems, Inc.
- Advanced Anti-Ballistic Composite, Ballistics Research, Inc.
- Dura-bloc, Range Systems

Blocks of various rubber compounds are stacked to form a barrier behind each target: 6 × 6-ft backstop at 50 m, 75 m, and 100 m, a 9 × 9-ft backstop at 150 m, 175 m, 200 m, and 250 m, and a 12 × 12-ft backstop at 300 m. Existing berms will be enlarged with on-site soil to support the traps. Block sizes vary slightly by vendor. Frontal berms of rubber blocks will be approximately 2 ft high and 4 ft wide to protect SIT mechanism from undershot. Frontal berm depth will vary from 8 in. to 1 ft, depending on vendor.

			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead projectiles and fragments are contained in rubber block material. Some lead dust created when fired projectiles impact deposited projectiles. Dissolved lead is contained; lead is bound in rubber blocks.	5
	Ease of Lead Recovery and Recycling	Limited recycling capability; most projectile-filled blocks are disposed of as hazardous waste. Vulcan rubber can be ground and sifted, making both rubber and lead available for recycling (Taylor 2008). Dura-bloc recycling program under development, and may be available in 2009 (Dahlberg 2008b).	3
	Protection from Weather Conditions	Vulcan Rubber and AABC blocks are impervious to water (Barrett 2008, Taylor 2008); therefore, no freeze/thaw issues in Massachusetts winters. Dura-bloc has a weather and UV coating, but compression of rubber is altered with site climate; the rubber contracts in cold climate (Dahlberg 2008b).	5
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Estimated capacity of approximately 10,000 rounds before recycling is advised (USAEC 1996). Some effect on training capacity, due to range downtime during maintenance activities. Replace filled or worn Vulcan Rubber and Dura-bloc blocks after 3,500–5,000 rounds per manufacturer (Taylor 2008, Dahlberg 2008b). Assuming an even distribution of projectiles across the range, approximately 260 rubber blocks would be replaced each year.	3
	Supports Necessary Training Quality (LOS, 5.56 ammo)	Ammunition: Up to 7.62mm. Some blocks can accept tracer fire, due to self-extinguishing capability. (Barrett 2008, Taylor 2008). Dura-blocs cannot accept sustained tracer fire, but can mitigate flare-ups with a maintenance intensive fire-retardant paint (Dahlberg 2008b). MAARNG can conduct most Army doctrinal training. May affect line of sight for downrange targets.	3
	Availability of Method	Widely available.	5
	Environmental Monitoring	Soil sampling, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3

RUBBER BLOCKS			
	Requirements		
ADAPTABILITY	**Emerging Information**	Rubber blocks could be compatible with new and emerging technologies as support structures for these technologies. However, they may need to be removed entirely in order to implement new technologies. Rubber blocks may be compatible with new ammunition depending on the projectile's penetration capabilities. Rubber blocks, however, can not accept tracer fire	3
	System Scalability	Rubber blocks at each SIT may cause line of sight issues. But because of their modular structure, they could be constructed could be constructed with sizes compatible with the distance of the target to the firing line	3
	BMP/P2 Technology Pairing	Could be used as a support structure for other projectile capture technologies, such as GEL-COR™. Could also be used in coordination with soil amendments or end of range berms	4
	Unintended Consequences	Creates some lead dust	2
	Technology Transfer	Could transport rubber blocks to other installations or ranges with ease due to their modular structure	5
COST	**Capital Cost**	Site preparation: A support framework is advised . Soil berms would be enlarged to support the traps, see Backstop Soil Site preparation cost sheet. Site preparation is $39,570.[a] Vulcan Rubber: Rubber blocks are 8 × 8 × 16 in. in size. Frontal Berms Per Trap: Nine blocks in a 3-by-3 configuration will form a frontal berm 4 ft wide and 2 ft high. Cost is $864 per frontal berm (9 blocks at $96 each), including shipping and delivery (Snyder 2009). Assume installation cost of $5,000. Range: $82,760 ($864 × 90+ $5,000 for installation) Backstop Berms Per Trap: A 6 × 6 ft is $4,320 per trap, 9 × 9-ft trap is $9,408, and 12 × 12-ft trap is $15,552.[b] Blocks are not interlocking and require a support structure (not supplied by vendor). Assume an installation cost of $55,000.[c] Range: $759,640 ($4,320 × 40 + $9,408 × 40 + $15,552 × 10 plus $55,000 for installation) including shipping. AABC: Rubber blocks are 1 ×1 × 1 ft in size. Frontal Berms Per Trap: Eight blocks in a 4-by-2 configuration will form a frontal berm 4 ft wide, 2 ft high, and 1 ft deep. Cost is $250 per block. Cost is $2,000 per frontal berm (8 blocks at $250 each), shipping from Kentucky is additional (Barrett 2009). Range: $180,000 ($2,000 x 90) Backstop Berms Per Trap: AABC for 5.56 caliber is $250/$\text{ft}^3$ (Barrett 2009). Assuming 1 ft depth for projectile traps, 6 × 6 ft is $9,000 per trap, 9 × 9-ft trap is $20,250, and 12 × 12-ft trap is $36,000. Range: $1,530,000 ($9,000 × 40 + $20,250 × 40 + $36,000 × 10), not including shipping or installation. Dura-blocs: Rubber blocks are 12 × 24 × 9 in. in size. Frontal Berms Per Trap: Six blocks in a 2-by-3 configuration will form a frontal berm 4 ft wide, 27 in. high, and 1 ft deep. Cost is $59 per block, with shipping. Cost is $354 per frontal berm (6 blocks at $59 each) (Donnelly 2009). Range: $31,860 ($354 × 90), plus $5,000 for installation. Backstop Berms Per Trap: Compression system of a rubber block wall	2

RUBBER BLOCKS			
		backed with a steel plate lined with 2 × 2-ft rubber panels. A 6 × 6-ft trap is $4,900, 9 × 9-ft trap is $11,000, 12 × 12-ft trap is $20,000, plus 15% for installation cost (Godfrey 2008). Range: $961,000 $836,000 for materials ($4,900 × 40 + $11,000 × 40 + $20,000 × 10), plus $125,000 for shipping and installation. A rubber block system would cost between $881,970 and $1.7 million, depending on the vendor.	
	O&M Cost	**Maintenance:** Modular system, only worn or filled blocks require replacement. Rotate blocks as needed, Vulcan Rubber and Dura-bloc blocks wear in “hot zones” after 3,000–5,000 rounds. (Dahlberg 2008, Taylor 2008). Vulcan Rubber requires the membrane ($80) be replaced every 3,000–5,000 rounds. Replacement blocks cost $80 for Vulcan Rubber, $250 for AABC, and $59 for Dura-bloc. Assume annual maintenance cost of $38,000.[d] **Disposal:** “The disposal cost for an AABC block containing lead projectiles at Fort Jackson is $425/block” (Spino 2007). Assume annual disposal cost of $110,500 (260 × $425). **Environmental Monitoring:** Annual sampling/monitoring estimated at $58,500. A rubber block system would cost $207,000 a year to maintain.	3

[a] Site preparation cost for a 6 × 6-ft trap is $370, 9 × 9-ft trap is $486, and 12 × 12-ft trap is $533, see the Backstop Soil Site preparation cost sheet. ($370 x 40 + $486 x 40 + $533 x 10 = $39,570)
[b] A 6 × 6-ft trap is five blocks wide and nine blocks high, or 45 blocks per trap. (45 blocks × $96 per blocks = $4,320). A 9 × 9-ft trap is seven blocks wide and 14 blocks high, or 98 blocks per trap (98 blocks × $96 per block = $9,408). A 12 ×12-ft trap is nine blocks wide and 18 blocks high, or 162 blocks per trap (162 blocks × $96 per block = $15,552).
[c] Assume $45,000 in labor for a 2 man crew working 5 hours per trap at $50/hour, plus $10,000 in materials ($45,000 + $10,000 - $55,000).
[d] Assume 780,000 rounds fired on Sierra Range annually (6,000 soldiers firing 130 rounds each). Therefore, 260 blocks would be replaced per year (780,000 total rounds/3,000 rounds per block) at a cost of $20,800 (260 × $80 per block), plus $10,000 for labor to inspect and rotate the blocks, plus $7,200 (90 × $80) for a rubber membrane on each trap.

GEL-COR™			
	GEL-COR™ is a new fireproof bullet-trapping medium, developed by researchers from the ERDC GSL and SuperTrap, Inc., that accepts bullets fired from any angle, producing little or no lead dust and reducing both fire risk and range noise. It uses an engineered mixture of chunk rubber and hydrated potassium or sodium polyacrylate-polyamide gels consisting of approximately 60% rubber and 40% hydrated polyacrylate (by volume). GEL-COR™ is typically used with SACON® as the supporting framework.		
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead projectiles and dust will be largely contained in GEL-COR™. Some ricochets are created when fired projectiles impact rocks or other deposited projectiles. Limited dissolution/corrosion of lead in soils at Camp Edwards.	4
	Ease of Lead Recovery and Recycling	Lead will be contained intact in GEL-COR™. No information is currently available as to whether lead can be removed from the material for recycling purposes.	1
	Protection from Weather Conditions	Lead and dust will be contained intact in GEL-COR™. However, undershot/overshot bullets that do not enter GEL-COR™ may ricochet and fragment, becoming exposed to weather conditions. "Limited corrosion processes and the soil's ability to adsorb metals will limit the dissolution and migration of metals from surface soils to subsurface soils" (MAARNG 2007b).	4
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	No effect on training operations. Minimal effect on training capacity when range is closed for GEL-COR™ replacement. Can be conducted during low optempo periods, October to March.	4
	Supports Necessary Training Quality (LOS, 5.56 ammo)	MAARNG can conduct Army doctrinal training. May have some line of sight impacts.	5
	Availability of Method	GEL-COR™ is patented and is licensed only through SuperTrap, Inc. It is not widely available	2
	Environmental Monitoring Requirements	Soil sampling, periodic soil removal, groundwater monitoring, lysimeters, and pH testing, see environmental monitoring cost sheet.	3
ADAPTABILITY	**Emerging Information**	Because Gel-Cor™ is a filler material it may be difficult to use in coordination with emerging technologies, unless it is used in coordination with a new supporting framework. However, will likely be able to be used with non-lead ammunition	3
	System Scalability	Used in coordination with a supporting structure, Gel-Cor™ may cause line of sight issues if placed at each SIT. But because Gel-Cor™ can be ordered by the linear foot, it can be scaled according to the SIT distance	3
	BMP/P2 Technology Pairing	Could be used with other support structures or moved to a end of range application	3
	Unintended Consequences	None	5
	Technology Transfer	Could be disassembled from its support structure and used in coordination with existing structures on other ranges or installations	4
COST	**Capital Cost**	Note: Costs for framework are not included. Framework can be dirt berms, steel and rubber trap systems, or SACON®. GEL-COR™ would be used as the bullet capture material, not to create a berm itself. **Frontal GEL-COR™ Berms:** Per Target: The cost of 1 linear foot of GEL-COR™ is $450–$2200. Using one block is an option for each frontal berm at a size of 2 × 2 ft. Each SACON® frontal berm would cost $900–$4400.	5

GEL-COR™			
		Range: $81,000-$396,000 **Backstop GEL-COR™ Berms:** Per Target: The cost of 1 linear foot of GEL-COR™ is $450–$2200. The 6 × 6 ft would be an option based on the SIT size. Each GEL-COR™ filler would cost $2,700–$13,200. The 9 × 9 ft would cost $4,050–$19,800, and the 12 × 12 ft would cost $5,400–$26,400. Range: $324,000–$1.6 million for GEL-COR™ material ($2,700 × 40 + $4,050 × 40 + $5,400 × 10) - ($13,200 × 40 + $19,800 × 40 + $26,400 × 10) A GEL-COR™ system would cost between $405,000 and $2 million depending on the linear foot cost.	
	O&M Cost	Not available	3

GRANULAR RUBBER			
• Reclining GranTrap, Meggitt Defense Systems Caswell • Environmental Projectile Catcher, STAPP • Super Trap® Backstop System, SuperTrap Granular rubber systems consist of a frame with a matrix of granular rubber between a rubber membrane cover and an impermeable liner. Different size systems were considered: a 6 × 6-ft backstop (50 m, 75 m, and 100 m), a 9 × 9-ft backstop (150 m, 175 m, 200 m, and 250 m), and a 12 × 12-ft backstop (300 m). When advised, the existing berms will be enlarged with on-site soil to support the traps. Frontal berms will be constructed of on-site soil.			
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Some lead is contained between the self-closing rubber membrane cover and non-permeable liner in the bottom of the system. There is little to no dust created from the impact of the projectile with the rubber material.	5
	Ease of Lead Recovery and Recycling	Trap allows sifting of granular rubber matrix to recover lead projectiles captured by the system.	4
	Protection from Weather Conditions	Rubber layers protect from weather conditions. Self-closing rubber membrane (cover) keeps most water outside of the system, non-permeable liner (bottom) does not allow migration of lead to ground surface, and the water collection system (on some models) conveys and collects any water that does enter the system for periodic removal and disposal.	4
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Capacity of 40,000–60,000 rounds per target before projectile removal is advised . Maintenance would be advised after 4–7 years[a] (assuming an even distribution of projectiles across the range). The process of separating the lead from the rubber matrix uses specialized equipment and will require range downtime. Maintenance downtime will not impact the ability of Sierra Range to satisfy throughput requirements, as maintenance will be conducted during off-peak training periods.	5
	Supports Necessary Training Quality (LOS, 5.56 ammo)	GranTrap: Up to .50 caliber ammunition STAPP: Up to 7.62mm ammunition. STAPP system can accept tracer rounds as long as self-closing cover is maintained with no holes. The granular rubber and cover extinguish the tracer by ultimately depriving it of oxygen (MAARNG 2007b). GranTrap cannot accept tracer rounds due to ignitability (Danielson 2008b). MAARNG can conduct Army doctrinal training, depending on vendor. May affect line of sight for downrange targets.	3
	Availability of Method	Widely available.	5
	Environmental Monitoring Requirements	Soil sampling, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
TA	**Emerging Information**	The granular rubber containment system may be compatible with emerging technologies as it fully contains projectiles. However, non-	3

GRANULAR RUBBER			
		lead ammunition may not be compatible with the top rubber membrane	
	System Scalability	Would be very difficult to construct granular rubber structures at all 90 SITs. Would also cause line of site issues	1
	BMP/P2 Technology Pairing	Could be used as an end of range projectile containment system in coordination with other BMP/P2 technologies behind the SITs or on the range	3
	Unintended Consequences	Rubber membrane or liner may fail and allow precipitation to interact with projectiles and leak from the trap	2
	Technology Transfer	May be difficult to disassemble an end of range granular trap because of its size and multiple components	2
COST	**Capital Cost**	**Frontal Soil Berms:** Per Target: Costs include labor, equipment rental, soil placement, transportation on-base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100 (4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top). Range: $9,270 ($103 × 90) **GranTrap:** Site preparation: Concrete pads are advised . A 12 × 8 pad for the 6 × 6-ft trap, a 13 × 10 for the 9 × 9-ft trap, and a 17 × 14 for the 12 × 12-ft trap (Danielson 2009). Enlarge soil berms to support the traps, see Backstop Concrete Pad Site preparation cost sheet. Site preparation is $93,550[b]. Per Trap: A 6 × 6-ft trap is $4,437, a 9 × 9-ft trap is $6,900, and a 12 × 12-ft trap is $10,700. Freight is $70,000 and installation of the traps is $350,831 (Danielson 2009). Range: $1,074,861 ($560,480 + $70,000 + $350,831 + $93,550). For 40 targets at $4,437 each, 40 targets at $6,900, and 10 targets at $10,700, the cost for GranTrap projectile traps is $560,480. **STAPP:** Site preparation: A soil berm is needed behind each STAPP system at a cost of $272,000 (40 × $1,300 + 40 × $3,600 + 10 × $7,600), see soil berm cost estimate sheet. Per Trap: The STAPP system costs $83/ft^2, without labor (Howe 2008). Accounting for 30º angle of the berm, a 6 ft tall trap (68 ft^2)[c] is $5,644; 9 ft tall trap (152 ft^2)[d] is $12,598; and 12 ft tall trap (269 ft^2)[e] is $22,300. Range: $1.2 million ($952,680 + $272,000). For 40 targets at $5,644 each, 40 targets at $12,598, and 10 targets at $22,300, the cost for STAPP projectile traps is $952,680. Supporting soil berms would cost $272,000. **Super Trap:** Site preparation: Enlarge soil berms to support the traps, see Backstop Soil Site preparation cost sheet. Site preparation is $39,570[f]. Per Target: A 10 ft tall system costs $1,650/linear ft, and approximately $3,000/linear ft for installation (Payton 2009). A 6 ft wide trap is $27,900, a 9 ft wide trap is $41,850, and a 12 ft wide trap is $55,800. Range: $3,387,570, including installation (40 × $27,900 + 40 × $41,850 + 10 × $55,800 + 39,570)	1

GRANULAR RUBBER			
		Granular rubber systems would cost between $1.1 million and $3.4 million, depending on vendor.	
	O&M Cost	**Maintenance:** Using the STAPP system as an example, projectile sifting is advised after approximately 40,000–60,000 rounds per target. With 90 targets, this equates to a total capacity of between 3.6 and 5.5 million rounds for a 10 lane system, assuming an even distribution of projectiles across the range. Projectile sifting requires a two-stage vacuum/blower to separate the rubber matrix from the projectiles in the collection trough, the rubber matrix material is recycled back into the trap. Any water in the water collection system is removed and the water is tested for disposal. The system cover shall be observed regularly and any holes patched. Annual STAPP maintenance cost: patch cover: $18,000 (90 × $200) water removal: $27,000 (90 × $300) projectile sifting: $108,000 (90 × $1,200) for a total of $153,000. Assume a two-man crew will take 1 day three times per year during training season working a 10 hour day (60 hours) to maintain the frontal berms at cost of $3,000 ($50 × 60 hours) for labor. Annual maintenance cost of $156,000. **Disposal:** Assume projectiles are disposed as hazardous waste for a cost of $7,300 (3.46 tons[g] × $2,100/ton[h]) **Environmental Monitoring:** Annual sampling/monitoring estimated at $58,500. A granular rubber system would cost $221,800/year to maintain.	3

[a] 40,000–60,000 rounds per target × 90 targets = 3.6 to 5.5 million projectiles range wide before projectile removal is advised . Assuming 780,000 rounds fired annually (6,000 soldiers × 130 rounds each), (3.6 million/780,000 = 4.6 years) and (5.5 million/780,000 = 7 years).
[b] Site preparation cost for a 6 × 6-ft trap is $865, 9 × 9-ft trap is $1,155, and 12 × 12-ft trap is $1,275, see the Gran Trap Site preparation cost sheet ($865 × 40 + $1,155 × 40 + $1,275 × 10 = $93,550).
[c] To allow for a 6 × 6-ft trap perpendicular to the shooter, and accounting for the 30º angle of the berm the STAPP system is resting upon, the actual area of the STAPP system is 67.44 ft^2 (11.24 × 6 ft).
[d] To allow for a 9 × 9-ft trap perpendicular to the shooter, and accounting for the 30º angle of the berm the STAPP system is resting upon, the actual area of the STAPP system is 151.65 ft^2 (16.85 × 9 ft).
[e] To allow for a 12 × 12-ft trap perpendicular to the shooter, and accounting for the 30º angle of the berm the STAPP system is resting upon, the actual area of the STAPP system is 268.68 ft^2 (22.39 × 12 ft)
[f] Site preparation cost for a 6 × 6-ft trap is $370, 9 × 9-ft trap is $486, and 12 × 12-ft trap is $533, see the Backstop Site preparation cost sheet ($370 × 40 + $486 × 40 + $533 × 10 = $39,570).
[g] Approximately 780,000 (6,000 soldiers × 130 rounds) rounds fired annually. A 5.56mm projectile weighs 4.02 grams. 780,000 × 4.02 g = 3,135,600 g or 6,913 lb or 3.46 tons. 1 gram = 0.00220462262. 2,000 lb = 1 ton.
[h] DRMS website states bulk solid hazardous waste (CLIN 9107) is $1.05/lb. 2,000 lb = 1 ton. $2,100/ton. $2,100 × 3.46 tons = $7,266 hazardous waste disposal cost (https://www.drms.dla.mil/hazmat/servlet/ShowContract?CONTRACT=SP440008D0013).

DECELERATION			
• Projectile Trap Rifle Model R494, Shooting Ranges International (SRI) • Total Containment Trap (T3), Action Target International (ATI) • Colt Projectile Catcher, Rapid Range LLC Steel plates on the top and bottom of trap funnel projectiles into a circular deceleration chamber. The chamber resembles the shell of a snail and projectiles revolve in it until they lose energy and drop into the collection chamber. Deceleration traps are only available in select sizes; therefore, the trap size would be consistent across the range. Installation is involved and usually performed by the vendor. Existing berms are enlarged with on-site soil to support the traps. Frontal berms are constructed of on-site soil.			
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead projectiles and fragments are captured in the chamber. Lead dust generated upon impact with steel plate funnel; this dust is not captured by system.[a] Lead dust is a significant issue. There is a chance lead will leach from system in the form of dissolved lead. Lead dust generated from striking the steel plate can be minimized by an oil coating[b] that is replaced during routine maintenance (Quinn 2008b).	3
	Ease of Lead Recovery and Recycling	Projectiles and debris can be collected from the system bucket for recycling.	5
	Protection from Weather Conditions	"Wet systems" are not recommended for outdoor ranges in regions that have freezing temperatures. SRI has no weatherproofing but claims that there will be no leaching if the equipment is properly maintained (Quinn 2008b). ATI contends there is potential that lead will leach from a decelerator in specific situations, but this effect can be mitigated with a drainage trough. Their galvanized steel surface will not degrade in outdoor conditions (Smith 2008).	3
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Up to 25,000 rounds between emptying of the collection tray can be handled before projectiles begin backing up into the trap (USAEC 1996). SRI advises emptying buckets after 3,000–5,000 rounds due to the weight of projectiles (Quinn 2008). This would be advised after 4–7 months (assuming an even distribution of projectiles across the range). Range downtime is significant for maintenance activities (2–8 hours per target per month). Assuming a crew of 4 maintains the range at 4 hours per target per month, range would be down for 11.25 days/month if crew works 8-hour days.	2
	Supports Necessary Training Quality (LOS, 5.56 ammo)	Deceleration traps can support ammunition up to and including .50 caliber. These systems typically require 8–12 m front to back to accommodate the size of the trap. Sierra Range can accommodate such a system but requires installation of large elevated berms/platforms behind each target (MAARNG 2007b).	2

DECELERATION			
		Likely to affect line of sight for downrange targets. SRI cannot handle tracer rounds due to the ignitability of the oil applied during routine maintenance (Quinn 2008). MAARNG cannot conduct Army doctrinal training if line of sight is impacted.	
	Availability of Method	Readily available from multiple vendors. Requires somewhat involved installation/construction.	5
	Environmental Monitoring Requirements	Soil sampling, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
ADAPTABILITY	**Emerging Information**	The deceleration system may be compatible with emerging technologies as it fully contains projectiles. However, non-lead ammunition may not be compatible with the chamber	3
	System Scalability	Would be very difficult to construct deceleration traps at all 90 SITs. Would also cause line of site issues	1
	BMP/P2 Technology Pairing	Could be used as an end of range projectile containment system in coordination with other BMP/P2 technologies behind the SITs or on the range.	3
	Unintended Consequences	Creates a lot of dust that is not captured by the system; potential for dissolved lead to be released into the environment	1
	Technology Transfer	May be difficult to disassemble a deceleration chamber because of its size and multiple components	2
COST	**Capital Cost**	**Site Preparation:** A deceleration trap would require a concrete footer and possibly a trench to maintain line of sight downrange. Enlarge existing soil berms and install concrete pads to support the traps, see Backstop Concrete Pad Site preparation cost sheet. Site preparation is $93,550.[c] **Frontal Soil Berms:** Per Target: Costs include labor, equipment rental, soil placement, transportation on base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100 (4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top). Range: $9,270 ($103 × 90) **ATI:** Per Target: $5,300/linear horizontal foot; installation fee is extra (Smith 2008). For 6 ft, cost is $31,800 per target. For 9 ft, cost is $47,700 and for 12 ft cost is $63,600. Range: $3,816,000, not including installation ($31,800 × 40 + $47,700 × 40 + $63,600 × 10). **SRI:** Per Target: $9,717, with custom specifications Range: $1,034,530, includes $160,000 installation cost (Quinn 2008) **Colt Projectile Catcher:** Per Target: $18,000–$20,000 per 5 × 7 × 12-ft box (Bavaro 2008) Range: $1,620,000 and $1,800,000 ($18,000 × 90), not including	1

DECELERATION			
		transportation and setup costs Decelerators would cost between $1,128,080 and $3,909,550 for the entire range.	
	O&M Cost	**Maintenance:** The initial contact portion of trap replaced after 250,000 rounds. Advised maintenance is 2–8 hours/month per target, depending on the number of rounds fired and whether automated projectile collection systems are included. Routine maintenance includes inspection of the trap components (inclined plate, filters, piping, and any associated projectile conveyor equipment, such as augers and collection buckets) (MAARNG 2007a). ATI dust collection unit filters are replaced every 2 years with average usage (good for 2,000 hours). Extended maintenance every 6 months (Smith 2008). Colt Projectile Catcher has a 1-in. thick AR steel plate at the back of projectile collection drawer. Replacement plate is $300 (Bavaro 2008). This plate needs to be replaced every 1–1.5 years. Annual cost of $27,000 ($300 × 90). SRI spare parts package is $5,960 (includes set of steel plates; one helical decel chamber; clamps; and five 3-gal buckets) (Quinn 2008). Annual cost of $540,000 ($6,000 × 90). Assume a two-man crew will take 1 day three times a year during training season working a 10-hour day (60 hours) to maintain the frontal berms at cost of $3,000 ($50 × 60 hours) for labor. **Environmental Monitoring:** Annual sampling/monitoring estimated at $58,500. Maintenance for deceleration traps is very labor intensive, estimate labor at $108,000 (4 hours/month × 90 traps × 12 months at $25/hour = $108,000). Annual maintenance cost of $196,500–$709,500.	2

[a] ATI has a vacuum system that continuously removes lead dust and other fine airborne particles from inside the decel chamber; however, this is not an option for smaller traps because the system requires a generator. Dust and fragments would be a significant issue without dust collection unit in place.
[b] This oil coating presents a fire hazard with tracer fire. The SRI trap cannot be used with tracer fire.
[c] Site preparation cost for a 6 × 6-ft trap is $865, a 9 × 9-ft trap is $1,155, and a 12 × 12-ft trap is $1,275, see the Backstop Concrete Pad Site preparation cost sheet ($865 × 40 + $1,155 × 40 + $1,275 × 10 = $93,550).

IMPACT TRAPS			
• Escalator, LE4000 model, Meggitt Defense Systems (Caswell) • Flat Trap, Action Trap International (ATI) • Steel Projectile Traps, MGM Targets (MGM) The general premise of the impact projectile trap is that projectiles strike a steel plate, thereby stopping and often fragmenting the projectile. When projectiles strike the plate, they are guided into a sand filled basin. The type and thickness of plating depends on the ammunition used, up to and including .50 caliber. Frontal berms will be constructed of on-site soil. The three vendors did not advise their system in this application, as this type of projectile trap is better suited to an end of lane application.			
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Projectiles fragment when striking the plate and create lead dust upon impact; projectile fragments can be captured in a box or tray. Lead dust cannot be captured with this alternative and could be released to the soil. Little protection from lead leaching to ground surface; dissolved lead is not contained. **Escalator Trap: "**Although most fragments fall downwards onto the range floor for recovery later, the trap does not contain these fragments, reducing any potential environmental benefit derived from employing a projectile trap" (USAEC 1996).	2
	Ease of Lead Recovery and Recycling	Projectiles can be recovered from a box or tray, which may be emptied after 3,000 rounds.	4
	Protection from Weather Conditions	There is little protection from the water leaching through the system unless modified. The steel is weatherproofed to mitigate system deterioration. ATI does not advise the flat trap for outdoor ranges (Smith 2008).	3
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Escalator trap capacity is approximately 250,000 rounds before steel plate replacement is advised (USAEC 1996). Lead projectile recovery would occur after 3,000 rounds per target, or every 4 months[a] assuming an even distribution of projectiles across the range.	4
	Supports Necessary Training Quality (LOS, 5.56 ammo)	MAARNG can conduct Army doctrinal training. Size of trap will have a significant effect on line of sight for downrange targets. Escalator trap can accept ammunition up to 7.62mm (USACE 1996). Caswell does not advise their escalator trap at this site as it is more appropriate for an end-of-lane application (Danielson 2008a). ATI does not advise their flat trap for rifle fire (Smith 2008).	3
	Availability of Method	Available from multiple vendors, although not widely available.	5
	Environmental Monitoring Requirements	Soil sampling, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
AB	**Emerging**	May or may not be compatible with new information or technologies	2

IMPACT TRAPS			
	Information	because of the deflection into sand or water-filled basins. These basins may be found to not properly prevent lead from leaching to groundwater. The deflection plates may also not be compatible with non-lead ammunition	
	System Scalability	Vendors recommended impact systems only for end of lane applications, not for behind each SIT. Would create some line of sight issues behind each SIT	1
	BMP/P2 Technology Pairing	Could be used as an end of range system in coordination with other technologies behind each SIT	3
	Unintended Consequences	Creates lead dust and projectiles in the water or sand filled basin may interact with precipitation	2
	Technology Transfer	Could be removed and transferred to the end of another installation or range	3
COST	**Capital Cost**	**Site preparation:** A support framework is advised . Soil berms would be enlarged to support the traps, see Backstop Soil Site preparation cost sheet. Site preparation is $39,570[b]. **Frontal Soil Berms:** Per Target: Costs include labor, equipment rental, soil placement, transportation on-base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100 (4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top). Range: $9,270 ($103 × 90) **ATI:** Site preparation: Flat trap is angled with a series of pulleys and would require a framing system and a custom design. Per Target: $55–60/ft^2. A 6 × 6-ft trap is $2,160 (36 × $60), a 9 × 9-ft trap is $4,860 (81 × $60), and a 12 × 12-ft trap is $8,640 (144 × $60). Range: Between $337,000 and $556,000 ($2,160 × 40 + $4,860 × 40 + $8,640 × 10) **MGM:** Per Target: $5,000–$6,000 per target, discounted with higher quantities (Gibson 2009). Range: Between $450,000 and $540,000 for 90 targets. The impact alternative would cost between $385,840 and $604,840 to implement.	
	O&M Cost	**Maintenance:** O&M includes removal of projectiles and projectile fragments from the trough or basin. Plates are observed for wear. The collected projectiles can be recycled, and the sand needs to be replenished. The trap shall be cleaned frequently by mining the lead from the sand and disposing of or recycling the metal. Maintenance for impact traps is estimated labor at $54,000 (2 hours/month × 90 traps × 12 months at $25/hour). Replace steel plates after 250,000 rounds. Assume traps are replaced every 28 years[c] at a cost of $550,000, or $19,650/year. Assume a two-man crew will take 1 day three times per year during training season working a 10 hour day (60 hours) to maintain the frontal berms at cost of $3,000 ($50 × 60 hours) for labor.	

IMPACT TRAPS			
		Annual maintenance cost estimated at $72,000. **Environmental Monitoring:** Annual sampling/monitoring estimated at $58,500. The impact alternative has an estimated annual maintenance cost of $130,500.	

[a] Assume 780,000 rounds per year fired on Sierra Range. With 90 targets, 8,666 rounds per target (780,000/90 = 8,666). Each target needs projectile recovery after 3,000 rounds (8,666/3,000 = 2.8 times per year)
[b] Site preparation cost for a 6 × 6-ft trap is $370, 9 × 9-ft trap is $486, and 12 × 12-ft trap is $533, see the Backstop Soil Site preparation cost sheet ($370 × 40 + $486 × 40 + $533 × 10 = $39,570).
[c] Capacity of 250,000 rounds per target with 90 targets = 22.5 million projectile capacity range wide. Assuming 780,000 rounds fired annually (6,000 soldiers × 130 rounds each), (22.5 million/780,000 = 28.8 years).

NON-LEAD AMMUNITION			
• Steel • Copper Historically, Army small arms ammunition is manufactured of lead. The majority of ammunition fired today in the U.S. military is manufactured with a lead core and copper jacket. Recently, the military has explored manufacturing and using ammunition that does not contain lead cores. Alternative materials for small arms ammunition include steel, copper, and tungsten-nylon (currently banned at Camp Edwards).			
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Ammunition will be lead-free. No contamination.	5
	Ease of Lead Recovery and Recycling	Ammunition will be lead-free. Steel or copper will be distributed over a relatively large area but concentrated behind targets.	N/A
	Protection from Weather Conditions	No protection from weather conditions. Because the ammunition is lead-free, there will be no lead migration.	N/A
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	No interruption of range operations.	5
	Supports Necessary Training Quality (LOS, 5.56 ammo)	Uncertainty that these alternative projectile materials provide realistic and safe training for the soldiers. Employing an untested ammunition type may result in safety mishaps. Training with the same ammunition used in combat provides the most realistic training for the soldier. The skills of sight alignment, sight picture, trigger control, and follow-through are perishable skills that must be routinely practiced. Substituting ammunition that does not provide the same stimuli to the soldier during the firing process will not allow the soldier to maintain proficiency (MAARNG 2007b). No line of sight impacts.	3
	Availability of Method	Copper and steel projectiles are both available commercially. Neither steel nor copper ammunition is stocked in the Army ammunition inventory.	2
	Environmental Monitoring Requirements	Copper projectile ammunition is thought to have relatively low human toxicity, is corrosion resistant, requires no projectile jackets, and equal lead projectile weights for 5.56mm small arms. The use of copper projectiles would dramatically increase the total copper loading at Camp Edwards (MAARNG 2007b). Some non-standard ammunition contain chemicals whose impacts on human health and the environment are not as well known or understood (MAARNG 2007b). Soil sampling, groundwater monitoring, and lysimeters, see environmental monitoring cost sheet.	4
ADAPTABILITY	**Emerging Information**	Depending on ballistic properties, may or may not be compatible with other bullet containment systems. However, would not need to be contained as effectively if there is not potential for contaminants to leach to ground water.	3

NON-LEAD AMMUNITION			
	System Scalability	Could function at Sierra Range	5
	BMP/P2 Technology Pairing	Could be used in coordination with other bullet containment systems	4
	Unintended Consequences	May contain contaminants, other than lead, that are mobile and may leach to groundwater	3
	Technology Transfer	If Army approved, could be used at other ranges or installations.	4
COST	**Capital Cost**	**Frontal Soil Berms:** Per Target: Costs include labor, equipment rental, soil placement, transportation on- base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100 (4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top). Range: $9,270 ($103 × 90) Estimate 780,000 rounds/year at Sierra Range (6,000 soldiers × 130 rounds each). **Lead:** Annual cost of $195,000 (780,000 × $0.25/round). **Copper:** Significantly (between three and five times) more expensive than lead ball ammunition (MAARNG 2007b). Annual cost of $375,000 (780,000 × $0.48/round). Camp Edwards buys lead ammunition at $195,000/year, copper ammunition would cost an additional $180,000/year ($375,000 - $195,000 = $180,000). **Steel:** NAMMO produces a 5.56mm lead-free projectile at about 15% more than lead projectiles. Annual cost of $225,000 (780,000 × $0.29/round) Camp Edwards buys lead ammunition at $195,000/year, steel ammunition would cost an additional $30,000/year ($225,000 - $195,000 = $30,000). The non-lead ammunition alternative would cost between $39,270 and $189,270 to implement.	5
	O&M Cost	**Maintenance:** Assume a two-man crew will take 1 day three times per year during training season working a 10-hour day (60 hours) to maintain the frontal berms at cost of $3,000 ($50 × 60 hours) for labor. **Environmental Monitoring:** None. **Ammunition:** Estimate an increase of $30,000–$180,000/year for alternative ammunition. The non-lead ammunition alternative would cost between $33,000 and $183,000 to maintain.	5

RAMP			
The proposed Sierra Range RAMP (i.e., BMP/P2 strategy) is comprised of three core elements: three dimensional, time phased, and process improvement. The three-dimensional element refers to the physical area of the range defined by the length x width x depth. Time phased refers to the actions advised before operations (e.g., soil conditioning, construction, etc.); near term operations (e.g., monitoring and maintenance, OMMP); and long term operations (e.g., projectile pocket remediation, review, modification, and implementation of OMMP based on observed and monitored conditions). The process improvement element is designed to be adaptable to the monitored conditions and applies previously reviewed complementary alternative P2 technologies as identified in an incremental process improvement strategy (ITRC EMP).			
			Rating
EFFECTIVENESS	**Lead Containment (projectiles, frag, dust, dissolved)**	Lead will be contained within the end berm, overshot barrier, wing walls and the boundaries of the range. Some lead dust and ricochets are created when fired projectiles impact rocks or other deposited projectiles. Rocks and debris will be removed from the berms and range floor. Limited dissolution/corrosion of lead in soils at Camp Edwards	4
	Ease of Lead Recovery and Recycling	Periodic lead recovery is advised to "mine" the projectiles from the berm face for recycling and disposal. Remove/recover lead in areas of concentrated projectile impact (in projectile pockets behind targets) every 5 years. There are vendors and established processes to recycle lead from soil	3
	Protection from Weather Conditions	Some protection from weather conditions in soil bems. Regular maintenance of projectile pockets and annual re-seeding of the berms will reduce the erosion and exposure of embedded projectiles to weather conditions. Geotextile berms will protect from weather conditions.	4
IMPLEMENTABILITY	**Supports Necessary Training Capacity (minimizes range downtime)**	Some range downtime for range floor and berm repair. Can be done during non peak training times.	4
	Supports Necessary Training Quality (LOS, 5.56 ammo)	MAARNG can conduct Army doctrinal training with minimal line of sight impacts	4
	Availability of Method	Widely available. Earth moving and survey equipment would be advised. Also requires soil and groundwater monitoring and sampling equipment	3
	Environmental Monitoring Requirements	Soil sampling, periodic soil removal, pH testing and maintenance, groundwater monitoring, lysimeters, see environmental monitoring cost sheet.	3
ADAPTABILITY	**Emerging Information**	Berms could be converted to support new projectile containment structures or removed entirely. Could also implement projectile containment systems behind each SIT. Would incorporate new technologies during the process improvement evaluation. Would also be effective at capturing non-lead ammunition	4
	System Scalability	Can construct berms to a scale appropriate for the range.	5
	BMP/P2 Technology Pairing	Can be paired with soil amendments, emerging technologies, and projectile containment systems behind each SIT, if deemed necessary	5
	Unintended Consequences	Earthen berms have the ability to erode which would decrease their ability to effectively capture projectiles and would increase the possibility of projectile fragmentation. Also would expose ammunition to weathering and precipitation. However, the RAMP includes plans to monitor and repair the range floor and berm floor.	3
	Technology Transfer	Soil from berms or geotextile covers on Sierra could be transported with trucks or heavy equipment for use on other ranges or installations	3

RAMP			
COST	**Capital Cost**	**Large Range Berms:** The cost for each berm includes mobilization, soil transportation, soil placement, and seeding. The 918ft x 12ft x 15ft end berm would cost $108, 078. The 900ft x 6ft x 3ft overshot berm would cost $7,503. Each wing wall in the first set of wing walls is estimated to be 180ft x 6ft x 6ft for a total cost of $9,401 ($4,701 x2). Each wing wall in the second set of wing walls is estimate to be 240ft x 6ft x 3ft for a total cost of $9,868 (4,934). **Frontal Soil Berms:** Per Target: Costs include labor, equipment rental, soil placement, transportation on-base, and seeding to create an earthen berm in front of each of the 90 target mechanisms. Assume on-site borrow and 1 hour of labor to shape each berm. The estimated cost per frontal berm is $100 (4 ft wide at top, 6 ft wide at bottom, 2 ft tall, and 2 ft deep at top). Range: $8,275 ($103 × 80) Note: An estimate for the geotextile covering is currently not available. Cost above only includes cost to create the berms. Also, the wing wall berms may be deemed unnecessary. Total cost: $143,125	5
	O&M Cost	Can not estimate long term O&M cost because of possibility of implementing new emerging technologies	N/A