# Environmental Management Systems of Military Training Ranges: Range Remediation and Sustainability

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## Introduction

Military training on large, dedicated training ranges is an activity common to militaries worldwide. Military readiness depends on the availability of an adequate natural resource base for a variety of logistic and training purposes (Kreizenbeck, 2004). Environmental and safety considerations arise from physical and chemical hazards to which the soldier or range worker may be exposed. In addition, The training activities themselves can introduce chemical constituents that may pose a risk to health and the environment in the future. Examples of inorganic constituents include lead, copper, zinc, and various nitrates. Organic constituent examples include RDX, perchlorate, ethylbenzene, hexachloroethane, diphenylamine, nitroglycerin, nitrocellulose, etc. The potential effect that training may have is a function of the training load, the condition of the training range before and after use, and the effectiveness of environmental management. The ultimate condition of a training range at the conclusion of use ranges from no significant impact to environmental restoration or remediation required.

In order to manage the risk posed to trainees and/or off-site receptors near ranges, the military must assess the risks, monitor hazards, and continually manage the ranges in a sustainable manner. Examples of some of the tools available to assist in risk management are provided in the following text. The first addresses baseline hazard assessments and mitigation on lands newly acquired for use as ranges, while the second describes a model developed specifically to address erosion and chemical buildup on ranges subjected to long-term training and military maneuvers.

## Case Study 2 – Estimating Range Carrying Capacity to Manage Risks Generated by Training

### Background

All environmental settings have limited carrying capacity to absorb stressors before adverse health or environmental consequences occur. Stressors can be physical, biological, or chemical. In the chemical case, a stressor in a military training situation is a ‘constituent’ and becomes a ‘contaminant of concern’ only when adverse health or environmental consequences occur, or are likely to occur, if there is no intervention. In the civilian sector, sites that require remediation are created in either a planned or unplanned fashion. In the military sector, training activities that lead to the creation of sites that may require remediation are planned. Table 1 presents a characterization of remediation sites by the activity that created them.

Table 1. Classification of Remediation Sites by Origin

| | PLANNED | UNPLANNED |
|---|---|---|
| Accidents/Spills | | X |
| Landfills/Past Disposal Practice | X | X |
| Operations | | X |
| Intentional Acts | X | |
| Training Range | X | |

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Operations include all beneficial economic activities that result in the gradual accumulation of constituents in the environment.  Examples include the unplanned loss of solvents from dry cleaners, re-distribution of inorganic constituents from mining activities, etc.  Intentional acts include the 'black sites,' 'midnight dumping,' 'obsolete pesticide dumping,' etc., and represent the willful action of perpetrators without regard to health or environmental impacts.  Past Disposal Practice begins as a best practices attempt to manage constituents but ends with the unplanned creation of a remediation site.  Training Range actions have the potential to always be managed with good awareness of risks to health and the environment.

Training range constituents derive from the limited set (as compared to civilian economic activities) of military activities.  Although the intensity of activity may be significant, the limited number of constituents makes health and environment management decisions, and remediation if necessary, amenable to systematic evaluation and management.

**Evaluation of Training Activities**

The carrying capacity of a training range depends on several factors including the environmental setting, existing conditions, intended use, and management practices.  The environmental setting includes those variables that determine the fate and effects of constituents introduced through training. Variables include soil, topography, climate, proximity of surface water and groundwater.  Existing conditions include changes to the environmental setting that have occurred prior to the planned use of the training range.  Intended use includes all planned training activities.  Management practices are those actions taken to enable training while minimizing adverse health an environmental effects.

Evaluation and management of health and environmental concerns on training ranges can follow the standard risk paradigm, as summarized as Figure 1:

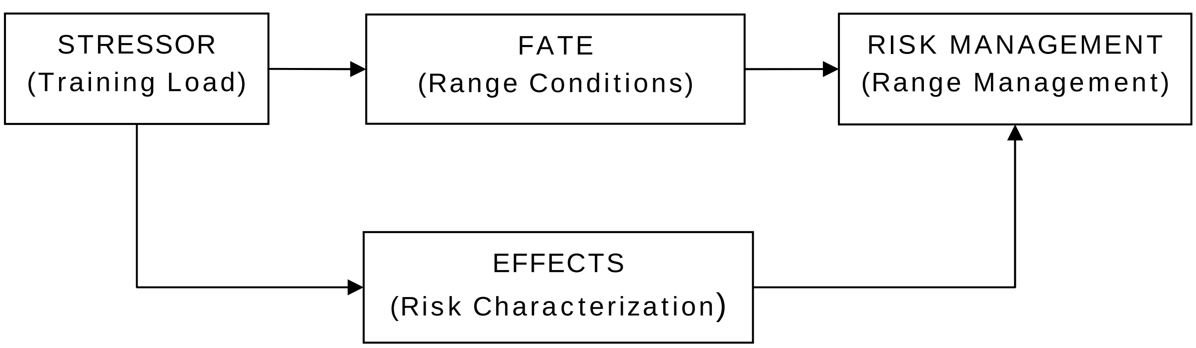


**Figure 1.  Training Ranges and the Risk Paradigm**

*Training Loads*

Training Loads that involve the live-fire of munitions introduces the largest mass of constituents to a range.  This type of training fulfills military requirements and may involve individual training, group exercises, and includes various weapons types.  Weapons can be discharged from central points to dispersed targets, or from dispersed points to central targets.  By knowing the weapon type, the type of constituent can be determined. For example, small arms fire introduces the constituents copper, lead, zinc, nitrocellulose, diphenylamine, etc. Artillery and tank training may introduce RDX, and if rockets are utilized, perchlorate may be present as a constituent. By knowing the level of training, individual or group, intensity and duration, it is possible to estimate the quantity of constituents that will be introduced to the range. However, to do that it is also necessary to have an understanding of the frequency of low order detonation and duds associated with each ordnance type. By knowing whether the training is from a central point to dispersed targets, or vice versa, the probable distribution of the constituents and the unexploded ordnance (UXO) in the environment can be mapped.

*Fate and Effects*

At the onset, there are two types of explosive or propellant chemical release that originate from training activities: 1) Load order detonation in which a small, but significant amount of the explosive load does not detonate; and 2) Duds resulting in UXO. In the former case, the shell is breached and chemicals are distributed throughout the detonation crater from which they can be leached by any incident precipitation. In the latter case, the shell remains in tact and will only be available for transport in the environment after the shell is breached from corrosion. Similarly, the metals associated with projectiles may be released in two ways: 1) Fines created as the projectile passes through the soil and is abraded; and 2) Formation of dispersed oxides over time as the projectile is subjected to geochemical attack. With respect to the second mechanism, experience in the U.S. has shown that in wet climates, steel jacketed military rounds can have all of the lead distributed into the soil within ten years of firing, while the hollow steel jacket remains.

The fate of constituents begins with the assumption that at the conclusion of a training event, constituents are uniformly mixed with soils in the target area. By knowing the unit of constituent per munitions unit, and estimating the volume of soil in the target area, average constituent concentrations in mass-to-mass units can be calculated. To this total is added the constituent load from previous training or other activities. For the inorganic constituents such as lead or zinc, natural background levels might also be included to better estimate the total load. The overall training load increases with additional training events and decreases with loss mechanisms as summarized in Figure 2:

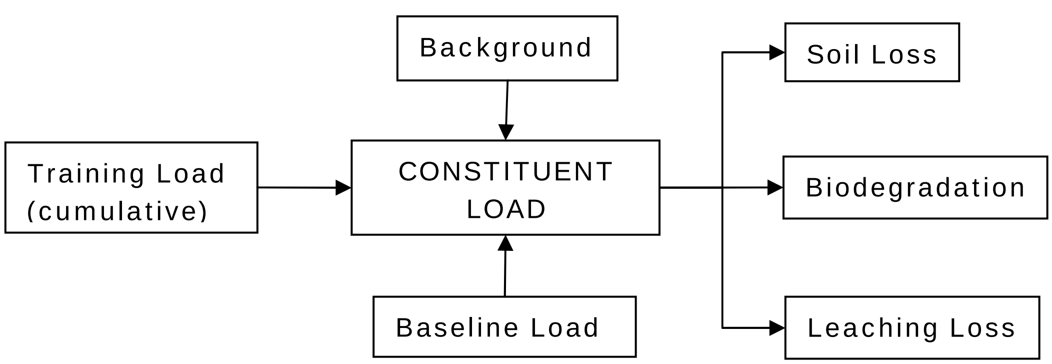


**Figure 2. Fate of Constituents**

Soil loss from the training range is best estimated using standard tools such as the Adapted Universal Soil Loss Equation (RUSLE.) The RUSLE calculation yields soil loss in tons per acre per year and is the product of training range empirical factors R, K, LS, C, and P where:

R = a rainfall and runoff factor
K = a soil erodibility factor
LS = a slope length and steepness factor
C = a cover and management factor, and
P = a support practice factor

The result of this calculation provides a measure of the range carrying capacity. It also provides a measure of the constituent load to lands and waters adjacent to the training range.

Biodegradation and leaching loss can be estimated using any standard method, although since the source term for the constituents is a calculated rather than a measured value, simple methods are likely to be sufficient. As with the soil loss calculation, these estimates are useful in determining the condition of the training range and the potential contribution of constituents to adjoining lands and waters.

Combining all of these factors, the present and future condition of a training range is presented as Figure 3. If the range condition is projected to exceed a target value, corrective actions might be implemented as an alternative to remediation. For example, the type or frequency of training might be modified, training mix sequenced differently, or type of training matched better with the inherent carrying of the range (training that introduces organic constituents might be conducted on ranges more conducive to biodegradation.)

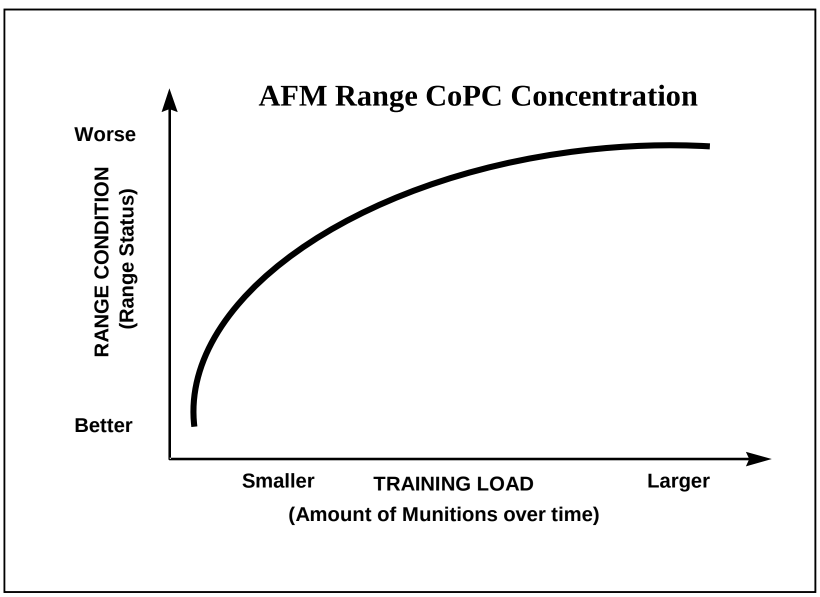


**Figure 3. Range Constituents of Potential Concern Concentration**

*Risk Management*

Training range risk management is required whenever current and projected future training events will produce environmental stress that exceeds environmental carrying capacity, as identified through the fate and effects (risk characterization) analyses. Risk management requirements are one cost element in the overall training budget for a specific range. For costing and funding purposes, a range remediation goal is chosen to achieve a future desired training range condition. Once the predicted future range condition is determined, the condition is compared to a baseline value, or condition of the range prior to initiation of new training activities. The larger the difference between baseline and projected future conditions, the more important the need for environmental risk management.

Required environmental risk management practices include those elements of the overall training budget that will allow the training range to maintain an environmentally acceptable status. They are defined as operations or structures that slow runoff water velocity and mitigate the effects of constituents, thus reducing the amount of constituents in the soil, leaching into the water table or carried by runoff waters. Examples of maintenance investment practices on military ranges include, but are not limited to, revegetation, surface scraping, and sediment retention structures. The execution of range risk management practices and their resulting level of effectiveness mitigate constituent effects and protect health and the environment without adversely impacting the military training requirement.

Risk management practices are defined as operations or structures that mitigate the effects of constituents, thus reducing the amount of constituents in the soil and water.

Repair practices are those that *directly affect range constituent weights* and whose benefit can be quantified. Soil & constituent removal is an example of a repair practice. Table 2 presents an example of repair practices. The first column identifies the practice. The second column is the unit of measure for construction. The third column provides the total acres affected by one unit of construction. The fourth column is a measure of the effectiveness of the practice, where the smaller the value the more effective the practice.

**Table 2. Example Repair Practices**

| Practice | Unit of Measure | Affected Acres/ Unit Quantity | Effectiveness Measure |
|---|---|---|---|
| Removal of soil (2”) | Acre | 1.00 | 0.15 |
| Removal of soil (5”) | Acre | 1.00 | 0.10 |
| Hydroseeding | Acre | 1.00 | 0.75 |
| Construction and maintenance of water holding areas | Acre | 1.00 | 0.85 |

A cost analysis is performed that compares the cost of practices with their ability to mitigate soil and or water contamination.

Initially, practices are identified and their total benefit is estimated. A simple calculation determines the number of acres affected by the remedial measure. Weighted averages can be determined by totaling the affected areas that can be remediated by a specific practice. Total costs are obtained by multiplying the area amenable to remediation by a specific method for that area by the unit cost.

**Case Study 1 – Hazard Assessment on Newly Acquired Range Lands**

Fort Irwin and the National Training Center in California are used to train United States (U.S.) Army brigade-sized units in a realistic battlefield environment. Due to changes in training requirements an additional 118,674 acres (48,012 ha) has recently been added to the training range and is known as the East Gate Expansion Area and the Western Expansion Area. The expansion areas were evaluated for compliance with the U.S. Endangered Species Act, the National Environmental Policy Act, and other pertinent legislation before being used for any training purposes. Based on existing information, it was known that mine sites represented the primary environmental hazard. An environmental team was mobilized to determine the nature of physical and chemical hazards posed by the mine sites, and to develop remedial solutions, to manage those risks deemed unacceptable.

The initial information and Environmental Baseline Study for the East and West Expansion units identified a total of 58 mines with 95 adits/shafts, prospect pits, trenches, surface mines, or borrow pits. Following careful field investigation the number of these features increased to 95 mines and 198 adits/shafts, prospect pits, trenches, surface mines, or borrow pits. Prospects were related to gold, silver, turquoise, iron, and titanium. Given the nature of the host rock and beneficiation methods, primary constituents of interest included arsenic, cyanide, lead, mercury, and selenium. With the analytical methods available, analyses were also obtained for barium, chromium, and silver. Slurry pH was also measured.

Upon arrival at a mine site, the environmental team would inventory and map all relevant features using GPS technology. Digital photos were taken to document anything of significance such as physical hazards and changes in ore characteristics as represented by color or texture. A field portable X-ray fluorescence (XRF) instrument, Thermo Niton series XL700, was used to measure total metal content. Lead, mercury, arsenic, and selenium were the XRF targets. Every attempt was made to identify an outcrop of the parent ore body or otherwise undisturbed rock for the purposes of determining the range of background mineral concentrations. Where XRF values exceeded preliminary remediation goals as established by the U.S. Environmental Protection Agency, samples were taken for laboratory analysis. In all, 196 XRF readings were taken and 55 soil samples were collected for laboratory analysis. Additionally, samples were collected in beneficiation areas (e.g., leach pads or mills), liquids and drum contents. These were analyzed for cyanides or petroleum products, as appropriate.

*Chemical Hazards*

No results were obtained indicating a significant release of chemicals as a result of mining activities in either expansion area. Releases of extremely low levels of cyanide at some of the precious metal processing sites were noted. Because extremely high natural levels of arsenic and lead were noted, an unacceptable risk from ingestion under normal risk assessment exposure scenarios might exist. The range for naturally occurring arsenic and lead were found to be up to a maximum value of 4,930 mg/kg and 6,230 mg/kg, respectively. Productive ores in this mining district are typically irregular masses of sulfides. The ores commonly contain complex mineral including various base metals, silver, arsenic, antimony, and sulfur.

From a training range management perspective, range managers cannot remove all naturally occurring arsenic and lead that is present in concentrations in excess of risk-based criteria for direct contact under an infrequent exposure scenario. Chemical hazards that exist at these sites by virtue of their mineral content are best addressed through institutional controls in the form of training guidelines, training frequencies, and positioning of training exercises outside the mining areas with toxic mineral levels.

*Physical Hazards*

Four types of physical hazards were identified: open shafts (8), adits of questionable structural integrity (13), sheer walls and escarpments (7), and unstable surfaces underlain by adits (1). Shafts, unstable surfaces and sheer walls pose a danger to soldiers training in the area, especially when exercises are run at night. Training with tanks dramatically increases the weight bearing capacity required for unstable surfaces and steep slopes.

Adits were inventoried both as potential hazards and as training assets. Tunnels and cave-like structures are useful for certain training purposes. Accordingly, any adit that was more than 15 feet in length and had an opening at least five foot high was marked for evaluation as a special training area. Tests for structural integrity and air quality are planned.

*Endangered Species*

Endangered species in the expansion areas include bats, burrowing owls, and the desert tortoise. Preliminary surveys confirmed that both bats and burrowing owls were using the vertical and horizontal shafts for habitat. As a consequence, closure of the shafts could sacrifice any individuals of those species in the shafts at the time, and would reduce the overall habitat for those species. Fifty three (53) shafts were found to be in active use or potentially could be in use by bats and burrowing owls. For shafts with habitat potential that are not retained for training, provisions for bat and owl ingress and egress must be included in closure plans.

Shallow prospect pits that do not pose a hazard to soldiers could act as a trap for the desert tortoise, a situation that was actually observed. Many of these pits were found to have sheer walls that the tortoise cannot surmount if it happens to fall in. Accordingly, a fifth hazard type was created: pits that could act as tortoise traps.

*Closure Design*

Three levels of response were developed to address the physical hazards:

1. Temporary access restrictions in the form of fencing or tank barriers;
2. Designs promoted by the American Cave Conservation Association (ACCA); and
3. Permanent closure using an innovative new design to reduce costs.

Temporary fencing can be as simple as a three strand wire configuration or a more challenging design using three rolls of concertina in a pyramid configuration. Fencing of either design is recommended when the ultimate nature of use or design of final closure is still undecided. As an example, some of the remote mines had not had an official bat survey conducted at the time that access restrictions were needed. Similarly, when expensive closure designs were appropriate, budget constraints could necessitate temporary closure until funds are available.

The ACCA designs are based on the realization that over time, individuals will attempt to break into mines left on public properties using a variety of tools such as hack saws and wrecking bars. Consequently, they call for an extremely robust closure design that specifies reinforced four-inch steel angle iron struts and slats set in reinforced concrete.

The third tier of designs was developed to meet the needs of the National Training Center. Because the mines are present in an active military training range with security provisions, the presence of trespassers is unlikely. The most likely individual to try to enter the closed mines will be a soldier in training who will have access to powerful means of breaching containment (hand grenades and automatic weapons.) Therefore, a design was developed to frustrate casual attempts at entry, but not a committed effort. Moreover, budget considerations and the need to haul materials into remote areas without road access suggested selection of lighter weight materials. Modular designs were developed to accommodate easy transport onto sites and subsequent assembly. Features were added to thwart use of hand tools.

The Army is now evaluating the blend of barriers and institutional controls that provide the best overall protection for the planned use of the properties going forward. Costs per mine of the designs range up to $20,000 depending on the provisions for bats and the degree of forced entry that is to be denied. A detailed cost comparison of each hazard type has been provided. A summary of approximate costs for each option for the different hazard types is provided in Table 3.

**Table 3. Comparison of Estimated Closure Costs**

| Hazard Type | Fencing | ACCA Design | CALIBRE Design |
|---|---|---|---|
| Vertical Shaft | $500 | $20,000 | $10,000 |
| Adit | $500 | $8,000 | $1,500 |
| High Wall | $1,500 | NA | NA |
| Unstable Surface | $1,000 | NA | $1,500 |

**Conclusion**

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