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Construction Engineering Research Laboratory

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Defilade, Stationary Target and Moving Target Embankment, Low Water Crossing, and Course Road Designs for Soil Loss Prevention

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Niels G. Svendsen, Dick L. Gebhart, and Michael L. Denight

Construction Engineering Research Laboratory
U.S. Army Engineer Research and Development Center
PO Box 9005
Champaign, IL 61826-9005

Prasanta K. Kalita

University of Illinois
Department of Agricultural and Biological Engineering
1304 W. Pennsylvania Avenue
Urbana, IL 61801-4797

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Abstract: Military training structure designs currently do not employ adequate soil loss prevention technologies that reduce soil loss sufficiently to extend embankment useful life. New range structures must have reduced maintenance requirements and maintain functionality over a longer training interval. Additionally, incorporating sustainability into the range designs should remain a high priority to meet environmental compliance regulations and provide a durable long-lasting structure useful for military training requirements. This report proposes several new range structure designs to begin the iterative process of developing new range edifices that reduce soil loss, control erosion, promote sustainability, and enhance training. The designs for Defilades, Stationary Targets Embankments, Moving Target Embankments, Low Water Crossings, and Course Roads are presented as a demonstration and validation template for installation training areas in temperate climates. These designs are meant to illustrate the use of soil loss prevention measures on range structures.

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Preface

This study was conducted for the Office of the Director of Environmental Programs, under project A896, “Base Facilities Environmental Quality”; Work Unit number F50G68, “Range Design.” The technical monitor was Bill Woodson, DAIM-ED.

The work was performed by the Land and Heritage Conservation Branch (CN-C) of the Installations Division (CN), Construction Engineering Research Laboratory (CERL). The CERL Principal Investigator was Dr. Dick L. Gebhart. Part of this work was done by Dr. Prasanta Kalita, University of Illinois, Department of Agricultural and Biological Engineering under contract no. DACA88-99-D-0002. Manroop Chawla is Acting Chief, CN-C, and Dr. John T. Bandy is Chief, CN. The associated Technical Director was Dr. William D. Severinghaus, CEERD-CV-T. The Deputy Director of CERL is Dr. Kirankumar V. Topudurti, and the Director of CERL is Dr. Ilker Adiguzel.

CERL is an element of the U.S. Army Engineer Research and Development Center (ERDC), U.S. Army Corps of Engineers. The Commander and Executive Director of ERDC is COL Richard B. Jenkins, and the Director of ERDC is Dr. James R. Houston.

1 Introduction

Background

To meet environmental compliance goals and achieve sustainability on ranges, the U.S. Army must rethink the design methodology applied during the construction of military training areas. New range structures must have reduced maintenance requirements and maintain functionality over a longer training interval. Additionally, incorporating sustainability into the range designs should remain a high priority to meet environmental compliance regulations and provide a durable long-lasting structure useful for military training requirements. In this report, several new designs are proposed that begin the iterative process of developing new range structures to reduce soil loss, control erosion, promote sustainability, and enhance training.

New designs and corresponding methodologies for evaluating the new designs should be presented for two critical training area elements, embankments and course roads. Embankments designs should be presented for firing and target positions, and road designs should be presented for low water crossings and course roads. Several design alternatives should be suggested for testing and evaluation. Additionally, supporting documentation for monitoring these structures should be provided to allow validation of each structure's effectiveness.

Approach

A research team consisting of members from the University of Illinois, Urbana-Champaign (UIUC) and the Engineer Research and Development Center's Construction Engineering Research Laboratory (ERDC-CERL) determined that problem visualization and input from various Integrated Training Area Management (ITAM) personnel were essential to develop a design and maintenance solution for larger ranges. To this end, the research team visited four installations between March 2003 and July 2004. The installations were visited in the following order: Camp Atterbury, IN; Fort Knox, KY; Fort Drum, NY; and Fort Benning, GA. ITAM personnel guided the visits at each installation and highlighted problem areas on various ranges. Once the site visits were completed, the standard designs for range structures and maneuver corridors were re-evaluated and redeveloped to increase sustainability.

Objective

The objective of this research was to develop improved embankment designs for defilades, stationary targets, and moving targets to better withstand soil loss. Additionally, improved designs for low water crossings and course roads and trails were also developed to improve overall integrity and decrease fugitive dust on training areas.

2 Designs for Training Areas and Maneuver Corridors

New designs and corresponding methodologies for evaluating the new designs are presented for two critical training area elements, embankments and course roads. Embankment designs are presented for firing and target positions, and road designs are presented for low water crossings and course roads. Several design alternatives are suggested for testing and evaluation. Additionally, supporting documentation for monitoring these structures is provided to allow validation of each structure's effectiveness.

Range Design

Embankments are one of the most prevalent range elements on a training area and are an integral part of stationary target structures, moving target structures, defilade emplacements, ordnance-stop embankments, and separation barriers. The main purpose of an earthen embankment is to deflect ordnance impact or ordnance effects and protect or conceal equipment and personnel. During military training, these earthen structures are subjected to repeated impact from ordnance ranging from 12 mm (50 caliber) to 120 mm projectiles from mechanized, aerial, and infantry weaponry. According to The Design Manual for RETS Ranges (USACE-ESC 1998), the minimum embankment design criterion for an embankment specifies that an emplacement withstand the force of the maximum ordnance directed at the target or firing mechanism. Over time, however, the impact of weaponry removes vegetation, promotes soil loss, and hampers training. Range redesign and improved maintenance are the main recourse to limit the extent of damage to range elements during military exercises.

Range course roads and trails are another dominating landscaped feature present on an installation training area or range. Roads and trails provide access to the majority of range elements for training and maintenance. Course roads and trails are routinely subjected to heavy-load traffic over a wide array of climate conditions. Most of these range course roads and trails are unimproved, consisting of poorly graded local aggregate and fill. Additionally, many of these range roads intersect with stream networks creating a potential point-source contaminant pathway and preferential drainage channel. Furthermore, dry weather conditions on unimproved roads generate large volumes of airborne particles that retard roadside vegetative development and obscure vision during training exercises. Heavy traffic, adverse climate conditions, poor road construction and infrequent maintenance contribute to the overall difficulty of maintaining a long-lasting course road or trail that withstands military maneuvers. Once again, range redesign and improved maintenance techniques are the most cost-effective way to limit environmental damage from military exercises.

The Design Manual for RETS Ranges (USACE-ESC 1998) is the primary guideline published to assist in the development of ranges. The manual provides generic design guidance and required interface points for the following range designs:

1. Anti-armor Tracking and Live Fire Range
2. Automated Field Fire Range
3. Automated Record Fire Range
4. Battle Area Course
5. Combat Pistol/Military Police Qualification Course
6. Combined Arms Collective Training Facility
7. Digital Multi-Purpose Range Complex
8. Digital Multi-Purpose Training Range
9. Fire and Movement Range
10. Infantry Platoon Battle Course
11. Infantry Squad Battle Course
12. Live Fire Exercise Breach Facility
13. Modified Record Fire Range
14. Multi-Purpose Scout Qualification Range
15. Multi-Purpose Machine Gun Range
16. Qualification Training Range
17. Rifle/Machine Gun Zero Range
18. Sniper Field Fire Range
19. Urban Assault Course

Of these designs, the tank gunnery range, the multi-purpose range complex, and the multi-purpose training range include the elements found in smaller ranges.

The design phase of the range development process is the logical point to implement changes that extend range longevity and reduce long-term maintenance costs. Svendsen et al. (2005) is a study of four military installations, where they found that range design improvements were possible and that all observed ranges exhibited some degree of environmental degradation; however, the environmental degradation differed in scale and severity at each range and often varied within a range. The investigators combined field observations, current range design guidelines and future range proposals to develop a consensus of range design and maintenance issues. These issues were investigated on temperate climate installations. The research team, after analyzing all the observations and discussions, drew the following conclusions:

1. Numerous range structures deviated from guidelines as specified in The Design Manual for RETS Ranges (USACE-ESC 1998) and quality control/quality assurance (QC/QA) adherence to design criteria was inconsistent. Dimensional parameters frequently deviated from design specifications, inadequate gradient being the most frequently violated parameter.
2. Poor vegetation and resultant soil loss problems were identified at all training ranges and at all visited installations. Ranges receiving the greatest level of training activity had severe localized erosion and the poorest vegetation. Firing points, trails, target emplacements, and staging areas had the greatest concentrations of problems.
3. Poor siting of range structures were significant impediments to sustainable range maintenance that increased design, construction, and maintenance costs.
4. Range structure profiles blended inadequately with the surrounding landscape and permitted effortless identification of critical training elements. Heavily used and inadequately maintained range structures reduce training effectiveness (e.g., bare soils on target positions allow trainees to identify target positions, thereby reducing the element of surprise).
5. Early problem identification is critical for cost-effective erosion control. Current procedures function to identify existing problems, but do not anticipate future problems.

Additionally, Svendsen et al. (2005) proposed a revised design methodology to improve erosion control, enhance range sustainability, and prevent degradation of downstream waterways by sediment contamination.

The design methodology proposed was:

- Modify existing designs to incorporate sustainable range elements and test these designs to determine superior performance in a military setting. Incorporate high performing elements into The Design Manual for RETS Ranges (USACE-ESC 1998).
- Develop range erosion control guidelines that incorporate sustainable range structures and range erosion control in a comprehensive manner. Add these erosion control guidelines into The Design Manual for RETS Ranges (USACE-ESC 1998).
- Develop general guidelines and recommendations on the repair and maintenance of ranges.
- Develop QC/QA procedures to ensure that construction projects and range maintenance practices follow design guidelines. Quality assurance should follow the design from inception through the end of the first maintenance cycle.

These design recommendations, in part, were suggested based on the results of embankment monitoring studies conducted by Svendsen (2005).

Embankment Design

Earthen embankments (berms) occur on most ranges and are ideally designed/constructed in a manner that offers the greatest protection of personnel and equipment. Specific berm types include, but are not limited to, separation barriers, firing stops, target positions, and firing positions. Targeting and firing emplacements have established specifications to guide the designer in the creation of these range structures, and the designs are discussed in the following sections. Currently, designs do not exist to guide engineers in the creation of separation barriers and firing stops; however, standard construction practices for earthen embankments would apply to these structures. Regardless, basic designs are essential to ensure that standard methods of construction are used on range structures.

Firing and target earthen berms are often greatly stressed as they are regularly subjected to blast and ordnance forces during military exercises. The orientation of multiple firing points in angle, height, and distance to multiple targets situated throughout a training area is a critical training-enabling design component. The positions of firing and target emplacements are outlined in range layouts in The Design Manual for RETS Ranges (USACE-ESC 1998). Four allowable berm composition types are outlined in Figure 1. The berms shown at the left in Figure 1 are allowable berm composition types for separation and ordnance-stop berms. The berms on the right are suitable for firing and target positions.

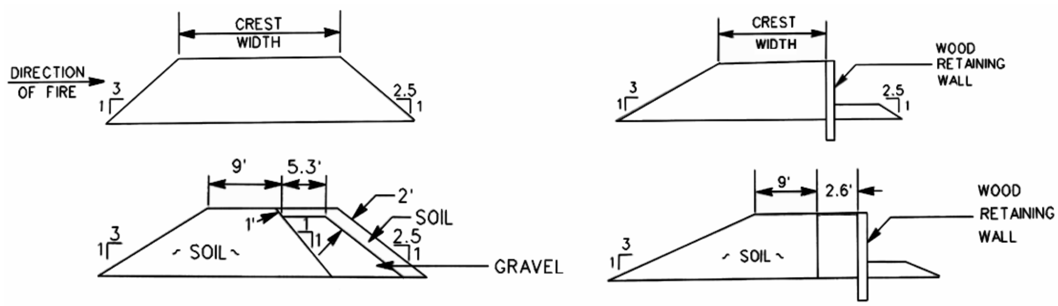

Figure 1. Embankment design variations for ranges.

Defilade Design

Defilades are used exclusively on larger ranges where mechanized weaponry is prevalent. Essentially, defilades are firing emplacements for armored and fighting vehicles. In The Design Manual for RETS Ranges (USACE-ESC 1998), three design options exist for the development of firing emplacements. All designs are similar, but are differentiated based on design cost. The design outlined in Figure 2 is the highest cost option available to the range designer. This option contains all elements found in the other design options. The primary construction materials in this design are rock riprap and a blast mat.

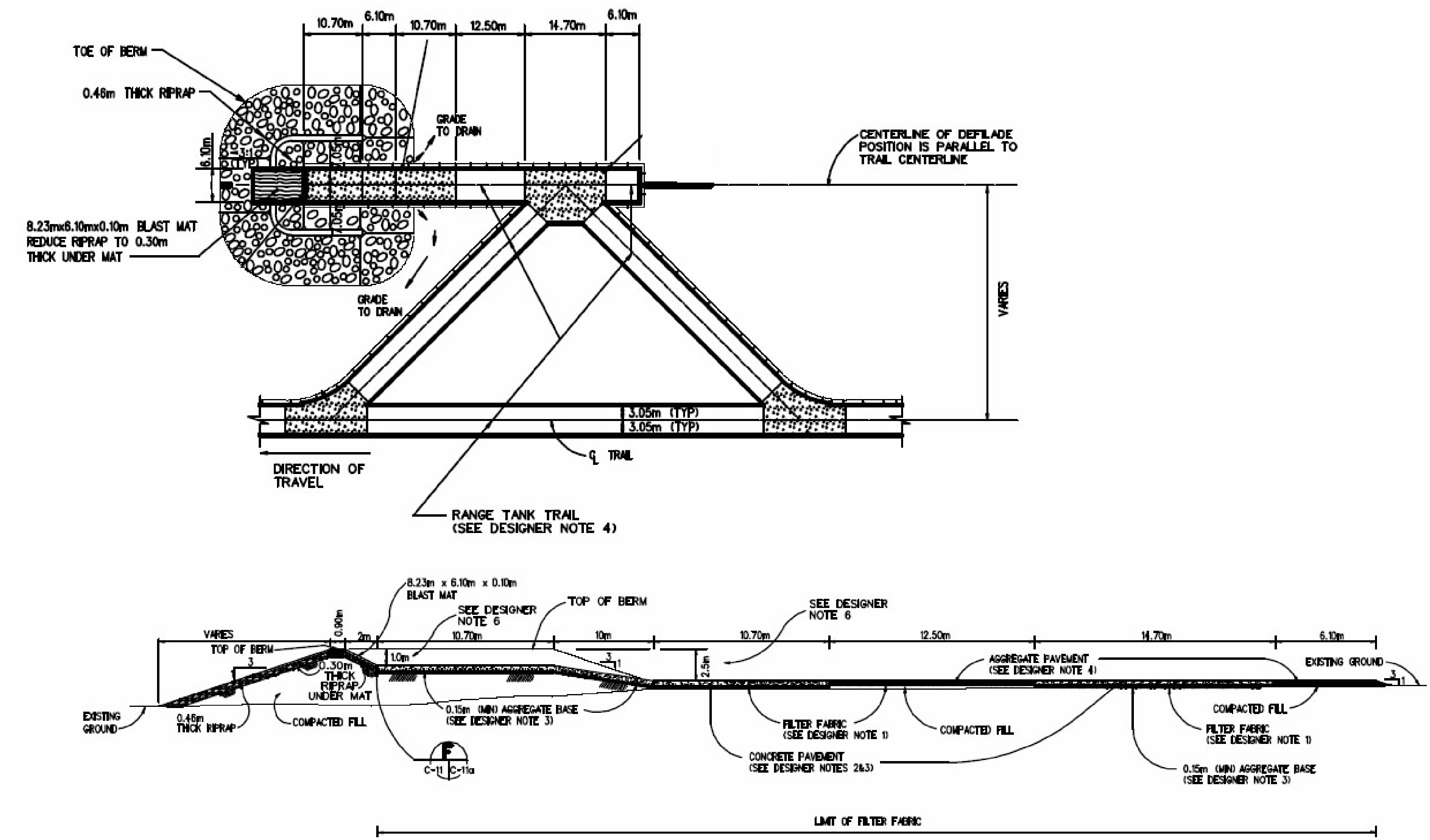

Figure 2. Standard defilade design for armored vehicle.

An armored vehicle can fire artillery from most locations on a range, but firing emplacements are designated engagement positions that allow tanks to maintain defensive hull down and turret down tactical positions. Defilades are not subject to intentional training fire, yet damage does occur from armored vehicles. Armored vehicles damage defilades mainly in two ways: armored vehicle collisions into the defilade structure, and the blast wave impact from the armored vehicle cannon. Damage to the embankment from both forces has the potential to affect embankment integrity depending on the local soil type and ambient soil moisture conditions. Reducing rock riprap and improving soil stability are potential design aspects that may extend defilade longevity while lowering associated costs.

Armor Stationary Target Design

Stationary emplacements are found on almost all ranges. They are used on small ranges as infantry target emplacements, and on larger ranges as armor target emplacements. Stationary target emplacements are smaller than general earthen embankments and moving target emplacements but are similar in size to firing emplacements. Figure 3 shows the basic design guidelines for this structure. Improvements to this structure, such as soil stabilization and reduced slope, may prolong target usefulness and reduce structure maintenance requirements.

Armor Moving Target Design

Moving target embankments are used exclusively on multi-purpose training ranges, multi-purpose range complexes, and tank gunnery ranges. They are used to protect armor target emplacements and are one of the largest structures constructed on a training facility. The embankment face exposure and berm slope length create vulnerabilities to erosion that generally are not found on other range structures. Figure 4 illustrates the target design.

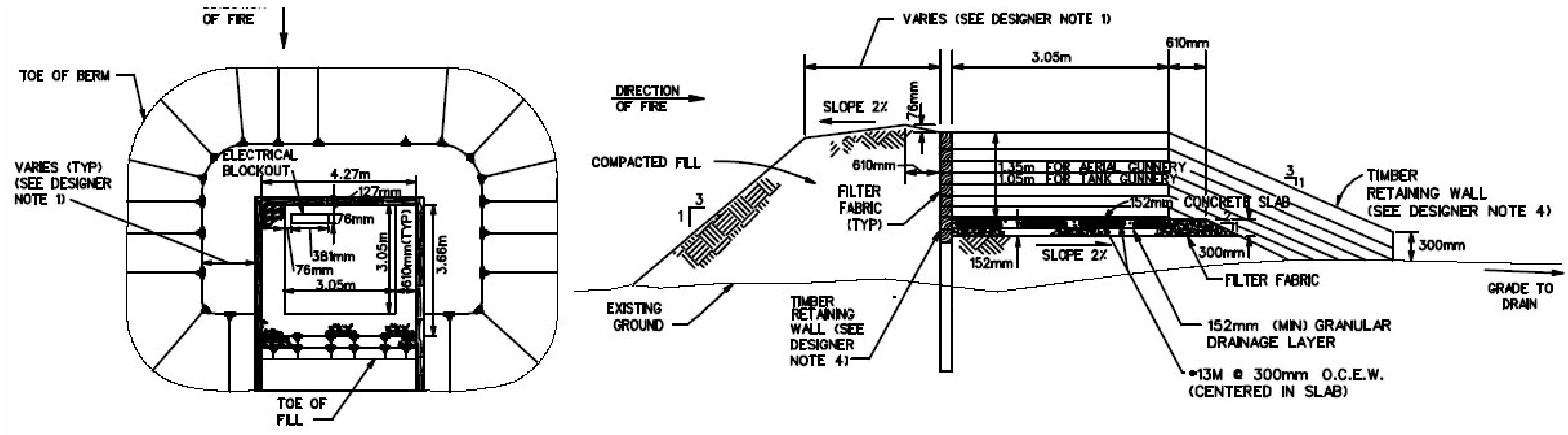

Figure 3. Stationary target design for armored vehicles.

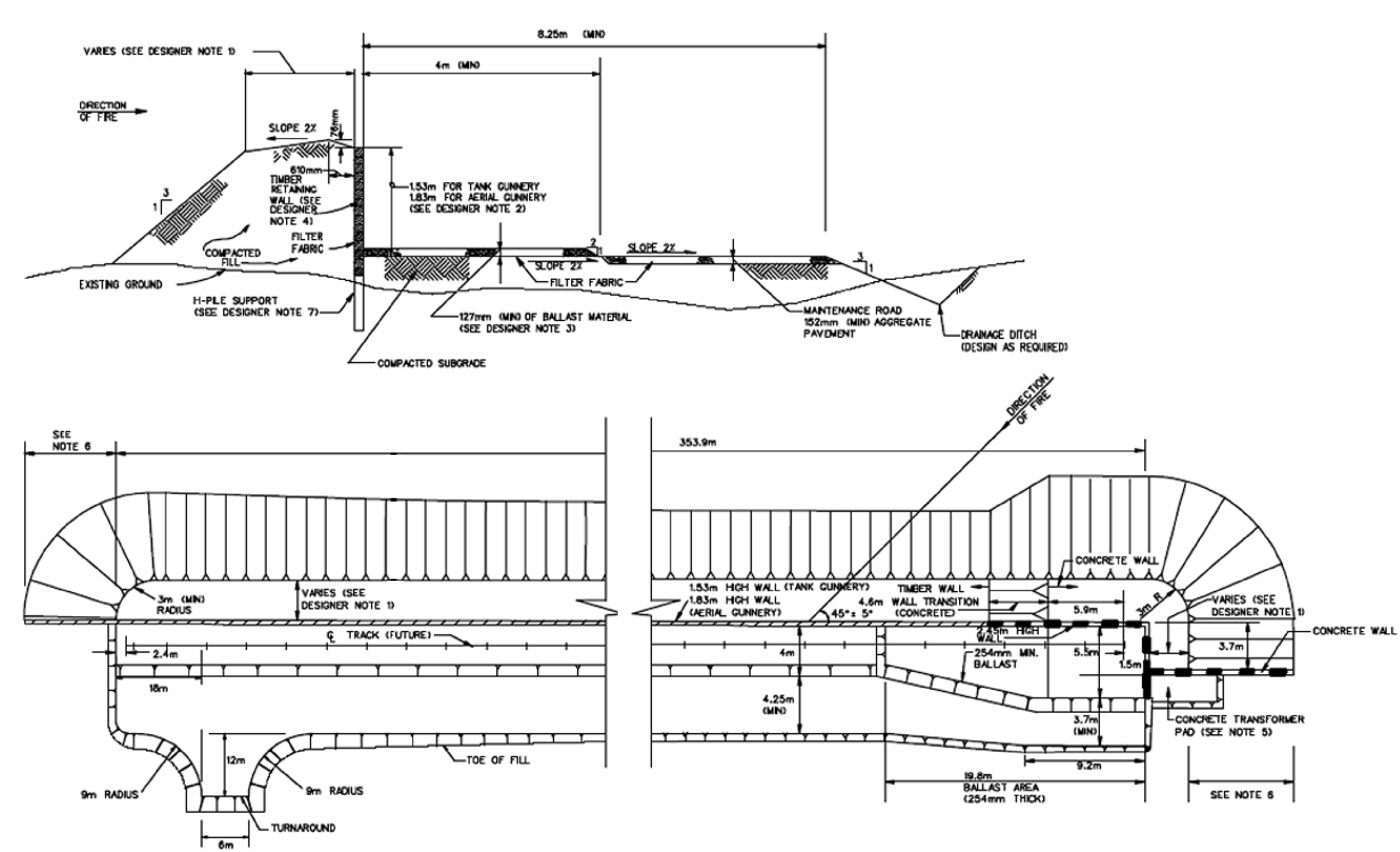

Figure 4. Moving target design for armored vehicles

Low Water Stream Crossings

On large ranges or training areas, military maneuvers utilize unimproved trails or slightly improved/improved roads to accomplish training mission objectives. Frequently these roads utilize low water stream crossings that facilitate stream fording. The vast majority of these crossings are not engineered and consist of a rock approach that often increases sediment production. Reducing the stream crossing sediment suspension levels is beneficial to stream crossing longevity and decreases stream ecological disturbance. Studies by Tollett et al. (2002) indicated that erosion and stream sedimentation are greatly reduced and habitat damage minimized when hardened stream crossings are used. Currently, low water stream crossing guidelines for military ranges do not exist and research studies indicate that such designs are warranted for inclusion into The Design Manual for RETS Ranges (USACE-ESC 1998).

General Range Design for Erosion Control

The sizes of numerous training range areas are vast. This scale in combination with erosion from numerous degraded structures has a potentially significant long-term impact on water quality and stream health. Therefore, it is essential that individual range elements minimize erosion and maintenance. Improvements can be made regarding range layout and range structure profiling. Proper placement of range structures, landscaped range profiles and better erosion control practices can provide a superior training experience for military personnel. In general, a comprehensive erosion control plan is required. Vachta and Hutchinson (1990) stress this point based on pilot studies of erosion control management methods at Fort McCoy in Wisconsin. The implementation of an erosion control plan should involve erosion control methods outlined by Vachta and Riggins (1988) in their evaluation of appropriate erosion control techniques for Army training lands.

3 Defilade Design and Testing

Defilade Test Objective

Field observations of defilade structures at several installations have identified the use of innovative range structure designs differing from the current standard designs and associated construction practices. The apparent durability of several of the alternative range structures merits further investigation. The demonstration and validation of modified firing emplacement designs should verify optimal stabilization/construction practices suitable for armor defilade positions. The overall objective is to demonstrate suitable and cost-effective site-specific defilade designs that minimize soil erosion and reduce maintenance costs on military ranges using a variety of defilade construction materials to meet range sustainability and environmental compliance goals.

Defilade Target Test Concept

The evaluation of new or modified designs for defilade positions should occur within close proximity to the testing authorities at an installation with field personnel cognizant of the requirements for conducting longer term demonstration and validation projects. The ideal scenario would give preference to installations with excellent long-term working relationships with testing authorities and a history of established collaborative effort with research facilities. The military post should be easily accessible and testing/field personnel must be familiar with the training areas, range facilities, and installation personnel to ensure the successful completion of the testing.

Test personnel should conduct the demonstration over a period of 1 to 2 years to provide sufficient data for scientific evaluation and validation of the new or improved designs. This period should be sufficient to allow the constructed structure soils to adequately consolidate, develop definitive soil erosion patterns, and provide ample time for vegetative growth. Coordination and preparation for the construction of the modified firing emplacements should require additional time beyond the timeframe given for the testing period. Construction should not take more than 3 months to complete prior to the demonstration period.

To facilitate the collection of meaningful range structure data and adequately test the new defilade designs, demonstration site locations require siting on a Multipurpose Training Range (MPTR) or a Multipurpose Range Complex (MPRC). Additionally, the topography and soil types of the selected areas must be conducive to accelerated erosion phenomenon that contribute to frequent and costly range maintenance activities when compared with similar range types in areas with less erosive soils and topographic gradients. The increased susceptibility to erosion is ideal for illustrating the effects of erosion on the operation and maintenance of military range defilade positions over a shorter testing period.

Demonstration and validation of modified defilade designs should use a variety of materials to construct or retrofit the existing emplacements. The use of geosynthetic materials, increased native vegetation, and non-standard blast mat materials typify these modifications. Each defilade position should be designated as a separate stabilization/construction practice treatment. The manipulation of standard defilade design parameters should provide the basis for these treatments.

Each treatment shall be monitored for performance and durability using estimates of erosion and sedimentation (both quantitative and qualitative), vegetation coverage, and effective precipitation using established monitoring and evaluation methods. Evaluation methods should consist of both qualitative (photography, videography, and physical descriptors) and quantitative (erosion pins/sediment catch-channel, digital vegetative cover analysis, training intensity, water quality) data collection and analysis from each demonstration site. A possible evaluation method might include the real-time utilization of security cameras to capture design effectiveness on dust control or blast mat effectiveness against weaponry blast waves. The methods used to collect information on the integrity of the new designs over the test timeframe should allow for direct comparisons between stabilization/construction design variations and the unimproved standard.

Defilade System Description

Defilades are firing emplacements for armored and fighting vehicles that are used exclusively on larger ranges where mechanized weaponry is prevalent. Defilades allow tanks to maintain defensive hull down and turret down tactical positions and provide an essential component for armor training. Defilade emplacements are used during military maneuvers to provide firing locations for M1A1/M1A2 tanks and Bradley Fighting Vehicles (BFVs). They provide engagement opportunities to targets that tactical commanders can use for training mechanized elements in conflict scenarios. Defilade emplacements comprise a comprehensive range of firing stations to enhance training and apply an element of realism to training missions.

Currently, three design options exist for the construction of firing emplacements; however, the lowest cost design is most commonly used. Examples of ranges where armor defilade targets are present are MPTRs and MPRCs. Defilades are not subject to intentional direct fire, yet damage does occur during military maneuvers. The most common damages are from armored vehicle collisions into the defilade structure and muzzle blast from the armored vehicle cannon fire. The focus of this demonstration and validation should be directed toward limiting muzzle blast damage (i.e., erosion and maintenance of vegetative cover) on the front of the defilade emplacement through use of alternative construction materials and stabilization practices. Figure 5 depicts defilade positions, and Figures 2 and 6 show similar standard designs for the structure.

Figure 5. Two examples of defilade armor emplacements.

The images in Figure 5 illustrate the front and rear views of a defilade position. The left image displays the embankment face/blast mat while the right image depicts the actual emplacement structure. The construction of the defilade in Figure 5 was recent, and the emplacement is in excellent condition. Items to note in these pictures are the blast mat in the left image and the limestone rock riprap on the defilade embankment. Furthermore, the design illustrates the use of a retaining wall not specified in the general design criteria. The standard design for armor defilade emplacements specifies how much area the defilade emplacement should occupy on the range. Referring to the right image of Figure 5, the actual firing position (including concrete tank pad) encompasses 60 m^2. When the armor emplacement embankment is taken into consideration, however, the range structure occupies an area five to six times that of the actual emplacement structure. A defilade armor emplacement and embankment may occupy an area as large as 250 m^2 using the least expensive design. Figure 6 illustrates defilade emplacement design. The Design Manual for RETS Ranges (USACE-ESC 1998) also specifies embankment design parameters and composition, shown in Figure 7.

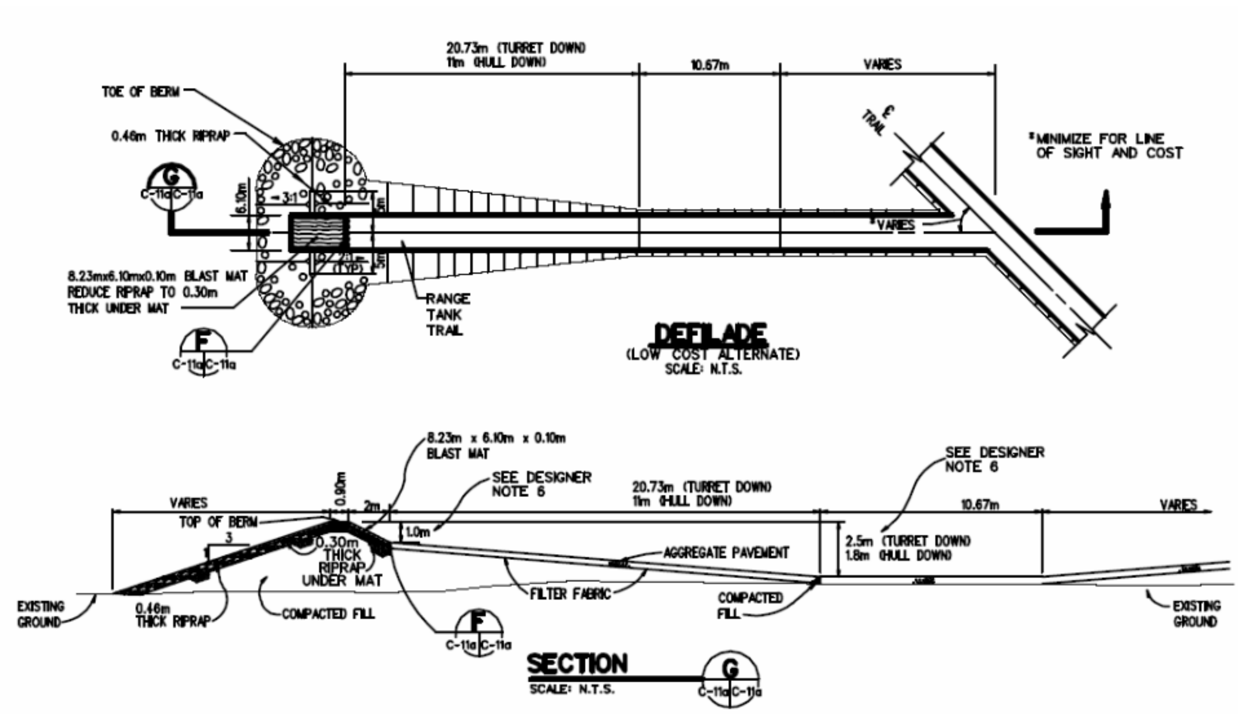

Figure 6. Low-cost defilade emplacement design option.

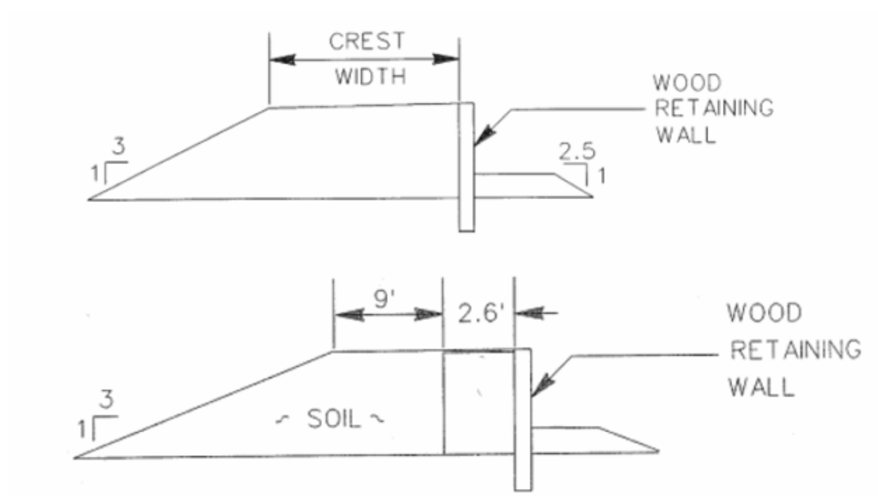

Figure 7. Design options for defilade: embankment earthen and earthen/rock.

The primary purpose of the embankment and blast mat in front of the defilade is to protect the firing emplacement from damage during military exercises. According to the The Design Manual for RETS Ranges (USACE-ESC 1998), the embankment should be of sufficient strength to withstand the impact of armored vehicles and the blast wave energy from the discharge of mechanized weaponry. The majority of the damage to this structure occurs on the embankment immediately in front of the firing retaining wall. The demonstration/validation should concentrate on design alternatives devised to limit or mitigate the structural and environmental damage from mechanized equipment. As mentioned previously, demonstration efforts should highlight the effectiveness of alternative materials and stabilization/construction practices on the embankments and not on the emplacement structure itself since most of the environmental compliance and maintenance issues are associated with erosion from the embankment face.

To demonstrate and validate the proposed stabilization/construction practices, defilade embankments on a range or several ranges should be modified to support separate design alternatives. Over the duration of the demonstration, precipitation, soil movement, vegetation characteristics, intensity of use, and the overall integrity of the modified structure should be observed and documented using standard methods of data collection for the aforementioned parameters.

Defilade Monitoring and Validation

Evaluation of defilade effectiveness, measured as extended useful life expectancy and pollution mitigation potential (minimizing erosion), should be estimated both qualitatively and quantitatively using the subtest procedures described below. To conduct the tests, seven stabilization/construction practices on armor defilade emplacements should be applied by modifying existing armor defilade embankments. Figure 8 shows the different configurations for each stabilization/construction practice demonstrated.

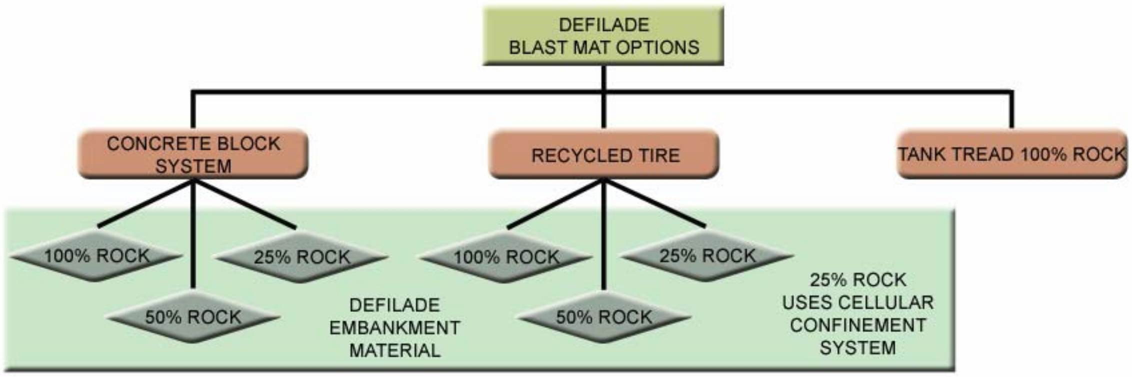

Figure 8. Diagram of planned defilade embankment demonstrations.

The new defilade constructions should validate alternative blast mat design options and reductions in embankment stabilization fill (riprap). Furthermore, the incorporation of geosynthetic materials into the range structure should demonstrate enhanced embankment stability in defilade design. As shown in Figure 8, the defilade demonstration/validation project should use three blast mat options: a cellular concrete block system, a used tank tread option, and a recycled tire option. Cellular concrete block systems (e.g., Cable Concrete®) are composed of blocks of high strength concrete threaded together with heavy-duty stainless steel cable for an articulating geo-forming stabilization material (see manufacturer's Design and Specifications for materials information). Field plots observed at Fort Drum, NY, have identified this product as a less expensive and potentially more robust blast mat than recycled tire blast mats (Figure 9). Similarly, tank tread blast mats offer a further cost savings benefit in that they are obtainable at many installations. Tank tread blast mats are created by connecting M1A1, M1A2, or BFV used tank treads together with cable or other fasteners. Typically, the positioning and placement of tank tread blast mats is identical to cellular block systems as shown in Figure 9. Field studies of used tank tread as an erosion control device have shown promise for embankment stabilization. The proposed defilade design utilizes recycled tire blast mats that are essentially tire pieces threaded together with metal fasteners. All three blast mat options should utilize rock riprap to stabilize the embankment face in the region of highest blast wave impact.

In addition to the blast mats, the tests should demonstrate the utility of geosynthetic materials in embankment stabilization during military training. The modified designs should integrate a cellular confinement system and/or geotextile into the emplacement soil matrix. Geosynthetic materials increase soil stability and embankment integrity by enhancing soil structural strength and increasing shearing resistance. Improved strength and stability are factors directly related to increasing emplacement design efficacy.

Figure 9. Blast mat options: recycled tire, cabled concrete and tank tread.

The control emplacement (i.e., low-cost defilade design option presented in The Design Manual for RETS Ranges [USACE-ESC 1998]) is essentially unaltered over the duration of the test. The retention of the original vegetation management practices and maintenance routines for the control should allow comparison of the original design to the modified designs. Two different blast mats, the cellular concrete block system and the used tank tread option, should combine riprap and geocells to determine the most cost-effective and robust defilade design. Short native grasses and naturalized non-native grasses, such as buffalograss, fescues, or bluegrasses, should provide vegetative cover on the embankments where the geocells are used. The selection of embankment grasses should depend on species fire resistance and tolerance for intermittent burning from weaponry blast waves. Once the embankments have been constructed, erosion/sedimentation, precipitation, runoff, soil moisture, and vegetative coverage data collection should begin as described below. Construction should be completed in accordance with specifications outlined in The Design Manual for RETS Ranges (USACE-ESC 1998), standard methods of embankment construction for compaction, and the design alterations specified in this document.

After the defilades are modified with each stabilization or construction practice, inspections of the embankments should occur on a monthly basis. The first 2 months after construction should be adequate for vegetation to establish with good cover (in temperate climates) but reseeding may be necessary in areas where initial growth is poor. After construction, indicators of design effectiveness include the time interval between maintenance cycles, so maintenance is not required over the test timeframe.

Measurements of Defilade Design Effectiveness

Validation of defilade stabilization/construction practices should be conducted by measuring soil erosion, soil moisture, vegetative cover, climate, and usage intensity.

Defilade Design Test Objectives

The objective of this test is to demonstrate the overall effectiveness of seven stabilization practices on defilade firing positions by comparing erosion/deposition, vegetative cover, and soil moisture as surrogates representing cost, sustainability, and environmental compliance. The optimal combination of practices that minimize berm maintenance, extend useful berm life, minimize soil erosion, and maintain environmental compliance should be determined.

Defilade Design Testing Criteria

Soil erosion data

Data collection on soil erosion should use two well-established methods: (1) erosion pin method for spatial soil loss measurement and (2) sediment channel method for gross soil loss measurement. The first method of soil movement measurement utilizes small graduated metal pins placed firmly in the ground below the frost line. The pins are spaced in a grid-like pattern over the study embankment face to record cumulative erosion/ deposition and to observe erosion/deposition spatial variability. When erosion or deposition occurs around the pin, the graduated marks on the pin should indicate the depth of erosion or deposition. The use of digital photography should facilitate the quick and permanent recording of soil level readings. The erosion pin method was adapted from Haigh (1977) and the FAO (1997). The second method of soil movement measurement consists of a geotextile-lined trench or tile dug around the range structure of interest to capture embankment runoff and erosion as adapted from Robichaud and Brown (2002) and FAO (1997). The erosion pin method should yield satisfactory results on range structure elements where grass or bare soil is present; however, this method is not practical on areas covered with rock riprap and would not yield satisfactory results on soil loss. Under these stabilization/construction practices, the sediment channel method for erosion measurement should provide the best data for soil loss determination.

Vegetative cover data

The testing authorities should complete a vegetative cover assessment for each range structure under demonstration using digital photography and a digital analysis system developed by CERL researchers (Denight 2005). This system uses highly specialized software to distinguish between vege tation and bare soil. The digital analysis system calculates the vegetation cover and determines a percent follar. By photographing known areas over time, direct comparisons between photographs are possible.

Precipitation data

The measurement of precipitation is simple and direct if the equipment is set up correctly. Rainfall data should be collected on a cumulative basis and stored in a data logger such as a HOBO® Event Logger integrated with a tipping bucket rain gauge. Ideally, testing personnel would integrate a tipping bucket rain gauge into a HOBO® Weather Station. Weather stations have multiple sensors to detect ambient atmospheric conditions in addition to rainfall (i.e., soil moisture). Regardless of the method chosen to measure precipitation, the location of the tipping bucket rain gauge must be protected from military activities and interference, but remain representative for the area of interest.

Soil moisture data

High soil moisture content often correlates well to soil erosion potential. Therefore, each embankment stabilization/construction technique should have soil moisture data collected from the upper, middle, and lower embankment positions to determine the relationship between erosion. In-situ HOBO® soil moisture sensors and soil samples should provide estimates of soil moisture content at surface and near-surface depths on the embankment face.

Defilade usage data

The testing authorities shall establish and maintain contact with range personnel during the test timeframe and shall advise installation managers on the progress of the demonstration/validation. Field personnel should collect range usage data from installation personnel and through visual inspection of the test plots. Range usage information is often available in database format to facilitate accurate and meaningful comparisons between defilade positions and embankment stabilization/construction practices.

Defilade Design Test Procedures

Soil erosion data

The use of erosion pins to quantify soil movement is particularly suited to measuring soil movement on military training range embankments. Damage to a portion of the pin system does not compromise the effectiveness of the remaining elements. Furthermore, this method provides a quick assessment of the spatial variation in erosion occurring over a landscape. Additionally, calculations of total soil movement from the grid area are readily determined when uniform soil movement assumption holds for a pin region. Erosion pins are approximately 3 to 5 mm (1/8- to 3/16-in. stock stainless steel rod T303 [ASTM A276-04, 2004]) in diameter and range from 0.7 to 1.0 m in length. For higher visibility, the pins shall be painted and marked with graduations or taped with adhesive graduations. Once fabrication is complete, pin placement should occur at a depth of 0.5 to 0.8 m to exceed the frost line depth. It is important to leave adequate graduations above the ground surface to allow for possible deposition of soil in the pin area. Additionally, pin graduation orientation shall face away from the sun to reduce fading of the markings. Pin readings should occur on a monthly, quarterly, or storm event-based timeframe using a digital camera to capture soil movement around the pin as measured by the pin markings. Three sets of soil pin arrays should assess soil movement from each defilade assuming that all or a portion of the embankment face is free of riprap. The pin array placement shall be as follows: embankment top, embankment middle, and embankment toe. An additional soil pin array around the base of the defilade face should determine where soil deposition is occurring. The pins shall be located on the embankment face and placed in such a manner as to be representative of erosion conditions on the structure. A central database should store the field-collected digital images to facilitate analysis of soil movement.

On embankment faces that are fully or partially covered with rock riprap, a sediment channel or tile is required to capture soil deposits from the structure. The channel covering should be a geotextile material/tile as per design specifications to facilitate the collection of deposited soil. Channel drainage shall direct flow to sediment traps to reduce soil lost from force of the blast wave. On defilades with substantial amounts of rock riprap, sediment channels/tile should be the primary method for soil erosion estimation. Data collection should occur on a monthly, quarterly, or storm event based timeframe. Field personnel should note regions of soil accumulation, collect the soil in the sediment channel/traps, and transport deposited soil to the lab for weighing. Field personnel should minimize damage to the geotextile channel or tile during soil collection to maintain sediment channel integrity. A central repository should store the field-collected observations to assist in data analysis.

Vegetative cover data

Vegetative cover of defilade faces should be evaluated using digital photo analysis with one sampling quadrat per face per time interval (quarterly). The sampling area should remain the same during the testing period to provide consistent measurements of vegetative cover. Digital analysis should provide a quick, cost-effective, and accurate measurement of cover for each embankment face. A central database should store the field-collected digital images to facilitate analysis for percent vegetative cover.

Precipitation data

Precipitation measurement should use a tipping bucket rain gauge. Tipping bucket rain gauges measure incremental precipitation in amounts equivalent to 0.01 in. (0.2 mm). The tipping bucket rain gauge utilizes two small containers balanced on a fulcrum. Each time the required amount fills one of the containers, a tip occurs, the water empties, and the second container positions for precipitation collection. At each tip, the data logger records the time and amount of rainfall. Field personnel should offload the data during scheduled visits. Due to the sensitive nature of the data loggers, data offload must occur infrequently to reduce analysis work during data reduction.

The precipitation data collection apparatus should be sited in an area that is protected from possible interference from military personnel and equipment. The ideal site location should be at least 100 m from trees and brush to reduce interference with these items. The transfer of precipitation data should be on a laptop or portable computing device and occur on a quarterly basis. The transfer of field-collected data to temporary storage devices should facilitate data relocation to a central repository.

Soil moisture data

The collection of soil moisture data should require soil moisture sensors and soil sampling methods to ascertain soil water content. A sensor array should collect data from the top, center, and bottom of the embankment, and a data logger should store the information for subsequent retrieval.

Field personnel should collect soil moisture sensor data and soil moisture samples for each of the embankment stabilization practices. Additionally, field personnel should transfer the soil moisture samples to a soil laboratory for analysis. The transfer of field-collected data to temporary storage devices should facilitate data relocation to a central repository. Field-collected soil samples should be weighed, dried at 100 °C for 48 hours, and reweighed to determine gravimetric soil-moisture content, as described by ASTM D2216-98 (2004). It may be possible to collect undisturbed soil samples with core samplers using standard methods to determine the bulk density of the soil. In that case, the volumetric soil-moisture contents can be determined by multiplying the bulk density values and the gravimetric soil-moisture content.

Defilade usage data

The collection of defilade/range use information is dependent on the recordkeeping practices of the installation(s) chosen for testing. Range information may be available in database or paper format. Additionally, observational information using security cameras and visual inspection would supplement reported range data. Field testing personnel shall collect defilade usage data from range personnel and transfer the information for subsequent analysis.

Defilade Design Data Required

Quarterly collection of all variables and data being evaluated should provide for a thorough comparison of stabilization practices.

Soil erosion data

Quarterly collection of erosion and deposition data from soil pins and sediment collection channels or traps should allow comparison of alternative embankment stabilization/construction techniques and their overall efficacy in improving environmental compliance and reducing soil erosion and maintenance requirements.

Vegetative cover data

Quarterly collection of vegetative cover data from stationary quadrats using digital photography should allow comparison of alternative embankment construction techniques and their inherent ability to support vigorous grass growth, which reduces erosion potential.

Precipitation data

The information collected from the data logger should consist of two parameters. The first parameter should be the time of the bucket tip for the rain gauge. The second parameter should be the reading of the bucket tip that for all instances is 0.01 in. The tipping time and rainfall amount are essential to determine rainfall intensity and storm duration. This information is necessary to assist in the calculation of sediment movement and excess rainfall.

Soil moisture data

Quarterly collection of soil moisture data for data loggers and soil samples should allow for comparison of alternative embankment stabilization/construction practices and their impact on soil moisture holding capacity.

Defilade usage data

Usage data required from range personnel should include collection of the following information for the entire testing period: troops trained, range utilization days, vehicle utilization, and weapons-type utilization. The use of supplemental visual inspections during each sampling period should assist in determining emplacement condition. Collection of usage data allows for accurate and meaningful comparisons between each alternative embankment stabilization/construction practice. Standardized data compilation should permit valid comparisons of treatments.

Defilade Design Analysis

The information generated from evaluations of the emplacement treatments is an integration of the factors that affect soil loss levels. Military training frequency, soil erosion rates, precipitation amount, vegetative cover, and defilade design parameters are all factors requiring consideration to provide a comprehensive analysis of stabilization/construction practice efficacy. These data should be analyzed for differences between the individual stabilization and construction practices to determine the least expensive yet most robust design modifications.

Soil erosion analysis

Analysis of field-collected data shall quantify the level of net soil movement occurring on the emplacement per pin area between sampling periods. Pin data analysis should illustrate the spatial variation in soil movement and illuminate areas of high soil movement. Additionally, soil erosion and deposition calculations for all pins shall establish net soil loss per emplacement over the testing period. Similarly, sediment channel data shall utilize the net soil loss from the embankment riprap/covered area to ascertain treatment effectiveness. The combination of sediment channel/ trap data and erosion pin data analyses should depend on the treatment. Comparisons of net soil loss for each emplacement to acceptable soil loss levels and other treatments should permit verification of emplacement effectiveness. This information, in conjunction with soil moisture, precipitation, and vegetative information, should allow a quantitative comparison between each demonstration.

Vegetative cover analysis

Digital analysis of each permanently located quadrat digital photograph should occur for all emplacements. Each image should be analyzed using software to estimate the degree of vegetative protection on each embankment. The data analysis should quantify the level of vegetation as a percentage of the quadrat area. In part, the vegetative cover information (when vegetation is used) is a measure of treatment effectiveness.

Precipitation analysis

Once the precipitation data have been collected, the data should be reduced to determine several pieces of useful information. This information should include the calculation of cumulative rainfall, rainfall intensity, time-based rainfall (e.g., 15-minute rainfall), and rainfall runoff rates. Combined with the soil erosion data, this information should facilitate calculation of erosion rates for each treatment corresponding to soil moisture, vegetation coverage, and embankment design modifications. Data collection and interpretation should use scientific methods and statistical analysis for all necessary data combinations and between treatment analyses.

Soil moisture analysis

The collection of soil moisture data for each embankment stabilization/ construction practice to determine differences in soil moisture holding capacity ultimately relates to erosion and vegetative growth. Comparisons of soil moisture-erosion/soil loss and soil moisture-vegetative cover between demonstrations should quantify the influence of soil moisture on berm integrity.

Defilade usage analysis

Emplacement usage data summarization should ensure that defilades are experiencing similar levels of use. Emplacement usage data are also useful in gauging the degradation of the emplacement structure due to training activities. Furthermore, emplacement usage data allow comparisons of treatments for design effectiveness.

Defilade Design and Test Criteria

The illustration of the seven defilade stabilization/construction practices and the testing protocol are described in the following drawings (Figures 10 through 18). The drawings follow the specifications outlined in The Design Manual for RETS Ranges (USACE-ESC 1998) but can be adapted to fit any defilade design. The most important item to remember when using these drawings is that only the embankment face and embankment composition may change. An embankment compacted with the optimum moisture content at the maximum dry density is recommended for all embankments to provide a reference for cataloguing vegetation and erosion measurements.

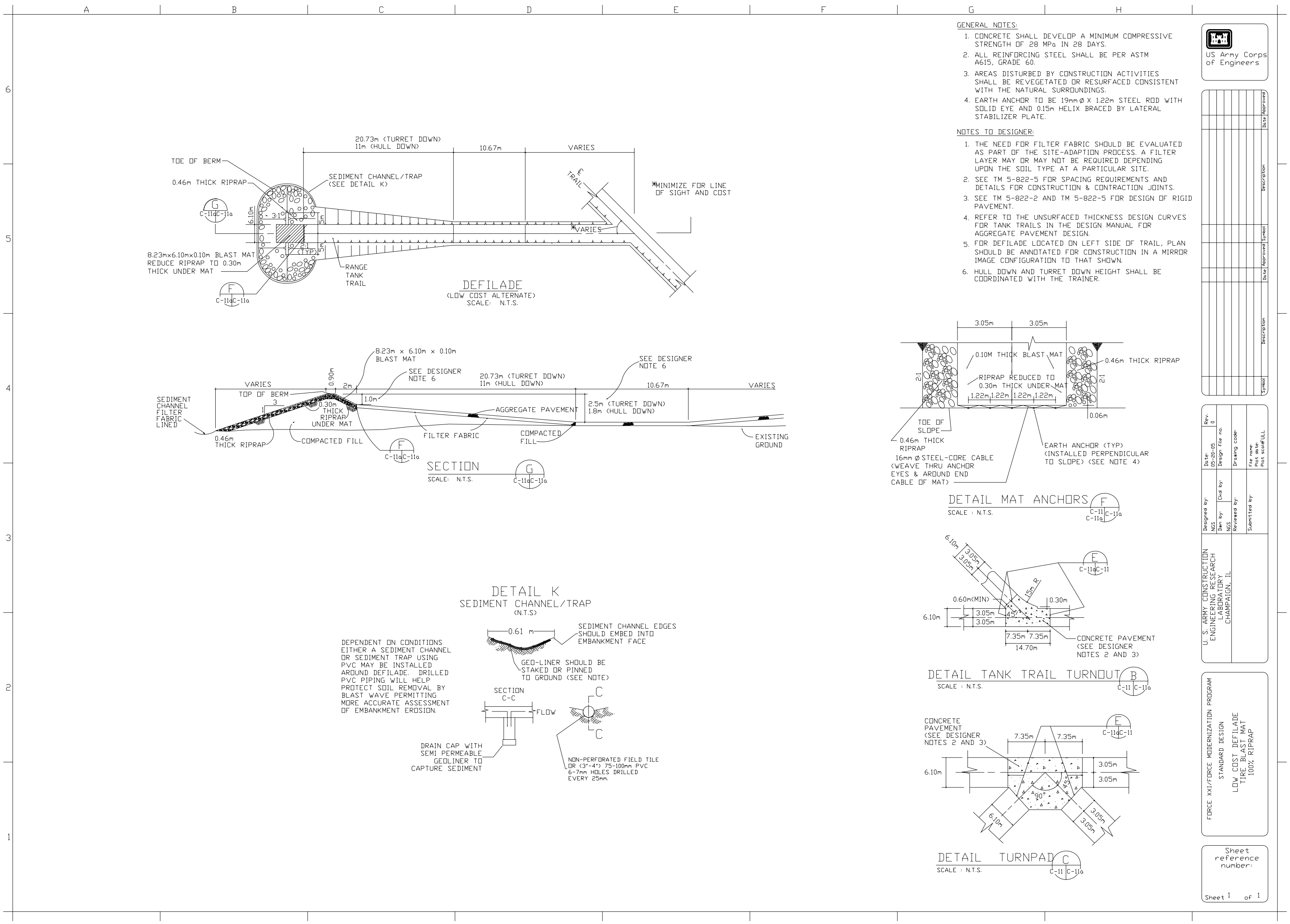

Figure 10. Design Alternative-1, Tire Blast Mat with 100% Rock Defilade.

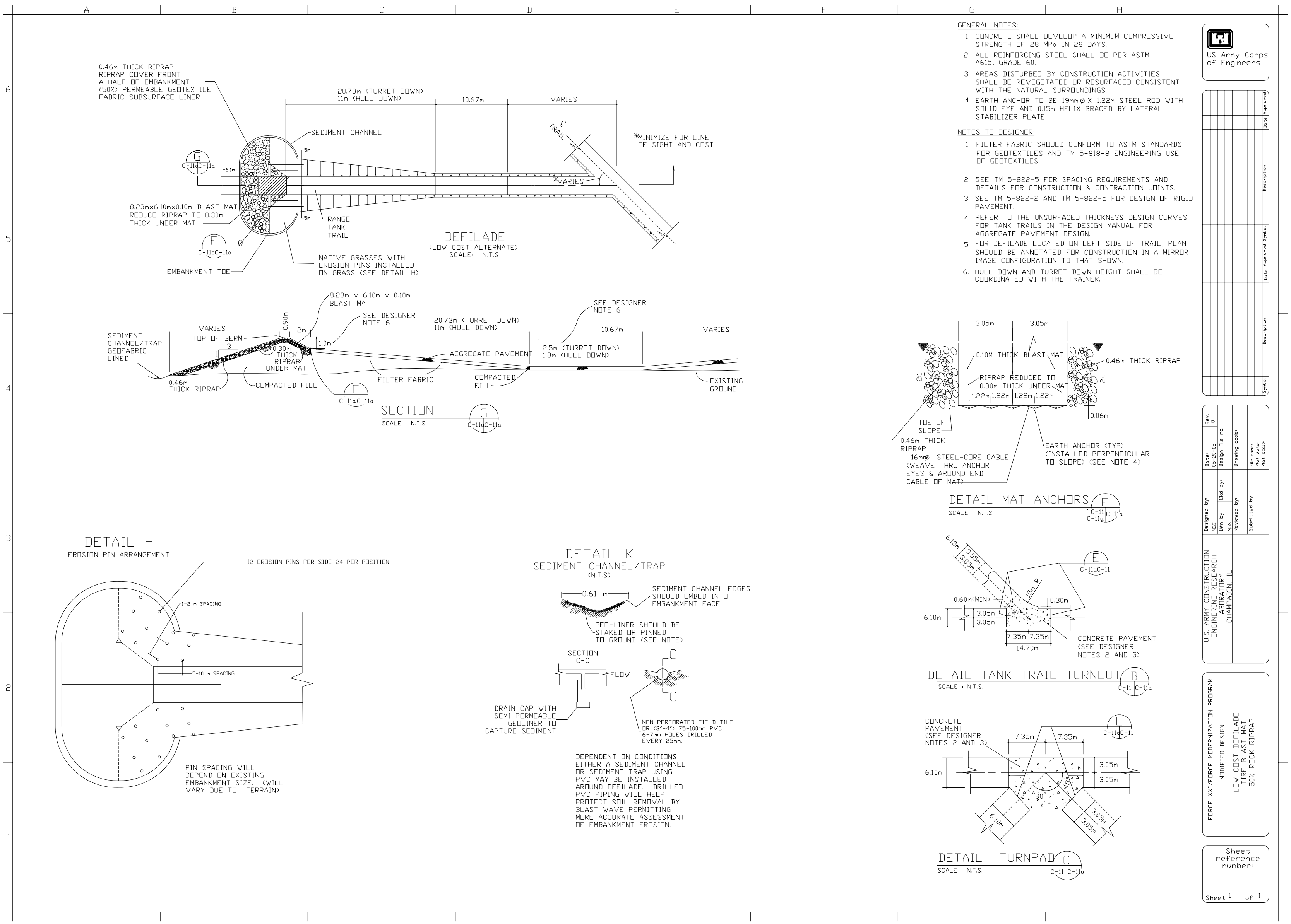

Figure 11. Design Alternative-2, Tire Blast Mat with 50% Rock Defilade.

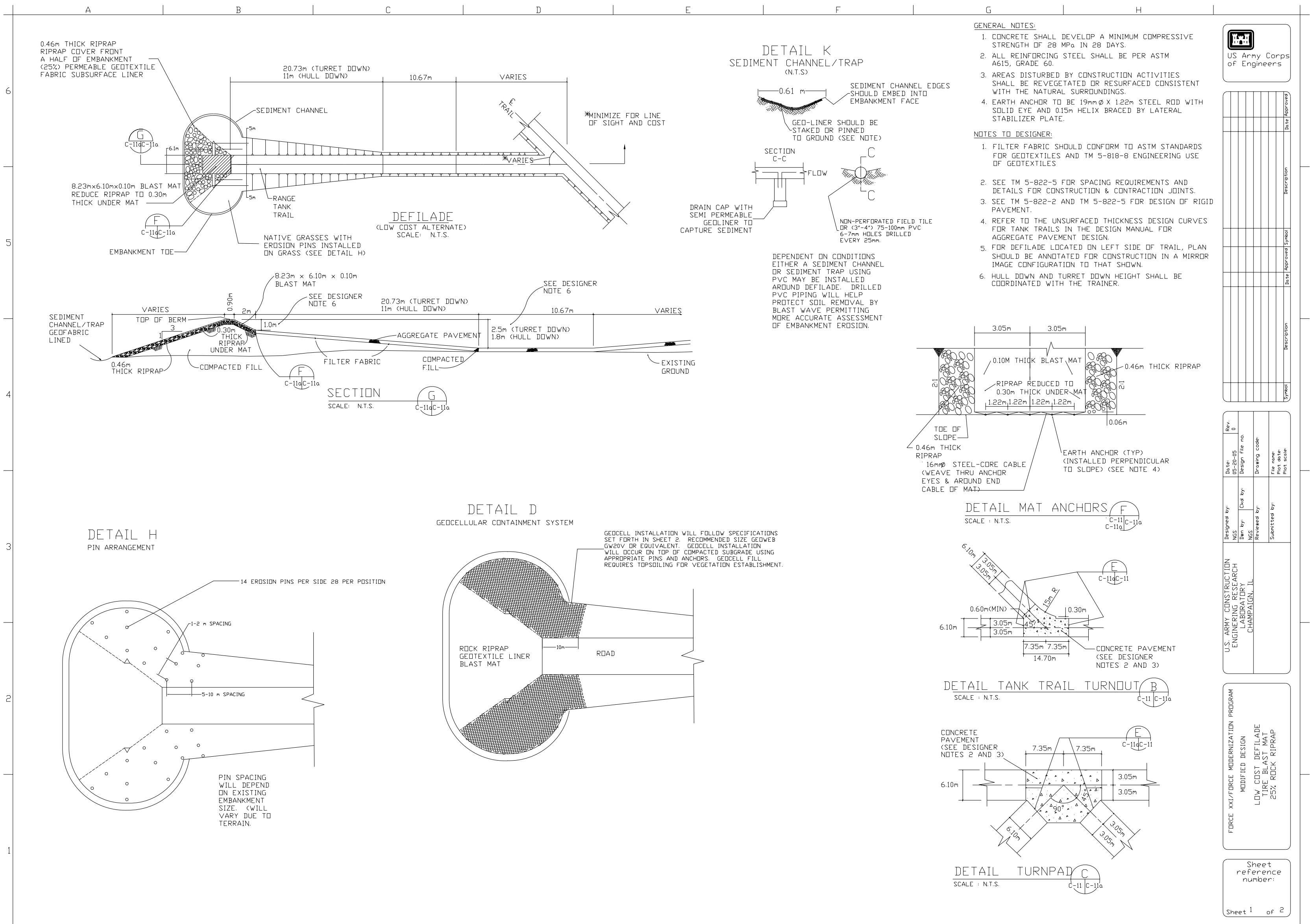

Figure 12. Design Alternative-3, Tire Blast Mat with 25% Rock Defilade with Geoweb® sheet 1.

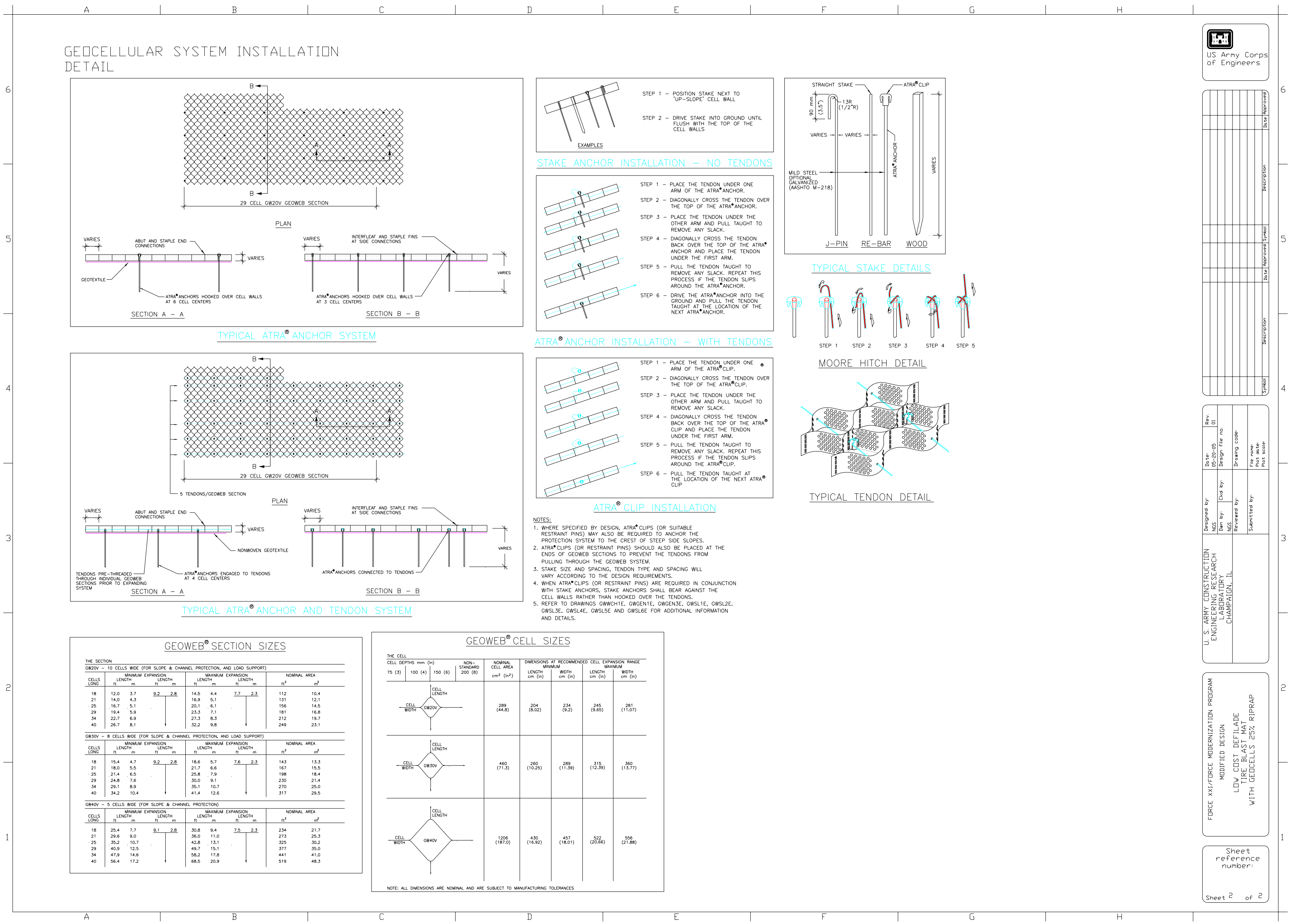

Figure 13. Design Alternative-3, Tire Blast Mat with 25% Rock Defilade with Geoweb® sheet 2.

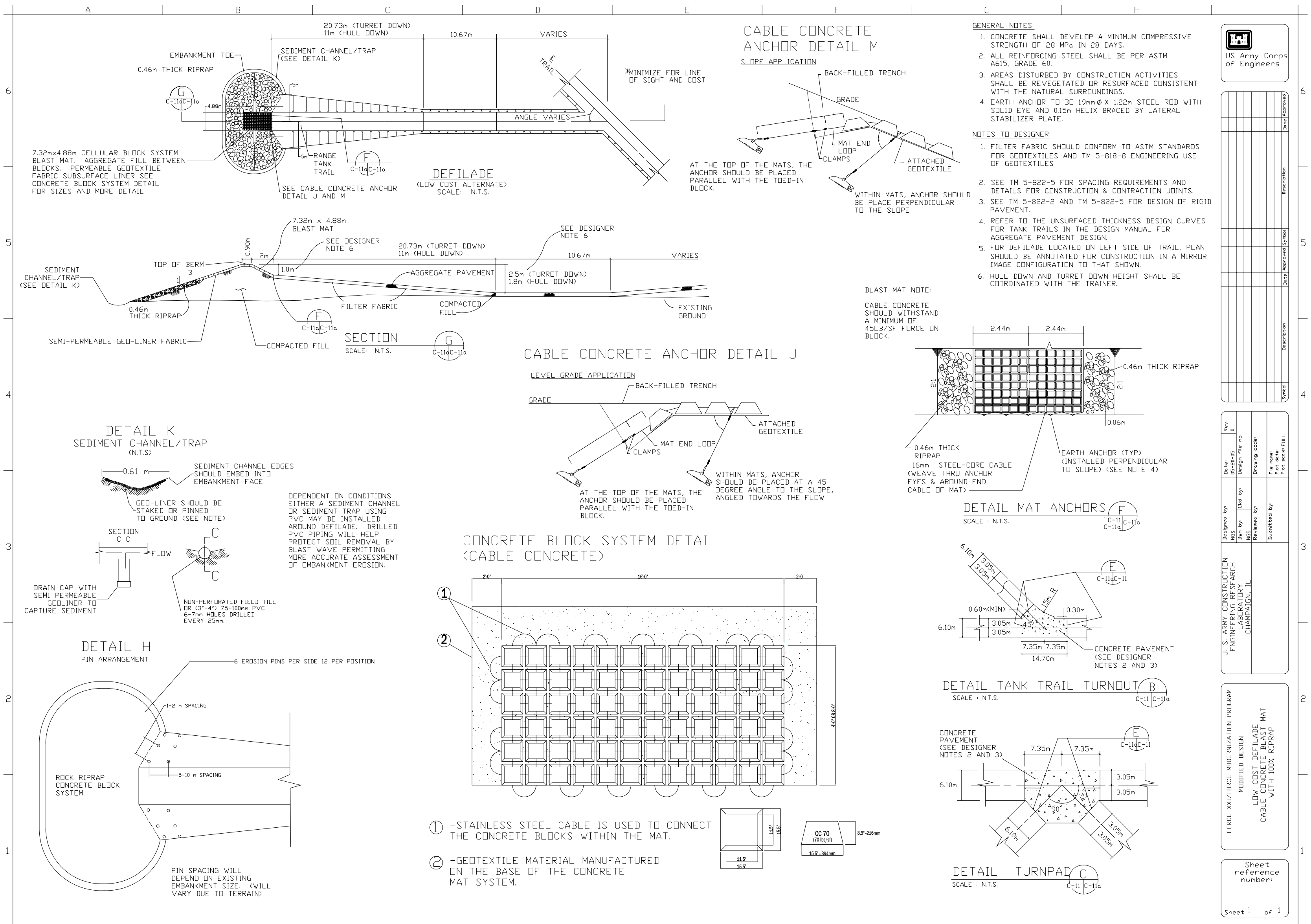

Figure 14. Design Alternative-4, Cable Concrete Blast Mat with 100% Rock Defilade.

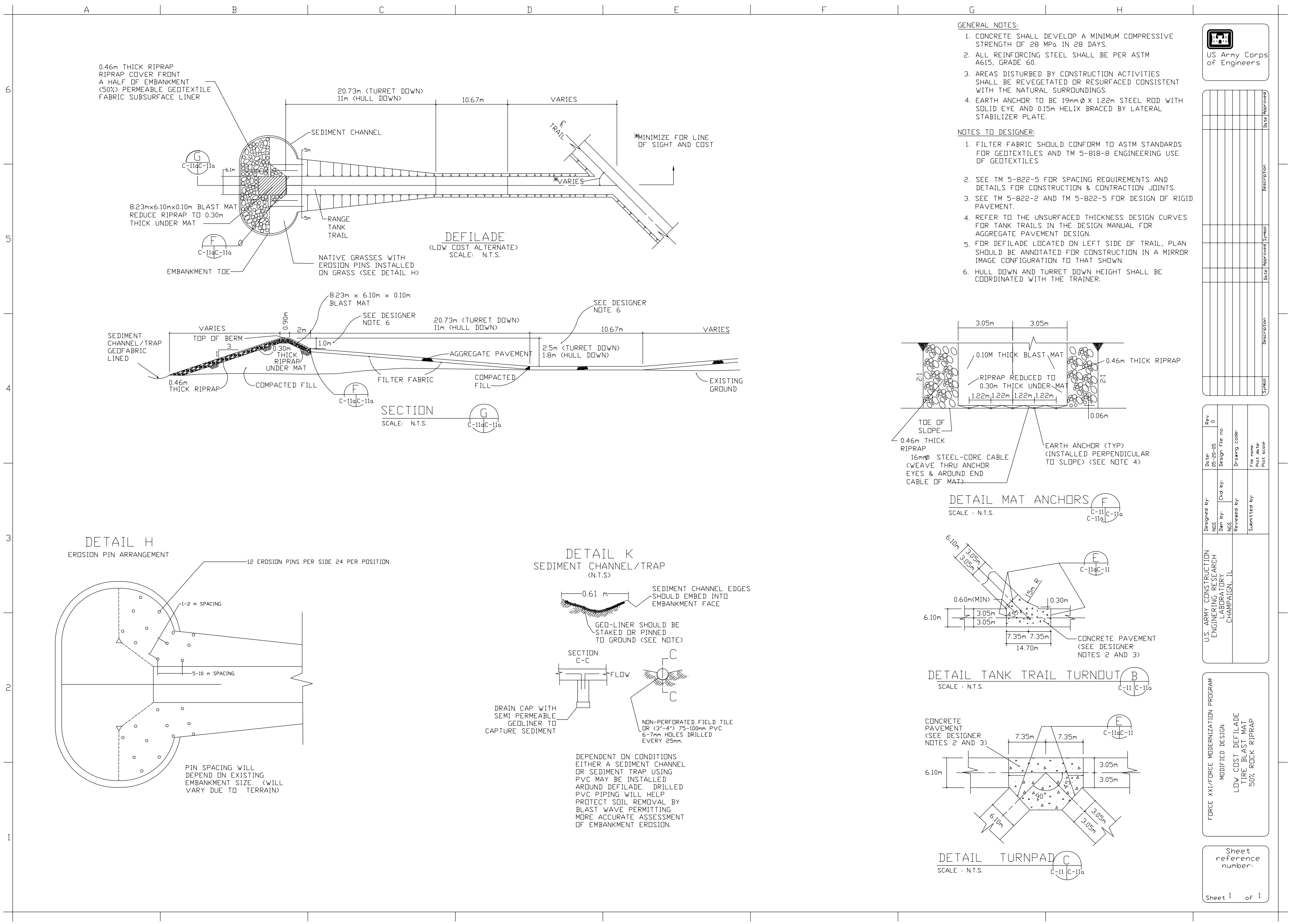

Figure 15. Design Alternative-5, Cable Concrete Blast Mat with 50% Rock Defilade.

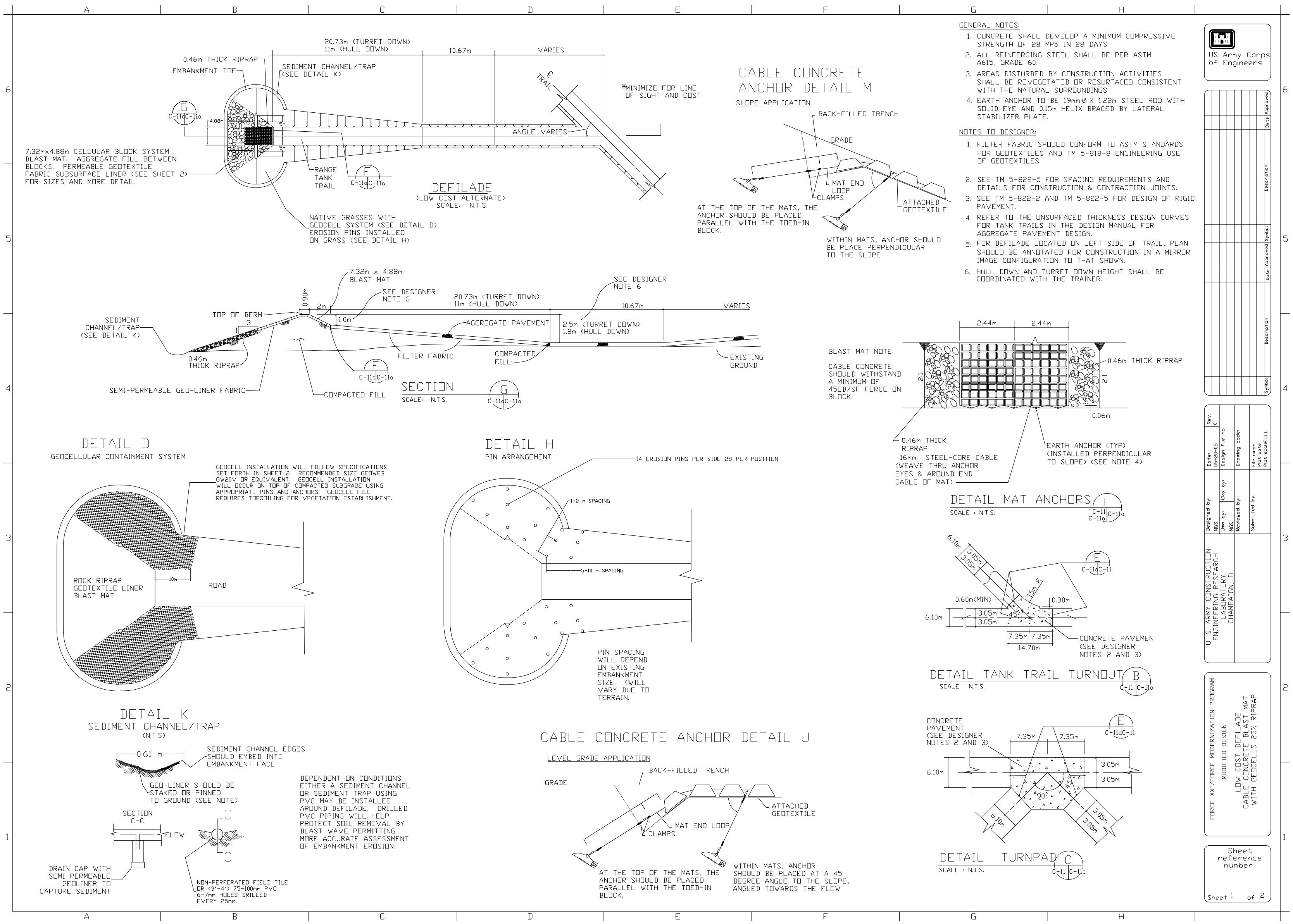

Figure 16. Design Alternative-6, Cable Concrete Blast Mat with 25% Rock Defilade with Geoweb® sheet 1.

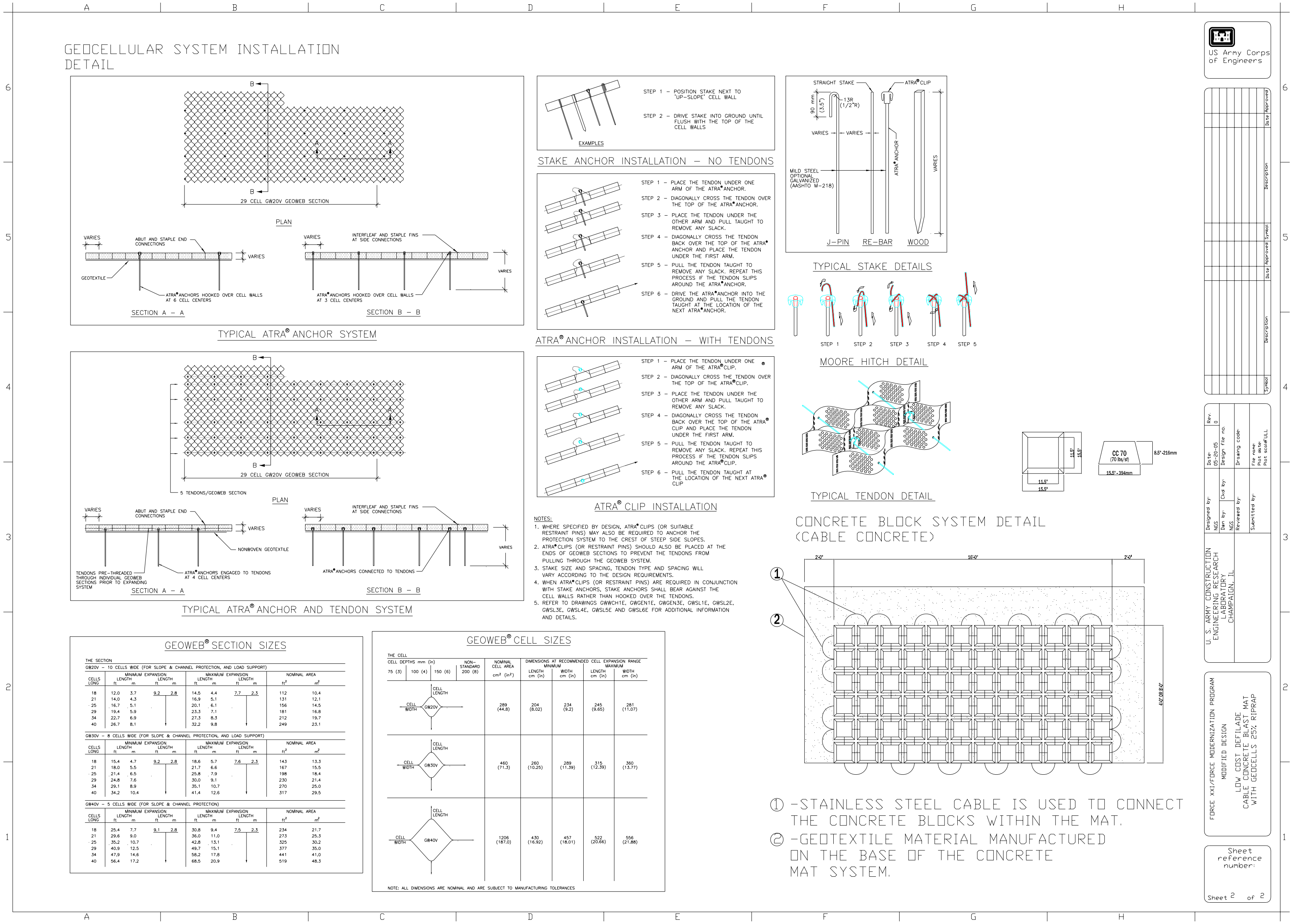

Figure 17. Design Alternative-6, Cable Concrete Blast Mat with 25% Rock Defilade with Geoweb® sheet 2.

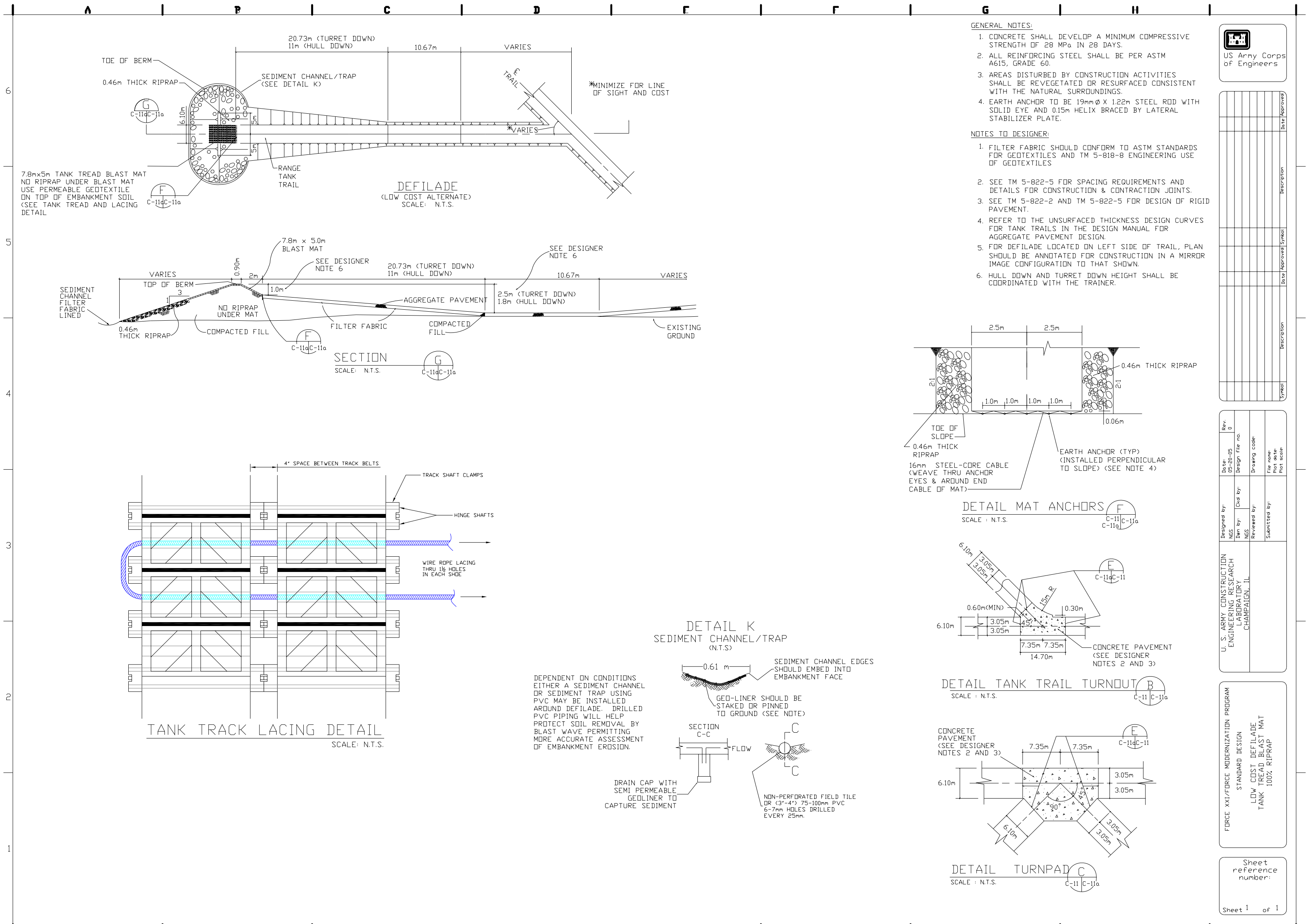

Figure 18. Design Alternative-7, Tank Tread Blast Mat with 100% Rock Defilade.

4 Armor Stationary Target Design and Testing

Armor Stationary Target Test Objective

Field observations of stationary target structures at several installations have identified the use of innovative range structure designs differing from current standard designs and construction practices. The apparent durability of these alternative range structures merits further investigation. The demonstration and validation of modified firing emplacement designs should verify optimal stabilization/construction practices suitable for armor stationary target positions. The overall objective is to demonstrate suitable and cost-effective site-specific stationary target designs that minimize soil erosion and reduce maintenance costs on military ranges using a variety of stationary target construction methods to meet range sustainability and environmental compliance goals.

Armor Stationary Target Test Concept

The evaluation of new or modified designs for stationary target positions should occur within close proximity to the testing authorities at an installation with field personnel cognizant of the requirements for conducting longer term demonstration and validation projects. The ideal scenario would give preference to installations with excellent long-term working relationships with testing authorities and a history of established collaborative effort with research facilities. The military post should be easily accessible and testing/field personnel must be familiar with the training areas, range facilities, and installation personnel to ensure the successful completion of the testing.

Test personnel should conduct the demonstration over a period of 1 to 2 years to provide sufficient data for scientific evaluation and validation of the new or improved designs. This period should be sufficient to allow the constructed structure soils to adequately consolidate, develop definitive soil erosion patterns, and provide ample time for vegetative growth. Coordination and preparation for the construction of the modified target emplacements should require additional time beyond the timeframe given for the testing period. Construction activities should not take more than three months to complete prior to the demonstration period.

To facilitate the collection of meaningful range structure data and adequately test the new stationary target designs, demonstration site locations require siting on an MPTR or an MPRC. Additionally, the topography and soil types of the selected areas must be conducive to accelerated erosion phenomenon that contribute to frequent and costly range maintenance activities when compared with similar range types in areas with less erosive soils and topographic gradients. The increased susceptibility to erosion is ideal for illustrating the effects of erosion on the operation and maintenance of military range stationary target positions over a shorter testing period.

Demonstration and validation of modified stationary target designs should use a variety of materials to construct or retrofit the existing emplacements. The use of geosynthetic materials, increased native vegetation, and nonstandard blast mat materials typify these modifications. Each stationary target position should be designated as a separate stabilization/construction practice treatment. The manipulation of standard design parameters should provide the basis for these treatments.

Each treatment shall be monitored for performance and durability using estimates of erosion and sedimentation (both quantitative and qualitative), vegetation coverage and effective precipitation using established monitoring and evaluation methods. Evaluation methods should consist of both qualitative (photography, video, and physical descriptors) and quantitative (erosion pins/sediment catch-channel, digital vegetative cover analysis, training intensity, water quality) data collection and analysis from each demonstration site. A possible evaluation method might include the real-time utilization of security cameras to capture design effectiveness. The methods used to collect information on the integrity of the new designs over the test timeframe should allow for direct comparisons between stabilization/construction design variations and the unimproved standard.

Armor Stationary Target System Description

Stationary target emplacements are found on many ranges. They are used on small ranges as infantry target emplacements. Larger ranges have both infantry and armor target emplacements. Stationary target emplacements are used during military maneuvers to provide target locations for M1A1 or M1A2 tanks and BFVs. They provide engagement opportunities from firing positions that tactical commanders can use for training mechanized elements in conflict scenarios. Stationary target emplacements comprise a more comprehensive range of firing elements to enhance training and apply an element of realism to training missions.

MPTRs, MPRCs, and Tank Gunnery Ranges are examples of ranges where armor stationary targets are present. Stationary target emplacements are smaller than both general earthen embankments and moving target emplacements, but are similar in size to firing emplacements. Stationary targets are subject to intentional fire and damages to target embankments range from vegetation loss to crater formation by artillery impact. For the purpose of demonstration and validation, the focus should be centered on armor stationary target emplacement embankments. Figure 19 depicts standard armor target emplacements, and Figure 3 shows standard designs for the structure.

Figure 19. Three examples of stationary armor target emplacements.

The left and center images of Figure 19 show the embankment face of the stationary target, while the image on the right displays the actual target emplacement structure. The middle image depicts cratering on the embankment face from military ordnance impact, while the leftmost image depicts a relatively undisturbed face. The standard design for stationary armored target emplacements provides specifications on how much area the stationary emplacement should occupy on the range. Referring to the rightmost image of Figure 19, the actual target mechanism encompasses an area of 17 m^2. When the armor target embankment is taken into consideration, however, the range structure occupies an area that is five to six times that of the target mechanism. A stationary armor target emplacement and embankment may occupy an area as large as 125 m^2 depending on topographical location and soil characteristics. Figure 3 illustrates the current recommended stationary target emplacement design. The Design Manual for RETS Ranges (USACE-ESC 1998) also specifies embankment design parameters and composition. Figure 20 shows the embankment composition options.

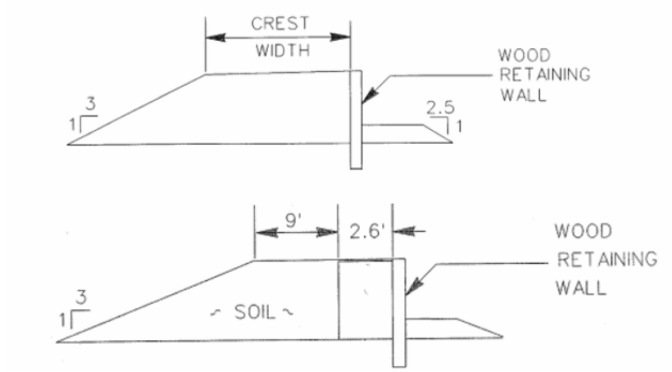

Figure 20. Design options for stationary embankment, earthen and earthen/rock.

The primary purpose of the embankment in front of the stationary target emplacement is to protect the target mechanism from damage during military exercises. According to The Design Manual for RETS Ranges (USACE-ESC 1998), the embankment should be of sufficient strength to withstand the impact of the largest weapon targeted to that emplacement location. The majority of environmental damage occurring on this structure is on the embankment immediately in front of the firing retaining wall. The demonstration and validation should concentrate on alternatives to current designs devised to limit or mitigate the environmental damage from mechanized equipment. As mentioned previously, demonstration efforts should highlight the effectiveness of alternative materials and stabilization/construction practices on the embankments and not on the emplacement structure itself, since most of the environmental compliance and maintenance issues are associated with erosion from the embankment face.

To demonstrate and validate the proposed stabilization/construction practices, stationary target embankments on a range or several ranges should be modified to support separate design alternatives. Over the duration of the demonstration, precipitation, soil movement, vegetation characteristics, usage intensity, and the overall integrity of the modified structure should be observed and documented using standard methods of data collection for the aforementioned parameters.

Armor Stationary Target Monitoring and Validation

Evaluation of armor stationary embankment effectiveness such as extended useful life expectancy and pollution mitigation potential (minimizeing erosion) should be measured both qualitatively and quantitatively using the subtest procedures described below. To conduct the tests, eight treatments on armor stationary target emplacements should be applied by modifying existing armor stationary target embankments. Figure 21 shows the suggested modified designs and configurations.

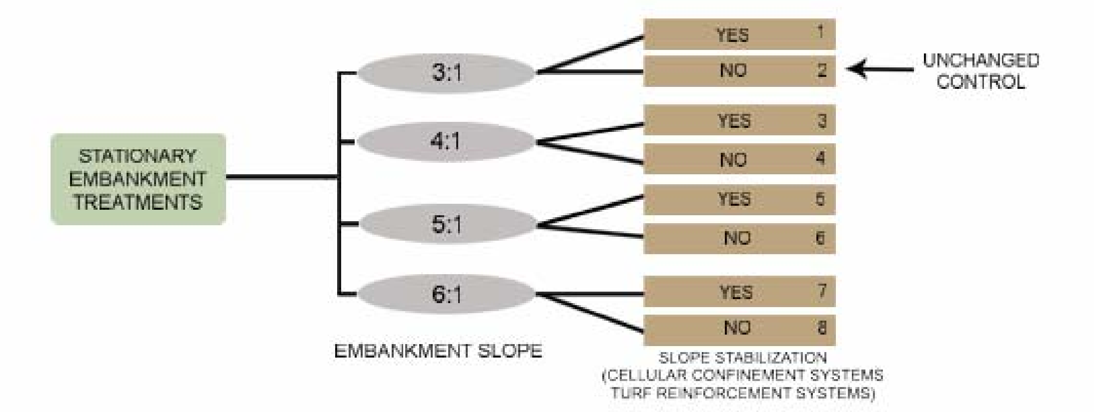

Figure 21. Planned stationary target embankment treatments.

The new stationary embankment constructions should validate the optimum configurations between slope and slope stabilization technique. The incorporation of geosynthetic materials into the range structure should demonstrate enhanced embankment stability in stationary target design that over time should require less maintenance. The control embankment should have a 3:1 side slope and should remain essentially unaltered over the duration of the demonstration. Over the demonstration/validation timeframe, original vegetation practices and maintenance routines should be retained. In addition to the control site, seven other embankments should require moderate to extensive earthwork to perform the desired tests. Embankment slope should vary at 33, 25, 20, and 17 percent (3:1, 4:1, 5:1 and 6:1, respectively). For each slope condition, two embankments (one with slope stabilization and one without) should be constructed. The slope stabilization technique should use cellular confinement systems, which have high load bearing capacities and offer exceptional erosion control and increased near surface shearing resistance. Once the embankment construction is complete, erosion/sedimentation, precipitation, runoff, soil moisture, and vegetative coverage data collection should begin as described below. Construction should be completed in accordance with specifications outlined in The Design Manual for RETS Ranges (USACE-ESC 1998), standard methods of embankment construction for compaction, and the design alterations specified in this document.

Short native grasses and naturalized non-native grasses, such as buffalograss, fescues, or bluegrasses, should provide vegetative cover on the embankments where the cellular confinement system is used. The embankment grasses shall be fire resistant/tolerant to withstand intermittent burning from weapons fire.

After the stationary targets are modified with each stabilization/construction practice, inspections of the embankments should occur on a monthly basis. The first 2 months after construction should be adequate for vegetation to be established with a good cover. Reseeding may be necessary in areas where initial growth is poor. With the new stabilization/construction practices, maintenance should not be required as frequently as with former design guidelines. Indicators of effectiveness include the time interval between maintenance cycles, so emplacement maintenance should be minimal over the test timeframe.

Measurement of Stationary Target Design Effectiveness

Validation of stationary target stabilization/construction practices should be conducted by measuring soil erosion, soil moisture, vegetative cover, climate data, and usage intensity.

Stationary Target Design Test Objectives

The objective of this test is to demonstrate the overall effectiveness of eight stabilization practices on stationary target emplacement positions by comparing erosion/deposition, vegetative cover, and soil moisture as surrogates representing cost, sustainability, and environmental compliance. The optimal combination of practices that minimize berm maintenance, extend useful berm life, minimize soil erosion, and maintain environmental compliance should be determined.

Stationary Target Design Test Criteria

Soil erosion data

Data collection on soil erosion should use two well-established methods: (1) erosion pin method for spatial soil loss measurement and (2) sediment channel method for gross soil loss measurement. The first method of soil movement measurement utilizes small graduated metal pins placed firmly in the ground below the frost line. The pins are spaced in a grid-like pattern over the study embankment face to record cumulative erosion/deposition and to observe erosion/deposition spatial variability. When erosion or deposition occurs around the pin, the graduated marks on the pin should indicate the depth of erosion or deposition. The use of digital photography should facilitate the quick and permanent recording of soil level readings. The erosion pin method was adapted from Haigh (1977) and FAO (1997). The second method of soil movement measurement consists of a geotextile-lined trench or tile dug around the range structure of interest to capture embankment runoff and erosion adapted from Robichaud and Brown (2002) and FAO (1997). The erosion pin method should yield satisfactory results on range structure elements where grass or bare soil is present; however, this method is not practical on areas covered with rock riprap and should not yield satisfactory results on soil loss. Under these stabilization/construction practices, the sediment channel method for erosion measurement should provide the best data for soil loss determination.

Vegetative cover data

The testing authorities should complete a vegetative cover assessment for each range structure under demonstration using digital photography and a digital analysis system developed by CERL researchers (Denight 2005). This system uses highly specialized software to distinguish between vegetation and bare soil. The digital analysis system calculates the vegetation cover and determines a percent follar. By photographing known areas over time, direct comparisons between photographs are possible.

Precipitation data

The measurement of precipitation is simple and direct if the equipment is set up correctly. Rainfall data should be collected on a cumulative basis and stored in a data logger such as a HOBO® Event Logger integrated with a tipping bucket rain gauge. Ideally, testing authorities should integrate a tipping bucket rain gauge into a HOBO® Weather Station. Weather stations have multiple sensors to detect ambient atmospheric conditions in addition to rainfall (i.e., soil moisture). Regardless of the method chosen to measure precipitation, the location of the tipping bucket rain gauge must be protected from military activities and interference, but remain representative for the area of interest.

Soil moisture data

High soil moisture content often correlates well to soil erosion potential. Therefore, each embankment stabilization/construction technique should have soil moisture data collected from the upper, middle, and lower embankment positions to determine the relationship between erosion. In-situ HOBO® soil moisture sensors and soil samples should provide estimates of soil moisture content at surface and near-surface depths on the embankment face.

Stationary target emplacements usage data

The testing authorities shall establish and maintain contact with range personnel during the test timeframe and shall advise installation managers on the progress of the demonstration/validation. Field personnel should collect range usage data from installation personnel and through visual inspection of the test plots. Range usage information is often available in database format to facilitate accurate and meaningful comparisons between stationary target positions and embankment stabilization/construction practices.

Stationary Target Design Test Procedures

Soil erosion data

The use of erosion pins to quantify soil movement is particularly suited to measuring soil movement on military training range embankments. Damage to a portion of the pin system does not compromise the effectiveness of the remaining elements. Furthermore, this method provides a quick assessment of the spatial variation in erosion occurring over a landscape. Additionally, calculations of total soil movement from the grid area are readily determined when uniform soil movement assumption holds for a pin region. Erosion pins are approximately 3 to 5 mm (1/8- to 3/16-in. stock stainless steel rod T303 [ASTM A276-04, 2004]) in diameter and range from 0.7 to 1.0 m in length. For higher visibility, the pins shall be painted and marked with graduations or taped with adhesive graduations. Once fabrication is complete, pin placement should occur at a depth of 0.5 to 0.8 m to exceed the frost line depth. It is important to leave adequate graduations above the ground surface to allow for possible deposition of soil in the pin area. Additionally, pin graduation orientation shall face away from the sun to reduce fading of the markings. Pin readings should occur on a monthly, quarterly, or storm event-based timeframe using a digital camera to capture soil movement around the pin as measured by the pin markings. Three sets of soil pin arrays should assess soil movement from each stationary target assuming that all or a portion of the embankment face is free of riprap. The pin array placement shall be as follows: embankment top, embankment middle, and embankment toe. An additional soil pin array around the base of the stationary target face should determine where soil deposition is occurring. The pins shall be located on the embankment face and placed in such a manner as to be representative of erosion conditions on the structure. A central database should store the field-collected digital images to facilitate analysis of soil movement.

On embankment faces that are fully covered or partially covered with rock riprap, a sediment channel or tile is required to capture soil deposits from the structure. The channel covering should be a geotextile material/tile as per design specifications (see Design and Specifications section) to facilitate the collection of deposited soil. Channel drainage shall direct flow to sediment traps to reduce soil lost from force of the blast wave. On stationary targets with substantial amounts of rock riprap, sediment channels/ tile should be the primary method for soil erosion estimation. Data collection should occur on a monthly, quarterly, or storm event based timeframe. Field personnel should note regions of soil accumulation, collect the soil in the sediment channel/traps, and transport deposited soil to the lab for weighing. Field personnel should minimize damage to the geotextile of the channel or tile during soil collection to maintain sediment channel integrity. A central repository should store the field-collected observations to assist in data analysis.

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The collection of stationary target/ range use information depends on the recordkeeping practices of the installation(s) chosen for testing. Range information may be available in database format or paper format. Additionally, observational information using security cameras and visual inspection would supplement reported range data. Field/testing personnel shall collect stationary target usage data from range personnel and transfer the information for subsequent analysis.

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Quarterly collection of all variables and data being evaluated should provide for a thorough comparison of stabilization practices.

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Quarterly collection of erosion and deposition data from soil pins and sediment collection channels or traps should allow comparison of alternative embankment stabilization/construction techniques and their overall efficacy in improving environmental compliance and reducing soil erosion and maintenance requirements.

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Quarterly collection of vegetative cover data from stationary quadrats using digital photography should allow comparison of alternative embankment construction techniques and their inherent ability to support vigorous grass growth, which reduces erosion potential.

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The information collected from the data logger should consist of two parameters. The first parameter should be the time of the bucket tip for the rain gauge. The second parameter should be the reading of the bucket tip that for all instances is 0.01 in. The tipping time and rainfall amount are essential to determine rainfall intensity and storm duration. This information is necessary to assist in the calculation of sediment movement and excess rainfall.

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Quarterly collection of soil moisture data for data loggers and soil samples should allow for comparison of alternative embankment stabilization/construction practices and their impact on soil moisture holding capacity.

Stationary target usage data

Usage data required from range personnel should include collection of the following information for the entire testing period: troops trained, range utilization days, vehicle utilization, and weapons-type utilization. The use of supplemental visual inspections during each sampling period should assist in determining emplacement condition. Collection of usage data allows for accurate and meaningful comparisons between each alternative embankment stabilization/construction practices. Standardized data compilation should permit valid comparisons of treatments.

Stationary Target Design Analysis

The information generated from evaluations of the emplacement treatments is an integration of the factors that affect soil loss levels. Military training frequency, soil erosion rates, precipitation amount, vegetative cover, and stationary target design parameters are all factors requiring consideration to provide a comprehensive analysis of stabilization/construction practice efficacy. These data should be analyzed for differences between the individual stabilization/construction practices to determine the least expensive yet most robust design modifications.

Soil erosion analysis

Analysis of field-collected data shall quantify the level of net soil movement occurring on the emplacement per pin area between sampling periods. Pin data analysis should illustrate the spatial variation in soil movement and illuminate areas of high soil movement. Additionally, soil erosion and deposition calculations for all pins shall establish net soil loss per emplacement over the testing period. Similarly, sediment channel data shall utilize the net soil loss from the embankment riprap/covered area to ascertain treatment effectiveness. The combination of sediment channel/trap data and erosion pin data analyses should depend on the treatment. Comparisons of net soil loss for each emplacement to acceptable soil loss levels and other treatments should permit verification of emplacement effectiveness. This information, in conjunction with soil moisture, precipitation, and vegetative information should allow a quantitative comparison of each demonstration.

Vegetative cover analysis

Digital analysis of each permanently located quadrat digital photograph should occur for all emplacements. Each image should be analyzed using software to estimate the degree of vegetative protection on each embankment. The data analysis should quantify the level of vegetation as a percentage of the quadrat area. In part, the vegetative cover information (when vegetation is used) is a measure of treatment effectiveness.

Precipitation analysis

Once the precipitation data collection is complete, data reduction should extract several pieces of useful information. This information should include the calculation of cumulative rainfall, rainfall intensity, time-based rainfall (e.g., 15-minute rainfall), and rainfall runoff rates. Combined with the soil erosion data, this information should facilitate calculation of erosion rates for each treatment corresponding to soil moisture, vegetation coverage, and embankment design modifications. Data collection and interpretation should use scientific methods and statistical analysis for all necessary data combinations and between treatment analyses.

Soil moisture analysis

The collection of soil moisture data for each embankment stabilization/construction practice to determine differences in soil moisture holding capacity ultimately relates to erosion and vegetative growth. Comparisons of soil moisture-erosion/soil loss and soil moisture-vegetative cover between demonstrations should quantify the influence of soil moisture on berm integrity.

Stationary target usage analysis

Emplacement usage data summarization should ensure that stationary targets are experiencing similar levels of use. Emplacement usage data are also useful in gauging the degradation of the emplacement structure due to training activities. Furthermore, emplacement usage data allow comparisons of treatments for design effectiveness.

Armor Stationary Target Design and Test Criteria

The illustration of the eight stationary target emplacement stabilization/construction practices and the testing protocol are described in Figures 22-26. The drawings follow the specifications outlined in The Design Manual for RETS Ranges (USACE-ESC 1998). The most important item to remember when using these drawings is that only the embankment face and embankment composition may change. An embankment compacted with optimum moisture content at the maximum dry density is recommended for all embankments to provide a constant reference for cataloguing vegetation and erosion measurements.

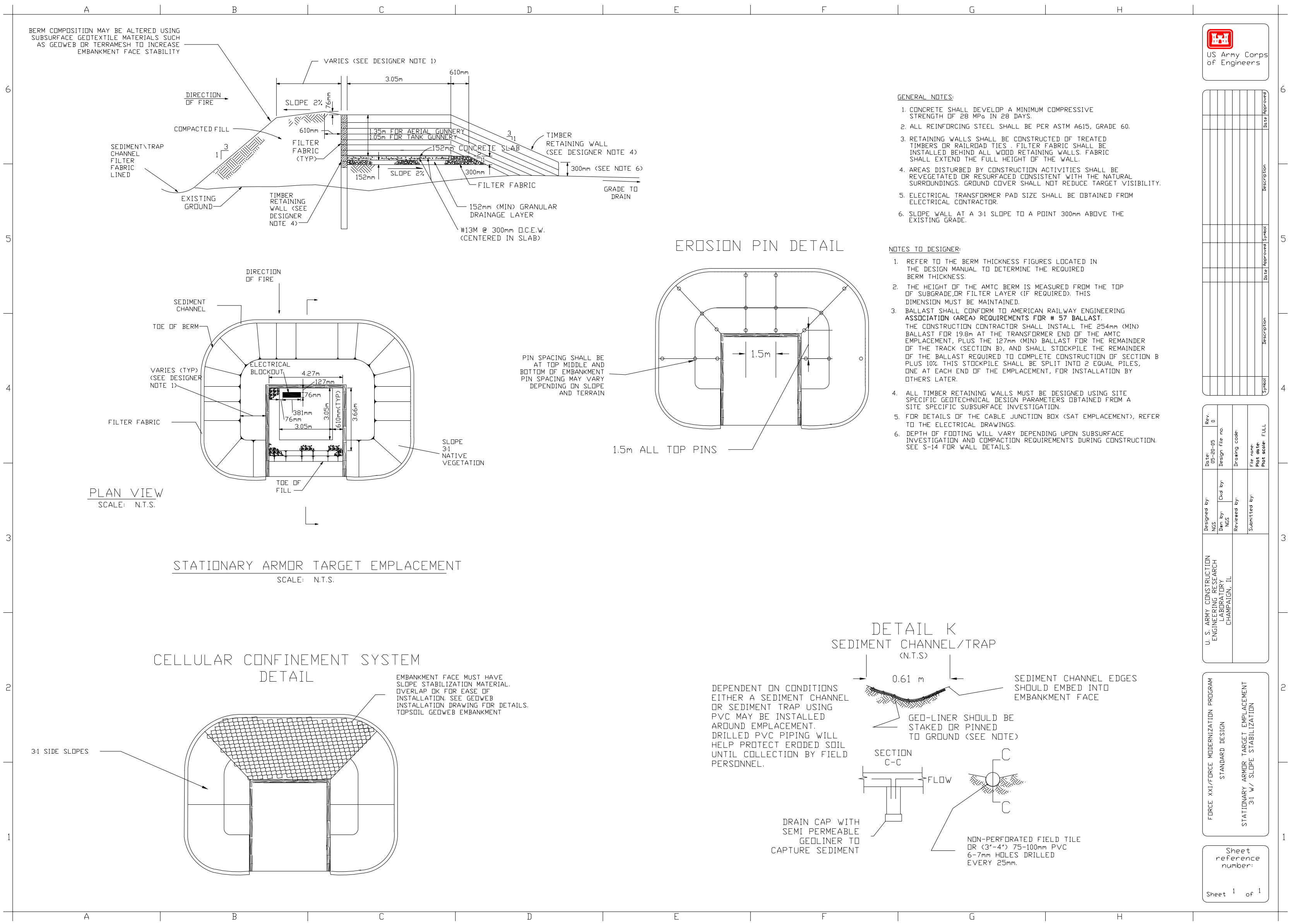


Figure 22. 3:1 Slope with and without slope stabilization stationary target embankment.

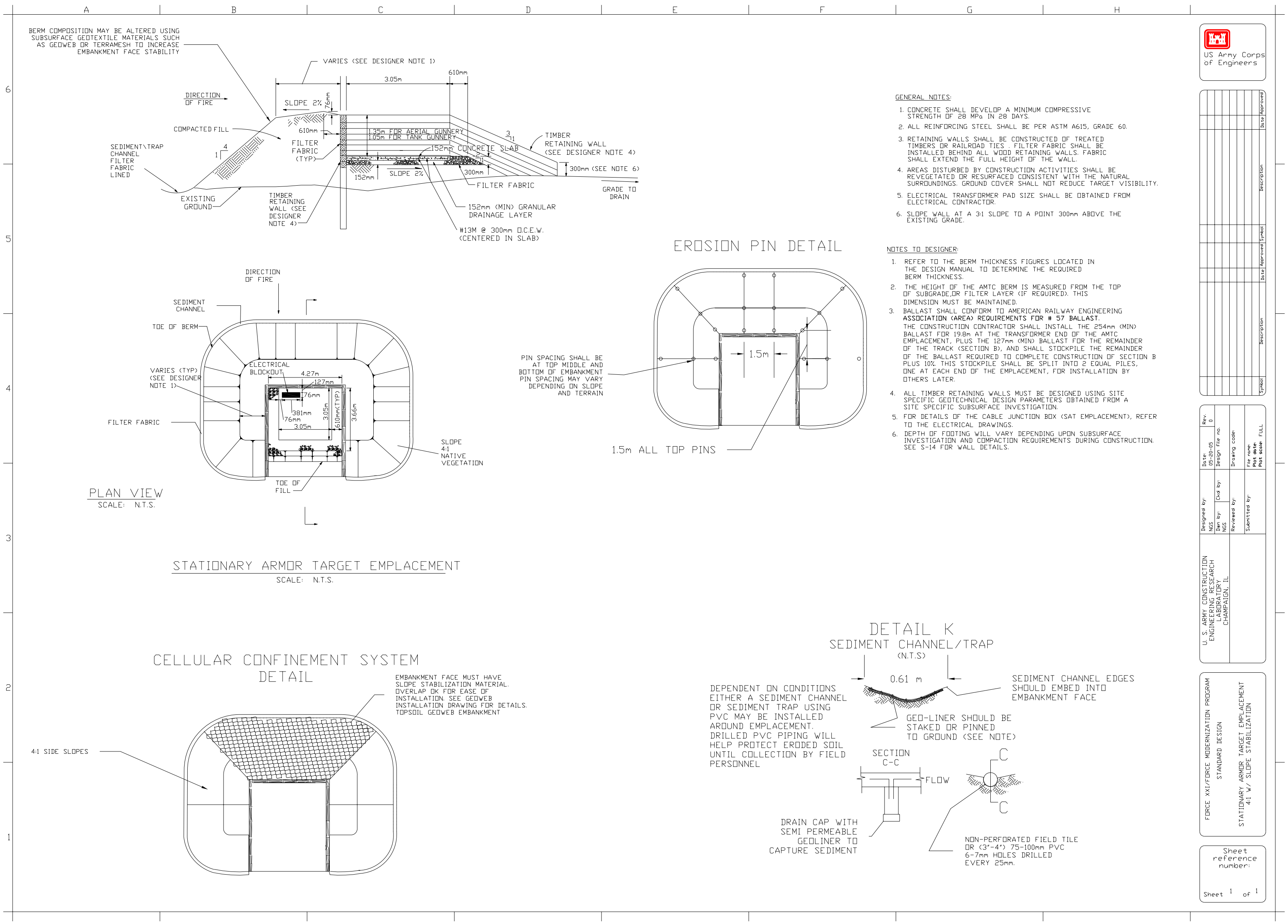


Figure 23. 4:1 Slope with and without slope stabilization stationary target embankment.

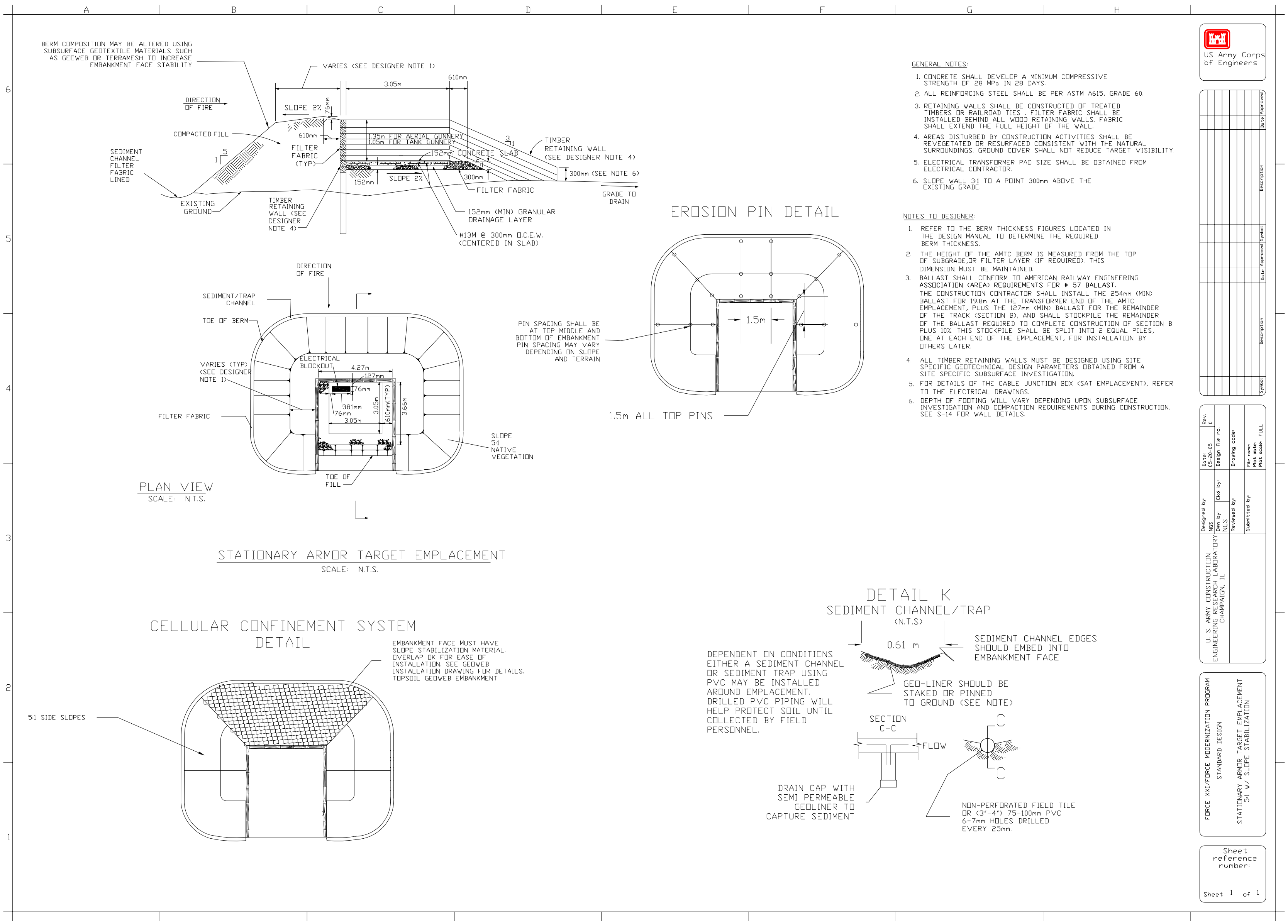


Figure 24. 5:1 Slope with and without slope stabilization stationary target embankment.

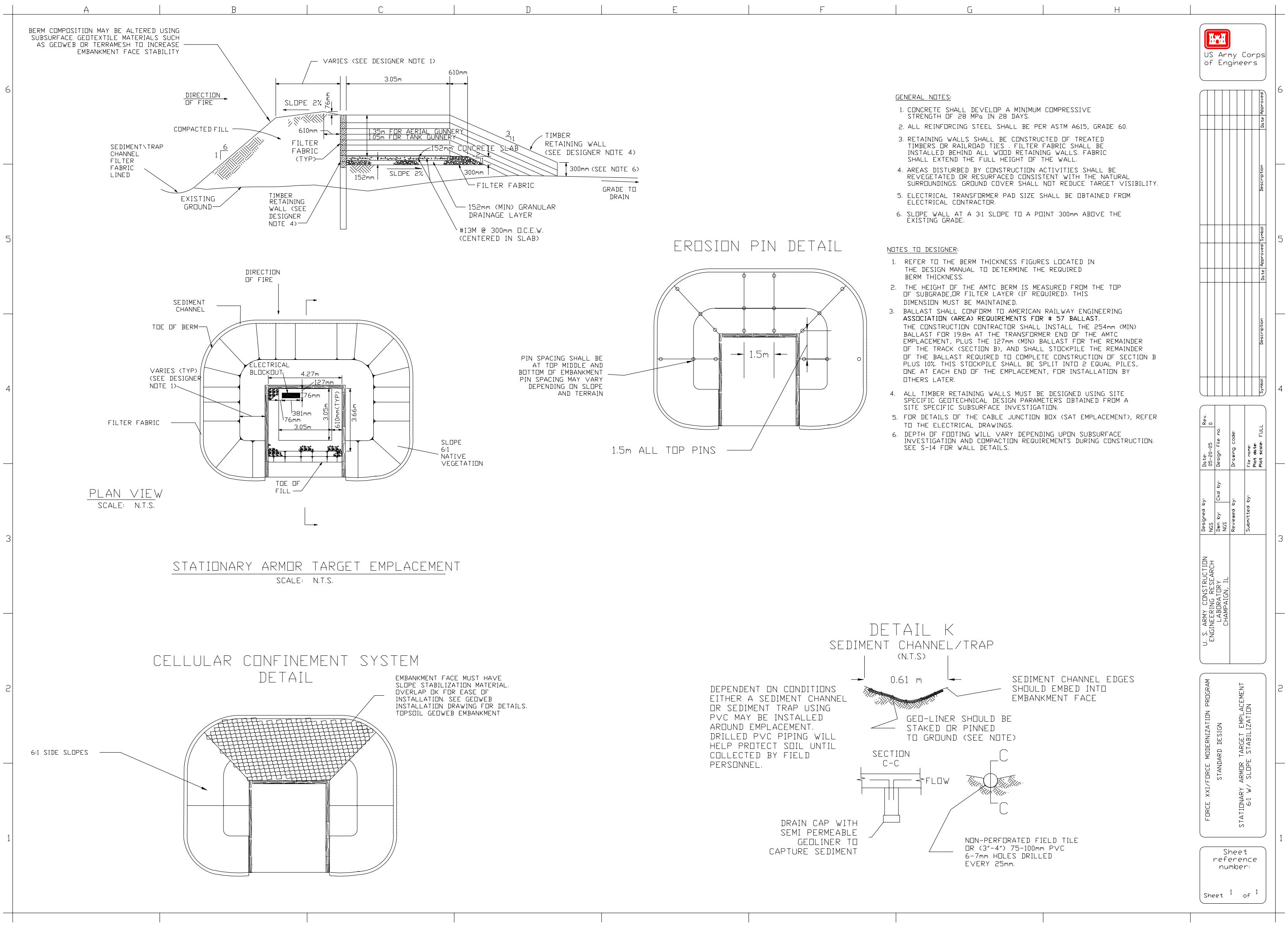
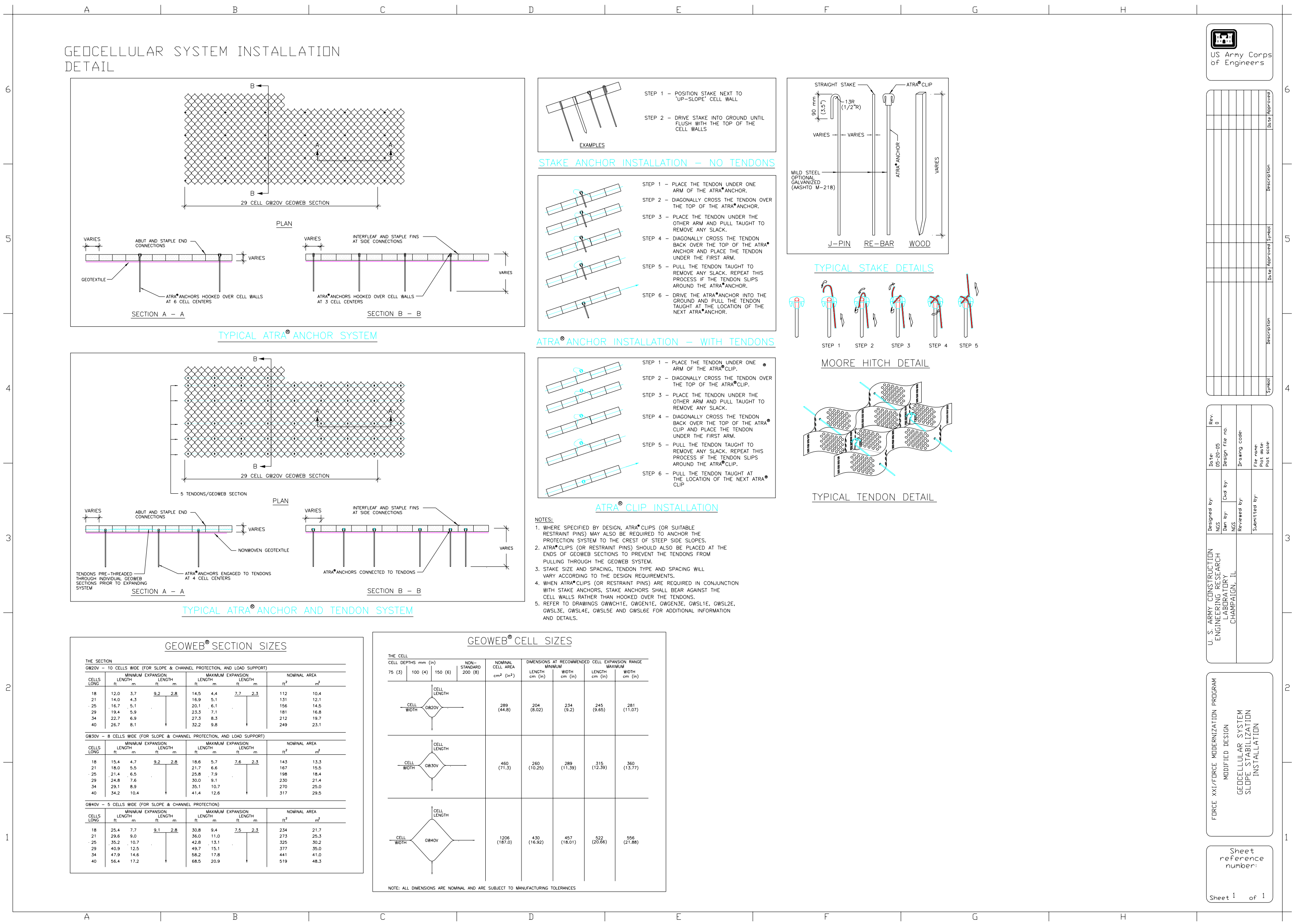


Figure 25. 6:1 Slope with and without slope stabilization stationary target embankment.



GEOWEB® SECTION SIZES

THE SECTION

GW20V – 10 CELLS WIDE (FOR SLOPE & CHANNEL PROTECTION, AND LOAD SUPPORT)

CELLS LONG	MINIMUM EXPANSION LENGTH ft	MINIMUM EXPANSION LENGTH m	MINIMUM EXPANSION LENGTH ft	MINIMUM EXPANSION LENGTH m	MAXIMUM EXPANSION LENGTH ft	MAXIMUM EXPANSION LENGTH m	MAXIMUM EXPANSION LENGTH ft	MAXIMUM EXPANSION LENGTH m	NOMINAL AREA ft^2	NOMINAL AREA m^2
18	12.0	3.7	9.2	2.8	14.5	4.4	7.7	2.3	112	10.4
21	14.0	4.3			16.9	5.1			131	12.1
25	16.7	5.1			20.1	6.1			156	14.5
29	19.4	5.9			23.3	7.1			181	16.8
34	22.7	6.9			27.3	8.3			212	19.7
40	26.7	8.1			32.2	9.8			249	23.1

GW30V – 8 CELLS WIDE (FOR SLOPE & CHANNEL PROTECTION, AND LOAD SUPPORT)

CELLS LONG	MINIMUM EXPANSION LENGTH ft	MINIMUM EXPANSION LENGTH m	MINIMUM EXPANSION LENGTH ft	MINIMUM EXPANSION LENGTH m	MAXIMUM EXPANSION LENGTH ft	MAXIMUM EXPANSION LENGTH m	MAXIMUM EXPANSION LENGTH ft	MAXIMUM EXPANSION LENGTH m	NOMINAL AREA ft^2	NOMINAL AREA m^2
18	15.4	4.7	9.2	2.8	18.6	5.7	7.6	2.3	143	13.3
21	18.0	5.5			21.7	6.6			167	15.5
25	21.4	6.5			25.8	7.9			198	18.4
29	24.8	7.6			30.0	9.1			230	21.4
34	29.1	8.9			35.1	10.7			270	25.0
40	34.2	10.4			41.4	12.6			317	29.5

GW40V – 5 CELLS WIDE (FOR SLOPE & CHANNEL PROTECTION)

CELLS LONG	MINIMUM EXPANSION LENGTH ft	MINIMUM EXPANSION LENGTH m	MINIMUM EXPANSION LENGTH ft	MINIMUM EXPANSION LENGTH m	MAXIMUM EXPANSION LENGTH ft	MAXIMUM EXPANSION LENGTH m	MAXIMUM EXPANSION LENGTH ft	MAXIMUM EXPANSION LENGTH m	NOMINAL AREA ft^2	NOMINAL AREA m^2
18	25.4	7.7	9.1	2.8	30.8	9.4	7.5	2.3	234	21.7
21	29.6	9.0			36.0	11.0			273	25.3
25	35.2	10.7			42.8	13.1			325	30.2
29	40.9	12.5			49.7	15.1			377	35.0
34	47.9	14.6			58.2	17.8			441	41.0
40	56.4	17.2			68.5	20.9			519	48.3

GEOWEB® CELL SIZES

THE CELL	NOMINAL CELL AREA cm^2 (in^2)	MINIMUM LENGTH cm (in)	MINIMUM WIDTH cm (in)	MAXIMUM LENGTH cm (in)	MAXIMUM WIDTH cm (in)
GW20V	289 (44.8)	204 (8.02)	234 (9.2)	245 (9.65)	281 (11.07)
GW30V	460 (71.3)	260 (10.25)	289 (11.39)	315 (12.39)	360 (13.77)
GW40V	1206 (187.0)	430 (16.92)	457 (18.01)	522 (20.66)	556 (21.88)

CELL DEPTHS mm (in): 75 (3), 100 (4), 150 (6); NON-STANDARD 200 (8). DIMENSIONS AT RECOMMENDED CELL EXPANSION RANGE.

NOTE: ALL DIMENSIONS ARE NOMINAL AND ARE SUBJECT TO MANUFACTURING TOLERANCES

Figure 26. Geocellular system slope stabilization installation.

5 Armor Moving Target Design and Testing

Armor Moving Target Test Objective

Field observations of moving target emplacement structures at several installations have identified the use of innovative range structure designs differing from current standard designs and construction practices. The apparent durability of these alternative range structures merits further investigation. The demonstration and validation of modified firing emplacement designs should verify optimal stabilization/construction practices suitable for armor moving target emplacement positions. The overall objective is to demonstrate suitable and cost-effective site-specific moving target emplacement designs that minimize soil erosion and reduce maintenance costs on military ranges using a variety of moving target emplacement construction materials to meet range sustainability and environmental compliance goals.

Armor Moving Target Emplacement Test Concept

The evaluation of new or modified designs for moving target emplacement positions should occur within close proximity to the testing authorities at an installation with field personnel cognizant of the requirements for conducting longer term demonstration/validation projects. The ideal scenario would give preference to installations with excellent long-term working relationships with testing authorities and a history of established collaborative effort with research facilities. The military post should be easily accessible and testing/field personnel must be familiar with the training areas, range facilities, and installation personnel to ensure the successful completion of the testing.

Test personnel should conduct the demonstration over a period of 1 to 2 years to provide sufficient data for scientific evaluation and validation of the new or improved designs. This period should be sufficient to allow the constructed structure soils to adequately consolidate, develop definitive soil erosion patterns, and provide ample time for vegetative growth. Coordination and preparation for the construction of the modified target emplacements should require additional time beyond the timeframe given for the testing period. Construction activities should not take more than 3 months to complete prior to the demonstration period.

To facilitate the collection of meaningful range structure data and adequately test the new moving target emplacement designs, demonstration site locations require siting on an MPTR or an MPRC. Additionally, the topography and soil types of the selected areas must be conducive to accelerated erosion phenomenon that contribute to frequent and costly range maintenance activities when compared with similar range types in areas with less erosive soils and topographic gradients. The increased susceptibility to erosion is ideal for illustrating the effects of erosion on the operation and maintenance of military range moving target emplacement positions over a shorter testing period.

Demonstration and validation of modified moving target emplacement designs should use a variety of materials to construct or retrofit the existing emplacements. The use of geosynthetic materials, increased native vegetation, terraces, and grass waterways should typify these modifications. Each moving target emplacement position should be designated as a separate stabilization/construction practice treatment. Manipulation of standard design parameters should provide the basis for these treatments.

Each treatment shall be monitored for performance and durability using estimates of erosion and sedimentation (both quantitative and qualitative), vegetation coverage, and effective precipitation using established monitoring and evaluation methods. Evaluation methods should consist of both qualitative (photography, video, and physical descriptors) and quantitative (erosion pins/sediment catch-channel, digital vegetative cover analysis, training intensity, water quality) data collection and analysis from each demonstration site. A possible evaluation method might include the real-time utilization of security cameras to capture design effectiveness during training. The methods used to collect information on the integrity of the new designs over the test timeframe should allow for direct comparisons between stabilization/construction design variations and the unimproved standard.

Armor Moving Target System Description

Moving target emplacements are located on larger ranges with both infantry and armor stationary target emplacements. Examples of ranges where armor moving targets are present are MPTRs, MPRCs, and Tank Gunnery Ranges. Moving target emplacements are generally the largest earthen structures encountered on a range. For the purpose of this demonstration and validation proposal, the focus should center on armor moving target emplacement embankments. Figure 27 depicts standard moving target emplacements, and Figure 28 shows standard designs for the structure.

Figure 27. Three examples of moving armor target emplacements.

All three images in Figure 27 illustrate the embankment face of a moving target emplacement. Each image shows substantial erosion or loss of vegetation on the berm face. Erosion levels of this magnitude can be reduced substantially by altering embankment construction and maintenance practices. The current standard design for moving armor target emplacements specifies how much area the moving emplacement should occupy on the range. The actual target mechanism area encompasses approximately 2900 m^2. When the armor target emplacement embankment is taken into consideration, however, the range structure occupies an area four to five times that of the target mechanism. A moving armor target emplacement and embankment may occupy an area as large as 15,000 m^2 depending on topographical location and soil characteristics. Figure 2 illustrates the recommended moving target emplacement design. The Design Manual for RETS Ranges (USACE-ESC 1998) also specifies embankment design parameters and composition. The embankment composition options are shown in Figure 28.

Moving armor target emplacements are used during military maneuvers to provide targeting locations for tanks, BFVs, and attack helicopters. They provide engagement opportunities that tactical commanders can use to train the troops in various scenarios involving mobile objectives. Moving emplacements comprise a more comprehensive range of target elements to enhance training scenarios and apply an element of realism to training missions.

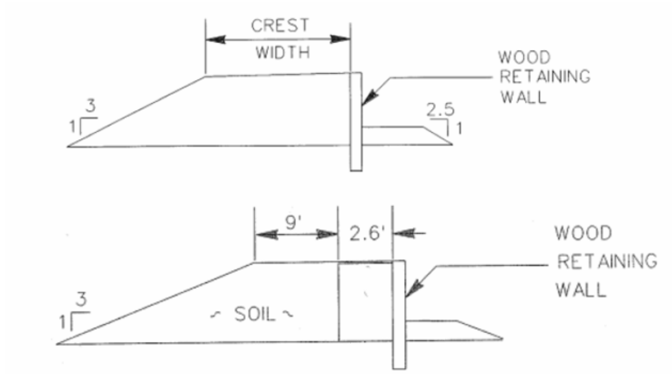


Figure 28. Design options for moving embankment earthen and earthen/rock

The primary purpose of the embankment in front of the moving target emplacement is to protect the target mechanism from damage during military exercises. According to The Design Manual for RETS Ranges (USACE-ESC 1998), the embankment should be of sufficient strength to withstand the impact of the largest weapon targeted to that emplacement location. The majority of environmental damage occurring on this structure is on the embankment immediately in front of the target mechanism. The demonstration and validation should concentrate on alternatives to current designs devised to limit or mitigate the environmental damage from mechanized equipment. As mentioned previously, demonstration efforts should highlight the effectiveness of alternative materials and stabilization/construction practices on the embankments and not on the emplacement structure itself, since most of the environmental compliance and maintenance issues are associated with erosion from the embankment face.

To demonstrate and validate the proposed stabilization/construction practices, moving target embankments on a range or several ranges should be modified to support separate design alternatives. Over the duration of the demonstration, precipitation, soil movement, vegetation characteristics, intensity of use, and the overall integrity of the modified structure should be observed and documented using standard methods of data collection for the aforementioned parameters.

Several of the armor moving emplacements should use erosion control structures on the embankment face to control water flow. The utility of these structures as part of a best management plan should be investigated. The two predominant natural erosion control structures should be terraces and grass waterways. Terraces are erosion control structures located across the slope of an embankment face that interfere with the movement of rainfall runoff and thereby slow the movement of soil transported in the flow. Grass waterways are contoured drainage channels with well-established vegetation that reduce erosion by using vegetation or small check dams to retard the runoff from upland areas. Agricultural operations frequently use terraces and grass waterways to control erosion; however, no information exists on their usefulness in erosion/runoff control on range structures.

Armor Moving Target Monitoring and Validation

Evaluation of armor moving embankment effectiveness, such as extended useful life expectancy and pollution mitigation potential (minimizing erosion), should be measured both qualitatively and quantitatively using the subtest procedures described below. To conduct the demonstration and validation, eight treatments should be applied by modifying existing armor moving target embankments. Figure 29 shows the different configurations for each treatment application.

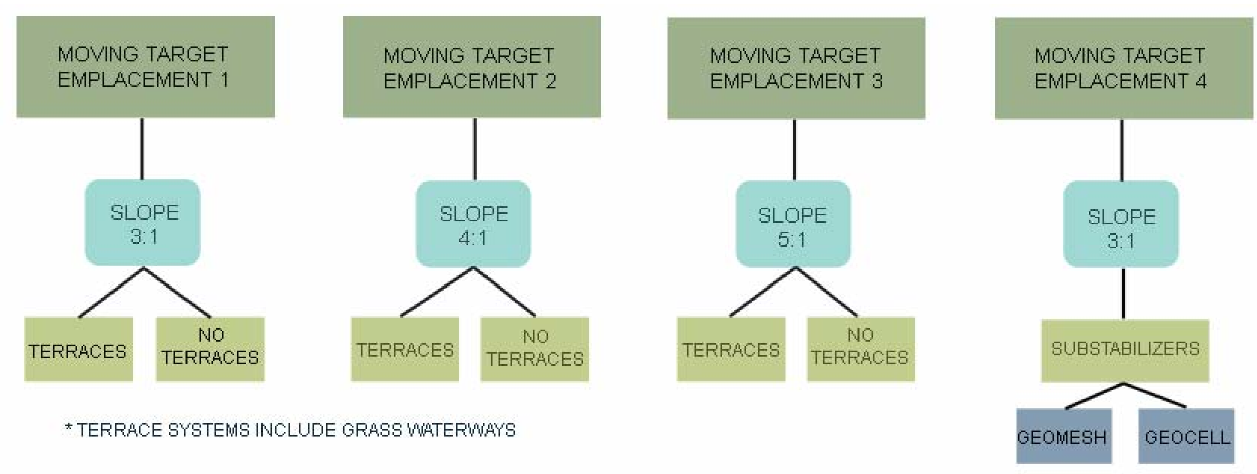


Figure 29. Eight moving target embankment treatments.

Two embankments should have 3:1 side slopes, one embankment should have a 4:1 side slope, and another should have a 5:1 side slope. The two embankments with 3:1 side slopes should require the least amount of construction and modification. The remaining two embankments should require more extensive earthwork due to alteration in slope angle (4:1 and 5:1 embankment slope). Each of the four embankments should have two study plots. Three embankments should have terraces and grass waterways installed on half of the embankment to reduce erosion while the other half should use vegetation practices to reduce erosion. Additionally, one embankment should have two treatments demonstrating the use of subsurface stabilization materials (geocellular confinement systems, turf reinforcement mats). On control embankments, short native grasses such as buffalograss should provide the vegetative cover on the embankments. Each treatment plot as well as the grass waterways and the terraces should be monitored over the testing period. Data should be collected for each plot on precipitation, soil moisture, erosion/sedimentation, and vegetation coverage using the subtests described in Chapter 3. Short native grasses and naturalized non-native grasses, such as buffalograss, fescues, or bluegrasses, should be used to establish vegetative cover on the embankments. The embankment grasses shall be fire resistant and tolerant to withstand intermittent burning from weapons fire. Once the embankments have been constructed, erosion/sedimentation, precipitation, runoff, soil moisture, and vegetative coverage data collection should begin as described below. Construction should be completed in accordance with specifications outlined in The Design Manual for RETS Ranges (USACE-ESC 1998), standard methods of embankment construction for compaction, and the design alterations specified in this planning document.

After the moving target emplacements are modified with each stabilization/construction practice, inspections of the embankments should occur on a monthly basis. The first 2 months after construction should be adequate for vegetation to be established with a good cover. Reseeding may be necessary in areas where initial growth is poor. With the new stabilization/construction practices, maintenance should not be required as frequently as with former design guidelines. Indicators of effectiveness include the time interval between maintenance cycles, so emplacement maintenance should be kept to a minimum over the test timeframe.

Measurement of Armor Moving Target Design Effectiveness

Validation of moving target emplacement stabilization/construction practices should be conducted by measuring soil erosion, soil moisture, vegetative cover, climate data, and usage intensity.

Armor Moving Target Emplacement Design Test Objectives

The objective of this test is to demonstrate the overall effectiveness of terraces, grass waterways, and soil stabilization systems on moving target emplacements by comparing erosion/deposition, vegetative cover, and soil moisture as surrogates representing cost, sustainability, and environmental compliance. The optimal combination of practices that minimize berm maintenance, extend useful berm life, minimize soil erosion, and maintain environmental compliance should be determined.

Armor Moving Target Emplacement Design Test Criteria

Soil erosion data

Data collection on soil erosion should use two well-established methods: (1) erosion pin method for spatial soil loss measurement and (2) sediment channel method for gross soil loss measurement. The first method of soil movement measurement utilizes small graduated metal pins placed firmly in the ground below the frost line. The pins are spaced in a grid-like pattern over the study embankment face to record cumulative erosion/deposition and to observe erosion/deposition spatial variability. When erosion or deposition occurs around the pin, the graduated marks on the pin should indicate the depth of erosion or deposition. The use of digital photography should facilitate the quick and permanent recording of soil level readings. The erosion pin method was adapted from Haigh (1977) and FAO (1997). The second method of soil movement measurement consists of a geotextile-lined trench or tile dug around the range structure of interest to capture embankment runoff and erosion adapted from Robichaud and Brown (2002) and FAO (1997). The erosion pin method should yield satisfactory results on range structure elements where grass or bare soil is present; however, this method is not practical on areas covered with rock riprap and should not yield satisfactory results on soil loss. Under these stabilization/construction practices, the sediment channel method for erosion measurement should provide the best data for soil loss determination.

Vegetative cover data

The testing authorities should complete a vegetative cover assessment for each range structure under demonstration using digital photography and a digital analysis system developed by CERL researchers (Denight 2005). This system uses highly specialized software to distinguish between vegetation and bare soil. The digital analysis system calculates the vegetation cover and determines a percent follar. By photographing known areas over time, direct comparisons between photographs are possible.

Precipitation data

The measurement of precipitation is simple and direct if the equipment is set up correctly. Rainfall data should be collected on a cumulative basis and stored in a data logger such as a HOBO® Event Logger integrated with a tipping bucket rain gauge. Ideally, testing authorities should integrate a tipping bucket rain gauge into a HOBO® Weather Station. Weather stations have multiple sensors to detect ambient atmospheric conditions in addition to rainfall (i.e., soil moisture). Regardless of the method chosen to measure precipitation, the location of the tipping bucket rain gauge must be protected from military activities and interference, but remain representative for the area of interest.

Soil moisture data

High soil moisture content often correlates well to soil erosion potential. Therefore, each embankment stabilization/construction technique should have soil moisture data collected from the upper, middle, and lower embankment positions to determine the relationship between erosion. In-situ HOBO® soil moisture sensors and soil samples should provide estimates of soil moisture content at surface and near-surface depths on the embankment face.

Armor moving target emplacement usage data

The testing authorities shall establish and maintain contact with range personnel during the test timeframe and shall advise installation managers on the progress of the demonstration/validation. Field personnel should collect range usage data from installation personnel and through visual inspection of the test plots. Range usage information is often available in database format to facilitate accurate and meaningful comparisons between moving target emplacement positions and embankment stabilization/construction practices.

Armor Moving Target Emplacement Design Test Procedures

Soil erosion data

The use of erosion pins to quantify soil movement is particularly suited to measuring soil movement on military training range embankments. Damage to a portion of the pin system does not compromise the effectiveness of the remaining elements. Furthermore, this method provides a quick assessment of the spatial variation in erosion occurring over a landscape. Additionally, calculations of total soil movement from the grid area are readily determined when uniform soil movement assumption holds for a pin region. Erosion pins are approximately 3 to 5 mm (1/8- to 3/16-in. stock stainless steel rod T303 [see ASTM A276-04]) in diameter, and range from 0.7 to 1.0 m in length. For higher visibility, the pins shall be painted and marked with graduations or taped with adhesive graduations. Once fabrication is complete, pin placement should occur at a depth of 0.5 to 0.8 m to exceed the frost line depth. It is important to leave adequate graduations above the ground surface to allow for possible deposition of soil in the pin area. Additionally, pin graduation orientation shall face away from the sun to reduce fading of the markings. Pin readings should occur on a monthly, quarterly, or storm event-based timeframe using a digital camera to capture soil movement around the pin as measured by the pin markings. Three sets of soil pin arrays should assess soil movement from each moving target emplacement assuming that all or a portion of the embankment face is free of riprap. The pin array placement shall be as follows: embankment top, embankment middle, and embankment toe. An additional soil pin array around the base of the moving target emplacement face should determine where soil deposition is occurring. The pins shall be located on the embankment face and placed in such a manner as to be representative of erosion conditions on the structure. A central database should store the field-collected digital images to facilitate analysis of soil movement.

On embankment faces that are fully covered or partially covered with rock riprap, a sediment channel/tile to capture soil deposits from the structure is required. The channel covering should be a geotextile material/tile as per design specifications to facilitate the collection of deposited soil. Channel drainage shall direct flow to sediment traps to reduce soil lost from force of the blast wave. On moving target emplacements with substantial amounts of rock riprap, sediment channels/tile should be the primary method for soil erosion estimation. Data collection should occur on a monthly, quarterly, or storm event based timeframe. Field personnel should note regions of soil accumulation, collect the soil in the sediment channel/traps, and transport depositional soil to the lab for weighing. Field personnel should minimize damage to the geotextile/tile during soil collection to maintain sediment channel integrity. A central repository should store the field-collected observations to assist in data analysis.

Vegetative cover data

Vegetative cover of moving target emplacement faces should be evaluated using digital photo analysis with one sampling quadrant per face per time interval (quarterly). The sampling area should remain the same during the testing period to provide consistent measurements of vegetative cover. Digital analysis should provide a quick, cost effective, and accurate measurement of cover for each embankment face. A central database should store the field-collected digital images to facilitate analysis for percent vegetative cover.

Precipitation data

Precipitation measurement should use a tipping bucket rain gauge. Tipping bucket rain gauges measure incremental precipitation in amounts equivalent to 0.01 in. (0.2 mm). The tipping bucket rain gauge utilizes two small containers balanced on a fulcrum. Each time the required amount fills one of the containers, a tip occurs, the water empties, and the second container positions for precipitation collection. At each tip, the data logger records the time and amount of rainfall. Field personnel should offload the data during scheduled visits. Due to the sensitive nature of the data loggers, data offload must occur infrequently to reduce analysis work during data reduction.

The precipitation data collection apparatus should be sited in an area that is protected from possible interference from military personnel and equipment. The ideal site location should be at least 100 m from trees and brush to reduce interference with these items. The transfer of precipitation data should employ a laptop or portable computing device and occur on a quarterly basis. The transfer of field-collected data to temporary storage devices should facilitate data relocation to a central repository.

Soil moisture data

The collection of soil moisture data should require soil moisture sensors and soil sampling methods to ascertain soil water content. A sensor array should collect data from the top, center, and bottom of the embankment, and a data logger should store the information for subsequent retrieval. Field personnel should collect soil moisture sensor data and soil moisture samples for each of the embankment stabilization practices. Additionally, field personnel should transfer the soil moisture samples to a soil laboraory for analysis. The transfer of field-collected data to temporary storage devices should facilitate data relocation to a central repository. Field-collected soil samples should be weighed, dried at 100 °C for 48 hours, and reweighed to determine gravimetric soil-moisture content, as described by ASTM D2216-98 (2004). It may be possible to collect undisturbed soil samples with core samplers using standard methods to determine the bulk density of the soil. In that case, the volumetric soil-moisture contents can be determined by multiplying the bulk density values with the gravimetric soil-moisture contents.

Armor moving target emplacement usage data

The collection of moving target emplacement/range use information depends on the recordkeeping practices of the installation(s) chosen for testing. Range information may be available in database or paper format. Additionally, observational information using security cameras and visual inspection would supplement reported range data. Field/testing personnel shall collect moving target emplacement usage data from range personnel and transfer the information for subsequent analysis.

Armor Moving Target Emplacement Design Data Required

Quarterly collection of all variables and data being evaluated should provide for a thorough comparison of stabilization practices.

Soil erosion data

Quarterly collection of erosion and deposition data from soil pins and sediment collection channels or traps should allow comparison of alternative embankment stabilization/construction techniques and their overall efficacy in improving environmental compliance and reducing soil erosion and maintenance requirements.

Vegetative cover data

Quarterly collection of vegetative cover data from stationary quadrats using digital photography should allow comparison of alternative embankment construction techniques and their inherent ability to support vigorous grass growth, which reduces erosion potential.

Precipitation data

The information collected from the data logger should consist of two parameters. The first parameter should be the time of the bucket tip for the rain gauge. The second parameter should be the reading of the bucket tip that for all instances is 0.01 in. The tipping time and rainfall amount are essential to determine rainfall intensity and storm duration. This information is necessary to assist in the calculation of sediment movement and excess rainfall.

Soil moisture data

Quarterly collection of soil moisture data for data loggers and soil samples should allow for comparison of alternative embankment stabilization/ construction practices and their impact on soil moisture holding capacity.

Armor moving target emplacement usage data

Usage data required from range personnel should include collection of the following information for the entire testing period: troops trained, range utilization days, vehicle utilization, and weapons-type utilization. The use of supplemental visual inspections during each sampling period should assist in determining emplacement condition. Collection of usage data allows for accurate and meaningful comparisons between each alternative embankment stabilization/construction practices. Standardized data compilation should permit valid comparisons of treatments.

Armor Moving Target Emplacement Design Analysis

The information generated from evaluations of the emplacement treatments is an integration of the factors that affect soil loss levels. Military training frequency, soil erosion rates, precipitation amount, vegetative cover and moving target emplacement design parameters are all factors requiring consideration to provide a comprehensive analysis of stabilization/construction practice efficacy. These data should be analyzed for differences between the individual stabilization/construction practices to determine the least expensive yet most robust design modifications.

Soil erosion analysis

Analysis of field-collected data shall quantify the level of net soil movement occurring on the emplacement per pin area between sampling periods. Pin data analysis should illustrate the spatial variation in soil movement and illuminate areas of high soil movement. Additionally, soil erosion and deposition calculations for all pins shall establish net soil loss per emplacement over the testing period. Similarly, sediment channel data shall utilize the net soil loss from the embankment riprap/covered area to ascertain treatment effectiveness. The combination of sediment channel/ trap data and erosion pin data analyses should depend on the treatment. Comparisons of net soil loss for each emplacement to acceptable soil loss levels and other treatments should permit verification of emplacement effectiveness. This information, in conjunction with soil moisture, precipitation, and vegetative information, should allow a quantitative comparison between each demonstration.

Vegetative cover analysis

Digital analysis of each permanently located quadrat digital photograph should occur for all emplacements. Each image should be analyzed using software to estimate the degree of vegetative protection on each embankment. The data analysis should quantify the level of vegetation as a percentage of the quadrat area. In part, the vegetative cover information (when vegetation is used) is a measure of treatment effectiveness.

Precipitation analysis

Once the precipitation data collection is complete, data reduction should extract several pieces of useful information. This information should include the calculation of cumulative rainfall, rainfall intensity, time-based rainfall (e.g., 15-minute rainfall), and rainfall runoff rates. Combined with the soil erosion data, this information should facilitate calculation of erosion rates for each treatment corresponding to soil moisture, vegetation coverage, and embankment design modifications. Data collection and interpretation should use scientific methods and statistical analysis for all necessary data combinations and between treatment analyses.

Soil moisture analysis

The collection of soil moisture data for each embankment stabilization/ construction practice to determine differences in soil moisture holding capacity ultimately relates to erosion and vegetative growth. Comparisons of soil moisture-erosion/soil loss and soil moisture-vegetative cover between demonstrations should quantify the influence of soil moisture on berm integrity.

Armor moving target emplacement usage analysis

Emplacement usage data summarization should ensure that moving target emplacements are experiencing similar levels of use. Emplacement usage data are also useful in gauging the degradation of the emplacement structure due to training activities. Furthermore, emplacement usage data allow comparisons of treatments for design effectiveness.

Armor Moving Target Design and Test Criteria

The illustration of the fourteen moving target emplacement stabilization/ construction practices and the testing protocol are described in Figures 30 through 34. The drawings follow the specifications outlined in The Design Manual for RETS Ranges (USACE-ESC 1998). The most important item to remember when using these drawings is that only the embankment face and embankment composition may change. An embankment compacted with optimum moisture content at the maximum dry density is recommended for all embankments to provide a constant reference for cataloguing vegetation and erosion measurement

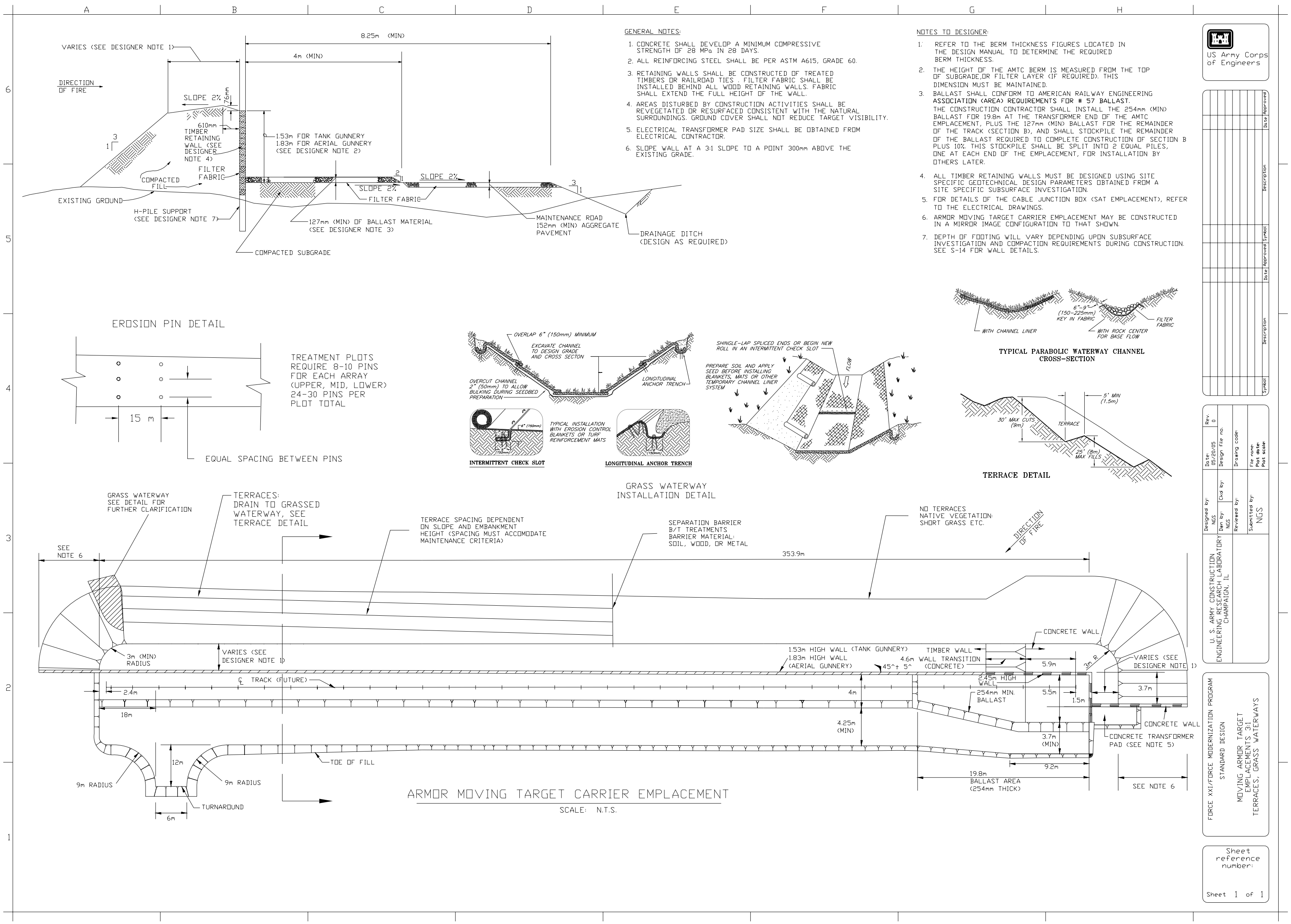


Figure 30. Armor moving target emplacement 3:1 terrace and grass waterways/native grass.

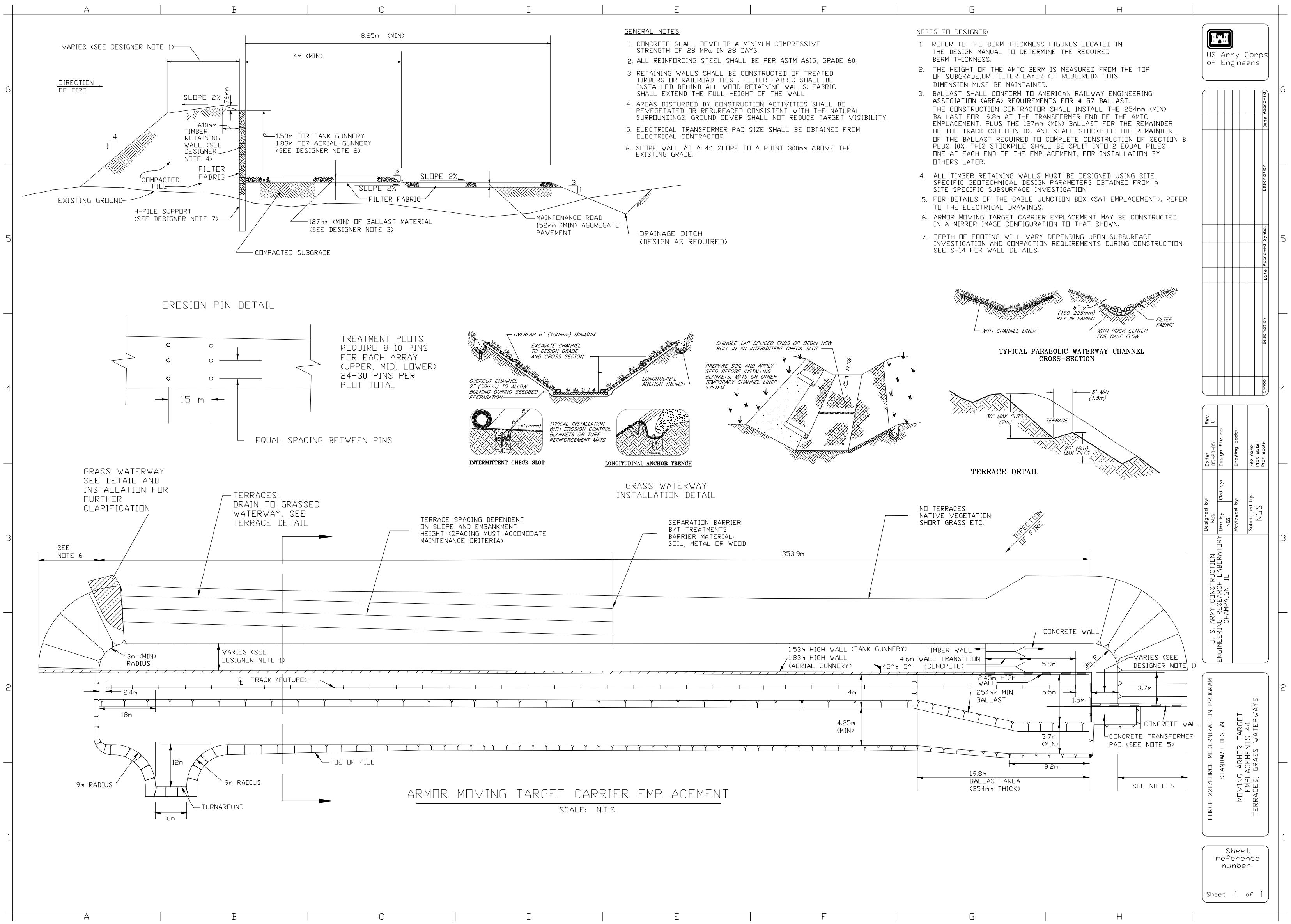


Figure 31. Armor moving target emplacement 4:1 terrace and grass waterways/native grass.

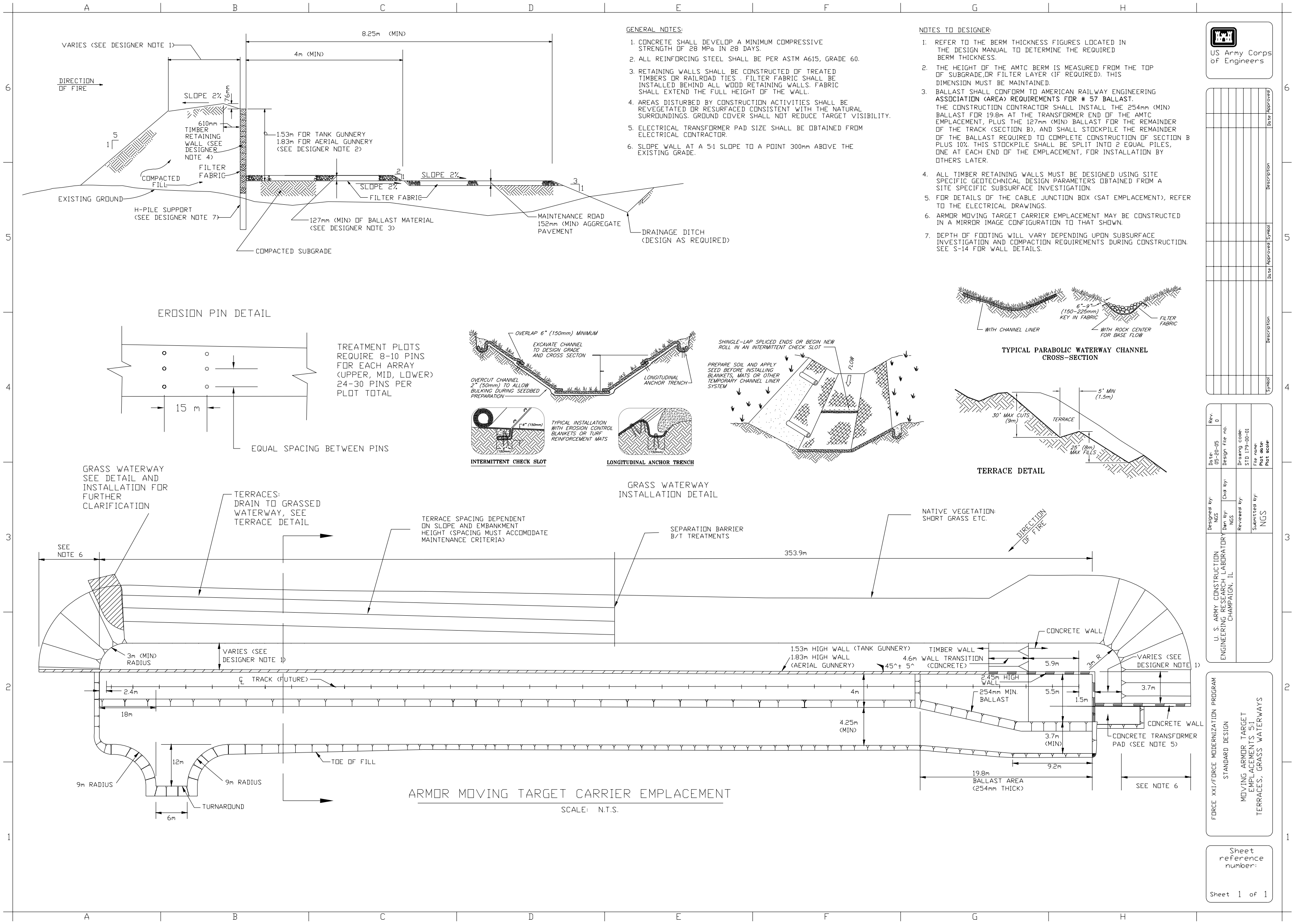


Figure 32. Armor moving target emplacement 5:1 terrace and grass waterways/native grass.

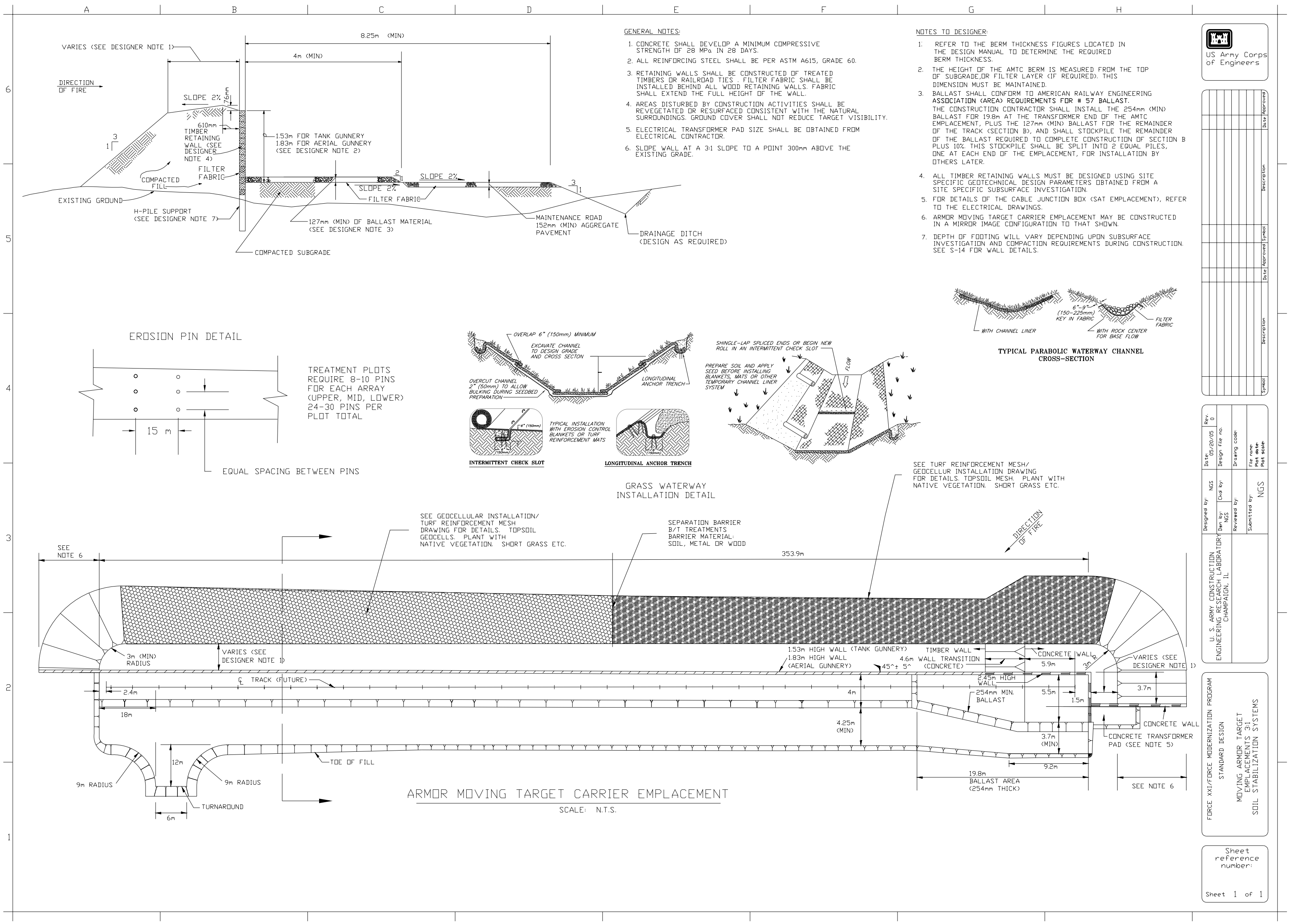


Figure 33. Armor moving target emplacement 3:1 soil stabilization system.

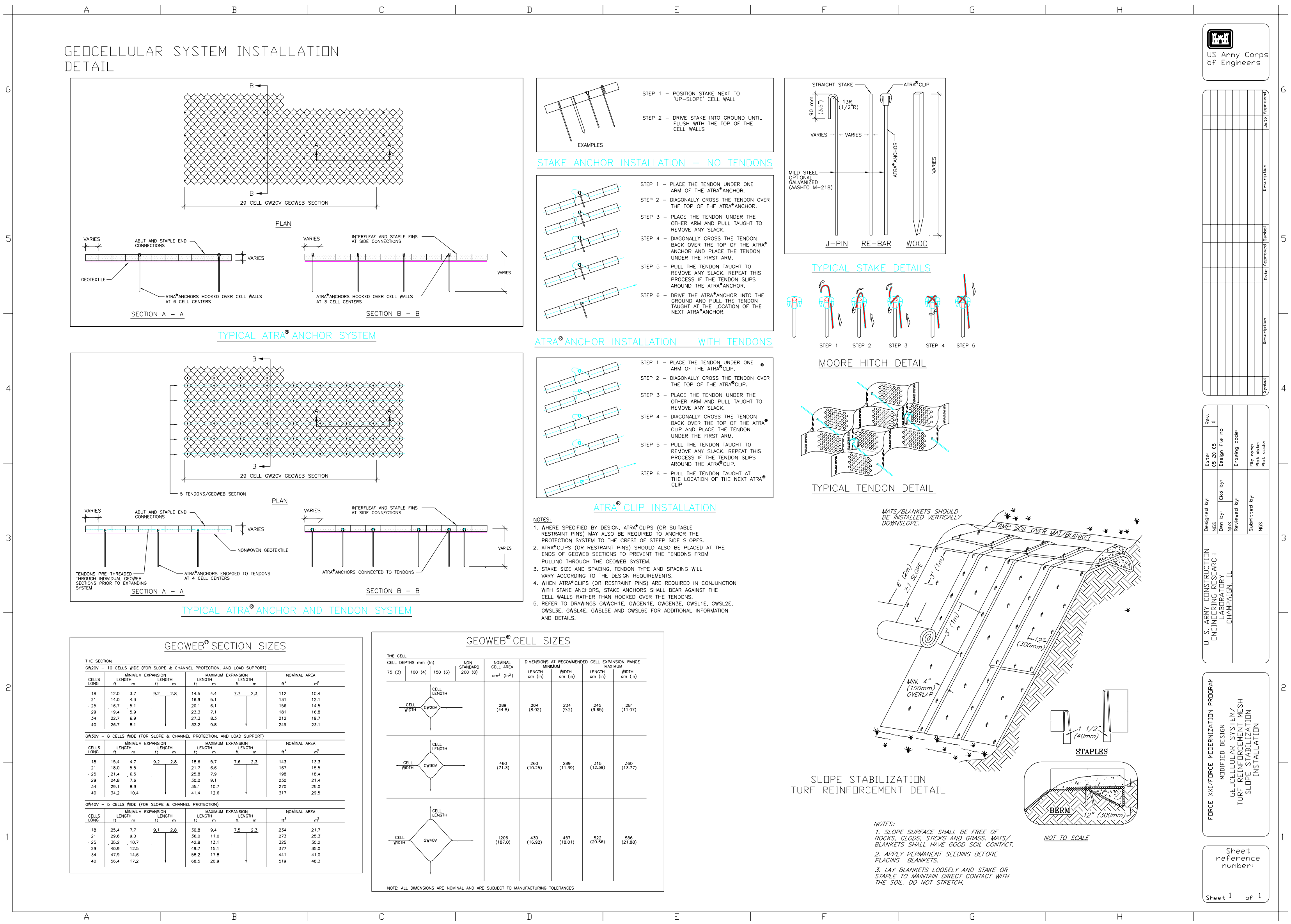


Figure 34. Armor moving target soil stabilization system installation.

6 Low Water Stream Crossing Design and Testing

Low Water Stream Crossing Test Objective

Military installations contain many miles of unimproved road networks. Often these networks cross wetlands, streams, and small rivers. It is widely recognized that the intersection of road networks with stream networks creates a locus for greater sediment discharge, stream habitat fragmentation, and increased maintenance expenditures. Field studies of hardened low water crossings have proven that, when implemented properly, these crossings maintain stream water quality, reduce stream habitat fragmentation, and decrease maintenance outlays over the unimproved fords. The apparent durability of these fording structures merits further investigation. The demonstration and validation of hardened low water crossing designs should verify optimal stabilization/construction practices suitable for road and trails at stream intersections. The overall objective is to demonstrate suitable and cost effective site-specific low water crossing designs that minimize suspended solids and turbidity, maintain stream habitat, and reduce maintenance costs on military ranges.

Low Water Stream Crossing Test Concept

The evaluation of new or modified designs for low water crossings should occur within close proximity to the testing authorities at an installation with field personnel cognizant of the requirements for conducting longer-term demonstration/validation projects. The ideal scenario would give preference to installations with excellent long-term working relationships with testing authorities and a history of established collaborative effort with research facilities. The military installation should be easily accessible and testing/field personnel must be familiar with the training areas, range facilities, and installation personnel to ensure the successful completion of the testing.

Test personnel should conduct the demonstration over a period of 1 year to provide sufficient data for scientific evaluation and validation of the new or improved designs. This period should allow for new structure settlement, a variety of storm flow events, the development of definitive erosion and sediment transport patterns, and stream bank vegetation establishment. Coordination and preparation for the construction of the modified firing emplacements should require some time in addition to the timeframe given for the testing period. Construction activities should not take more than 2 months to complete prior to the demonstration period.

To facilitate the collection of meaningful range data and adequately test the new low water crossing designs, demonstration site locations require siting on a heavily used range course road or tank trail. Additionally, the topography and soil types of the selected areas must be conducive to accelerated erosion and high peak flow phenomenon that contribute to frequent and costly range maintenance activities when compared with similar range types in areas with less erosive soils and topographic gradients. The increased susceptibility of localized land degradation and rapidly peaking storm flows is ideal for illustrating the effects of erosion, sediment transport, and low water stream crossing integrity over a wide range of stream flows over a shorter testing period.

Demonstration and validation low water stream crossing designs should use a variety of materials to harden the stream crossing area. The use of geosynthetic materials, articulated roadbed systems, increased embankment vegetation, and grass waterways should typify these modifications. Each low water stream crossing should be designated as a separate treatment. The articulated roadbed systems should provide the basis for two treatments in addition to an unimproved control.

Each treatment shall be monitored for performance and durability using estimates of upstream and downstream turbidity and suspended solids (both quantitative and qualitative), streambank vegetation coverage, and effective precipitation using established monitoring and evaluation methods. Evaluation methods should consist of both qualitative (photography, video, and physical descriptors) and quantitative (suspended sediment measurement, digital vegetative cover analysis, water crossing usage, precipitation) data collection and analysis from each demonstration site. The methods used to collect information on the integrity of the new designs over the test timeframe should allow for direct comparisons between low water stream crossing design variations and the unimproved standard.

Low Water Stream Crossing System Description

Low water crossings are present in any location where unimproved roads and trails intersect the stream network. On an installation, such an intersection might be located anywhere in the training area. Maneuver areas, tank trails, and range course roads are all examples where low water crossing are suitable. For the purpose of this demonstration and validation proposal, the study should center on frequently used fords on range course roads or tank trails. Figure 35 shows a typical unimproved low water stream crossing. Currently, a standard design does not exist for hardened low water stream crossings.

Figure 35. Unimproved low water stream crossing.

The unimproved low water stream crossing shown in Figure 35 illustrates the importance of improving this area. Numerous crossings have created runoff and gullies at the ingress and egress of the crossing. The image shows substantial erosion and loss of vegetation on the streambank. Erosion levels of this magnitude can be reduced substantially by using streambank stabilization construction and maintenance practices. By hardening the low water stream crossing and improving the streambank, reduced erosion is achievable, thereby reducing required maintenance. As mentioned previously, The Design Manual for RETS Ranges (USACE-ESC 1998) does not specify any standard for range course roads or tank trail low water stream crossings.

Given that military training areas often encompass several hundred hectares, it is not surprising that range trails frequently intersect streams, thus making stream crossings part of the vehicle roads and trails system. The fording of these stream channels is detrimental to downstream water quality and stream habitat health. Increased sedimentation levels can affect photosynthesis, impair habitat and decrease the distribution of fish species (Allen 1995). Since the majority of stream crossings on military lands are unimproved, tanks and other mechanized vehicles cross the stream channel on the streambed. Brown's 1994 study of off-road vehicle activity observed that vehicle crossings displaced considerable amounts of sediment on the river bed. She found that upstream sediment levels from the low water crossings were significantly lower than downstream levels after vehicle fording. Studies of low water stream crossings by Sample et al. (1998) found that unimproved stream crossings had higher downstream turbidity, total solids, total dissolved solids, and total suspended solids levels after simulated vehicle crossings. Research on hardened low water stream crossings at Fort Polk, LA, found that improved stream crossings created less downstream sediment levels than unimproved stream crossings (Tollett et al. 2002). These studies signify the potential of hardened low water stream crossings as a BMP for stream protection at military installations to improve range sustainability.

To demonstrate and validate the proposed stabilization/construction practices, low water crossings on a range or tank trail should be modified to support the suggested alternative designs. Over the duration of the demonstration, precipitation, upstream and downstream water quality, vegetation characteristics, number of vehicle crossings, and overall integrity of the modified structure should be observed and documented using standard methods of data collection for the aforementioned parameters.

To provide for adequate comparison of the low water stream crossing designs, similar embankment and ingress and egress soil stabilization practices are required. The treatments should be designed in a manner that identifies the most effective stream crossing hardening technique.

Low Water Stream Crossing Monitoring and Validation

Evaluation of low water crossing effectiveness such as extended useful life expectancy and pollution mitigation potential (minimizing sediment transport) should be measured both qualitatively and quantitatively using the subtest procedures described below. To conduct the demonstration and validation, two treatments should be applied by modifying existing low water stream crossings. Figure 36 shows the three configurations for testing and control.

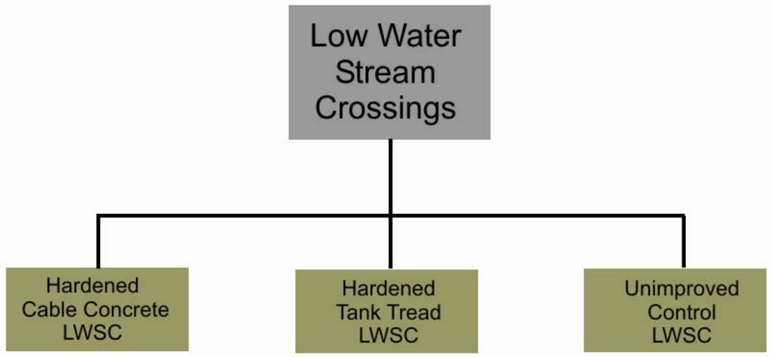


Figure 36. Three low water stream crossing design for demonstration and validation.

The goal of this demonstration and validation is to compare the improvements a hardened road-stream network intersection offers over that of the unimproved low water crossing. The two hardened crossings should undergo substantial streambank stabilization near the ingress and egress to facilitate longer periods between maintenance while maintaining the integrity of the road network. Vegetative stabilization techniques and rock riprap should provide the bulk of the streambank restoration. Data should be collected for each plot on precipitation, sediment transport, and vegetation coverage using the subtests described in Chapter 3. Short native grasses and naturalized non-native grasses, such as buffalograss, fescues, or bluegrasses, should be used to establish vegetative cover on and near the streambanks. Additionally, other vegetation (shrubs, trees) appropriate for riparian areas are required. Construction should be completed in accordance with specifications outlined in the demonstration-validation guidelines.

After the low water crossings modifications, inspections of the embankments should occur during installation visits. The first 2 months after construction should be adequate for vegetation establishment with a good cover if seeding occurs during the proper growth season. Reseeding may be necessary in areas where initial growth is poor. With the new stabilization/construction practices, maintenance should not be required as frequently as with former design guidelines. Indicators of effectiveness include the time interval between maintenance cycles, so emplacement maintenance should be kept at a minimum over the test timeframe.

Measurement of Low Water Stream Crossing Effectiveness

Validation of low water stream crossings stabilization/construction practices should be conducted by measuring upstream and downstream sediment transport, vegetative cover, climate data, and usage intensity.

Low Water Stream Crossing Design Test Objectives

The objective of this design test is to demonstrate the overall effectiveness of roadway hardening and streambank soil stabilization systems on low water stream crossings by comparing upstream and downstream sediment movement and vegetative cover as surrogates representing cost, sustainability, and environmental compliance. The optimal combination of practices that minimize crossing maintenance, extend useful life, minimize soil movement, and maintain environmental compliance should be determined.

Low Water Stream Crossing Design Test Criteria

Suspended sediment/sediment transport data

Data collection on sediment transport near the low water crossing should require the use of a suspended sediment monitoring system. Generally, this system consists of a sensing technology that monitors stream sediment continuously and without interaction from the testing authority except during periods of data collection. The system should monitor upstream and downstream sediment concentrations, storing this information on a data logger for later retrieval by the testing authorities. This suspended sediment monitoring system should allow direct comparison of upstream and downstream sediment levels during stream crossings and storm events.

Vegetative cover data

The testing authorities should complete a vegetative cover assessment for each range structure under demonstration using digital photography and a digital analysis system developed by CERL researchers (Denight 2005). This system uses highly specialized software to distinguish between vegetation and bare soil. The digital analysis system calculates the vegetation cover and determines a percent follar. By photographing known areas over time, direct comparisons between photographs are possible.

Precipitation data

The measurement of precipitation is simple and direct if the equipment is set up correctly. Rainfall data should be collected on a cumulative basis and stored in a data logger such as a HOBO® Event Logger integrated with a tipping bucket rain gauge. Ideally, testing authorities should integrate a tipping bucket rain gauge into a HOBO® Weather Station. Weather stations have multiple sensors to detect ambient atmospheric conditions in addition to rainfall (i.e., soil moisture). Regardless of the method chosen to measure precipitation, the location of the tipping bucket rain gauge must be protected from military activities and interference but remain representative for the area of interest.

Low water crossing usage data

The testing authorities shall establish a method of counting and logging low water stream crossings. Field personnel should collect low water crossing data from data loggers and through visual inspection of the test plots. These data should facilitate accurate and meaningful comparisons between low water stream crossing stabilization/construction practices.

Low Water Stream Crossing Test Procedures

Suspended sediment/sediment transport data

Suspended sediment levels should be evaluated using a suspended sediment monitoring system. The system should provided continuous logging and data storage. The system shall consist of an optical sensor capable of detecting the suspended particle properties of water such as a turbidity sensor. Researchers at Kansas State University in Manhattan, KS, have developed an optical sensor that reduces the effects of non-soil objects (e.g., algae, organic matter, and various microorganisms) on the readings so that data collection captures suspended sediment concentration (Zhang 2005). Furthermore, the sensor was designed to measure suspended sediment concentrations with different texture compositions and is capable of removing the influence of water color to increase measurement accuracy. This sensor is placed at the desired depth in the stream and can be used with an array of sensors to detect suspended sediment at several depths. To meet the monitoring needs of the study and provide accurate comparesons between upstream and downstream locations across several streams, a sensing technology of this type is required. The data from the sensors should be stored on a datalogger similar to the CR23X Micrologger® (Campbell Scientific, Logan, UT). The datalogger should provide accurate and reliable data storage in conjunction with a rechargeable battery and solar array. Field collection of sensing data shall occur on a quarterly basis. Periodically, the sensing array should be inspected and cleaned to minimize debris buildup at the sensor/stream interface.

Vegetative cover data

Vegetative cover of low water crossings should be evaluated using digital photo analysis with one sampling quadrat per streambank per time interval (quarterly). The sampling area should remain the same during the testing period to provide consistent measurements of vegetative cover. Digital analysis should provide a quick, cost effective, and accurate measurement of cover for each streambank side. A central database should store the field-collected digital images to facilitate analysis for percent vegetative cover.

Precipitation data

Precipitation measurement should use a tipping bucket rain gauge. Tipping bucket rain gauges measure incremental precipitation in amounts equivalent to 0.01 inches (0.2 mm). The tipping bucket rain gauge utilizes two small containers balanced on a fulcrum. Each time the required amount fills one of the containers, a tip occurs, the water empties, and the second container positions for precipitation collection. At each tip, the data logger records the time and amount of rainfall. Field personnel should offload the data during scheduled visits. Due to the sensitive nature of the data loggers, data offload must occur infrequently to reduce analysis work during data reduction.

The precipitation data collection apparatus should be sited in an area that is protected from possible interference from military personnel and equipment. The ideal site location should be at least 100 m from trees and brush to reduce interference with these items. The transfer of precipitation data should employ a laptop or portable computing device and occur on a quarterly basis. The transfer of field-collected data to temporary storage devices should facilitate data relocation to a central repository.

Low water stream crossing usage data

The collection of low water stream crossing usage data depends on installation of traffic counters or other traffic sensing devices that can accurately detect the number of vehicles moving past a given point. These instruments are placed near the entrance of the crossing to minimize false readings. This crossing usage data should be field collected and noted. Additionally, observational information using photography and visual inspection would supplement logged data. Field/testing personnel shall collect moving target emplacement usage data from range personnel and transfer the information for subsequent analysis.

Low Water Stream Crossing Design Data Required

The collection of all variables and data being evaluated should provide for a thorough comparison of low water crossing construction practices.

Suspended sediment/sediment transport data

Quarterly collection of suspended sediment data from the data logger should allow comparison of alternative stabilization/construction techniques and their overall efficacy in improving environmental compliance and reducing suspended sediments and maintenance requirements.

Vegetative cover data

Quarterly collection of vegetative cover data from stationary quadrats using digital photography should allow comparison of vegetation establishment and their ability to support vigorous grass growth, which reduces erosion potential.

Precipitation data

The information collected from the data logger should consist of two parameters. The first parameter should be the time of the bucket tip for the rain gauge. The second parameter should be the reading of the bucket tip that for all instances is 0.01 in. The tipping time and rainfall amount are essential to determine rainfall intensity and storm duration. This information is necessary to assist in the calculation of sediment movement and excess rainfall.

Low water crossing usage data

Collection of usage data from range personnel should require collection of the following information for the entire testing period: number and type of vehicles crossed. The use of supplemental visual inspections during each sampling period should assist in determination of crossing condition. Collection of usage data allows for accurate and meaningful comparisons between the two low water crossing treatments and the unimproved control. Standardized data compilation should permit valid comparisons between treatments.

Low Water Stream Crossing Design Analysis

The information generated from evaluations of the crossing treatments should examine the factors that contribute to soil erosion and sediment production. Military vehicle crossing frequency, stream flow, precipitation amount, vegetative cover, and low water crossing stabilization technique should require a comprehensive analysis to determine stabilization/construction practice efficacy. The data should be analyzed to detect significant differences between the individual stabilization/construction practices and determine the least expensive, yet most robust design modifications.

Suspended sediment/sediment transport data analysis

Analysis of field-collected data shall quantify the level of suspended sediment at the upstream and downstream locations of each site for vehicle crossings and storm events. In addition, the two treatment sites and the unimproved site should be compared with one another. The significance, if any, of upstream and downstream data shall be statistically determined. In addition, these upstream/downstream differences shall be compared with the other treatments to determine the optimal crossing design.

Vegetative cover analysis

Digital analysis of each permanently located quadrat digital photograph should occur for all crossing treatments. Each image should be analyzed using software to estimate the coverage of vegetative protection on each crossing treatment. The data analysis should quantify the level of vegetation as a percentage of the quadrat area. In part, the vegetative cover information (when vegetation is used) is a measure of treatment effectiveness.

Precipitation analysis

Once the precipitation data collection is complete, data reduction should extract several pieces of information. Useful information should include the calculation of cumulative rainfall, rainfall intensity, time-based rainfall (e.g., 15-minute rainfall), and rainfall runoff rates. Combined with the soil erosion data, this information should facilitate calculation of erosion rates for each treatment corresponding to soil moisture, vegetation coverage, and embankment design modifications. Data collection and interpretation should use scientific methods and statistical analysis for all necessary data combinations and between treatment analyses.

Low water stream crossing usage analysis

Crossing usage summarization should ensure that moving target emplacements are experiencing similar levels of use. Crossing usage data are also useful in gauging the degradation of the crossing structure due to training activities. Furthermore, crossing usage data allow comparisons of treatments for design effectiveness.

Low Water Stream Crossing Design and Test Criteria

The design and construction of a hardened ford is relatively inexpensive and can be done quickly with contractors having prior installation knowledge of this type of construction. The general construction procedure as adapted from Sample et al. (1998) follows.

1. The bottom of the stream crossing should be excavated to a depth of 1.0 m (3 ft) or until a rock ledge or hard clay pan is encountered. The minimum width of the excavation should be 6.1 m (20 ft). The length of the excavation should equal the width of the stream channel plus 3 m (10 ft) on either side with excavation depth tapering to 0.5 m (1.5 ft) for the remaining approach distance.
2. Approaches on each side should be cut where necessary so that a maximum grade of 25 percent is not exceeded (16 percent recommended). The approach road should be a minimum of 5.0 m (16.3 ft) in width and extend either side of the crossing for a minimum of (82 ft) 25 m.
3. Upon completion of excavation, geotextile fabric (nonwoven) shall be laid to cover the surface of the excavated area. The excavated area shall be filled 0.45 m (18 in.) with 15 cm (6 in.) rock riprap and compacted. A second layer of 5-7 cm (2–3 in.) rock shall fill 0.3 m (12 in.) with compaction occurring every 0.15 m (6 in.).
4. Once the rock road bed has been constructed and compacted across the stream channel, articulated concrete or tank tire mats with geotextile backing (or placed nonwoven geotextile) 4.9 m (16 ft) in width shall be placed on the aggregate base. The articulating concrete or tank tread shall be anchored upstream, downstream, and through out with edges placed at an angle as described in detail C in the low water stream crossing drawing (Figure 37).

5. A layer of 19 mm (3/4 in.) aggregate shall be placed on the articulating concrete/tank tread base to fill the voids. Streambed material may be used as well.
6. The dimensional requirements described above may change due to suitable streambed excavation levels.
7. To provide drainage for the approaches, V-ditches should be constructed on both sides of the ingress and the egress. The side slopes of the V-ditches shall not be less than 3:1. On low water stream crossings where approach grades are greater than 5 percent, a layer of riprap shall be applied to the drainage ditch properly sized to accommodate the velocity and volume of flow of the runoff.
8. Grubbing and channelization should be minimized.
9. All bare areas of soil should be covered in rock rip or planted with native riparian vegetation.

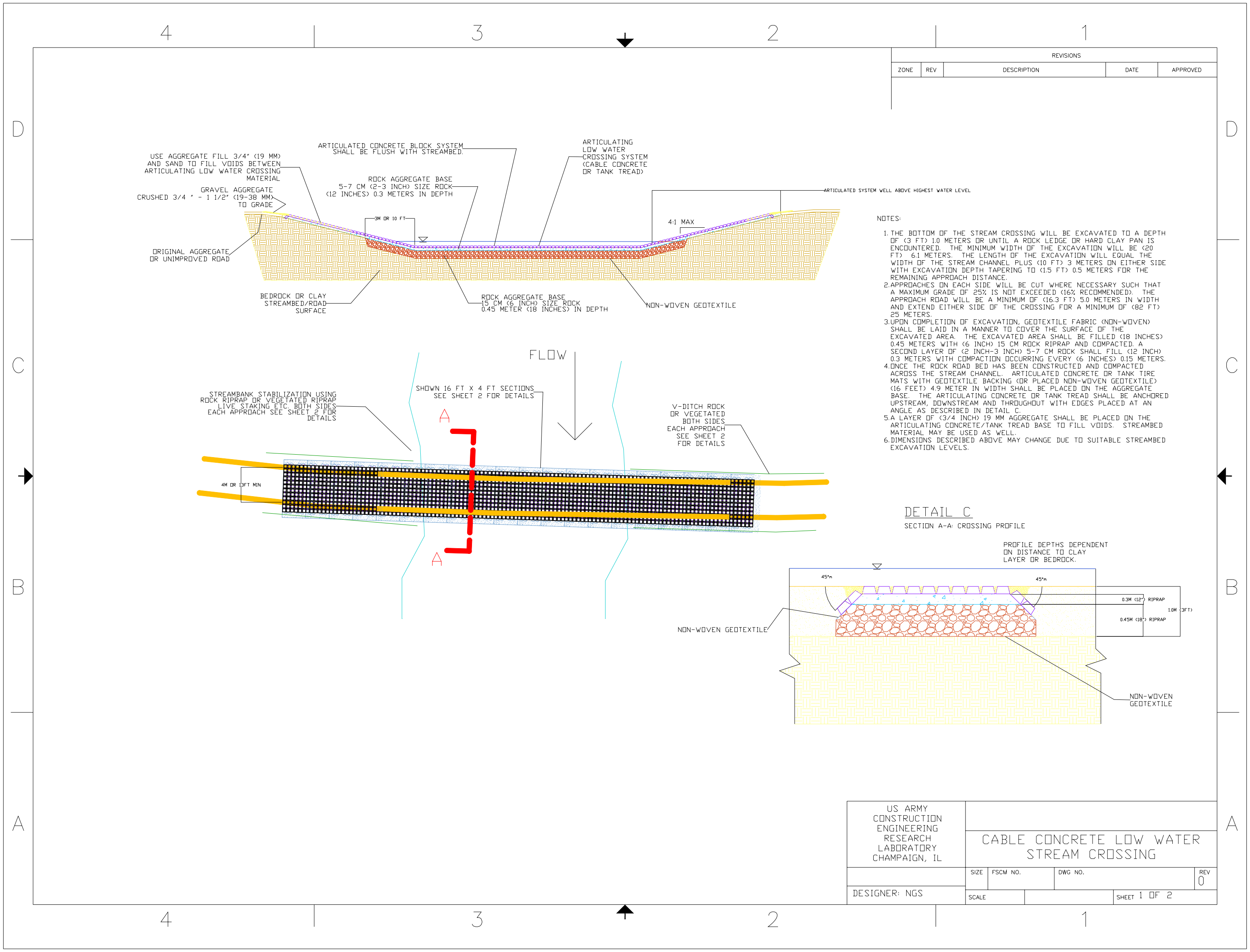


Figure 37. Low water stream crossing using cable concrete (sheet 1).

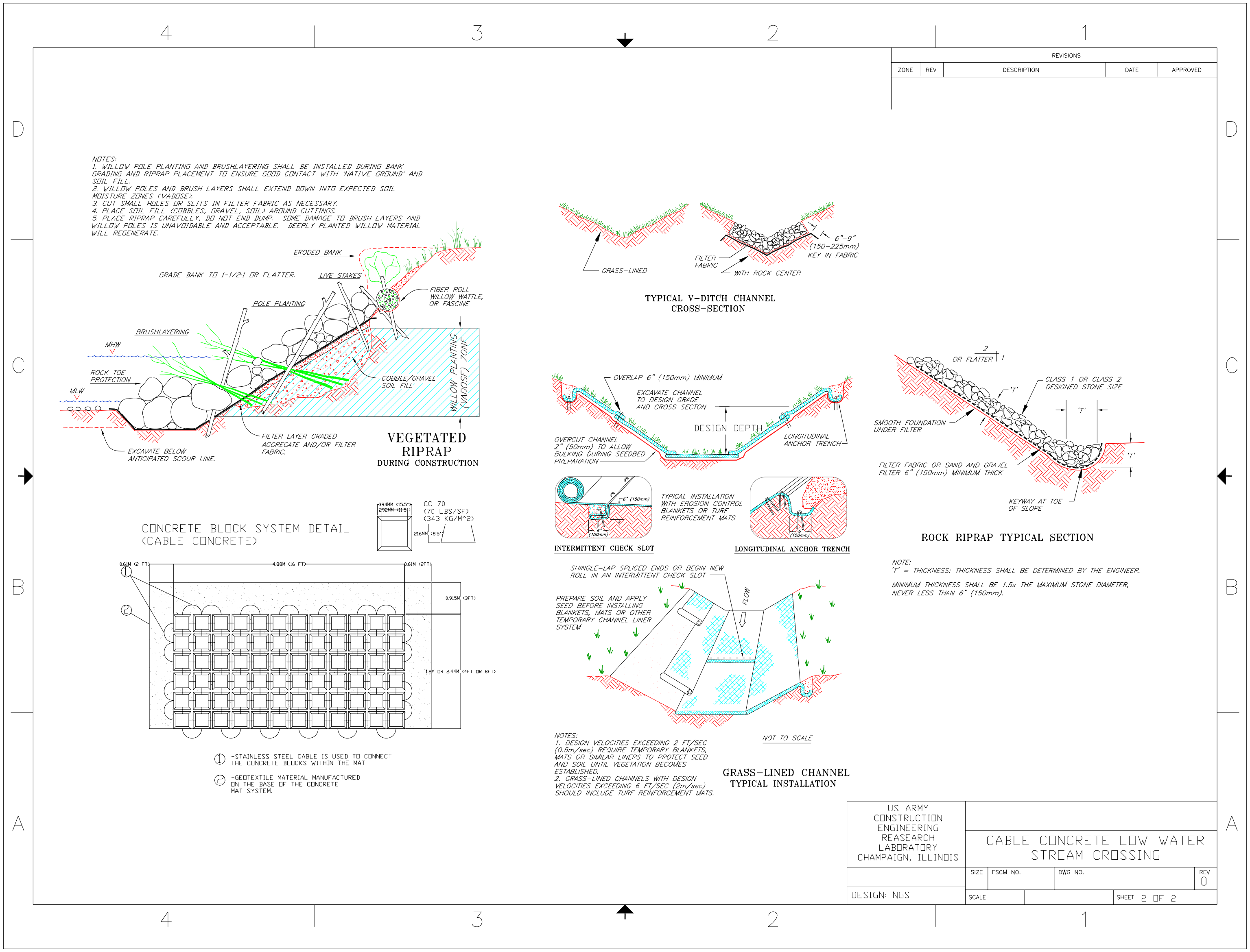


Figure 38. Low water stream crossing using cable concrete (sheet 2).

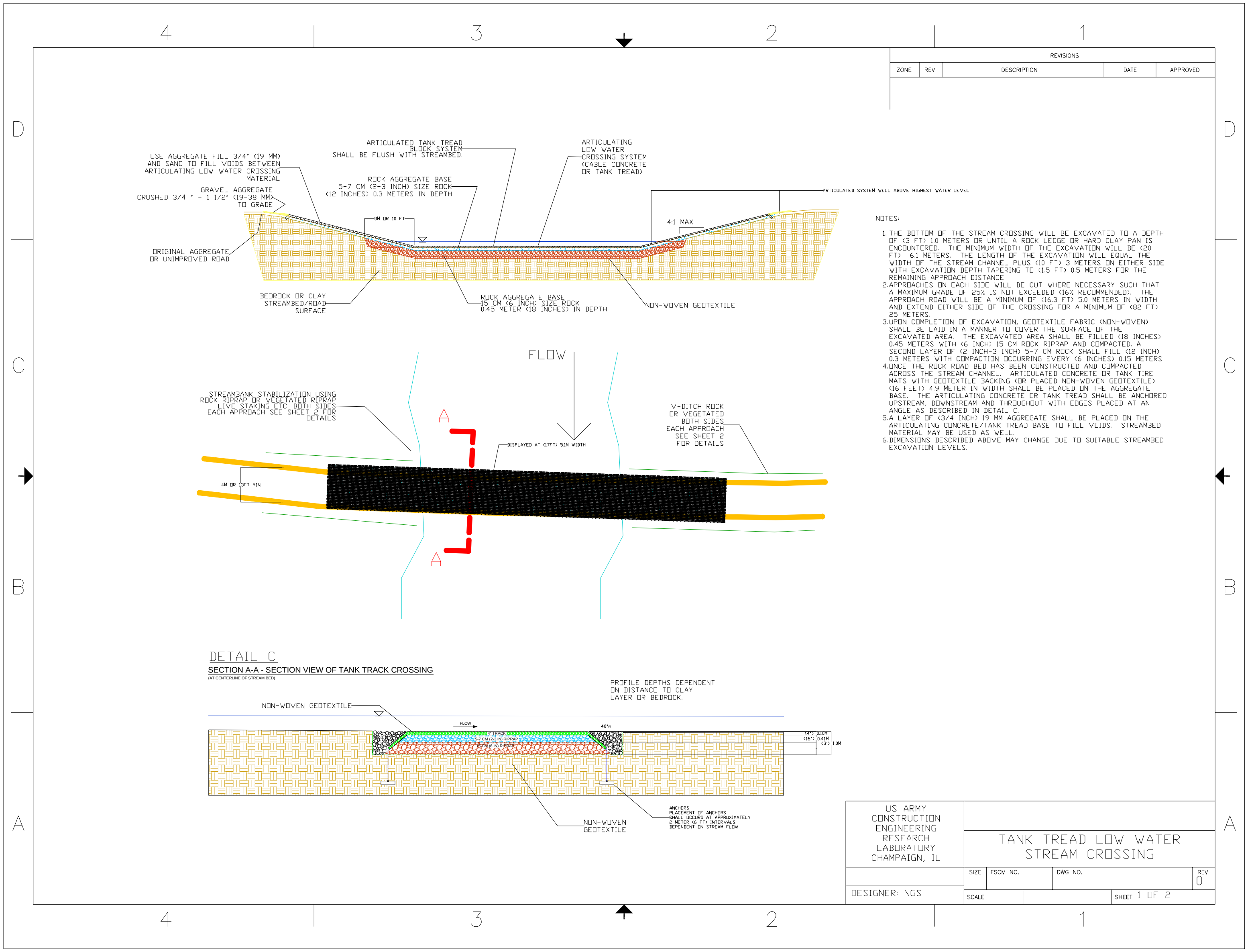


Figure 39. Low water stream crossing recycled tank tread (sheet 1).

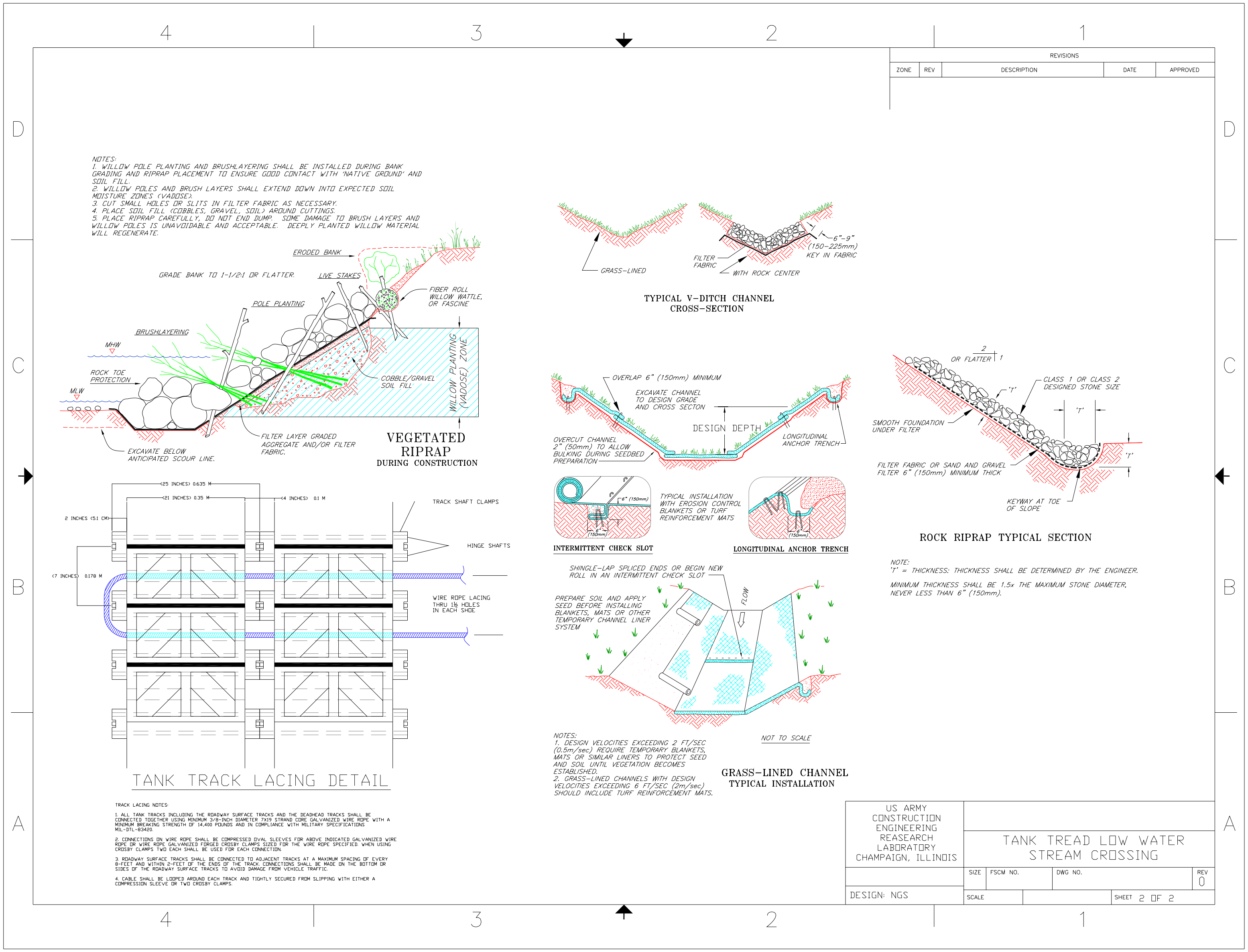


Figure 40. Low water stream crossing recycled tank tread (sheet 2).

7 Course Roads and Trails Design and Testing

Course Roads and Trails Test Objective

Field observations of course roads on ranges at several installations have shown that, when constructed properly, the current suite of standard designs are adequate and appropriate. However, field inspections of installation course roads have also identified numerous instances where construction of course roads deviated from the established guidelines resulting in roads of questionable quality. Poor road quality creates significant maintenance issues. For example, dust from course roads can lead to numerous significant problems such as visibility reduction, increased vehicle maintenance, increased road maintenance, environmental degradation, increased sedimentation, air pollution, and associated health risks. Road deterioration can increase because of loss of fines (i.e., <0.075 mm), since they act as road surface binders. This loss can cause road safety issues, increased vehicle maintenance, and increased road maintenance. The use of dust suppressants has been shown to lower road maintenance requirements, vehicle maintenance costs, and mitigate environmental and health impacts associated with road dust. The overall objective of this effort is to demonstrate suitable and cost effective site-specific dust control methods to minimize dust and its negative effects on the training mission.

Course Roads and Trails Test Concept

The evaluation of dust suppressants on course roads should occur within close proximity to the testing authorities at an installation with field personnel cognizant of the requirements for conducting longer term demonstration and validation projects. The ideal scenario would give preference to installations with excellent long-term working relationships with testing authorities and a history of established collaborative effort with research facilities. The military installation should be easily accessible and testing/field personnel must be familiar with the training areas, range facilities and installation personnel to ensure the successful completion of the testing.

At a minimum, the demonstration should be conducted over a period of 1 year to provide sufficient data for scientific evaluation and validation of dust control treatments. This period should be adequate to account for weather conditions through the seasons that may affect the potential for dust generation by vehicles using course roads. Coordination and preparation for incorporating dust palliatives into road materials should require some time in addition to the timeframe given for the testing period. It is anticipated that control and test sections would take less than a month to establish on existing course roads.

Demonstration and validation of dust control measures on course roads should use calcium chloride ($CaCl_2$) flake incorporated into road surface materials. The use of $CaCl_2$ as a dust palliative is recommended because it is inexpensive, readily available, and nonhazardous to the environment. One test section and one control section should be established on existing course roads within an active training range. The control section should consist of untreated, existing crushed limestone base, and the treatment section should consist of 20 cm (8 in.) of crushed limestone base with a 1.3 percent weight of dry $CaCl_2$ content. The entire length of each section should be scarified and pulverized to a depth of 20 cm (8 in.) and properly graded and crowned to ensure adequate surface water runoff. The treatment section should have a 38 percent $CaCl_2$ solution sprayed onto the surface. Both the control and treatment sections should then be compacted using a steel wheel roller.

Treatment and control sections shall be evaluated for performance and durability using visual estimation, qualitative and quantitative dust obscuration measures, and moisture content and density of each section. A possible evaluation method might include digital image analysis to evaluate the effectiveness on dust control when vehicles pass over the course road sections. The methods used to collect information on the integrity of the incorporation of $CaCl_2$ over the test timeframe should allow for direct comparisons between the test sections and the unimproved control section.

Course Roads and Trails System Description

Course roads and trails are an integral component of the military range and of the installation overall. The road and trail transportation network facilitates two mission critical functions: training and maintenance. Most installation course roads are unimproved and generally consist of a combination of local soils and gravel. Course trails consist primarily of local soils with sporadic surface hardening. A well-maintained and stable course road is achieved by maintaining a proper balance of coarse and fine particles on the road surface. A well-maintained and stable trail is somewhat less straightforward in description, but generally allows safe vehicle passage during dry weather and does not exceed allowable soil erosion limits.

Course Roads and Trails Monitoring and Validation

Evaluation of course road and trail effectiveness such as extended useful life and dust suppression potential (obscuration minimization) should be measured both qualitatively and quantitatively using the subtest procedures described below. To conduct the demonstration and validation, one treatment should be applied by modifying an existing course road. The two configurations for testing and control should consist of a course road that receives moderate to heavy range traffic. The testing configuration of course road should require a 1.3 percent by weight of $CaCl_2$ flake mixed with crushed limestone (to a depth of 20 cm or 8 in.) or other similar suitable roadbed material in use at the testing installation. After the roadbed has been established, a 38 percent solution by volume of $CaCl_2$ shall be sprayed on the surface of the properly crowned and compacted roadbed. The control configuration of the course road should be comprised of crushed limestone or other similar suitable roadbed material in use at the testing installation. The surface of the control course road shall be crowned and compacted. The length of the test sections should depend on the installation sites chosen. Once the test and control roadbed has been constructed, no further maintenance shall be performed.

The goal of this demonstration and validation is to compare the improvements that $CaCl_2$ flake/solution and compaction method has over an unimproved range course road. The improved course road should facilitate longer periods between maintenance and maintain the integrity of the road network. The incorporation of $CaCl_2$ flake into the roadbed should be the major road improvement. Data should be collected on similar improved and unimproved course roads using the subtests described in the next section. Construction should be completed in accordance with specifications outlined in this demonstration/validation report in addition to those specified in The Design Manual for RETS Ranges (USACE-ESC 1998).

After the course road modifications, inspections should occur on a frequent basis. The roadbed should be ready for use 1 week after construction. This should provide adequate time for the $CaCl_2$ spray and compaction to stabilize the road bed. With the new stabilization/construction practices, maintenance should not be required as frequently as with former design guidelines. Indicators of effectiveness include the time interval between maintenance cycles, so road maintenance should be kept to a minimum over the test timeframe.

Measurement of Course Roads and Trails Effectiveness

Validation of course road integrity should be conducted by measuring dust suppression effectiveness (obscuration) and road integrity factors such as potholing and washboarding.

Course Roads and Trails Design Test Objectives

The objective of this design test is to demonstrate the overall effectiveness of roadbed hardening of range course roads by measuring dust suppression and road integrity as surrogates representing cost, sustainability, and environmental compliance. The optimal combination of practices that minimize road maintenance, extend useful life, minimize soil movement (dust), and maintain environmental compliance should be determined.

Course Roads and Trails Design Test Criteria

The testing authorities should complete an assessment of the improvements $CaCl_2$ flake/solution additive has over the standard course road. The foundation of this assessment should be based on capturing dust obscuration over a specified distance against a standardized target. The field data collection system uses digital photography while the laboratory system analyzes the field-collected digital images using a digital analysis system developed by U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL) researchers. This system uses highly specialized software to distinguish levels of obscuration. The digital analysis system calculates obscuration and permits comparison between the treated and untreated control road test sections. By capturing several images over time, direct comparisons between the $CaCl_2$ road and the unimproved road are possible.

Course road integrity data

Course road integrity should be evaluated over the testing period. This data should consist of observations on both the test and control course road sections. Evidence of potholing, washboarding, and overall road condition should be noted. The evaluation of both sections should provide an additional measurement of comparison of the $CaCl_2$-treated course road to the untreated course road. Additionally, course road samples shall be gathered to determine course road moisture content.

Course road usage data

The testing authorities shall establish a method of counting/logging range course road vehicle passes. Field personnel should collect course road data from traffic counters and through visual inspection of the test plots. This data should facilitate accurate and meaningful comparisons between course roads using $CaCl_2$ flake and the unimproved roadbed.

Course Roads and Trails Test Procedure

The procedure for capturing obscuration data should require the following equipment: a digital camera (infrared or optical) mounted on a tripod and a target mechanism for each monitored plot. Using techniques developed by Gebhart et al. (1996) information regarding the level of dust suppression can be obtained using the following general technique. The camera, aimed at the target, is positioned on one side of the road at a specified distance from the center of the road. At the other side, at the same distance from the center of the road as the camera, is the target, a black and white placard similar to a secchi disk. After a vehicle passes, the digital camera captures several images at specified intervals (e.g., 0 seconds, 5 seconds, 10 seconds). These images are stored for later analysis using image analysis software and techniques developed by ERDC-CERL researchers. This technique evaluates brightness and opacity of the image to determine the level of target obscuration at each of the plots during a vehicle pass.

Course road integrity data

The testing authorities shall perform a walkthrough evaluation of the course road plots. The integrity of the road should be assessed by noting the severity of potholing, washboarding, and overall road quality. A record log noting the number of potholes and washboard sections should assist with the quantitative assessment of road conditions. Field collection of course road material shall require sampling at three course road locations to determine the soil and gravel distribution of the test road. The samples shall be double bagged and placed in a cooled airtight container for transport back to the lab. Field/testing personnel shall collect course road integrity data and transfer the information for subsequent analysis in digital format.

Course road usage data

The collection of course road vehicle usage data is dependent on installation of traffic counters or other traffic sensing devices that can accurately detect the numbers of vehicles moving past a given point. These instruments should be placed near the entrance of the test sections to minimize false readings. This road usage data should be field collected and noted. Additionally, observational information using photography and visual inspection would supplement logged data. Field/testing personnel shall collect course road usage data from range personnel and transfer the information for subsequent analysis.

Course Roads and Trails Design Data Required

The collection of all variables and data being evaluated should provide for a thorough comparison of road stabilization/construction practices. Obtaining relevant digital information after multiple vehicle passes should require a series of time-lapsed images following each vehicle pass. These images should be captured at sequenced intervals (e.g., 5 seconds) to obtain an average level of obscuration. Images should be taken at each study plot. This information should permit the comparison of the $CaCl_2$-treated road to the untreated road where the level of obscuration is an indicator of the dust suppression on the two road plots.

Course road integrity data

During each installation visit, the testing authorities shall perform an evaluation of the course road integrity over the monitoring period. The field personnel shall note the road conditions (e.g., number of potholes, road deterioration, and washboarding) for each treatment. This information shall be recorded and transferred for later analysis in digital format. Additionally, sufficient course road sample sizes shall be obtained from each of the study plots. These samples, once transported back to the laboratory, should allow determination of course road moisture content and supplement the obscuration data measured at each study plot.

Course road usage data

The testing authorities should collect the following information for the entire testing period: number and type of vehicles crossing. This data shall be collected from a traffic-counting device. The use of supplemental visual inspections during each sampling period should assist in determination of road conditions. Collection of usage data allows for accurate and meaningful comparisons between the $CaCl_2$-treated course road and the unimproved course road. Standardized data compilation should permit valid comparisons between treatments.

Course Roads and Trails Design Analysis

The information generated from evaluations of the construction/stabilization treatments is an integration of the factors that affect dust generation. This data should be analyzed for differences between the individual construction/stabilization practices to determine the least expensive yet most robust design modifications.

Once the field-collected data have been stored in a centralized database and the monitoring of the course road has been completed, analysis of the obscuration data should occur. Using the digital images of the two plots, an estimation of the mean level of opacity/brightness shall be conducted for each set of vehicle passes between each plot. Using image analysis software such as ASSESS (Lamari 2002), techniques developed by ERDC-CERL researchers (Gebhart et al. 1996) should be used to assess the level of dust suppression of the two treatments.

Course road integrity analysis

The course road integrity shall supplement the information determined by the obscuration analysis. High levels of dust tend to displace fine particles in the roadbed mix. The movement of these particles from the roadbed leads to road instability and results in road deterioration. Lower levels of roadbed deterioration as determined from the test plot surveys often indicate higher road integrity and better dust suppression. Ideally, the course road integrity surveys should corroborate the findings of the obscuration analysis. Upon return from each field visit, the testing authorities shall determine the moisture content of the course road samples using ASTM standard test methods, (ASTM D2216-98, 2004). This information should supplement the obscuration data taken during each visit and should permit the determination of the effects of moisture on course road dust suppression.

8 Conclusion

The design alternatives suggested for defilade, stationary target and moving target embankments, low water stream crossing, and courses roads are an attempt to identify and incorporate techniques using measures to control soil loss, improve durability, and decrease maintenance. Over the monitoring period for these structures, insight should be obtained as to which design alternatives require further study and what areas of design need further improvements.

As mentioned at the beginning of this report, these designs are the first step of an iterative process to incorporate sustainability elements into the range design process. It is recommended that, once the evaluation of these structures is complete, the designs should be revised to reflect the lessons learned over the monitoring period. This process should be repeated until the desired design goals are met.

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14. ABSTRACT

Military training structure designs currently do not employ adequate soil loss prevention technologies that reduce soil loss sufficiently to extend embankment useful life. New range structures must have reduced maintenance requirements and maintain functionality over a longer training interval. Additionally, incorporating sustainability into the range designs should remain a high priority to meet environmental compliance regulations and provide a durable long-lasting structure useful for military training requirements. This report proposes several new range structure designs to begin the iterative process of developing new range edifices that reduce soil loss, control erosion, promote sustainability, and enhance training. The designs for Defilades, Stationary Targets Embankments, Moving Target Embankments, Low Water Crossings, and Course Roads are presented as a demonstration and validation template for installation training areas in temperate climates. These designs are meant to illustrate the use of soil loss prevention measures on range structures.

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