PUBLIC WORKS TECHNICAL BULLETIN 200-1-130
31 OCTOBER 2013

EVALUATION OF EROSION CONTROL BLANKETS ON MILITARY FIRING RANGES

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US Army Corps of Engineers
441 G Street NW
Washington, DC 20314-1000

CECW-CE

Public Works Technical Bulletin 31 October 2013

No. 200-1-130

FACILITIES ENGINEERING ENVIRONMENTAL

EVALUATION OF EROSION CONTROL BLANKETS ON MILITARY FIRING RANGES

1. Purpose

a. The Public Works Technical Bulletin (PWTB) summarizes a demonstration of different types of erosion control blankets on stationary infantry target berms at Camp Atterbury Joint Maneuver Training Center (CAJMTC), Indiana. It communicates the lessons learned and the pros and cons of different product types under adverse conditions found on military firing ranges (e.g., bullet and blast impacts).

b. All PWTBs are available electronically at the National Institute of Building Sciences’ Whole Building Design Guide webpage, which is accessible through this link:

http://www.wbdg.org/ccb/browse_cat.php?o=31&c=215

2. Applicability This PWTB applies to engineering activities at all US Army facilities. The intended audience is public works, natural resources, and environmental personnel.

3. References

a. AR-200-1, “Environmental Protection and Enhancement,” 13 December 2007.

b. Clean Water Act of 1977 (PL 95-217, U.S. Code, Title 33 Part 1251).

c. Executive Order (EO) 13514, “Federal Leadership in Environmental, Energy and Economic Performance,” 5 October 2009

4. Discussion

a. AR 200-1 contains policy on environmental responsibilities for all Army organizations and agencies. Specifically, AR 200-1 requires military installations to be good stewards of land resources through the minimization of environmental impacts of training.

b. The Clean Water Act dictates how Army training lands must be managed to maintain water quality standards. Sediment is one of the nation’s leading causes of water quality concerns. Properly designed and installed sediment and erosion control best management practices (BMPs) can help military agencies meet required water quality standards.

c. Goal 2 of EO 13514 established targets to improve water resources management and the reduction of stormwater runoff.

d. Erosion control blankets (ECBs), turf reinforcement mats, hydromulch, and compost blankets are BMPs to stabilize exposed slopes or recently disturbed soil surfaces by reducing raindrop energy and runoff velocity while retaining seed and topsoil. The ability of ECBs to increase slope stability has been well documented in general. However, specific documentation is lacking for effectiveness on firing ranges and impact berms. The damaging nature of impacts on military firing range embankments provides a unique situation for slope stabilization.

e. Appendix A contains background information on the maintenance of military firing ranges due to soil loss, the contributing erosion processes, and a review of erosion control practices applicable to military firing range berm stabilization.

f. Appendix B provides a summary of the Camp Atterbury demonstration, including erosion control practices selected for testing.

g. Appendix C discusses results and observations from the six-month demonstration at CAJMTC.

h. Appendix D lists the lessons learned from the demonstration, which are summarized here. In conditions where vegetation cannot be established by seeding alone due to training intensity, applying ECBs can minimize costs associated with maintaining earthen structures on firing ranges. This demonstration showed that quick vegetation establishment was obtained by using a range of products, from an inexpensive ECB to a more expensive turf reinforcement mat. Establishing vegetation in this way resulted in reduced sediment loss in most cases, compared with the control. ECB treatment selection should be based on cost, availability, color, and maintenance factors. ECB can be combined with native vegetation species establishment for long-term erosion control for earthen structures on firing ranges.

i. Appendix E provides source information for different erosion control products. This section also provides reference information and acknowledgements for those assisting with demonstration.

j. Appendix F spells out the abbreviations used in this document.

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APPENDIX A:
FIRING RANGE EMBANKMENT STABILITY AND EROSION CONTROL BLANKETS

Soil Loss Maintenance Issues

Earthen embankments are essential to military firing ranges because they provide protection to personnel utilizing the ranges and to the mechanized targetry behind some types of ranges. Earthen embankment design varies according to the training objective and the embankment’s location in the range.

Military firing range embankments fall into four main categories: target emplacement berms, firing emplacement berms, projectile stop berms, and separation berms (USACE 1998). While this document focuses on a demonstration involving stationary target emplacement berms, the advantages to slope stability from vegetation establishment are directly applicable to other types of earthen embankments.

The Ranges and Training Lands Program (RTLP) Range Design Guide (USACE 1998) provides an excellent description of earthen embankment design for military training ranges. The design manual neglects, however, to incorporate proper range elements to reduce soil loss from the earthen embankments, as discussed in ERDC/CERL TR-06-14 (Svendsen et al. 2006). This lack of inclusion results in increased range maintenance costs, possible safety issues, and potential contributions to overall installation erosion and water quality degradation (Svendsen et al. 2006; USAEC 1998).

Over time, soil displacement from water, wind, or projectile impacts requires that berms be rebuilt to maintain their protective function. Depending on the number and size of the embankments, this maintenance requirement can be costly. In addition, range downtime for maintenance can be detrimental to the Army mission. For example, rebuilding a typical small-weapons training facility at Camp Atterbury requires approximately 6-8 personnel to work 3-5 days, depending on the level of maintenance required. As embankment sizes increases, the associated costs and downtime for maintenance also increases.

Soil Erosion Processes on Military Firing Range Embankments

Soil erosion is the displacement of soil particles from one location, and their transfer and deposition to a separate location. Erosion and deposition of soil particles is a wellresearched and well-understood phenomenon. The Universal Soil Loss Equation (USLE) is an easily understood model for estimating erosion from agricultural production lands that demonstrates the major factors contributing to erosion rates (Schwab et al. 1993).

The USLE equation is:

$$A = RKLSCP$$

where:

A = average annual soil loss

R = rainfall factor — higher intensity storm events result in higher erosion rates

K = soil erodibility factor — soil texture, clay content, and structure affect erosion rates – generally low cohesion (“less sticky”), smaller particles with poor structure (more individual particles as opposed to clumps of soil particles) results in increased erosion rates

L = slope length factor — increased lengths of continuous slope increase erosion rates

S = slope degree factor — increased slope results in increased erosion rates

C = cropping and management factor — vegetated or other cover reduces erosion rates when compared with bare soil conditions

P = conservation practice factor — terracing or other conservation practices reduce erosion rates

From reviewing this simple equation, it is apparent why slope stability is such an issue on firing range earthen embankments. Even without repeated bullet impacts, the slopes increase the risk of soil loss. The impacts of projectiles dislodge soil particles and destroy any soil structure previously found in the profile. This highly disturbed surface reduces the soil’s ability to establish a vegetation cover. Due to continuing the overall mission and intensive training schedules, ranges cannot be set aside for long periods of time to allow proper establishment of vegetation on the slopes. As illustrated by the rainfall factor in the USLE equation, a single rain event following weeks of range use could result in high levels of sediment loss.

Erosion Control Practices and Application for Firing Ranges

Long-term erosion control efforts are generally aimed at improving or establishing a vegetation cover on the impaired surface (USAEC 1998). Vegetative cover reduces soil loss and stabilizes slopes in three interrelated ways.

1. Initially, vegetation and litter from dead plant material intercept the raindrops before they strike the soil surface, diminishing the energy which dislodges and transports soil particles. In the case of military firing embankments, this function is critical as projectiles already have loosened and dislodged soil particles reducing the energy required to displace the soil particles.

2. Also, vegetation and litter on the soil surface reduce the velocity of the water running across the soil surface. Consequently, this reduction decreases the energy of the overland flow which reduces the ability of the water to transport soil particles down the slope.

3. Furthermore, the root structure of vegetation decreases rill and inter-rill erosion by holding the soil structure together, thereby reducing the ability for raindrops and overland flow to dislodge and transport soil particles.

Thus, vegetation establishment and maintenance are critical components for stabilizing the soil surface on firing range earthen embankments. However, the intensity of training and the increased disturbance resulting from bullet impacts often makes vegetation establishment from seeding alone difficult. Numerous studies have shown that soil erosion can be significantly reduced by applying temporary groundcovers such as rolled blankets with natural or synthetic fibers or compost covers (Babcock and McLaughlin 2011; Benik et al. 2003; Bhattarai et al. 2011; Lancaster and Austin 1994; Xiao and Gomez 2009). An excellent summary of different erosion control methods, method benefits and limitations, and relative costs is given in the California Department of Transportation Erosion Control Toolbox (CALTRANS 2012).

Rolled Products

Rolled ECBs are treatments recommended for reducing erosion and aiding the establishment of vegetation on slopes. ECBs are constructed of natural or manufactured fibers and act as temporary cover for the bare soil surface (Lancaster and Austin 1994). Many ECBs are constructed of wood fibers, jute, biodegradable plastics, straw, or other natural fibers. Some ECBs utilize a netting to give the blanket strength, while others utilize the natural material to provide all of the blanket’s lateral strength.

ECBs provide many of the same benefits as established vegetation cover. This similarity means an ECB can reduce erosion and enhance vegetation establishment by reducing raindrop energy as the raindrops strike the soil surface. If installed properly, the ECB contacts the soil surface and decreases the velocity of overland flow. The ECB aids in vegetation establishment by holding the seed and soil particles in place prior to germination. Additionally, the cover of an ECB improves moisture conditions for germination and growth.

Turf reinforcement mats (TRM) supply many of the same functions as an ECB (e.g., soil and seed holding capacity, moisture regulation, and raindrop and flow energy dissipation) but are generally constructed of a more durable material such as synthetic fibers and filaments. TRMs are designed to help hold soil particles in place while vegetation is initially established but are also utilized as a permanent product to give stability to the soil surface (Lancaster and Austin 1994). TRMs are often used in hydraulic applications such as stream bank stabilization or in locations such as drainage channels where the shear stresses of water flow may exceed the limits of natural vegetation. In many applications, the TRM is installed on the soil surface with a seed/soil mixture then worked into the mat as opposed to being secured to the soil surface.

Compost

An alternative practice to rolled erosion control products is the application of compost over freshly seeded slopes. Compost covers or compost blankets have been found effective in controlling runoff and erosion (Bhattarai et al. 2011). Some well-documented benefits of compost are improved water retention, moderated soil temperature, and nutrient supply (Faucette et al. 2004; Bhattarai et al. 2011; Risse and Faucette 2001; Xiao and Gomez 2009). Bhattarai et al. (2011) and Xiao and Gomez (2009) indicate the success of a compost application for erosion prevention depends in large part on the particle size distribution of the compost. Bhattarai et al. (2011) used treatments of compost, mixed compost and mulch, and mulch. The results indicated that a mixture of large and small particles (mulch and compost) resulted in the lowest concentration of sediment in the runoff. Xiao and Gomez (2009) also concluded that low organic matter, small particle sizes, or high bulk density could decrease the effectiveness of the compost for erosion control.

Though rolled erosion control products and compost improve conditions on a relatively non-disturbed site, it is unknown if they can stand up to the repeated projectile impacts on military firing ranges long enough to allow for the establishment of vegetation cover. The following appendices document the demonstration of the application of erosion control technologies on military firing range earthen embankments. They also outline the lessons learned and observations from the range managers participating in the demonstration.

APPENDIX B:
DEMONSTRATION OF EROSION CONTROL PRACTICES ON MILITARY FIRING RANGE EMBANKMENTS

Demonstration Design

A demonstration and assessment of the feasibility of using recommended erosion control methods (rolled ECBs, compost application, and hydromulch) was performed on military firing range earthen embankments at Camp Atterbury, Indiana. Through discussions with Camp Atterbury Range Managers, Range 14 was selected as the demonstration site. Range 14 has a high level of utilization and historically has the required high levels of maintenance and berm re-facing. The range contains 16 firing positions with above-grade, emplaced, stationary infantry targets (SIT) at 50 m, 100 m, 150 m, and 250 m distances. A standard above-grade SIT emplacement consists of a concrete emplacement with treated timber front- and side-wall protection and a protective earthen berm (USACE 1998). According to the RTLP Range Design Guide, standard SIT emplacement berms require maintenance on 6-month cycles under normal usage. According to Camp Atterbury staff, the Range 14 berms are rebuilt every 3 to 6 months, depending on breaks in scheduling or anticipated future training intensity. Typical Camp Atterbury SIT berms are shown in Figure B-1 and Figure B-2.

Figure B-1. A typical SIT emplacement berm at Camp Atterbury demonstration site (ERDC-CERL 2011).

Figure B-2. A typical SIT emplacement with treated timber at Camp Atterbury demonstration site (ERDC-CERL 2012).

At Camp Atterbury, these small-arms ranges are utilized frequently, limiting downtime for maintenance. Consequently, after berms are rebuilt, they cannot be set aside to allow time for vegetation establishment and this leads to rapid degradation of the berm faces. Figure B-3 illustrates the pattern erosion and soil displacement typical of the protective earthen berms at Camp Atterbury. If the earthen berms are not maintained properly through periodic replacement of eroded soil, projectiles begin hitting the treated timbers, increasing risk of injury, and requiring replacement of the timber and possibly the targetry mechanism which increases maintenance costs. Figure B-4 illustrates a berm which has failed, resulting in damage to the timber wall and possible damage to the targetry mechanism from projectile damage.

Figure B-3. Typical pattern erosion and soil loss on SIT emplacement berm at Camp Atterbury demonstration site (ERDC-CERL 2012). Note: photo is taken looking toward target.

Figure B-4. Berm failure and timber beam damage (top of photo) resulting from projectile impacts at Camp Atterbury demonstration site (ERDC-CERL 2012).

Erosion Control Treatments Demonstrated

A total of seven products or treatments were selected for the erosion control demonstration at Camp Atterbury (Table B-1 and Figure B-5–Figure B-11). Each treatment was replicated five times over four distances from the firing points (50 m, 100 m, 150 m, and 250 m). Two replications of each treatment were applied at the 50m distance since range managers indicated this distance generally experiences the highest level of use. The center-most eight firing lanes were utilized, as range managers suggested these would have the most uniform rates of usage. The current methodology Camp Atterbury was using for reseeding and erosion prevention (hydromulching) was replicated ten times. The rolled erosion control products were chosen to demonstrate a range of strengths (ECB and TRM). A less-expensive straw erosion control blanket was selected as a lower-strength alternative to some of the other products. Due to concern with disposal and maintenance issues (e.g., net wrapped in mowers), a net-free product was selected as an alternative to the netted products. The compost was obtained from the Bartholomew County Solid Waste Management District.

Table B-1. Treatments demonstrated at Camp Atterbury small-arms range.

Treatment Number	Treatment	Treatment Class	Figure Number
1	Double-net recycled plastic TRM	TRM	Figure B-5
2	Double-net excelsior TRM	TRM	Figure B-6
3	Net-free excelsior ECB	ECB	Figure B-7
4	Double-net excelsior ECB	ECB	Figure B-8
5	Double-net straw ECB	ECB	Figure B-9
6	Hydromulch	Hydromulch	Figure B-10
7	Compost	Compost	Figure B-11

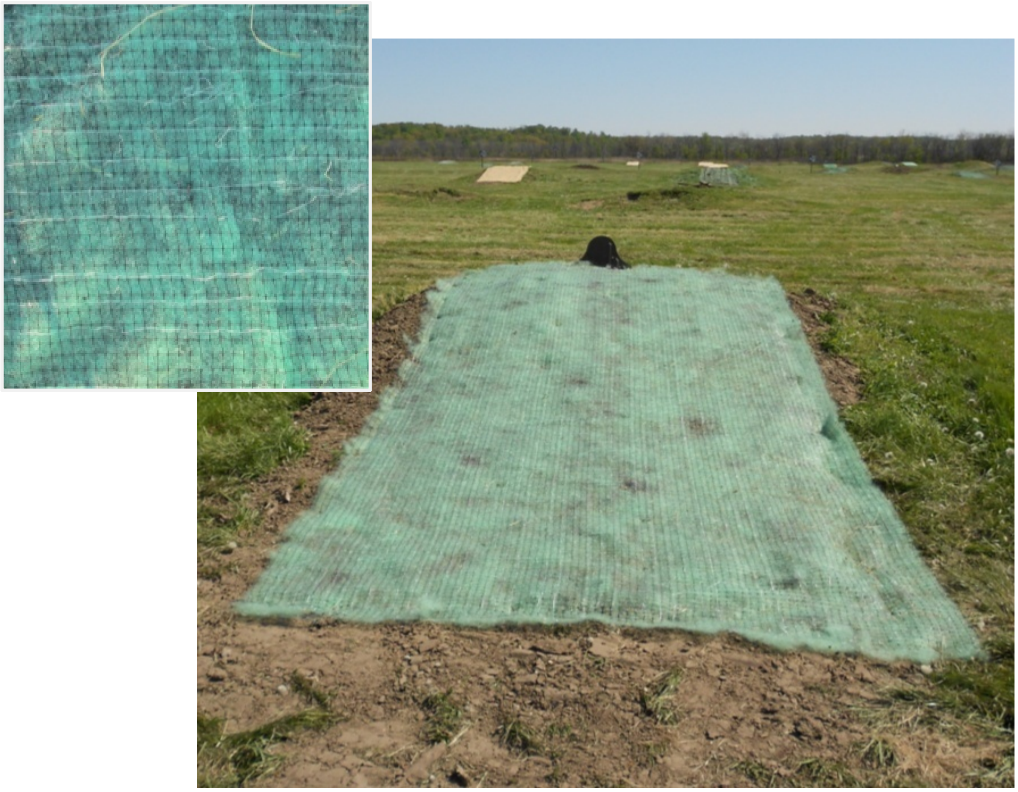

Figure B-5. Treatment #1: Double-net recycled plastic TRM treatment installation (ERDC-CERL 2012).

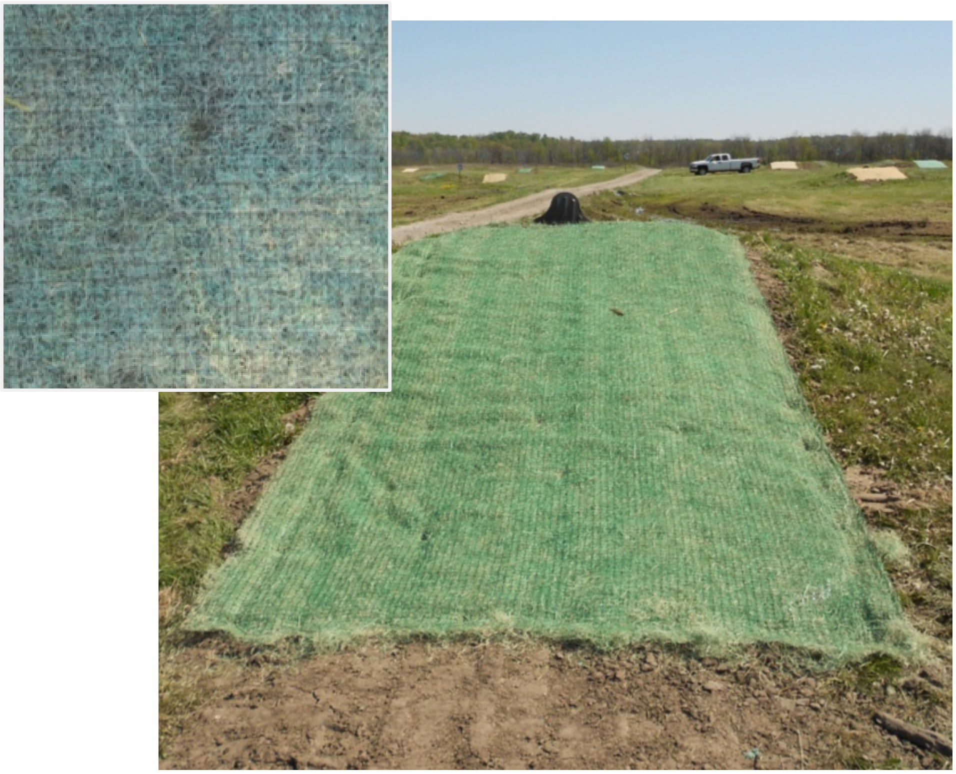

Figure B-6. Treatment #2: Double-net excelsior TRM treatment installation (ERDC-CERL 2012).

Figure B-7. Treatment #3: Net-free excelsior ECB treatment installation (ERDC-CERL 2012).

Figure B-8. Treatment #4: Double-net excelsior ECB treatment installation (ERDC-CERL 2012).

Figure B-9. Treatment #5: Double-net straw ECB treatment installation (ERDC-CERL 2012).

Figure B-10. Treatment #6: Hydro-mulch (Camp Atterbury current treatment) installation (ERDC-CERL 2012).

Figure B-11. Treatment #7: Compost installation (ERDC-CERL 2012).

Erosion Control Treatment Installation

The earthen embankments in Range 14 were rebuilt during the week of 9-13 April 2012. A skid-steer loader was used to fill the cavity with soil. The skid-steer loader and tracks were used to pack the soil to create a firm surface for maximum impact resistance. The surface of each berm receiving a treatment was scratched with a rake to create a suitable seedbed. A low-maintenance seed mixture (Table B-2), used by Camp Atterbury range managers for small-arms firing ranges, was seeded at a rate of approximately 10 lb per 1000 ft^2 for all treatments. The seeded soil surface was raked again to increase the seed-soil contact and improve seed uniformity.

The low-maintenance seed mixture was used for this demonstration as it is currently utilized for all Camp Atterbury small-arms ranges. However, once established, deep-rooted native vegetation species could be used for longer-term soil stabilization on firing ranges. Several PWTBs have been published that describe the benefits of native vegetation and best methods for establishing them (USACE 2010, 2011, 2012).

The TRM and ECB were installed according to manufacturer recommendations. The products were installed from the top of the berm (i.e., even with the treated timber) to approximately 30 cm beyond the bottom of the berm face (See Figure B-5–Figure B-9 of installed products). The ECB and TRM products were secured with 8” wire staples with approximately 1 staple per cubic yard of material. Compost was installed at a rate of 0.0025 m3 per m^2 resulting in a depth of approximately 2.5 cm. The hydromulch was applied at a rate consistent with current Camp Atterbury range management practices. An elevation survey of the rebuilt soil surface for each berm was taken using Trimble Real-Time Kinematic (RTK) survey equipment capable of sub-centimeter measurements. This allowed for an estimation of soil lost following the demonstration period.

Table B-2. Low-maintenance seed mix used for Camp Atterbury small-arms ranges.

Percent Pure Seed	Variety
63.7%	Tall fescue
24.63%	Perennial ryegrass

Percent Pure Seed	**Variety**
9.74%	Creeping red fescue
1.04%	Crop seed (*undefined on seed label)
0.81%	Inert matter
0.08%	Weed seed

In ideal slope stabilization conditions, a good vegetation cover would be established prior to any additional disturbances on the surface. However, due to the intensive use of firing ranges at Camp Atterbury, the range was not taken off-line except for the rebuilding and occasional maintenance (e.g., mowing) of the berms. As such, training commenced the week following the demonstration installation. While not ideal for erosion control, this is typical for military installation training requirements making the short timeframe necessary for realistic demonstration.

The products remained in place until 16 October 2012 resulting in a 6-month demonstration. The data from monthly site assessments were analyzed to determine the effect of treatment on soil loss. Both volume of soil lost over the demonstration and maximum depth of removed soil (Figure B-12) were recorded and used as indicators of treatment success. The penetration of bullets into the protective wooden beam is the basic indicator of berm failure and drives the need to reface the berm. This condition (berm failure) is more correlated with maximum depth of soil removed, rather than volume of soil removed. A statistical analysis was performed to assess the difference of soil loss and maximum depth of soil removed of each treatment compared with the control treatment (Camp Atterbury’s current method). Results of the analyses are summarized in Appendix C.

Figure B-12. Schematic of maximum depth measurement used to quantify treatment success at Camp Atterbury demonstration site (ERDC-CERL 2012).

APPENDIX C:
SUMMARY OF DEMONSTRATION RESULTS

This demonstration was designed to assess the ability of ECBs and other similar erosion control methods to minimize soil loss over time from military firing range earthen embankments. Through minimizing soil loss from earthen embankments, the installation reduces range maintenance costs and possibly reduces sediment loading and deposition in nearby streams.

The demonstration was performed from April-October 2012. Coincidentally, this time period was one of the driest on record for the location, which resulted in lower soil losses from all firing berms. As described in Appendix A, the process of soil loss from earthen embankments on firing ranges contains two major elements — (1) projectile impacts that loosen soil particles and (2) subsequent rainfall events that remove those loosened soil particles. Lower soil losses also are evident because the firing berms did not require rebuilding during the 6 month demonstration period, even under typical training intensities. Generally, the berms on this range required maintenance more than twice per year. Figure C-1 illustrates one site’s change in vegetation 14 May to 18 July 2012.

Figure C-1. Change in vegetation cover on Treatment #3 from 14 May (left, with target up) to 18 July 2012 (right, with target down) due to extremely dry conditions (ERDC-CERL).

As could be expected, the drought conditions greatly influenced demonstration results. Differences in berm condition that most likely would have been noticed between treatments in a typical year were not as apparent during drier conditions. Even if soil particles were loosened at different rates, the lack of major rain events resulted in lower soil loss across all treatments. Furthermore, although the lifespan of the firing berms was apparently increased over the demonstration compared with previous years, this cannot be solely attributed to the soil erosion control methods demonstrated due to the dry conditions.

Despite limitations due to low rainfall, several significant observations could be made from the demonstration regarding the use of ECBs on firing berms. As described in Appendix A, ECB, TRM, and compost covers have been well documented in their ability to reduce sediment loss and quickly improve vegetation establishment. Due to the intensive soil disturbance observed on military firing range embankments, it was unknown if these erosion control products would withstand repeated impacts long enough to improve slope stability. Over the 6-month demonstration, installation range use data indicates 353,939 rounds were fired on the demonstration range.

As illustrated in Figure C-2, the distance of the target from the firing point was a significant factor in determining soil loss. The intensity of impacts is higher on shorter-distance targets (50–100 m) than on the longer-distance targets (150-250 m), resulting in much higher depths and volumes of soil loss for the near targets. Due to the large range of soil loss observed for each treatment across all distances, the differences between treatment methods were relatively small. At a 70% confidence interval, the double-net excelsior ECB and the double-net straw ECB significantly reduced the mean depth of soil removed when compared with the hydromulch control averaged across all distances.

Some additional observations can be made from looking at Figure C-2. The compost treatment at the closer distances (50 m) did not reduce the depth of soil loss when compared with the hydromulch condition. However, the compost treatment significantly reduced the depth of soil loss at the other distances. This reduction could be caused by the low cohesiveness of the compost particles. While the cover seemed to be effective at reducing soil loss at longer-distance berms, the low-cohesive cover may not withstand bullet impacts at closer ranges.

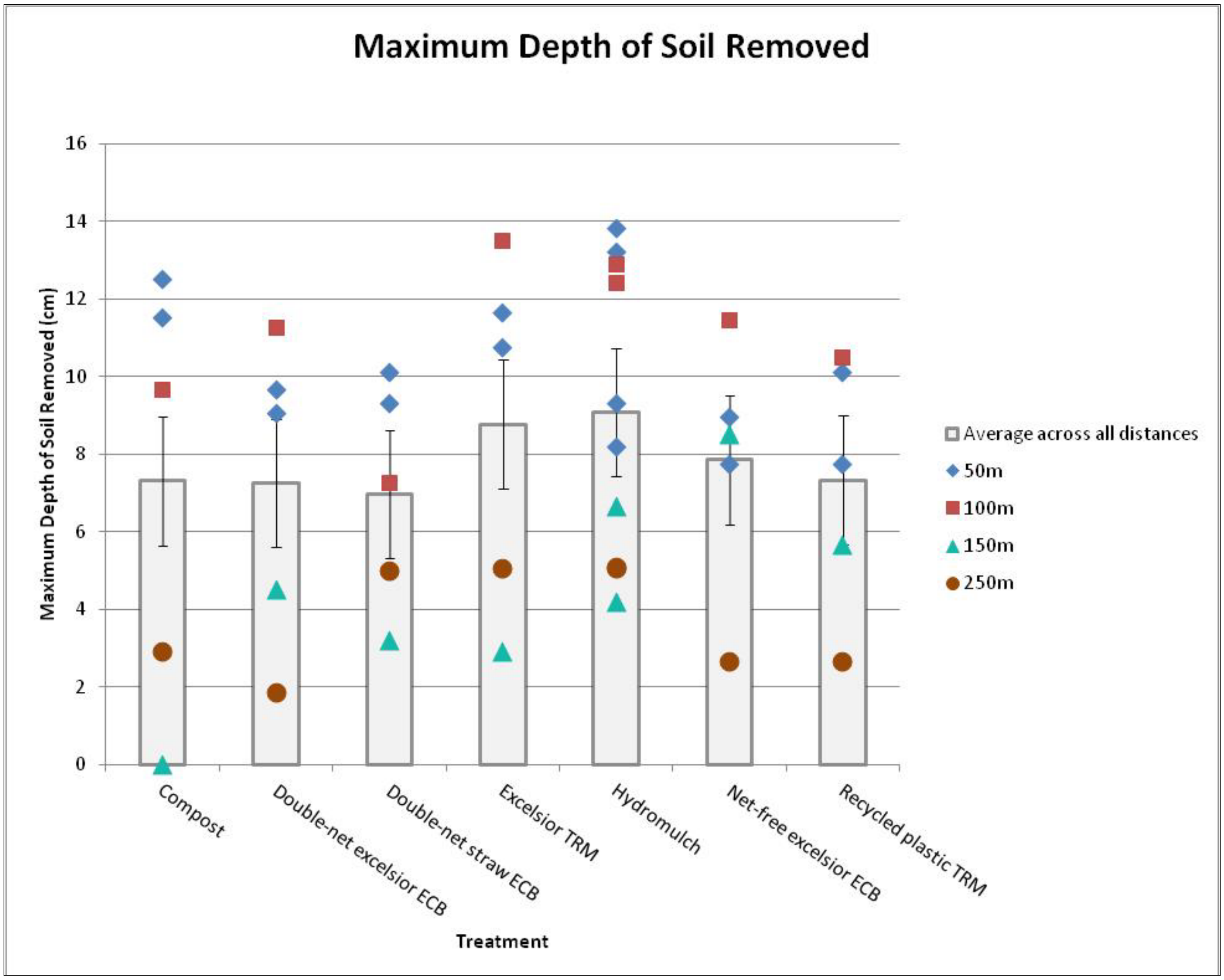

Figure C-2. Measured maximum depth of soil loss following the six-month demonstration. The points represent actual depths measured by distance, while the bars represent the average depth across all distances.

Due to the significance of distance to the observed data, a general linear model classifying data by distance was created to estimate the effectiveness of the treatments and distances on the observed depth of soil removed (Table C-1). The linear model was created by using distance-classified variables. The model's R^2 value was 0.79, indicating it accounts for 79% of the variability observed in the data. For example, since the model was based on distance-classified variables, the model estimate for depth of soil removed (cm) on the 100 m net-free excelsior ECB is calculated by simple addition (3.68 + 7.33). Again, much lower depths were observed for the 150 m and 250 m target distances.

The model agrees with the comparison of the mathematical means by treatment because the double-net excelsior ECB and double-net straw ECB both reduce the predicted depth of soil loss compared with the hydromulch condition. However, the model also indicates the compost, net-free excelsior, and recycled plastic TRM generally reduced the depth of soil loss. As illustrated in Table C-1 and Figure C-2, the excelsior TRM did not reduce the depth of soil loss compared with the control treatment. Additionally, it does not appear the added strength, thickness, (and cost) of both TRM treatments resulted in increased performance when compared with alternative rolled erosion control products and compost covers.

Table C-1. General linear model classified treatment parameters for estimation of maximum depth of soil lost in demonstration. Model estimation of the soil lost for each berm can be calculated by adding the erosion control treatment at 250 m distance parameter to the distance from firing point correction parameters.

Parameter	**Parameter Estimate (cm)**	**Standard Error**
Erosion control treatments at 250 m from firing point		
Compost	3.13	1.06
Double-net excelsior ECB	3.08	1.06
Double-net straw ECB	2.79	1.06
Excelsior TRM	4.59	1.06
Hydromulch	4.90	0.87
Net-free excelsior ECB	3.68	1.06
Recycled plastic TRM	3.15	1.06
Distance from firing point correction parameters		
50 m distance	6.44	0.84
100 m distance	7.33	0.97
150 m distance	0.67	0.97

Similar trends in soil loss by treatment and distance were observed by using the metric of volume of soil loss; however, the differences between treatments were not as significant under this metric as those observed between maximum depths (Figure C-3). This difference is likely due to the confounding factor of slope length. Depending on a berm’s location and elevation, it may be required to be larger or smaller than other berms. As such, a larger berm with a longer slope face would likely have a larger calculated soil loss than that of the smaller berm, regardless of erosion treatment. In this case, soil loss is more of a function of berm size than treatment performance, making soil depth loss a better indicator of relative treatment performance.

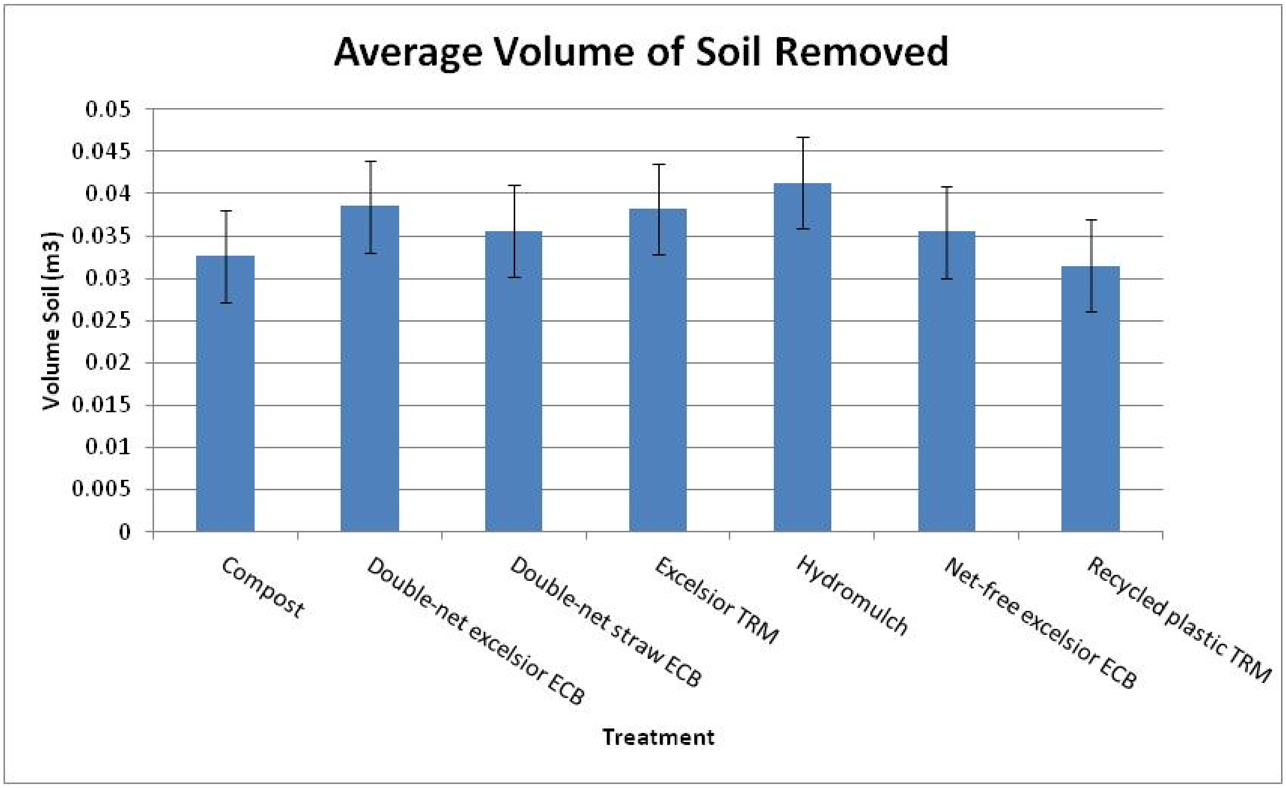

Figure C-3. Measured volume of soil lost following the six month demonstration. The error bars on the average represent the standard error of the mean.

During the first and second month of demonstration observations, it was apparent that vegetation stand establishment was improved with the use ECBs, TRMs, and compost covers when compared with Camp Atterbury’s current approach of hydromulching. The compost cover resulted in the quickest vegetation establishment; however, some of this vegetation establishment was due to weed seed in the compost (Figure C-4). The initial cover created by the ECB, TRM, and compost was greater than the cover created by the hydromulching. With the level of training observed (e.g., training and bullet impacts on berms began the following week), the increased cover improved growing conditions by holding seeds and topsoil in place longer than the control treatment allowing increased vegetation establishment. In the extreme dry conditions observed over the demonstration period, the cover created by ECB, TRM, and compost also likely aided vegetation establishment by providing shade to the soil and reducing soil moisture loss. Higher vegetation establishment rates could likely be achieved with higher rates of hydromulch and seed in the control treatment though this was not demonstrated.

Figure C-4. Vegetation establishment on compost treated berm (left) compared with hydromulch treated berm (right) one month after treatment installation (ERDC-CERL 14 May 2012).

Another consideration when determining proper methods for vegetation establishment and temporary soil particle stabilization is ease of product application and maintenance following installation (e.g., mowing). For a comparison, the application of ECBs and compost took a crew of three persons approximately 5 min. per berm, whereas hydromulching required a crew of three persons approximately 1 min. per berm. The maintenance crew generally trimmed around the targetry with string weed trimmers. Mowing around the treatments was not an issue in the current year due to the lack of moisture; however, in a typical year the treatments may have caused maintenance issues. Net-free products should be considered in areas anticipated to be mowed with a low deck height. An additional maintenance consideration is non-degradable products must be removed when berms are rebuilt, slightly increasing labor requirements. For this demonstration, the products were removed from all berms by installation staff in less than 30 min., so removal effort was relatively minor in this demonstration.

Though it does not affect actual ability of the treatment to improve slope stability, an ideal SIT earthen berm is covered with vegetation to camouflage the target. Thus, a bare soil berm or a brightly colored ECB in front of the target provides an easier target than a grass-covered berm. Therefore, an observed benefit or detriment of different treatments is the ability to mask the bare soil until vegetation is established. With this as a metric for determining product performance, a green colored treatment (e.g., the recycled plastic TRM, excelsior TRM, and the hydromulching) or darker color (e.g., the compost) would provide a better camouflage for the target than a brighter colored, reflective treatment. Many products are available in both a green or natural color, an option which could be kept in mind when determining which product would be most appropriate for the application.

APPENDIX D:
CONCLUSIONS AND LESSONS LEARNED

The demonstration at Camp Atterbury assessed the ability of ECBs and other, similar erosion control methods to minimize soil loss over time from small-arms firing range earthen embankments. The demonstration was performed from 9 April – 16 October 2012. The bulleted list below summarizes observations discussed in the previous appendices.

- Initial vegetation stand establishment was increased through the use of all but one of the erosion control products when compared with Camp Atterbury’s current practice of hydroseeding.

- It is well known and documented that vegetation stand establishment could be improved with erosion control products and compost blankets, but not whether they could withstand projectile impacts. This demonstration found that the treatments also withstood projectile impacts long enough to increase vegetation establishment on small-arms firing range earthen embankments.

- With the exception of the double-net excelsior TRM, the increased initial vegetation establishment found with erosion control treatments generally reduced soil loss when compared with Camp Atterbury’s current practice of hydroseeding.

- The extra cost and strength of the TRMs did not result in reduced depth of soil loss when compared with other treatments tested.

- Reduction of soil loss was likely due to increased initial vegetation establishment. Product lifespan (past 1-2 months) and strength was not as crucial a consideration under conditions tested. For larger slopes, manufacturer recommendations should be considered with regard to product strength requirements.

- As a corollary to the previous observation, ECBs cannot be used *in place of* vegetation establishment since they begin to break down after a few months in the areas experiencing the most bullet impacts.

- If possible, ranges should be set aside for a few weeks following berm rebuilding to allow time for vegetation establishment prior to range utilization. Because this set-aside period may not be possible due to training needs and schedules, berms should be rebuilt during periods of slow range utilization to decrease the potential of projectile impacts during initial vegetation establishment.

- Installation range managers at Camp Atterbury commented that the different colored products increased or decreased training effectiveness based on their ability to camouflage the target. Products matching the surrounding area provide an enhanced training benefit compared with brightly colored products or bare soil.

- While lower weight or lower strength treatments may have increased vegetation cover as well as heavier products, extra care should be used when installing these products to ensure they stay in place. Additionally, extra monitoring of the berms may be necessary to re-staple if the products come loose soon after installation.

- From this demonstration, the selection of erosion control products for initial establishment of vegetation on firing berms should be made based on color (camouflaging effect), cost, availability, and consideration for maintenance (e.g., if planning on mowing directly over blankets at a low deck height, a net-less product may be desired).

- This demonstration utilized a low-maintenance turf grass mixture typically used on Camp Atterbury small-arms ranges. For longer-term erosion control, consider using native vegetation species (as described in USACE 2010, 2011, and 2012) in conjunction with ECBs.

- If locally available, weed-free compost is a low-cost alternative to rolled erosion control products. However, the low cohesiveness of the product may not improve soil retention in close range, intensively utilized firing berms, or berms with higher slopes. Compost covers with a larger distribution of particle sizes will perform better than a compost cover with either all large or small sized particles (Bhattarai et al. 2011).

In general, quick vegetation establishment on berms should be the goal for erosion control. Quick establishment of vegetation was obtained during this demonstration by using a range of products, from an inexpensive ECB to a more expensive TRM. While the demonstration focused on above-grade SIT emplacement earthen embankments, the observations are applicable to other firing range earthen embankments. Actual erosion control treatment selection should be based on cost, availability, color, and maintenance factors.

APPENDIX E:
REFERENCES, RESOURCES, AND ACKNOWLEDGEMENTS

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Resources for ECBs and other Erosion Control Products

A partial list of major manufacturers of reinforced vegetation products is shown below. This list is not exhaustive and does not constitute an endorsement of these products by the US Army or the federal government.

Company	Website	Corporate HQ Location
American Excelsior Company	www.americanexcelsior.com	TX
BOOM Environmental Products	www.boomenviro.com	MA
Contech Engineered Solutions LLC	www.conteches.com	OH
DeWitt Company	www.dewittcompany.com	MO
East Coast Erosion Control	www.eastcoasterosion.com	PA
Enviroscape ECM	www.strawblanket.com	OH
Erosion Control Blanket	www.erosioncontrolblanket.com	Canada
Geo-Synthetics, LLC	www.geo-synthetics.com	WI

Company	**Website**	**Corporate HQ Location**
Granite Environmental, Inc	www.erosionpollution.com	FL
Green Solutions	www.greensolutions.us	LA
Invisible Structures, Inc	www.invisiblestructures.com	CO
L & M Supply	www.landmsupplyco.com	GA
North American Green	www.nagreen.com	IN
Volm	www.volmbag.com	WI
Western Fiber Company	www.westernfiber.com	CA

Acknowledgements

This project was performed by the US Army Engineer Research and Development Center – Construction Engineering Research Laboratory (ERDC-CERL) at Champaign, IL. The demonstration was conducted at Camp Atterbury Joint Maneuver Training Center near Edinburgh, IN. The authors gratefully acknowledge the cooperation and assistance of Rick Yarger, Carl Smith, and Mike Peterkin of Camp Atterbury; Ron Geater of American Excelsior Company; and the Bartholomew County Recycling Center.

APPENDIX F:
ACRONYMS AND ABBREVIATIONS

Term	**Spellout**
AR	Army Regulation
CECW	Directorate of Civil Works, United States Army Corps of Engineers
CEHNC	Corps of Engineers – Huntsville Center
BMP	best management practice
CEMP-CE	Directorate of Military Programs, United States Army Corps of Engineers
CERL	Construction Engineering Research Laboratory
DPW	Directorate of Public Works
ECB	erosion control blanket
ERDC	Engineer Research and Development Center
HQUSACE	Headquarters, United States Army Corps of Engineers
POC	point of contact
PWTB	Public Works Technical Bulletin
RTK	real time kinematic
RTLP	Ranges and Training Lands Program
SIT	stationary infantry target
TRM	turf reinforcement mat
USACE	United States Army Corps of Engineers
USLE	universal soil loss equation