COMBATING SOIL EROSION ON MILITARY LANDS:

Best Management Practice Development & Verification

Range Revegetation Pilot Project – Fort Hood, TX

Draft Report

February 2007

TABLE OF CONTENTS

EXECUTIVE SUMMARY

Organization of This Report

This report provides a background to erosion control programs being used and/or studied on Fort Hood with a focus on water quality, soil erosion and natural resource related to military training requirements in the United States. It presents findings from recent university research conducted at Fort Hood and discusses management strategies to reduce soil erosion and sediment runoff programs led by Fort Hood Integrated Training Area Management and USDA-Natural Resources Conservation Service.

The *Executive Summary* presents a basic overview of the regulatory framework in which Fort Hood operates and provides perspectives about land use and natural resources management options currently implemented or under research programs for the installation.

The main body of the report discusses the overall framework in which the military views sustainable practices (i.e., the need to manage lands to sustain training operations and the responsibility to sustain natural resources to support future training) and presents an overview of processes that influence soil erosion. A summary of the proper design and operations of several BMPs developed and implemented at Fort Hood by the Integrated Training Area Management (ITAM) and the United States Department of Agriculture Natural Resource Conservation Service (NRCS) is presented. Some of the BMPs discussed in this report include contour ripping of soils, use of compost as a soil amendment, the maintenance of tank trails and hilltop access trails, and the use of check dams and sedimentation ponds to trap sediments. Recommendations for future research needs are presented.

In addition, appendices present detailed findings of research projects recently carried out on Fort Hood. Topics addressed in the appendices cover the issues:

- Evaluation of contour ripping and gully plugs and impacts on water quality and soil erosion,
- Evaluating the extent to which land applied composted dairy manure may improve rangeland vegetation,
- Monitoring how the application of compost to restore rangelands may affect runoff water quality,
- Using high-tech methods to measure sediment buildup in sediment retention ponds on Fort Hood and downstream in Belton Lake to determine how erosion from the installation and upper reaches of the watershed may be affecting water resources,
- A description of how Federal laws, Army regulations, and other policies affect natural resources management policies at Fort Hood and other military reservations.
- A bibliography and list of additional readings with more information about these topics.

Background

The major environmental dilemma facing Fort Hood and many military reservations is the need to maximize the opportunities for military training at the installation while managing natural resources using sustainable practices to protect the environment. This report describes efforts that are now underway to implement accepted practices and develop innovative strategies to manage and rehabilitate military training lands at Fort Hood in a manner that fully supports military training while sustaining natural resources and water quality. Materials herein are based upon Best Management Practices (BMP's) already developed and implemented by Fort Hood Integrated Training Area Management, Directorate of Public Works and USDA – Natural Resources Conservation Service as well as new BMP's being studied by Texas Agricultural Experiment Station scientists.

The management of training lands at Fort Hood presents significant challenges. To protect and defend the nation it is vitally important that Fort Hood allows for as much military training as possible. At the same time, training at the installation has to be carried out in such a way that natural resources and water supplies are not jeopardized. This report suggests that significant advances are being made through research, demonstration and education efforts to develop innovative strategies to maximize training opportunities while protecting water quality. Research in this report suggests that the application of composted dairy manure has the potential to reestablish rangeland vegetation while, if managed properly, not increasing the risk of nutrient runoff. Field demonstrations at Fort Hood are leading to the development of specific BMPs that can be used at the installation related to such issues as the optimal amount and timing of compost application and integration of erosion control practices as well as factors to consider when selecting and reseeding with rangeland vegetation. Findings also suggest that that innovative, non-invasive, high-tech methods that utilize geographic positioning systems (GPS) and geographic information systems (GIS) have the potential to increase our understanding of issues related to erosion and sediment runoff. However, more work needs to be done to develop new best management practices and to verify the success of BMPs that are now being implemented.

Federal Laws and Regulations

The National Environmental Policy Act (NEPA) requires federal agencies to evaluate the environmental impacts of land-use management actions at military installations and to consider alternative practices. When projects are implemented that may degrade the environment, NEPA can require that environmental assessments, environmental impact statements, and a record of environmental consideration be developed. Most of these regulations related to how the Army should comply with NEPA are codified in Title 32, Part 651 of the Code of Federal Regulations (CFR). This section of the CFR addresses military issues related to environmental protection and enhancement, environmental analyses of Army actions, and natural resources management. Military activities must comply with provisions of the Clean Water Act, the Safe Drinking Water Act, and the Endangered Species Act. The Clean Water Act requires states to develop and implement pollution prevention plans. The Safe Drinking Water Act sets standards for public drinking water. The Endangered Species Act ensures that federal programs do not jeopardize threatened and endangered plant and animal species. Army bases must comply with regulations of the U.S. Army Corps of Engineers related to wetlands management.

The Department of Defense (DoD) has developed many regulations and programs to protect water resources and the environment. The 1960 Sikes Act requires that programs be developed to conserve and rehabilitate natural resources on military installations and mandates that an integrated natural resources plan must be developed for each military installation in the United States. A 2003 DoD directive states that military training lands need to be managed in accordance with principles of environmental sustainability. The Army Sustainable Range Program was created in 2005 to provide leadership into such issues as range and training land management programs (RTLP) and ITAM. In turn, ITAM components address such issues as land conditions trend analysis, training requirements integration, range and training land assessment, land rehabilitation and maintenance, and sustainable range awareness. RTLP and ITAM programs provide technical support and training to personnel at Fort Hood and other bases.

ITAM and the Army Environmental Center work with the NRCS to manage land restoration and management programs, and with the United States Fish and Wildlife Service to protect threatened and endangered species. The Directorate of Public Works Environmental Division implements conservation and endangered species management programs at Fort Hood while the Directorate of Plans, Training, Mobilization and Security is responsible for the planning and management of rangelands at the base.

Environmental Concerns Associated with Military Training

Because military training involves the intensive and recurring use of many soldiers, armored vehicles, and ordinances, these activities have the potential to adversely affect natural resources over the short- and long-term. Some of these environmental challenges posed by training maneuvers include the formation of gullies, losses in vegetation that increase erosion, and increases in sediment runoff from the use of tank trails and stream crossings.

Best Management Practices to Control Erosion and Sediment Runoff

BMPs that have been successful at Fort Hood include mechanically ripping soils to promote infiltration and reduce the volume of runoff, the use and management of small watershed dams to trap sediments, and developing maneuver access structures that allow military vehicles more efficiently train without the hindrance of gullies or other landscape impediments. Further, since 2000, the Army has implemented a “training out area program” that rests certain areas on the installation for up to a year in order to foster the recovery of range vegetation. Water quality monitoring at Fort Hood confirms that these BMPs have the potential to protect water quality by controlling sedimentation and erosion. One potential BMP that is being field-tested at Fort Hood centers on the establishment and maintenance of vegetation through the application of composted dairy manure. The innovative practice seeks to reduce the extent of bareground vulnerable to erosion, while promoting healthy vegetation that is beneficial to the training mission.

AN OVERVIEW OF SUSTAINABILITY OF TRAINING LANDS ON MILITARY INSTALLATIONS, FORT HOOD, TX

Military land managers are challenged to maintain natural resources for the purpose of military training and troop readiness. The primary focus for military training lands centers on the development and testing of weapons systems and maintaining combat readiness for all military personnel. In the past, lesser emphasis was given to soil erosion, water quality, water quantity, vegetation management, and the sustainability of natural resources. However, current DoD training doctrine and policy focuses significant efforts on maintaining "healthy" and stable training lands, and recognizing that the quality of these lands provides for sustainable high quality training opportunities. Preferably, the training mission should be accomplished in an environmentally sound manner that meets military requirements and promotes the sustainability of ecosystems so that the military mission is not compromised by a degraded landscape (Garten et al., 2003). In essence, 'Healthy training areas equal healthy training!'

Maintaining "healthy" training lands requires a focus on soil and vegetation characteristics within training areas. Vegetation characteristics and the conservation of landscapes are highly dependent on soil quality, which is defined as "the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health" (Doran and Parkin, 1994). It has been well-documented that vehicular traffic on agriculture and forest lands can cause critical adverse impacts on the maintenance of landscape and soil systems (Barnes et al., 1971; Jakobsen & Moore, 1981; Soane et al., 1981a; Soane et al., 1981b). Disturbance of soil structure followed by a change in the physical properties of the soil is a commonly-reported effect associated with the use of heavy vehicles in military training (Iverson et al., 1981; Prose, 1985; Braunack, 1986; Thurow et al., 1993; Milchunas et al., 1999), forestry (Hatchell et al., 1970), and agriculture (Voorhees et al., 1986; Alakukku and Elonen, 1995).

Concurrent to training impacts on soil characteristics and vegetation dynamics, sediment has been identified as an important non-point source pollutant in streams, rivers and lakes. Sediment adversely impacts aquatic organisms and habitat and can act as a carrier of other non-source pollutants (Ermine & Ligon, 1988). Off-road military traffic is a major issue in the management of the military's primary training maneuver lands because these activities increase erosion (Severinghaus et al., 1979, Johnson, 1982, Goran et al., 1983, Braunack, 1986, Shaw & Diersing, 1990, Diersing et al., 1990). Fuchs et al. (2003) found the strongest correlation between total plant cover and cumulative sediment loss in the rangelands of Fort Bliss. Though there are obvious climatic differences between Fort Hood and Fort Bliss, the factors causing sediment losses at Fort Bliss may also occur to some extent at Fort Hood.

The ongoing monitoring activities associated with current erosion control programs at Fort Hood as well as the Range Revegetation Pilot Project use research to develop and refine BMPs for integrated erosion control. The program overviews contained herein, along with the supporting study results contained in appendices, describe how integrated data collection programs are helping to evaluate BMPs to reduce erosion and protect water quality.

Sustainability on Military Lands

Sustainability of military training lands poses non-traditional issues for the management of natural resources. Sustainability has a dual meaning regarding military training lands: 1) maintenance of "realistic" systems for training of military personal, and 2) maintenance of the natural resource base upon which military personal train. “Left to itself, live-fire training and maneuvering would epitomize unsustainable activity (Lillie & Martin, 2003).” DoD’s Natural Resources Management Program Directive 4700.4 (1989) instructs the Office of the Secretary of Defense to “act responsibly in the public interest in managing its lands and natural resources (DoD, 1989).”

Sedimentation in area streams and lakes is a water quality issue associated with intensive training activities on Fort Hood. BMPs designed to reduce storm water runoff and associated sediment losses from training lands are a primary focus of Fort Hood’s ITAM and DPW environmental programs. BMPs (sedimentation structures, contour soil ripping, reseeding, gully repair, etc.) have been implemented in many high-risk areas to reduce water quality concerns. The following overview illustrates sustainable rangeland management practices the military and NRCS are using to decrease erosion and protect water quality.

Overview of Soil Erosion

Erosion and sedimentation are naturally-occurring processes that occur when soils are detached from one location, transported and deposited downstream. These processes are ongoing on most lands maintaining active soil genesis. The processes of erosion and sedimentation, in and of themselves, are not detrimental to sustainability of natural resources. In many cases, these natural processes are vital to the maintenance of ecosystems. However, accelerated rates of erosion and sedimentation have the potential to adversely impact watershed quality. Maintenance of a balance between soil genesis and erosion/sedimentation is crucial for long-term sustainability of viable ecosystems.

In systems highly impacted by anthropogenic forces, the natural balance for soils management can become a significant management impediment. Traditionally, soil erosion concerns have focused on soils and systems associated with agriculture production and in areas where soils have been severely disturbed by mining, construction, and other activities. Military training lands can be added to this list of systems significantly impacted by soil erosion and deposition. In most cases, military lands have been considered rural landscapes, but with the expansion of communities in and around military installations a multitude of new environmental challenges has arisen for military land managers. Processes such as soil erosion and sedimentation with their potentially adverse effects on surrounding landscapes and water quality can be added to the challenges.

BRIEF OVERVIEW OF BEST MANAGEMENT PRACTICES EMPLOYEED ON FORT HOOD TO COMBAT EROSION

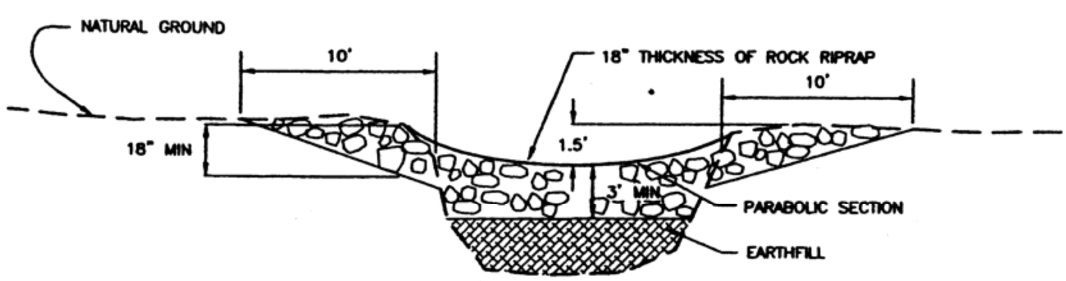
Mechanical Land Treatment - Contour Ripping

Contour ripping refers to the modification of soil physical properties and/or plant communities with mechanical tools (NRCS, 2002). Traditionally, the purpose of mechanical soil treatments were to support: 1) reduction of compacted soil layers, 2) reduction of water runoff and increased infiltration, 3) modification of sod-bound conditions to increase plant vigor, 4) renovation of plant communities, and 5) reduction of nutrient loads in runoff (NRCS, 2002). As designed by NRCS, contour ripping is a viable tool for restoring sustainable soil characteristics.

Gully Plugs (Maneuver Access Structures)

The MAS BMP was developed and implemented in partnership between Fort Hood and USDA-NRCS

Gully plugs or maneuver access structures (MAS) are constructed with selected rock varying in size from 4 – 12 inches in diameter. They are constructed to form a weir in the gully channel to keep the flow of water in the center of the gully. They are placed in a stair-step method so the elevation of the top of one gully plug is level with the tow of the plug above it. Eventually the once-deep gully will fill with silt, starting on the upstream side of the MAS, and form a stair-step down the slope. These structures are placed in line across the slope to enhance the flow of maneuver traffic. Military trainers have accepted the use of MAS to enhance the flow of maneuvers.



Compost as a Soil Amendment

The compost BMP is being actively researched in partnership between the Texas Agricultural Experiment Station, USDA-NRCS and Fort Hood land management entities.

In restoring drastically disturbed landscapes, the inclusion of additional nutrients into the restoration program can potentially have a beneficial impact on the overall efficacy of the restoration project. Traditional use of inorganic fertilizer is one means for increasing the amount of nutrient stored in rangeland systems. However, the potential opportunity for using organic forms of nutrient enhancement on Fort Hood was presented with the availability of composted dairy manure from an adjacent watershed impacted by nutrient impairments.

Augmenting nutrient availability in rangeland systems has been questioned because most native rangeland species have evolved under nutrient-limiting processes. However, the potential for positively influencing restoration programs on Fort Hood while reducing water quality issues in an adjacent watershed presented a viable research program. Efforts are ongoing at Fort Hood to evaluate the efficacy of nutrient amendments to assist in revegetating rangelands used for military training maneuvers.

Range Planting

The following information is extracted from Texas - NRCS Code 550 Field Tech Guide Manual (2006)

The practice of range planting serves to:

- Prevent excessive soil and water loss
- Improve water quality.
- Produce more forage for livestock.
- Improve the visual quality of rangeland.
- Provide or improve forages and cover for wildlife.
- Restore historic plant communities.

The practice applies to land where the planned use is rangeland, native pasture, and grazed forest and wildlife land. Generally, seeding will not be done when 15% or more of the desirable plants are present, well-distributed over the treated area, and can be managed to a stand within an acceptable time frame.

Species, cultivars or varieties recommended for reseeding must be adapted to climate conditions, soils, landscape position, and ecological sites; and must be compatible with management objectives. Species, cultivars, or varieties selected should provide adequate cover to control erosion by wind and/or water within an acceptable period of time. Suitable seedbed preparation and planting methods are required to meet any special needs for obtaining an acceptable establishment of planted species. To enhance the success of reseeding efforts, management efforts must consider such factors as planting depth, planting dates, seeding rates, the use of soil amendments and fertilizer needs for establishment, seed quality standards, and weed control.

Combat Trail Maintenance/Hilltop Access Trails

Materials regarding Combat Trail Maintenance/Hilltop Access Trails is derived from Fort Hood Integrated Training Area Management guidelines.

Concentrated runoff from vehicle movement over combat trails, hilltop access points and stream beds is thought to be a major cause of erosion and sediment runoff into Lake Belton and streams in the region (*Fort Hood Environmental Assessment*, 2006). Currently, the Army's ITAM program is leading several land management efforts to protect water quality at the installation. Efforts include hardening stream crossings, developing hilltop access trails, improving staging areas to reduce erosion, and constructing and maintaining tank trails to reduce land damage and sediment runoff. Well-designed and managed tank trails can reduce the extent that heavy vehicles have to cross rangelands when traveling to sites where training is scheduled, thus limiting the amount of soil that would otherwise be disturbed (Fort Hood Environment Conference, 2002).

<u>Sediment Retention Structures</u>

The following information is extracted from the NRCS TR-60 publication – Earth Dams & Reservoirs (July 2005)

Reservoirs used to store runoff will trap a large portion of suspended sediments in the runoff. Therefore, allocating storage capacity for the amount of sediment that is expected to accumulate over the design life of the reservoir is required. Criteria and general procedures needed to determine the volume required for sediment accumulation and its allocation in the reservoir are contained in the USDA-NRCS National Engineering Handbook-3 (NEH), Sedimentation.

NEH-3 includes procedures for determining:

- Sediment yield for present and future conditions after planned land treatment measures are applied in the drainage area of the dam,
- Trap efficiency of the reservoir,
- Distribution and types of sediment expected to accumulate,
- Proportion of submerged and aerated sediments,
- Sediment densities and compaction.

If the amount of sediment accumulation calculated exceeds two watershed inches in 50 years for the uncontrolled drainage area of the dam, it will be necessary to reevaluate the entire watershed to determine if more economical methods of reducing sediment yield or trapping sediment may be feasible and applicable.

BEST MANAGEMENT PRACTICES FOR COMBATING EROSION ON MILITARY LANDS – FORT HOOD, TX

Mechanical Land Treatment - Contour Ripping

Soil compaction often limits the amount of moisture infiltrating into rangeland soils. Mechanical treatments including soil ripping (also referred to as soil contouring, chiseling or deep profiling) can accelerate the recovery of damaged rangelands. In many studies, it has been demonstrated that ripping has the potential to increase soil porosity and infiltration rates, retain soil moisture, and improve seedbeds to foster vegetative growth.

The NRCS Conservation Practice Standard

The NRCS has established standards for grazing land mechanical treatments in Code 548. The standard recommends that soil ripping, contour furrowing, subsoiling and pitting should be applied to fracture compacted soil layers, to reduce water and nutrient runoff and increase infiltration, and to stimulate and increase vegetative growth. Soil ripping refers to the practice of pulling a heavy shank equipped with a broad lifting tip 12 to 20 inches deep through the contour of the soil. Typically, the space between rips varies from 10 to 30 feet. NRCS advises that ripping should occur at a depth that correlates with the most restrictive soil layer. The code advises that ripping should be accomplished in a manner that has the least potential adverse effects on natural resources. Therefore, the area of soil surfaces disturbed by ripping should be minimized, and desirable range and forage species should be introduced soon after soil ripping has been practiced.

Investigations into the effectiveness of soil ripping and related methods to increase infiltration and water availability date back to the 1960s (Branson, Miller, & McQueen, 1966; Gifford, Thomas, & Coltharp, 1977). These studies suggest that soil ripping has the potential to enhance stored soil water and protect water quality.

More recently, research at Fort Hood by the Texas Agricultural Experiment Station (TAES) and the Blackland Research & Extension Center (BREC) has demonstrated the effectiveness of soil ripping and gully plugs by monitoring water quality trends at sites where these BMPs are utilized (Hoffman, Wolfe, & Rosenthal, 2005). Subsoil ripping has been implemented along contour elevations throughout rangelands in several subwatersheds at Fort Hood. Results suggest that soil ripping, when done in association with other practices, reduced sediment erosion by 7% in areas with highly-erodible soils, and has the potential to effectively increase infiltration and lessen stormwater runoff and sediment losses to downstream watersheds (Rosenthal, Hoffman & Wolfe, 2003).

Studies in South Texas showed that ripping is an effective practice to increase water availability to rangeland vegetation in drought-prone areas of West Texas (Hanselka, McKown, & Mercado, 2006). Studies in Australia demonstrate that soil ripping is an effective practice to enhance available soil moisture in desert ecosystems (Mullan & White, 2001). Soil ripping can effectively increase infiltration in compacted soils at sites damaged by mining (Ashby, 1997) as well as wetlands near riparian and inland areas (Daniels et al., 2005). Other studies suggest that soil ripping can increase the amount of water stored in soils, can promote vegetative growth in arid regions where dryland farming is practiced (Baumhardt & Jones, 2002), and can increase the reproductive potential of seeded range species when combined with the use of soil amendments to increase organic matter and nutrients (Montalvo, McMillan, & Allen, 2002). Allen & Musick (2001) suggest that deep ripping soils on the High Plains may increase infiltration over the short-term but note that it may difficult to sustain these benefits over the full growing season.

Note: Specific results of water quality monitoring on lands treated with the combination of contour ripping and gully plugs are presented in Appendix A.

<u>Gully Plugs (Maneuver Access Structures)</u>

Information on gully plugs (MAS) were extracted from the Fort Hood-ITAM Workplan - LRAM Section (Fort Hood-ITAM, 2006)

In the three major maneuver lanes at Fort Hood, 270 miles of gullies have been created that range from 1-6 feet in depth. These gullies present a major obstacle to maneuvers as well as other types of training. The normal practice to correct gully-eroded sites is to use heavy equipment to create areas smooth enough for vehicles to traverse easily, and to establish vegetation to prevent erosion. However, this is not practical in military maneuver training lanes with heavy vehicles. Vegetation is impossible to maintain in adequate stands to prevent erosion. By trial, it has been found that the BMP for this situation is to use rocks to create a series of check dams within the gully network.

The ITAM and NRCS Conservation Practice Standard (specifically designed for Fort Hood)

Gully plugs are constructed by excavating a notch across the gully and filling this area with rocks to form a weir that is keyed into the bottom of the channel and into either bank. The plugs should be 20 feet wide to allow tanks and other vehicles to safely cross the gullies. Horizontal spacing allows the elevation of the top on one gully plug to be level with the toe of the one above it, which will eventually create a stair-step effect by capturing sediment behind each plug. This slows erosion by stabilizing the gully and not allowing it to become deeper and wider.

When available, the rocks for gully plugs at Fort Hood are obtained from the a sanitary landfill as new compartments are opened. Gully plugs are an excellent way for the installation to recycle a natural resource that would otherwise be an expense for disposal.

The only cost involved is for breaking, sorting and hauling the rocks. When the landfill rock is not available, rocks for gully plugs can be obtained from commercial sources at comparable cost.

The management objectives for the use of gully plugs or mass structures are to maximize available training lands in the three major training lanes. These lanes have become an obstacle course because of the gully network that has developed, but the use of gully plugs enables training to be enhanced at these sites.

Dairy Compost as a Soil Amendment -Draft Version of SOP Development

Soil nutrients play a vital role in land management and are commonly used to enhance plant growth and production. However, nutrients in the form of commercial fertilizers and composted animal waste are a source of nitrogen and phosphorus, which can contaminate surface- and ground-water resources. The use of composted dairy manure on military training areas is now being evaluated as a means to restore basic soil processes to improve current vegetation and establish new vegetation. Development of this draft standard operating practice (SOP) focuses on vegetation response and water quality issues.

Objectives:

The primary benefit of improved vegetation on training areas is to combat accelerated erosion due to soil disturbance by military vehicles in an effort to sustain training areas for future use. The primary objective of applying composted dairy manure to military training areas is to improve vegetation and reduce soil erosion and runoff at sites where vehicle traffic has resulted in soil compaction, loss of vegetation and increased soil erosion. Benefits include stabilization of soils through the introduction of organic matter and increases in soil nutrients and vegetation cover.

Conditions Where Practice Applies

The practice applies on military lands where the use of vehicles has the potential to significantly increase natural erosion processes. Though potentially beneficial on all landscapes, it is anticipated that the practice is most conducive for level to gently rolling rangeland systems in semi-arid and arid regions of the western United States. The practice should be well-monitored if the application of compost takes place in close proximity to creeks, streams, rivers, and their tributaries.

Planning Considerations

1. Soil characteristics: texture, nutrients, etc.
2. Landscape characteristics: slope, vegetation, drainage, terrain etc.
3. Proximity of compost supply: local or, transported to the application site.
4. Method of application: equipment needs, time required, etc.
5. Climate: weather patterns, access for vehicles, etc.
6. Quality of material: organic matter, nutrient values, mineral content, etc.
7. Economics: cost of material, land application, transportation, etc.
8. Training Scheduling and Grazing Management: ITAM Out-area programs
9. Others

Erosion is a naturally occurring phenomenon on all rangeland systems. This process is offset by the genesis of soils from underlying parent material. The process becomes a challenge when erosion is accelerated outside the range of natural variation. During the impacts of military training, activities associated with secondary impacts (i.e., livestock and wildlife grazing), the natural variation of erosion is often exceeded. In these cases, it becomes necessary for land managers to decrease the erosion rate to sustain the rangeland resources. The use of soil amendments provides a tool to improve land processes and provides a strategic approach to minimize soil erosion.

Land Evaluation:

Land Evaluation must be carried out to determine:

1. The extent of area where selected land management practices may be applicable for implementation.
2. Current rate of erosion in comparison to the natural rate of variation associated to specific soil series.
3. Current landscape characteristics including soils, slope, vegetation, drainage patterns, terrain and other aspects that might influence the beneficial impacts of management practices.
4. Historical climatic patterns that may influence the application of the management practices or impact the outcomes (i.e. nutrient loading in runoff).
5. Economic feasibility in comparison to other BMPs designed to counteract the erosion process.
6. Matching nutrient applications to soil nutrient needs is critical. Nutrients of any form should not be over-applied. Soils should be tested prior to land application to determine the rate of composted manure to apply.

Caution should be taken during the planning process to evaluate potential deleterious impacts that may result from the application of composted manure. The primary concern is increased nutrient loads in area streams and waterbodies. Land application of compost has the potential, at high application rates, to increase nutrient loads to receiving waters, resulting in an increased risk of eutrophication. Climate and rainfall considerations must be addressed in the planning process to develop optimal land application programs.

Design Considerations

In many cases, restoration of soil and vegetation characteristics will require a concerted effort across multiple activities including soil reconditioning (compost) and physical containment (check dams, retention ponds, etc.). Therefore, the solutions for combating soil erosion must include a strategic view incorporating multiple BMPs as well as training schedules and grazing management.

Site Preparation

Site preparation may be necessary in some areas due to the extreme disturbance that has taken place (tank dig areas, extreme rutting, gullies etc.). However, it is recommended that site preparation be limited to those areas that are strategically located to increase the efficacy of the soil stabilization activities due to the higher costs of extensive site preparation.

Where feasible and necessary, it is recommended that sites be prepared by the use of railroad ties and rails placed in tandem behind a tractor and drug across the treatment areas to level the land by filling ruts. This will allow easier access for compost spreaders and reseeding equipment.

Compost Quality & Acquisition

Operations where manure is utilized to develop compost must follow technical guidelines to ensure quality control and quality assurance (QA/QC) of the finished product. Properly composted dairy manure requires that providers follow a set of guidelines for development of the product. This includes turning material five times within 15 days with the material reaching between 140^{o}-160^{o} F between turns. Users of these composted products should verify that vendors are properly manufacturing compost materials.

Compost Application

Application of compost provides one of the most challenging aspects of using the material for large-scale land application on military primary training maneuver areas. The expected disturbance to the terrain through the use of military heavy tracked vehicles is easily understood. Equipment requirements focus on the use of heavy tractors pulling compost spreaders capable of withstanding the unusual and unpredictable terrain associated with training areas. Prototypical spreaders have been designed and built for evaluation and are available for review and demonstration.

Reseeding Activities

Reseeding is a common practice employed by military personnel to combat the loss of vegetation due to regular training maneuvers. In many cases, reseeding is critical to revegetate drastically disturbed sites. The decision to reseed is contingent on site-specific indicators including the vegetation cover existing prior to training and the potential of the seedbank to provide the basis for revegetation.

Caution must be taken in addressing whether seed mixes and species used in reseeding are native or non-native; perennial or annual, and the purpose of reseeding programs (i.e., minimizing soil erosion), and secondary uses (i.e., enhancing conditions for wildlife and livestock).

Preliminary results indicate that reseeding may not be necessary in coordination with compost application where suitable seedbanks are already in place to provide the basis for restoration activities. The capability of seedbanks to revegetate rangelands should be evaluated before seeding programs are initiated.

Vegetation Monitoring

Before a reseeding program is implemented, a vegetation monitoring system should be developed that identifies existing rangeland plant species and communities before any soil amendments are applied. This will allow for comparison of outcomes from the use of soil amendments and will help evaluate the efficacy of reseeding practices. Development of a systematic protocol of line transects for gathering data is recommended including species composition, cover class and other vegetation related indicators (e.g. annual and perennial species).

After treatment efforts have been implemented, periodic monitoring will provide a basis upon which efficacy of soil amendments can be compared to pre-treatment status. It is recommended that monitoring occur at least twice per year with assessments taking place to optimize impacts on vegetation in cool and warm seasons.

Monitoring Soil Erosion and Water Quality

Plans to use composted dairy waste in a rangeland restoration project should include a watershed management protection plan that contains a water quality monitoring component. The water constituents of greatest concern include erosion processes and losses of phosphorus and other nutrients. Monitoring nutrient losses in runoff will assist land managers in determining appropriate nutrient rates for the areas being restored. Water quality data can also be used to evaluate the effectiveness of BMPs implemented during the restoration program. Sediment losses need to be assessed on a watershed basis. Runoff water in streams containing phosphorus concentrations between 0.01 and 0.03 mg/L are considered to be non-eutrophic and not degrading water quality. According to EPA guidelines, discharges to streams should not contain phosphorus levels higher than 0.1 mg/L. If the stream empties into a lake, discharges should not exceed 0.05 mg/L and discharges directly into a lake should not contain phosphorus concentrations greater than 0.025 mg/L.

Note: Supporting research results can be found in Appendix B.

Range Planting

Reseeding on highly disturbed training lands provides an opportunity to establish vegetation after significant training. The seedbed should be firm, free of weed competition, and not have a restrictive layer such as a plowpan. Cover crops (NRCS Standard 340) may be beneficial to establish native rangeland species that provide cover and litter. Reduction of less desirable plant species can be accomplished through herbicide application or prescribed burning. Removal of highly competitive species is important to the successful establishment of seeded species.

Seeding Operation

Drilling

Whenever possible native grasses should be seeded with a grass drill equipped with double disk openers having depth bands followed by a cultipacker, press wheels or drag chains (press wheels or cultipacking are preferred). Seed should be planted ¼ to $^{3}/_{4}$ inches deep. The distance between rows should not exceed 12 inches.

<u>*Broadcasting*</u>

Broadcasting may be used where dead litter crops are not required and the seed can be firmly anchored into the soil. Seedbed modification by cultipacking or other means can accomplish this. Cultipacking before and after seed placement is preferred. Hand broadcasting is acceptable where equipment cannot be operated because of terrain, and an adequate stand of grasses can be expected on the seeded area.

Fertilizer

Fertilizer is not normally recommended when reseeding native rangeland because it will encourage excessive weed growth. However, it may be necessary to fertilize on coarse textured or severely eroded soils that may not have residual or inherent fertility of sufficient levels to support emerging grasses during establishment. In these cases, fertilizer application should follow the emergence of the seeded grasses to limit weed growth. A soils test should be taken prior to fertilization. The soil test should note "for establishment" instead of listing a yield goal that would be for production purposes.

Reseeding Native Range or Woodlands Following Brush Management

Seeding is generally not recommended as long as at least 15% of the important grass species are well-distributed over the site. Seeding may be needed where there is significant ground disturbance. Mechanical methods to remove brush, such as dozing, rootplowing, raking, chaining and/or burning can be a part of the seedbed preparation. Additional seedbed preparation may be needed with heavy equipment so that seeding equipment can get over the area. It may be necessary to plant cover crops for two consecutive years prior to seeding to reduce resprouting of oak and other brush species. On soils subject to wind erosion, vegetative cover needs should be established to reduce erosion threats.

Fort Hood Range Planting Program

Information on Range Planting Program was extracted from the Fort Hood-ITAM Workplan LRAM Section (Fort Hood-ITAM, 2006)

Military training inherently involves activities that degrade vegetation and cause soil compaction. Without an adequate cover of grasses and forbs, erosion may damage training lands and deteriorate training land health. This may lessen the amount of training the Army is able to conduct on these lands. RTLA inventories indicate that there are in excess of 15,000 acres in maneuver training lanes at Fort Hood that were in a C3 or no-go condition. Approximately half of these acres have been treated with a series of practices to-date and vegetation establishment is a key part of the process. Native and adapted species are used that compliment the site conditions. The addition of compost is being used where soil conditions warrant. It is planned that compost may be applied to roughly 2,500 acres, annually over the next few years.

Sustainable Management Objectives

The objectives of this program are

1) to establish a desirable vegetative cover

- Where none currently exists.
- Where training activities have denuded rangelands.
- Where the conditions of these areas are such that natural recovery is not possible.

2) to mitigate erosion rates to acceptable levels.

By accomplishing this, training lands will be able to support the desired level of training for a much longer period of time.

Process

Identify areas needing seeding and establishment by:

- RTLA surveys and Field observations
- Maneuver damage reports from units (if available)
- Coordination with environmental entities
- Monitor contract for compliance

Note: Reseeding study results particular to Ft. Hood compost revegetation program can be found in Appendix C.

<u>Combat Trail Maintenance</u>

Information on Combat Trail Maintenance was extracted from the Fort Hood-ITAM Workplan LRAM Section (Fort Hood-ITAM, 2006)

There are 400 miles of combat trails identified on Fort Hood of which 364 miles are not fully serviceable. These trails are unserviceable partly due to the lack of proper maintenance and the fact that they may have been built with unsatisfactory construction materials. Once the base materials on these trails gives way, the supporting sub-base rapidly degrades. With very limited or no maintenance, the trails soon develop very large potholes. This causes traffic to divert to alternate routes and the trails become wider (in some cases they grow to a width of 100-200 feet). This additional area is bare of any vegetation and continually churned by tracks and wheels, thus producing very high erosion rates. These areas produce 60% of the sediment that is transported by runoff from the maneuver training areas. Surveys indicate that improving 1 mile of training lands will protect an additional 40 acres on the site.

Restoration of the trails to serviceable condition may require completely rebuilding these structures. This means providing a stable sub-base, proper drainage and stable base material. The sub-base must be a minimum of 6 inches thick, have a low organic content and be compacted to 95% density. In areas of soils with high clay content, the sub-base should be stabilized with lime or have an additional 6 inches of base applied. Site preparation will include grading to provide adequate drainage so water will not pond in bar ditches. Hardened low water stream crossing or adequate culverts should be provided at drainage points. The flex base will have a surface thickness of 10 inches and will be compacted to 100% density.

Improvement of trails will provide trainers better access to training areas and will cause less stress on equipment and personnel. As a result of deteriorated trail conditions, there have been numerous cases of vehicles being damaged and soldiers being injured, some seriously. This work will be accomplished by a combination of DPW in-house forces and by contract.

Sustainable Management Objective

The Combat Trail Improvement Program will provide trainers with adequate, clean and safe access to all training areas. It will save time (allowing more meaningful training time) and reduce repair costs to vehicles and related personnel injuries.

The Combat Trail program will greatly help trainers to have better access to all training areas in a manner that will protect personnel and equipment. It will help to increase training time and will aid in producing combat ready forces.

Process

- Identify trails for improvement with priority in the "Training Out-Areas."
- Locate the coordinates of trails with global positioning systems (GPS).
- Develop GIS layers to calculate the length of trails and generate cost estimates
- Coordinate with environmental entities
- Prepare contract
- Supervise contract for quality and quantity

<u>Hilltop Access Trails</u>

Information on Hilltop Access Trails was extracted from the Fort Hood-ITAM Workplan LRAM Section (Fort Hood-ITAM, 2006)

The topography of the installation is a cut plain with hard limestone-capped hilltops ranging from 80 to 160 feet above the valley floors. The hillside slopes range from 20 to 45%. Track vehicles are able to access the hilltops until water erodes away the soil, leaving a vertical rock ledge of 4-10 feet at the top of the slope. When paths become inaccessible, other trails must be created until hundreds of abandoned sites exist on the installation today. These sites are not only sources of erosion and sediment production, but also present a safety hazard. Tanks and other military vehicles have overturned and seriously injured soldiers.

To mitigate this problem, selected sites are being improved and hardened. This provides safe, semi-permanent access and significantly reduces erosion rates. This project is important to improve training and enable the Army to accomplish its mission, and provides maneuver access across the landscape. This project is accomplished by contract and DPW in-house resources.

Sustainable Management Objective

The Hillside Access Trail (HAT) improvement program will help to maximize the availability of the training areas and enable units to train to military standards.

Process

- Identify sites to improve and sites to block
- GPS route and enter into the GIS
- Coordinate with environmental entities
- Develop contract and supervise contract for compliance

<u>Sediment Retention Ponds</u>

In development

Note: Results of bathymetric studies on sediment retention ponds and the Cowhouse Arm of Lake Belton can be reviewed in Appendix D.

RECOMMENDATIONS & FUTURE ACTIVITIES

General: An integrated set of BMPs should reduce runoff and erosion potential.

PL566 structures **-** effectively remove more than 90% of sediment entrained in runoff (Haan et. al. 1994)

BREC water quality monitoring indicates that sediment loads from training areas utilizing PL566 structures show no significant increase despite training activity (storm events of similar intensity compared within House Creek watershed, 1997 vs. 2000). BREC bathymetric surveys indicate significant sediment deposition is occurring. BREC personnel are providing scientifically derived information to help Fort Hood land managers determine management strategies (i.e. drain/dry cycles, dredging requirements etc.)

Recommendations:

- Protect the integrity of training structures with riparian buffers and gully plugs
- Review policy regarding vehicular traffic adjacent to structures
- Monitor sediment deposition within structures to predict the usable life span
- Drain pond and dry sediments to reduce stored sediment volume
- Build structures with "leaky" bottoms to promote self drain/dry cycling
- Remove accumulated sediments to rejuvenate structure capacity

Mechanical treatment -contour ripping effectively reduces overland flow and increases infiltration (Miyamoto et. al. 2004, Luce 1997, Pikul et. al. 1996)

BREC water monitoring indicates that the combined use of contour ripping and gully plugs reduces runoff by 60% and sediment loss by 90% (Shoal Creek study)

Recommendations:

- Continued use of NRCS methodology for contour ripping
- Seed ripped areas with both native and non native plant species
- Apply soil amendment (compost) and seed directly to the ripped area
- Mix ripped soil with seed and amendment (chain drag)
- Re-apply treatment as necessary (time or activity based)

Maneuver Access Structures (gully plugs) effectively slow runoff and decrease entrained sediment loads (Nyssen et. al. 2004, Xu 2004) while providing crossing points for military traffic (Kramer 1999)

BREC water quality monitoring indicates that combined use of gully plugging and contour ripping reduces entrained sediment concentrations by 70% and sediment loss by 90% (Shoal Creek study)

Recommendations:

- Continued utilization of MAS
- Install MAS to budget limit
- Monitor MAS for signs of sediment deposition and sedimentation
- Install MAS or similar structures in smaller gullies to prevent severe gully formation
- Design MAS to facilitate and encourage vehicular traffic

Compost Soil Amendments

- Current research indicates the use of compost at rates equivalent to 15 yd^3/ac (in some cases up to 30 yd^3/ac) could be acceptable. Care must be taken to minimize water quality concerns when higher rates of compost are applied. Compost rate from 60-90 yd^3/ac show the highest statistical relevance, but further research is necessary to alleviate water quality concerns.
- It is recommended that compost be incorporated at some level into the base soils on treated sites. Broadcast methods placing compost on the soil surface may increase the likelihood of nutrients within compost treatments moving to off-target sites due to runoff and overland flow of soils and compost materials.
- Recommend a winter/early spring application window (Jan.-April.). This is encouraged to take advantage of spring rainfall and optimum reseeding windows for rangeland grasses (before March 15).
- Current research indicates the use of compost within protected watersheds (gully plugs, contour ripping, sedimentation ponds) to minimize direct conduit to waterbodies on the installation and downstream receiving reservoirs.
- It is recommended that a systematic water quality monitoring program be implemented at the outflow of treated watersheds to monitor nutrient loads generated from treated landscapes.
- Current research recommends a native seed mix consisting of NRCS-provided species. However, research should be continued on a combination of native and non-native species.

- Recommend that a systematic compost quality program be implemented to monitor and provide quality assurance for compost physical and chemical properties.
- Recommend research activities focus on further evaluation of the value of "re-seeding" in restoration. Initial results indicate that re-seeding with native seed mixes may influence the levels of ground cover for treated areas and across fertilization treatments. Verification through field studies is required to fully understand seeding benefits.

General Observations, Professional Judgments, Planned Activities and Future Research – Compost Studies

Several early experiments and demonstration projects are being retired from the active collection of data due to their diminishing return on data and the increased pressure for assessing new projects being implemented. New research has been established to further evaluate the impacts of seeding and fertility treatment (compost vs. fertilizer) on Fort Hood training areas. Associated with these activities, soil scientists are evaluating the impacts of fertility on a naturally-occurring soil protein that has been linked to soil stability. These efforts seek to understand the relationships between plant species composition, fertility and soil biochemistry and the influence of range rehabilitation efforts on soil compaction and stability.

After three years of evaluation, the large-scale application of compost across vast landscapes appears to be limited by the economic viability of the practice. The purchase, transportation and application of large quantities of compost may be cost-prohibitive compared to other soil management practices. However, it is felt that compost can play a significant role in the restoration of military training lands. Therefore, research projects are being implemented to evaluate the benefits of combinations of soil management practices. Primarily, efforts will be implemented in 2007 to analyze the combination of contour ripping and compost soil amendments in coordination with applicable vegetation establishment and sustainability parameters. This direction has been requested by Fort Hood ITAM personnel and will include evaluation of such programs as seeding rangelands (or not) and the use of a series of seed mixes agreed upon by military, agency and academic personnel.

Components focused on examining how these programs may affect water quality will be included in all compost, fertility, and soil management studies to rehabilitate rangelands. Research plots will be instrumented and monitored by BREC personnel to provide water-related results based upon land management practices that are implemented.

Parallel to these research areas, efforts should be implemented to evaluate the potential use of compost in association with dredged sediment. Dredging practices have been proposed to reduce the amount of sediment in the Cowhouse Arm of Belton Lake and in installation sediment retention ponds. Compost could provide a beneficial amendment that can reduce the potential for crust formation on dredged soils after they are applied to the landscape. The overall push of this integrated research program is to further develop standard operating procedures for the use of compost in association with other land management practices to minimize sedimentation and deposition of soils disturbed by military training.

Continued support of the Range Revegetation Pilot Project will provide research based integrated erosion control programs that can be implemented by Fort Hood land managers to maximize training opportunities while maintaining the integrity of the natural resources on which the military trains.

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Appendix A – Gully Plugs & Ripping Monitoring Results

(Shoal Creek, Fort Hood)

EVALUATING LAND MANAGEMENT PRACTICES USING MULTI-YEAR STORMWATER DATA

FY-2006 Status Report

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November 2006

ABSTRACT

We used stormwater runoff data to determine the effectiveness of two best management practices (BMPs) upon reducing erosion accelerated by military training activities at Fort Hood, Texas. Due to the nature of the heavy vehicles involved, military maneuvers damage vegetation and alter soil conditions resulting in vegetation loss, soil compaction, stormwater runoff channelization, erosion, and large gully system development. These conditions contribute to training disruption and subsequent alluvial sedimentation of downstream waterbodies. Natural Resources Conservation Service (NRCS) and Integrated Training Area Management (ITAM) land managers have implemented numerous erosion-reducing BMPs across the Fort Hood reservation. Two in particular, Maneuver Access Structures (MAS), or gully plugs, and Mechanical Treatment (MT), deep soil ripping on the contour, were heavily implemented in the Shoal Creek watershed. Blackland Research and Extension Center (BREC) staff members measured stormwater runoff and associated sediment loads from this watershed for five years before and four years after the BMPs were installed. Differences in storm runoff and sediment loss before and after BMP implementation were compared using non-parametric statistical methods to quantify BMP effectiveness. BMPs reduced mean storm runoff by 60 percent and sediment concentration in runoff more than 79 percent. Mean sediment load per storm event was reduced greater than 90 percent. Water quality data quantified the BMPs effectiveness of reducing storm runoff, and associated erosion, in heavily disturbed landscapes.

INTRODUCTION

In 1995 the Texas Agricultural Experiment Station's Blackland Research and Extension Center (BREC) along with the Natural Resources Conservation Service (NRCS) and Fort Hood Integrated Training Area Management (ITAM) staff, implemented a reservation-wide surface water monitoring program, which included over a dozen stream gauging stations equipped with automated stormwater runoff sampling capabilities. This network was deployed to help Fort Hood resource managers track and assess their watershed management and protection plans. Coordinated efforts by BREC, NRCS and ITAM assist Fort Hood land managers in maintaining high quality training areas while protecting water resources for future generations. Lake Belton lies adjacent to Fort Hood along its eastern boundary and is the water supply for the surrounding population of more than 250,000 people. The Temple-Belton-Killeen Metroplex in Central Texas is currently experiencing substantial economic growth and its population is expected to double by 2050 making water from Lake Belton an extremely important commodity.

Fort Hood is a United States Military Reservation located on the northern end of the Edwards Plateau in Central Texas approximately 100 kilometers north of Austin. The reservation established in 1942 encompasses some 88,000 hectares with just over 26,000 hectares assigned to vehicular maneuver training. Fort Hood accommodates two armored divisions and support groups including: Headquarters III Corps, the 1st Cavalry Division, 4th Infantry Division, 13th Corps Support Command, 3d Signal Brigade, 89th Military Police Brigade, 504th Military Intelligence Brigade, 21st Cavalry Air Combat Brigade, and 31st Air Defense Brigade (Jones 2005). Almost 12,000 tracked and wheeled vehicles use

Fort Hood including: the M1A2 Abrams Main Battle Tank, the M2A2 Bradley Infantry Fighting Vehicle, the M109A6 Paladin Howitzer, the familiar "HUMMWV", and a fleet of large cargo, transport, and support trucks. In addition, there are considerable numbers of civilian off-road vehicles and heavy land-moving equipment in use (Kramer 1999).

The varied traffic experienced in the maneuver training areas provides a significant source of ground disturbance resulting in vegetative cover loss, soil compaction and bare ground exposure (Anderson et. al. 2005). Althoff and Thein (2005) measured significantly reduced vegetative biomass, higher soil bulk densities, and decreased soil porosity within tank tracks at Fort Riley, Kansas while Fuchs et. al. (2003) correlated sediment loss with plant cover affected by M1A1 tank traffic, at the Fort Bliss Military Reservation in New Mexico. Range grass establishment and rhizome production at the Yakima Training Center in Washington were negatively impacted by tracked vehicle pressure with trafficked areas showing decreased vegetative cover and increased bare-ground (Palazzo et. al. 2005). Disturbance during wet conditions amplifies the effects and subsequent land degradation (Althoff and Thein 2005, Fuchs et. al. 2003). Most of this disturbance has been measured through direct ground measurement, aerial photography, and satellite imagery techniques (Herl et. al. 2005, Palazzo et. al. 2005).

The high traffic volume when combined with vegetative cover loss and seasonal heavy rainfall events leads to soil erosion and entrainment of eroded soils in storm runoff (Althoff and Thein 2005). Unchecked, eroding gully systems worsen and may affect a significant portion of the catchment. Additionally, eroded gullies contribute significant amounts of sediment to local streams and lakes where it may be stored for long periods of time (Gomez 2003). The sedimentation experienced by Lake Belton has been identified as

Fort Hood's prime environmental concern by Fort Hood land managers. Aerial photos from 1995 and 2000 show visible alluvial delta formation in the Cowhouse Creek arm of Lake Belton. In addition to environmental impacts, gully formation from channel erosion results in loss of valuable training area by posing a hazard to vehicular and foot traffic.

Considerable time and effort has been spent to predict the impacts of military maneuvers on training area conditions and determining the best mitigation plans using computer modeling techniques. Modeling, when coupled with empirical measurements, allows land managers to predict erosion potential based upon landscape characteristics and land use activity (Anderson et. al. 2005, Harrison and Doe 1997). Many best management practices (BMP) developed to address erosion and sediment control on military reservations can be modeled prior to actual installation. This helps land managers select, size, and place appropriate BMPs with efficiency in order to gain maximum training, environmental, and economic benefit (Warren et. al. 2000).

While most studies focus on training impacts and computer modeling to predict future impacts, less attention is paid toward assessing BMP effectiveness to restore and maintain training lands to usable status. The costs associated with BMP implementation can be significant; therefore a clear understanding of the improvement gained from a particular BMP has training, ecological, and economic worth. In this report, we demonstrate how storm water runoff data may be useful for quantifying erosion-reducing BMP effectiveness at the watershed scale. Our results have allowed land managers to promote two specific BMPs and justify their investments. Furthermore, these data can be used to develop and calibrate the many computer model routines designed for use on military lands. The ability to predict training impacts should be augmented with the ability to predict effectiveness of specific land management strategies.

Water mediated erosion is a function of storm water runoff, local geology, and land use (Hauer and Lamberti, 1996). We measured the storm flow, sediment concentration in those flows, and determined the sediment mass lost from training areas for more than ten years in several Fort Hood sub-watersheds. Comparing the pre and post BMP storm event variables, normalized by precipitation, provided a quantitative measurement of BMP effectiveness to reduce runoff and erosion. The method could be easily adapted to measure the trends for other water-born constituents such as petroleum products, nutrients, or other toxicants.

Two BMPs extensively implemented at Fort Hood are Maneuver Access Structures (MAS); rock cobble dams placed perpendicular to the slope within gully systems (NRCS 2000), and large area Mechanical Treatment (MT), contour ripping of the soil profile (NRCS 2001). Both BMPs are designed to slow or reduce stormwater runoff. Since water mediated erosion is a function of runoff, these BMPs ultimately reduce erosion.

MT, such as pitting, contour furrowing or sub-soiling, modify the physical soil and plant conditions resulting in reduced storm water runoff and increased infiltration (NRCS 2001). Ripping the soil on the contour accomplishes several things that directly affect runoff and sediment loading. During a large storm event, overland flow is intercepted and drains into the fractured soil profile. This BMP, when heavily implemented (Figure 1), effectively eliminates overland flow and runoff channelization. There is some evidence of increased soil moisture in the ripped areas enhances seed germination, survival, and growth which leads to increased vegetative cover. The improved vegetation further decreases overland flow and erosion by slowing runoff from large storm events.

MAS have many names; gully plugs, check dams, rock crossings, etc. They are constructed from stone cobble ranging from 0.2 to 0.3 meters in diameter that is precisely placed within an eroding channel using earth-moving equipment. The resulting permeable dam is placed perpendicular to the eroding channel spanning the distance between the banks. Successive gully plugs are installed in "stair-step" fashion with the top of one roughly equal in level to the base of the one preceding it (Figure 2). These structures are typically 10 to 15 meters in length, 4 to 6 meters in width, and 1 to 3 meters high but actual dimensions depend upon the size of the channel within which they are located (NRCS 2000). They function by temporarily ponding overland flow from large rain events and permitting slow drainage through the structure. This reduces the energy of the flowing water such that sediment loads are deposited in the channel directly above the gully plug (Kramer 1999). Visual observation indicates sedimentation is occurring above the MAS in the Shoal Creek Watershed and the gullies are gradually filling in.

Additionally, the MAS improve training area safety as military personnel enjoy increased maneuverability in locations where MAS are installed. The structures are designed to support tracked and wheeled vehicle traffic, thus providing needed maneuver lanes across the training area. Limestone formations dominate the Fort Hood landscape and is the material mined for MAS construction. The rock cobble is a bright white making the structures easily visible during the day. They exhibit a unique heat signature easily recognized with night vision equipment. This design artifact promotes safe maneuvering across the training areas both day and night.

MATERIALS AND METHODS

Experimental Area: Fort Hood's landscape is generally rolling with interspersed ridges and plateaus where elevations range from 120 to 180 m above mean sea level. The average annual precipitation for the area is approximately 310 mm. Historically Fort Hood was covered with tall grass prairies and several small mountain ranges. Much of the area has been forever changed by military activity. Shifts in plant community structure are noticeable. The vegetation now present on the installation is the result of many variables operating over the past five decades including; the extent of vehicular ground disturbance, restoration/maintenance activities, livestock grazing, and climatic conditions (Jones 2005).

The Shoal Creek watershed is located in the northwest corner of Fort Hood. It comprises 22.5 square kilometers and 95 percent is contained within the reservation boundary. Two soil types dominate the area, Slidell and Ulysses. Slopes range from 3 to 20 percent and numerous limestone based ridges rise up to 60 m in elevation from the lower prairies. The prairie areas receive the maximum impacts from tracked and wheeled vehicular traffic and therefore suffer the greatest impact. As of 2001, over 63 km of eroding gullies were mapped within this area. BREC began collecting storm water runoff data in this watershed in 1997.

Water Quality Monitoring Equipment: The stream gauging station was placed at the Shoal Creek basin outflow and outfitted with an equipment shelter, a solar panel / battery power supply system, an ISCO 4230 Bubble Flow Meter (ISCO, Inc., Lincoln, NB), an ISCO 3700 Automated Water Sampler, and a Texas Electronics TX25 (Texas Electronics, Dallas, TX) tipping bucket rain gauge (Figure 3). The equipment shelter was located approximately 5 meters above the channel bottom such that the electronic equipment was safe from submersion due to flood conditions. It was also positioned so that the solar panel and rain gauge received full exposure to the sky. The ISCO 4230 Bubbler Flow Meter determines stream stage by forcing a metered amount of air, supplied by an internal air compressor, through a 5 mm vinyl tube to an outlet fastened near the channel bottom. The pressure needed to force air through the line is calibrated to the corresponding stream stage. A 10 mm vinyl tube connects the ISCO 3700 automated water sampler to its sampling point adjacent to the bubble flow meter outlet point. The tubing for both the bubble flow meter and automated water sample tubing were housed in a 25 mm polyethylene irrigation conduit pipe to add protection. The gauging station was visited every 7-10 days to service and download data from the electronic equipment, check battery voltage, and check for unexpected damages due to vandalism, insects, rodents, etc. Numerous unexpected problems were corrected during these routine maintenance visits insuring that the gauge would function and collect data during stormwater runoff events.

Stream discharge determination: Water velocity at the gauge location was estimated mathematically using Manning's equation (Grant and Dawson 1995). A stream cross-sectional and slope survey was conducted at the gauging point using a tape and transit while Manning's roughness coefficient was estimated through a visual assessment using USDA descriptions (Brakensiek 1979). These data were used to calculate a stream stage-discharge relationship with FlowMaster PE 6.0 software (Haestad Methods, Inc., Waterbury, CT). The ISCO 4230 bubble flow meter was programmed with the stage-discharge relationship data to yield estimates of continuous stream flow, above the air bubble outlet, and stormwater sampling elevation. The experimental period yielded a total of 51 useable storm runoff data points with 29 pre BMP events and 22 post BMP events.

Automated water sampling: Stormwater runoff samples were collected with ISCO 3700 automated samplers. This equipment, which can collect up to 24, discrete, one liter samples, was programmed to collect samples at 30 minute intervals when sufficient flow depth to cover the sampler intake was present (approximately 40 cm). Many decisions must be made to design a sampling configuration and collection scheme employed at a particular location (Harmel et. al. 2002). In this case, the sample intake, and bubble outlet lines were offset from the channel bottom for physical protection. The Shoal Creek watershed, pre 2001, exhibited dramatic stormwater flows with accompanying high sediment loads. The bubble outlet and intake lines required excavation from deposited sediment in the stream channel multiple times until they were finally raised to the current position. An average storm event in this watershed produced a one to four hour runoff event with three to eight runoff samples. Whenever possible, three samples were selected for laboratory analysis of entrained sediment. These included: the first sample collected, the sample closest to the maximum height of the hydrograph, and the sample closest to the middle of the descending arm of the hydrograph.

Sediment Determination: All stormwater runoff samples were transported to the BREC Water Science Laboratory as soon as practical following a storm event where they were stored at 4 degrees Celsius until analysis. The measurement of total suspended solids (TSS) was used to determine the suspended sediment load in storm runoff events. TSS concentrations were determined gravimetrically using Standard Method 2540 D, total suspended solids dried at 103-105 ^{o}C (Standard Methods 2005). Suspended sediment loads per individual runoff event were calculated by associating measured flow data with measured TSS concentrations. The runoff hydrograph, from individual storms, was divided into sections representing the individual time interval in which each TSS sample was collected. Sample concentrations were then multiplied by the runoff volumes for each time segment of the runoff event to determine the mass of suspended sediment entrained in the associated runoff volume.

BMP Implementation: The Shoal Creek watershed received two concurrent BMP treatments. With a severely eroded gully system threatening training interruptions and downstream environmental consequences, NRCS and ITAM personal implemented MAS (gully plugging) and MT (contour ripping) management practices to mitigate the problem. A total of 211 MAS, were installed in the Shoal Creek watershed. 135 were placed in the eroding channel system between August and November of 2002 and an additional 76 were installed between May and June of 2003. Contour ripping was implemented within the Shoal Creek watershed in the summer of 2002. A bulldozer equipped with two 0.5 meter chisels, set on a 2.5 meter center, and a Global Position System (GPS) receiver allowed the operator to follow the terrain contour and rip the ground to an effective depth of approximately 0.1 to 0.25 meters. Rips were spaced an average of 5 meters apart. 1512 acres, or 22%, of the watershed was ripped in November and December of 2001. Storm water monitoring commenced in 1997 and continued through the winter of 2005-2006.

Statistical Procedure: Erosion and runoff were evaluated as functions of precipitation. In order to discount the possibility that observed differences between the two periods were due to precipitation, cumulative and maximum rainfall amounts per storm event were compared between the pre and post BMP periods using a non-parametric Wilcoxon statistic (Ott 1992). This test was chosen over the more familiar students-t test because precipitation data did not fit a normal (Poisson) distribution. Following the examination of precipitation, comparisons of standardized response variables between the two periods were carried out. The measured response variables, due to land management BMPs, included: runoff volume, TSS concentration, and total sediment load as TSS entrained per storm event. All response variables were standardized by precipitation amount and intensity to account for any measured effects due to precipitation rather than the BMPs treatment. A total of 29 pre BMP events and 22 post BMP events were compared for this analysis. All statistical calculations were performed using Statistical Analysis System's JMP 5.0 software (SAS Inst., Cary, N.C.).

RESULTS

Wilcoxon (Rank Sums) results for cumulative precipitation per event, maximum precipitation per hour per event, and response variables standardized by cumulative precipitation per storm event and by maximum precipitation per hour per storm event are presented in Table 1. Precipitation amounts and intensities were not statistically different between the pre and post BMP periods (Prob> Z = 0.8195 and 0.7826 respectively). However, all standardized response variables were significantly different between the two periods (Prob< Z = 0.0003 or better). Means were calculated for all response variables and the percentage change was determined between the two periods. Results are shown in Table 2. Cumulative precipitation was plotted against runoff depth for the pre and post BMP periods (Figure 4). A noticeable difference between the two periods is expressed. Similarly, maximum stream flow was plotted against total suspended solids (Figure 5). The mean values for both maximum stream flow and total suspended solids were reduced between the pre and post BMP periods.

DISCUSSION

Erosion of the Shoal Creek watershed was reduced more than ninety percent between the pre and post BMP periods as a result of installing 211 gully plug dams within eroding gully channels and deep contour ripping 22% of the area. There was no statistical difference in cumulative precipitation or maximum precipitation per hour between the two monitoring periods indicating that the observed differences were not due simply to weather patterns. However, all standardized response variables were statistically different between the pre and post BMP periods (Table 1). These data indicate that measured differences were due directly to BMP effect. Mean runoff was reduced 61%, mean TSS was reduced 70%, and mean sediment load was reduced 91% between pre and post BMP periods (Table 2).

Mechanisms involved in these reductions are physical in nature. Intercepting storm water runoff by MT (contour ripping) reduces runoff volume by increasing soil infiltration. The mass of entrained constituents lost from the watershed was subsequently decreased as less water volume was discharged per storm event. Figure 4 demonstrates that runoff volumes were reduced between the two treatment periods, in response to precipitation. The result is statistically inferred as a result of BMP implementation. Slowing storm water runoff using MAS (gully plugging) in eroding channels decreases the flow energy reducing channel erosion and allowing suspended sediment to settle. This lowers the sediment concentration in the remaining flow and is evident in Figure 5 which illustrates lowered sediment concentration (mg/L) associated with peak flow energies (m3/s) per storm event for the pre and post BMP implementation periods. Lower energy in storm flows when combined with lower sediment concentrations ultimately results in significantly reduced sediment loads being lost from the training area (Table 2). The management practices reduced both runoff energies and volumes which in turn reduced erosion and subsequent sedimentation of local waterbodies. Water quality and quantity monitoring proved to be useful for evaluating BMP effectiveness. Based on these results, we can highly recommend the use of MT and MAS to reduce storm water runoff and associated erosion.

It should be noted that the effectiveness of these BMPs is temporary. Contour rips will eventually settle leading to reduced storm water infiltration and increased runoff. NRCS estimates that MT (contour ripping) effectiveness will last between 5-7 years depending upon weather conditions and military activity. Similarly, gullies containing MAS will fill in with deposited sediment leading to eventual overtopping and new gully formation. No estimate yet exists regarding MT or MAS life expectancy; however, as BREC continues to monitor storm runoff and sediment losses from the Shoal Creek watershed this issue will be addressed. Over time we expect to track the reduction of BMP effectiveness evident as increased storm flows and sediment loss. Finally, the individual BMP effect cannot be separated within the study confines. The primary function of Fort Hood training areas is military training and conducting research is secondary. BREC and cooperating partners must work within these constraints.

CONCLUSIONS

Water quality data analysis allowed BREC staff to determine BMP effectiveness and give Fort Hood land managers a tool to justify BMP costs and for tracking training area conditions. The ongoing assessment of BMP performance will help make decisions as to when to add new or re-implement older BMPs. A successful program to sustain usable training areas should adopt the idea that BMPs are not one-time endeavors but rather an ongoing process. Training lands will not sustain themselves when subjected to the constant pressures of military maneuver activities. Controlling storm water runoff is the key to reducing water mediated erosion. This study demonstrates that use of MT (contour ripping) and MAS (gully plugging) to control water mediated erosion is highly effective during the first three years following installation. Continued water quality monitoring will help Fort Hood land managers determine when BMPs begin to lose effectiveness and when to re-apply the treatment.

Acknowledgments: The authors would like to thank Mr.'s Jerry Paruzinski, Don Jones, and Chris Miller of the Fort Hood ITAM staff for their support, Mr.'s Fred Schrank, Jeff Goodwin, and Robert Ziehr, of the NRCS for their field expertise, and Dr. Joaquin Sanabria for his help with the statistical analysis.

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Table 1. Shoal Creek area statistics and Best Management Plans (BMP) implementation dates

Description	Value or Dates
Watershed area (Ha)	2235
Eroded gully system (linear, Km)	63
Number of MAS installed, per Km	211, 3.3
Area of contour ripping (Ha), percent	578, 22
Dates of MAS installation	March 3, 2002 – April 6, 2002
Dates of contour ripping	June 12, 2002 – November 15, 2002
Pre BMP period	October, 30, 1997 – November 15, 2002
Post BMP period	November 15, 2002- December 31, 2005

Table 2. Wilcoxon rank sums results, oneway analyses of response variables per event by period (pre vs. post BMP), two sample tests, with normal approximation. Runoff, total suspended solids (TSS) concentration, and sediment load normalized by cumulative and maximum precipitation.

Variable	Z	Prob>[Z]
Cumulative Precipitation	0.228	0.8195
Runoff / Cumulative Precipitation	4.857	<0.0001
TSS concentration / Cumulative Precipitation	3.585	<0.0003
Sediment load / Cumulative Precipitation	6.350	<0.0001
Max Precipitation per hour	0.276	0.7826
Runoff / Max Precipitation per hour	4.738	<0.0001
TSS concentration / Max Precipitation per hour	4.221	<0.0001
Sediment load / Max Precipitation per hour	6.306	<0.0003

Table 3. Response variable means and percent change between pre and post BMP periods

Response Variable	Pre BMP	Post BMP	% Difference
Mean Runoff (mm)	15.48	5.97	61
Mean Total Suspended Solids (mg/L)	6668	1392	79
Mean Sediment load (Mg)	2049	192	91

Article: Evaluating land management practices using multi-year stormwater data

Figure 1. Aerial view of Mechanical Treatment (MT), soil ripping on the contour.

Article: Evaluating land management practices using multi-year stormwater data

Figure 2. Maneuver Access Structures (MAS), stair-step installation and water ponding.

Article: Evaluating land management practices using multi-year stormwater data

Figure 3. Gauging station schematic

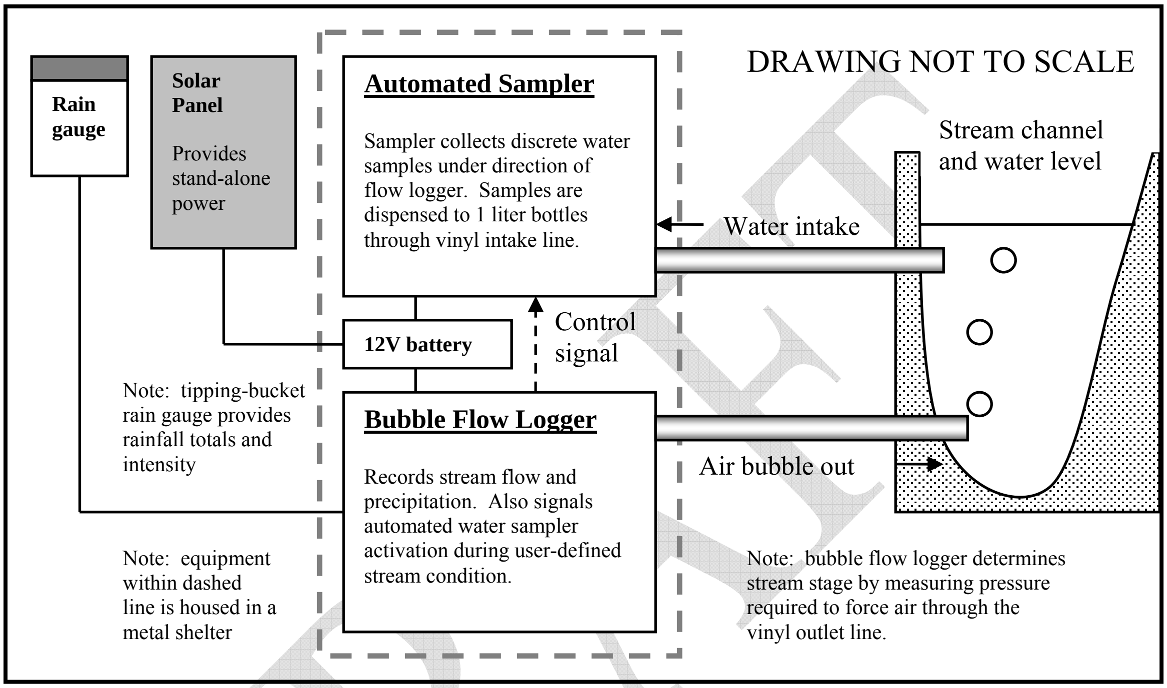

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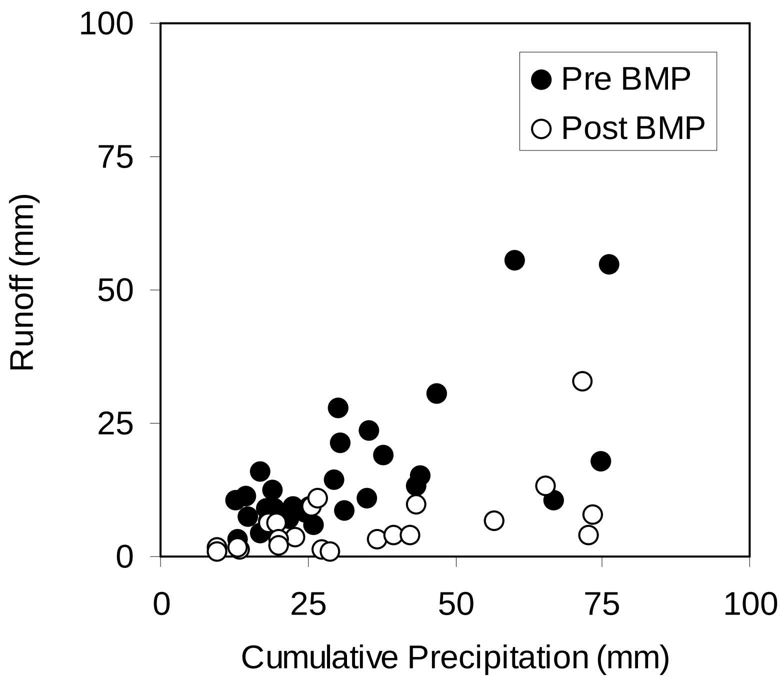
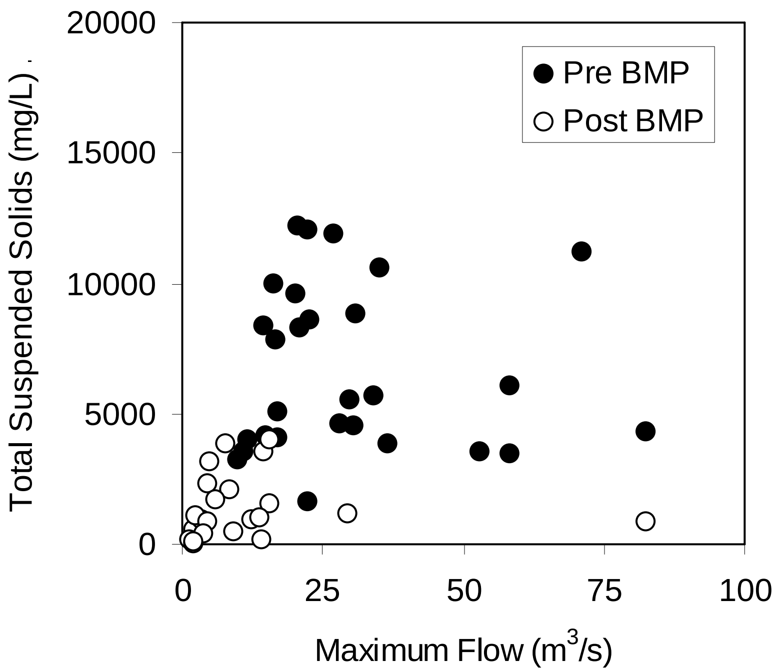
Figure 4. Reduction in storm water runoff expressed as cumulative precipitation versus storm water runoff for individual storm events between pre and post BMP periods.



Article: Evaluating land management practices using multi-year stormwater data

Figure 5. Storm flow energy and entrained sediment load expressed as maximum storm flow per event versus total suspended solids concentration between pre and post BMP periods.



Appendix B – Compost Soil Amendment Research Results – Fort Hood

RANGE REVEGETATION PILOT PROJECT, FORT HOOD, TEXAS

FY-2006 Status Report

Project Leaders
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Texas Agricultural Experiment Station
Texas Water Resources Institute
Blackland Research and Extension Center

In cooperation with
U.S. Department of Agriculture
Natural Resources Conservation Service
And
U.S. Department of the Army

November 2006

Compost Soil Amendment

Multiple demonstration and research programs have been implemented on Ft. Hood training lands to evaluate the potential and efficacy of composted dairy manure for restoration of military training lands. Initial focuses for the program centered on determining the needs and logistics for transporting and applying materials on the dynamic terrain posed by military training lands. Further studies focused on determining rates of compost that optimize nutrient availability while minimizing water quality concerns. The most recent set of replicated studies have further evaluated water quality impacts by rate and a comparison of compost response to that of commercial, inorganic, fertilizer and no treatment. The vegetation and water quality results of the demonstration and research studies are contained within this section of the report in order of implementation.

Training Area 51 (Georgetown & Manning Mtn. Road) Demonstration Sites (~5, 8 & 10 tons/ac, respectively)

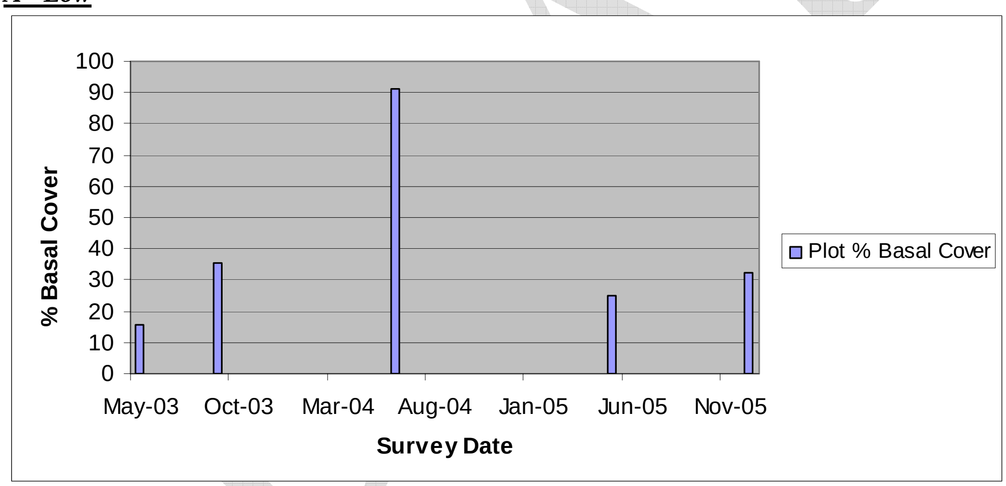
Plant Basal Cover

The original demonstration site was initiated in May of 2003 to establish that it was logistically feasible to transport and apply composted dairy manure on Fort Hood's primary training maneuver lands. Due to timing and circumstances, it was not possible to obtain baseline vegetation data on these sites; thus, results indicated illustrate the change in plant basal cover and bareground over time and do not make comparisons across treatments. This site continues to be monitored as a demonstration site to increase anecdotal evidence of the long-term impacts of restoration on heavily trained areas. From the time of establishment until winter 2005, this site was not heavily disturbed by military training. Subsequently, it has incurred significant training activities.

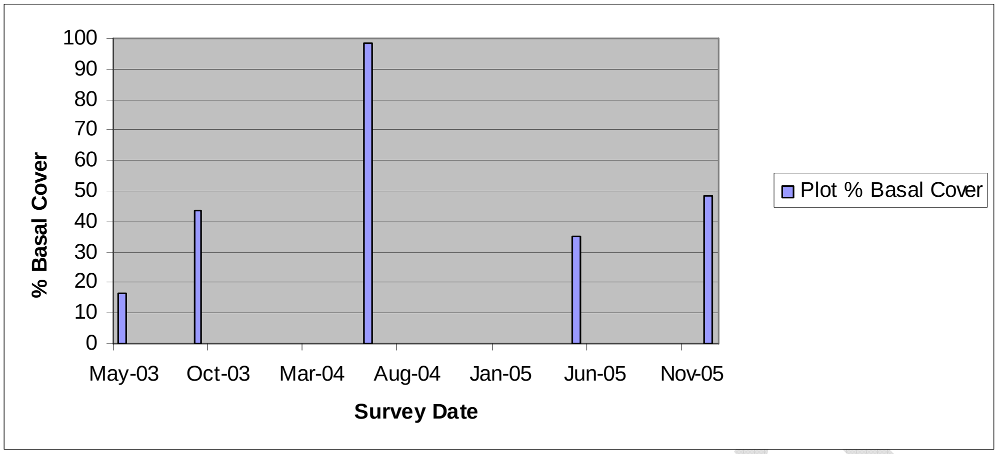
The data (Figure 1a,b,c) seem to indicate, albeit circumstantial, that there was an increase in vegetation taking place between treatment time (May 2003) and return training time (January 2005). Post-training in winter 2005, it appears that the system has settled back to a level similar to 5-months post-treatment. Indications are that without significant training, the system had the potential to increase vegetation cover and reduce bareground. However, it appears heavy training post-treatment will revert the system to a stage similar to 5-months post-treatment for all treatments. Anecdotally, we feel that this starts to place parameters on the efficacy time of the treatment at or about 1.5-2 years, without heavy training. Further monitoring on subsequent sites will expand upon this indication.

Figure 1 a, b, c. Comparisons of % plant basal cover over time for low, moderate and heavy treatments (~5, 8 & 10 tons/ac, respectively) on Demonstration Site established in May 2003

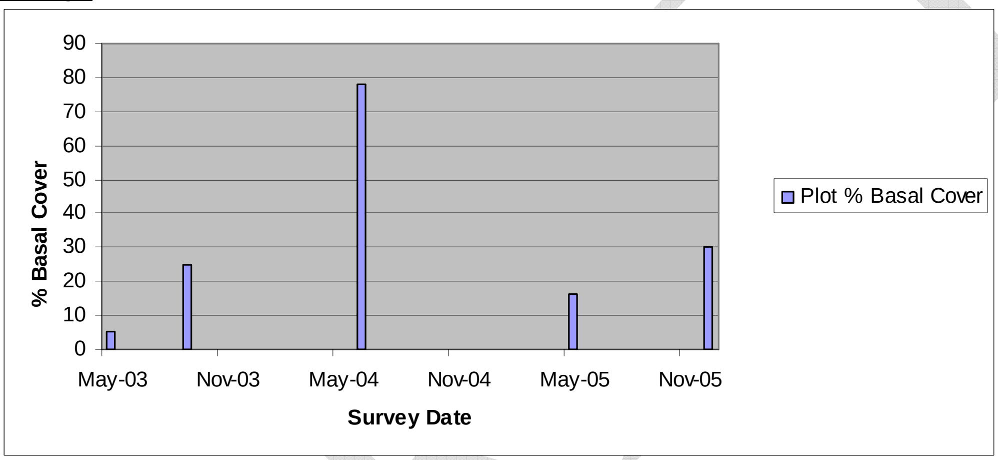
A - Low



B - Moderate



C - High



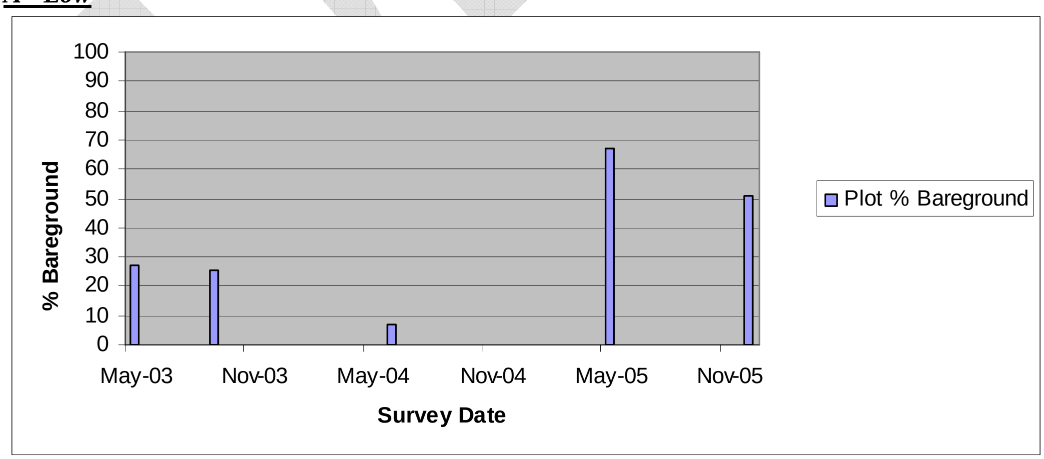
Bareground

Bareground (Figure 2a & b) has varied considerably over the time of these demonstration sites (Figure 3a,b,c). Initially bareground was relatively uniform across all treatment plots with it being slightly higher on the heavy treatment plot. It decreased considerably between the initial treatment and the point at which heavy training was resumed on the plots. The apparent discrepancy between plant basal cover and bareground is explained by a shift in the amount of litter on the soil surface. Due to site preparation, there were high levels of plant litter on all plots immediately post-treatment (at the time of initial vegetation data collection). As the site recovered, litter was greatly reduced and replaced by plant basal cover. Upon the initiation of training maneuvers, bareground became the dominant ground cover class and has remained so through subsequent collections periods. This would indicate that site preparation techniques, leveling and disking promote litter accumulation; whereas, military maneuver training promotes increases in bareground. Again, these data are not compared to baseline or control sites, so all suppositions are anecdotal, but further analysis of later experimental plots may reveal this more thoroughly.

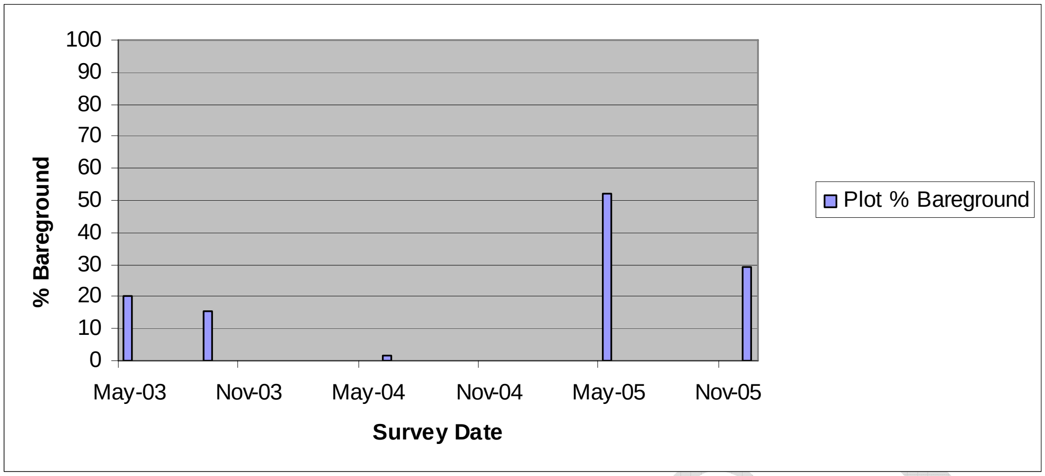
Figure 2a. Post-Site Preparation **2b**. 1-year Post-Treatment

Figure 3 a, b, c. Comparison of % bareground over time for low, moderate and heavy treatments (~5, 8 & 10 tons/ac, respectively) on Demonstration Site established in May 2003

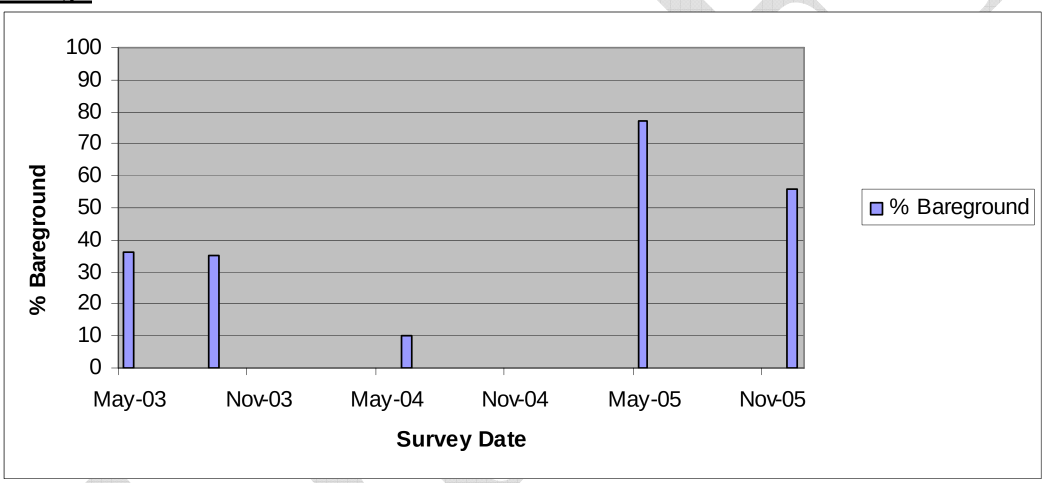
A - Low



B - Moderate



C - High



Training Area 44 (Elijah Road)
Bermed Watershed Replications (0,15,30,60,90 cy/ac, respectively)

Materials & Methods

The original design of the experiment was conducted as a complete block randomized with five compost rates across three blocks. Due to unforeseen circumstances, Block 1 received duplicate application of compost, thus confounding data from the block. Final analysis was carried on Blocks 2 & 3. The point-intercept method of determining ground cover was employed to provide a conservative estimate of cover categories. Ground cover categories were split into "plant," "bareground," "litter," and "rock." Intercept with a "plant on a transect prompted a recording of the species for analysis based upon species composition. Current analysis focuses on impacts of compost on ground cover categories based on the following multivariate model.

Model used for the multivariate repeated measures analysis of variance (Srivastava & Carter, 1983).

$Y_{t1}\ Y_{t2}\ Y_{t3}\ Y_{t4} = \beta_1 + \tau_j + \delta_{ijk} + \varepsilon_{ij}$

Where:

$Y_{t1}\ Y_{t2}\ Y_{t3}\ Y_{t4}$ = ground cover variables measured over four times

β_1 = block effect, i= 2,3

τ_j = compost rate effect, j=0,15,30,60,90 yd^3/ac

δ_{ijk} = sampling error associated with variability between sections k (k=1,2,3) within a plot receiving the i^{th} compost rate on the j^{th} block.

ε_{ij} = experimental error

Hypotheses comparing compost-rate, time and compost-rate*time are tested with the experimental error. The purpose of including sampling error term in the model is to reduce the magnitude of the experimental error and increase the power of the hypothesis tests.

Results & Discussion

Tabular results of multivariate analysis of variance is presented in Table 1.

<u>Annual Forbs</u>

The interaction Treatment*Time is highly significant at 0.001. During the second year the 90 cy/ac rate indicates a significantly higher annual forb cover class compared to any of the other rates, and also showed a steep increasing trend (Figure 4). The 60, 30, and 15 cy/ac rates had decreasing trends in annual forb cover class during the second year.

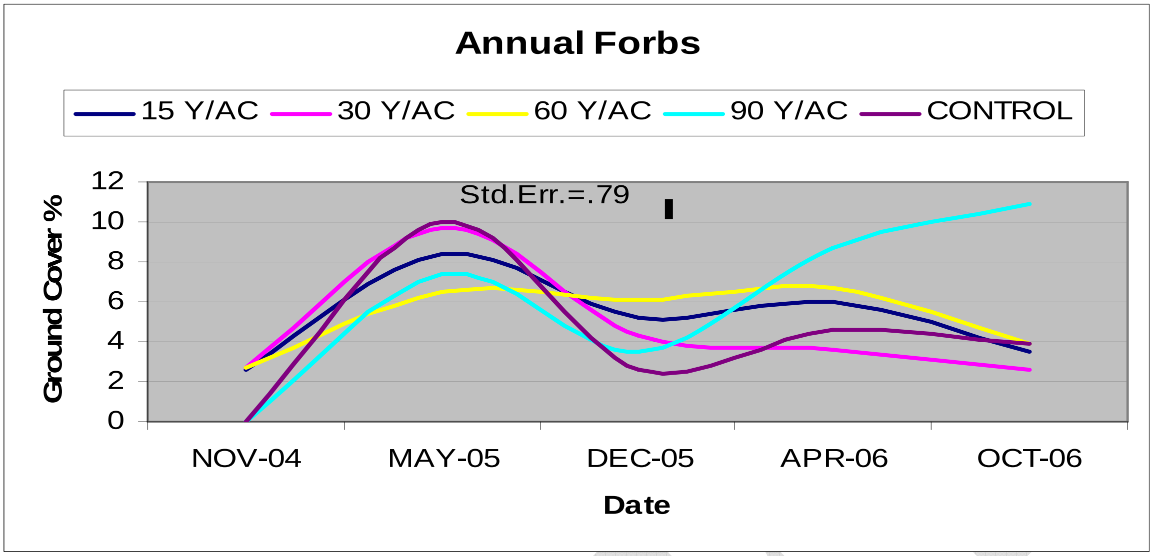
Under normal circumstances, annual forbs would not be considered desirable ground cover in efforts to minimize soil erosion; however, in severe situations (immediately post-training), this growth form may be the only plant cover suited to the situation. Over a two year period, the high rate of compost can have a substantial effect in the maintenance of an annual forb crop while more desirable species are reestablished; however, at the high rates, compost would pose potential water quality problems that would minimize any vegetation gain.

Table 1. Multivariate analysis of variance results for compost rate study.

Source of Variation	Wilk's Lambda Value	F	Numerator D.F.	Denominator D.F.	Pr > F
Annual Forbs					
Time	0.0717	54.96	4	17	<.0001
Time * Compost Rate	0.2760	1.72	16	52.573	0.0712
Compost Rate [1]	-----------	4.18	4	20	0.0128
Annual Grasses					
Time	0.3825	15.33	2	19	0.001
Time * Compost Rate	0.5747	1.52	8	38	0.1844
Compost Rate [1]	-----------	2.47	4	20	0.0776
Perennial Forbs					
Time	0.1705	20.67	4	17	<.0001
Time * Compost Rate	0.2213	2.10	16	52.573	0.0228
Compost Rate [1]	-----------	5.91	4	20	0.0026
Perennial Grasses					
Time	0.0484	83.40	4	17	<0.0001
Time * Compost Rate	0.2040	2.24	16	52.573	0.014
Compost Rate [1]	-----------	1.75	4	20	0.1796
Bare Ground					
Time	0.1580	22.64	4	17	<.0001
Time * Compost Rate	0.2304	2.03	16	52.573	0.028
Compost Rate [1]	-----------	2.81	4	20	2.81

[1] This factor was randomized and evaluated with a conventional ANOVA hypothesis test.

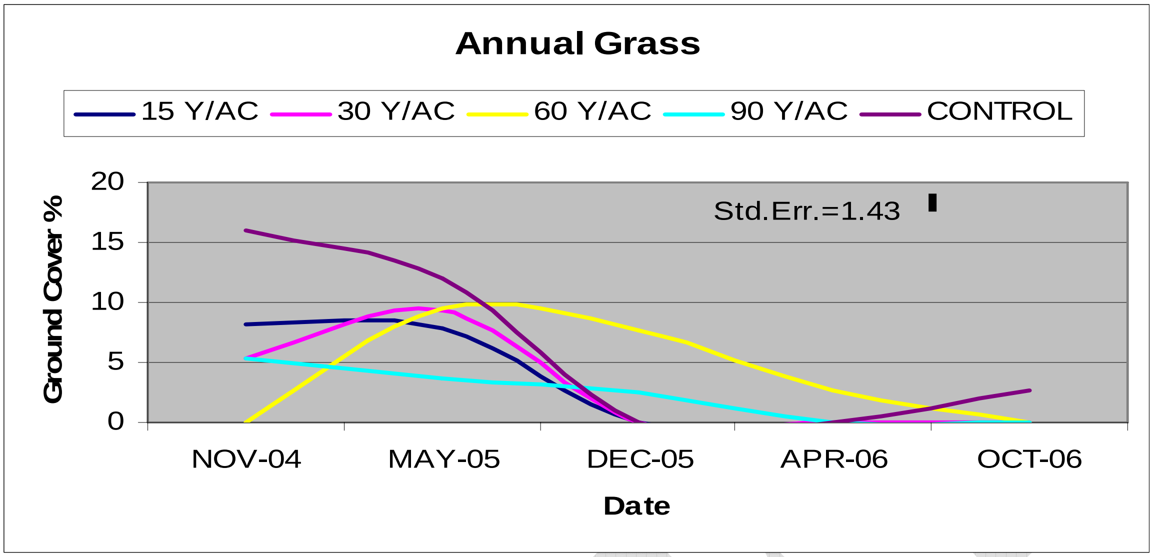
Figure 4. Results of multivariate analysis for compost rate impacts on annual forbs.



<u>Annual Grasses</u>

The effects of time and treatment are significant at levels 0.001 and 0.078 respectively. The time is significant due to seasonal variation. The 60 cy/ac rate had significantly higher annual grass ground cover at the end of the first year and beginning of the second, but the ground cover dropped to zero by the end of the second year (Figure 5). For this site, annual grasses do not play a significant roll or make-up for the plant community.

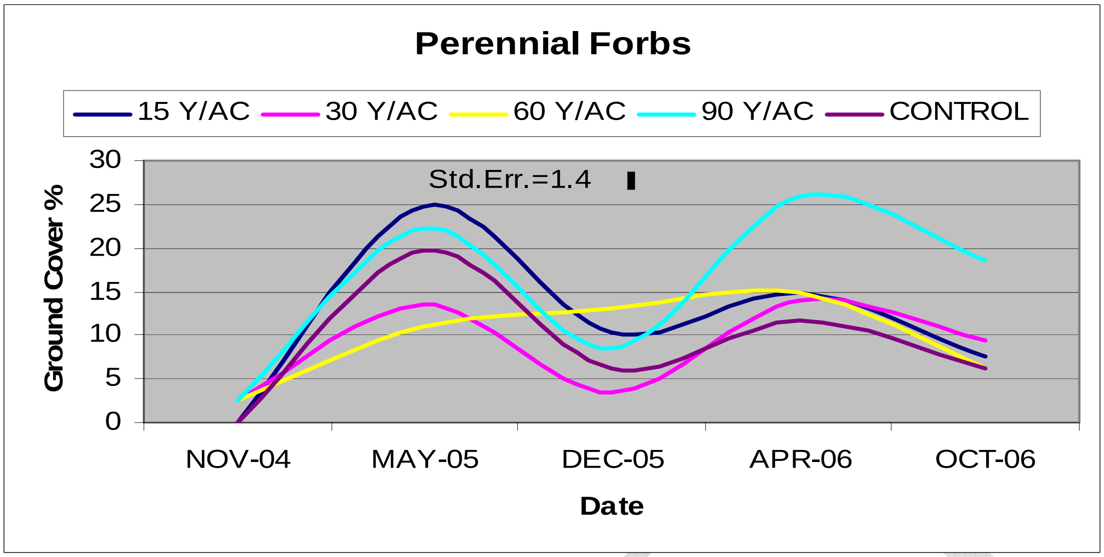
Figure 5. Results of multivariate analysis for compost rate impacts on perennial forbs.



Perennial Forbs

The Treatment*Time interaction was significant at 0.023 level. This suggests that the five rates have different time patterns. The 90 cy/ac compost rate is showing a highly significant perennial forb cover class than any other compost rate in the second year (Figure 6). The residual effect of compost with the retention of nutrients in the soil provides the time required to establish a healthy perennial forb component within the community. The 30cy/ac compost rate also presented a significantly higher perennial forb cover class than the control by the second year of data collection. Only the 90 cy/ac had a perennial forb component with an upward trend during the two years; however, recommending 90 cy/ac as a compost rate for revegetation will elevate water quality issues.

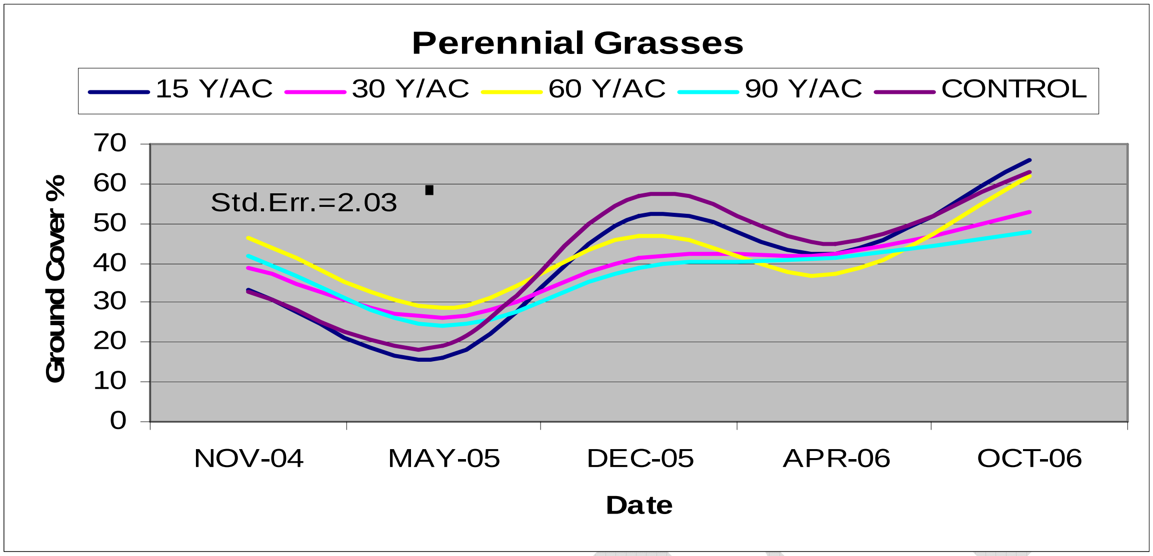
Figure 6. Results of multivariate analysis for compost rate impacts on perennial forbs.



Perennial Grasses

The Treatment*Time effect was significant at 0.014 level. That means that all the five compost rates present a seasonal pattern, but that pattern is not the same for all treatments. The seasonal changes in perennial grass cover are not parallel. All the rates, including the control have shown and increasing trend of perennial grasses over the two years of data collection. After two years, the 15 and 30 yd^3/acre present significantly higher perennial grass cover compared to the 60 and 90 yd^3/acre treatments at the end of the second year, but are not significantly different from the control plot. The data does not show evidences of beneficial effects on perennial grasses since the control.

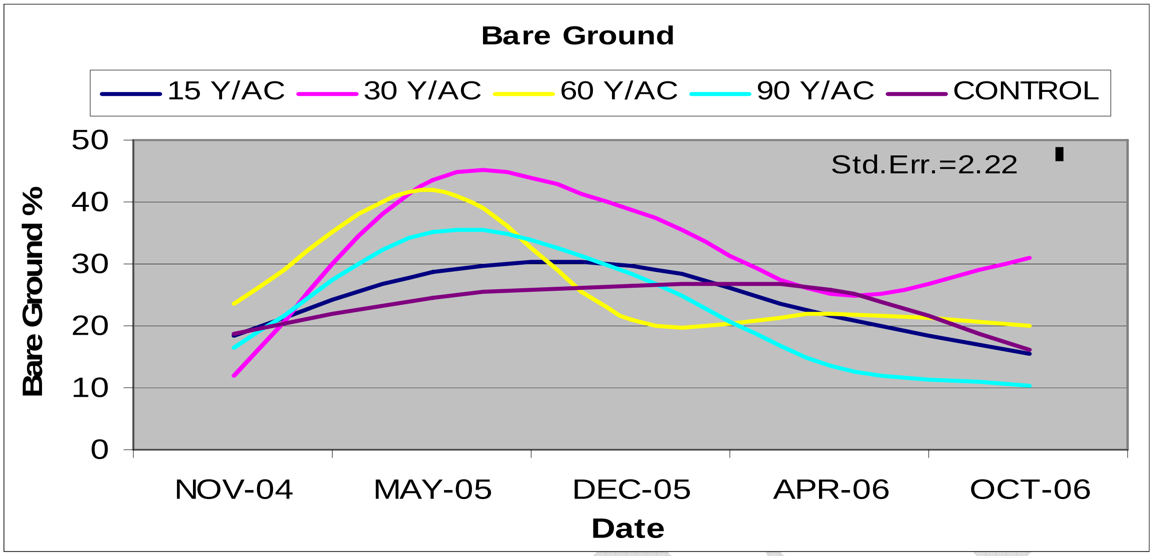
Figure 7. Results of multivariate analysis for compost rate impacts on perennial grasses.



<u>Bareground</u>

The interaction Treatment*Time is highly significant at 0.001. The time pattern is different for most of the compost rates. The lowest bare ground by the second year of the experiment is associated with the 90 cy/ac, this rate also showed the steepest decrease of bareground (Figure 8). The apparent revegetation benefits of using 90 cy/ac could result in water quality problems.

Figure 8. Results of multivariate analysis for compost rate impacts on bareground.



Experimental Conclusions

Based upon this experiment, we conclude that there is little to no evidence that high rates of compost, in excess of 30 yd^3/acre, are justified. There is no evidence that erosion control growth forms, perennial grasses or forbs, are significantly influenced by the higher rates. Further, the use of such rates per acre would significantly increase the cost of treatment for large scale land application.

Training Area 43
Non-Randomized Comparison between compost and commercial fertilizer

This experiment was conducted in a factorial arrangement of three fertilization treatments (compost, fertilizer, control) by two seed treatments (seed/no-seed) on five blocks. The six treatments were not randomized within blocks. The lack of randomization did not allow the use of conventional analysis of variance; instead, a multivariate analysis of variance, similar to the one employed for the repeated measures analysis in the previous section, was used. Each plot was separated into three sections to estimate sampling error. The following ANOVA model was employed:

$Y_{k1,11}\ Y_{k2,11}\ Y_{k3,11}\ Y_{k1,12}\ Y_{k2,12}\ Y_{k3,12} = Di + \beta_j(D_i) + F_k + S_l + FS_{kl} + DF_{ik} + DS_{il} + DFS_{ikl} + \delta_{ijkl} + \varepsilon_{ijkl}$

Where:

Y = Percent ground cover, k1, k2, k3: compost, fertilizer, control respectively
11 & 12: seed, no-seed respectively

D_i = Date effect, 1: Aug-05, Dec-05, Apr-06

$B_j(D_i)$ = blocks nested in dates, j: 1,2,3,4,5

F_k = fertilization treatment

S_l = seed treatment effect

δ_{ijkl} = sampling error

ε_{ijkl} = experimental error

Results & Discussions

Tabular results of multivariate analysis of variance is presented in Table 2.

Annual Forbs

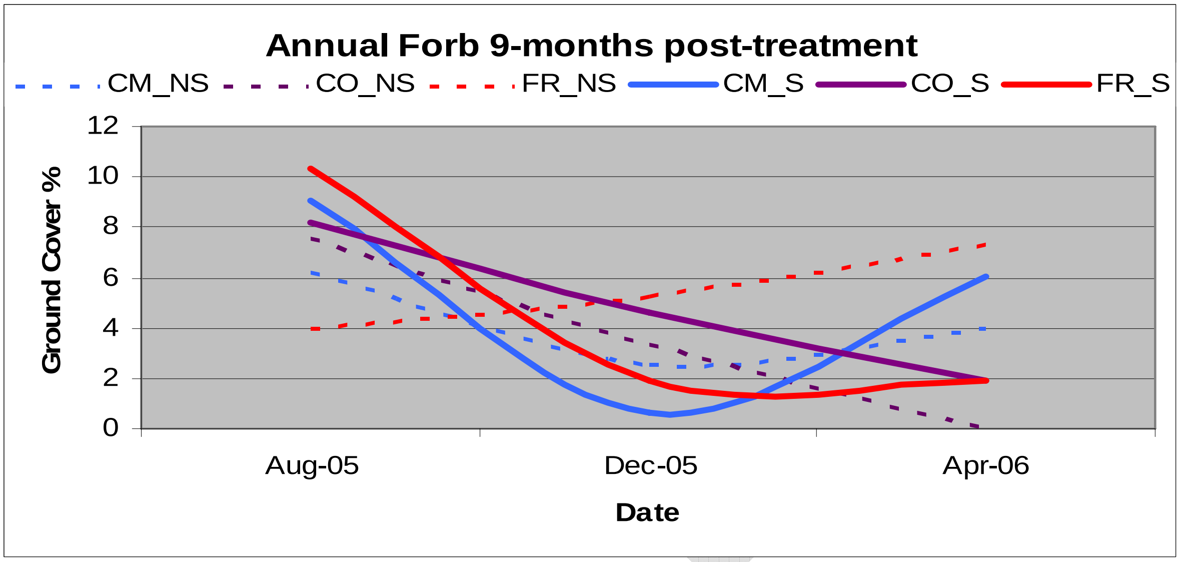
The interaction Fertilizer Treatment * Seed * Time is significant at the 0.065 level. Graphic results of annual forb impacts are found in Figure 9 a&b. Plots receiving a seed treatment showed a decrease in the annual forb component of the plant community. On a percentage basis, there is a tendency in the no seed treatments for a higher annual forb ground cover. In combination, these two results would indicate that the use of NRCS recommended seed mix, with its composition of native/perennial species, had an effect on the amount of annual forb production in the treatment plots (establishment of perennial systems reduced the annual crop). Further supporting the benefit of seeding is the tendency for annual forb ground cover to increase toward the end of the 14-month post-treatment period for all treatments not receiving a seed treatment. The compost-seed treatment shows mainly seasonal variability, and at the end of the 14-month post-treatment time there was an indication of some decline in annual forb ground cover. At the end of 14-months, compost and control plots not receiving a seed treatment have significantly higher annual forb production than those receiving seed treatments. The lack of significance for the fertilizer-no seed treatment is attributed to the loss of nutrient efficacy from commercial fertilizers 14-months post-treatment.

Table 2. Multivariate analysis of variance results for fertility comparison study.

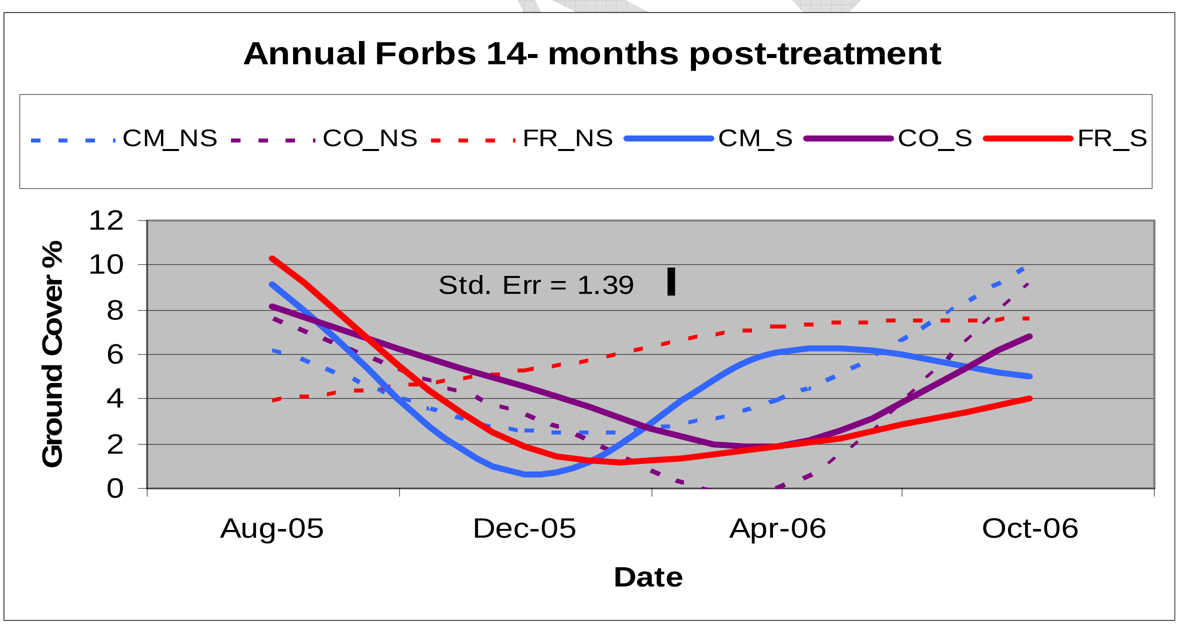
Source of Variation	Wilk's Lambda Value	F	Numerator D.F.	Denominator D.F.	Pr > F
Annual Forbs					
F.Treatment	0.9981	0.03	2	37	0.9669
Seed	0.9744	1.00	1	38	0.3244
F.Treatment*Seed	0.9603	0.76	2	37	0.4730
F.Treatment*Time	0.8760	0.84	6	74	0.6404
Seed*Time	0.7693	3.80	3	38	0.0178
F.Treatment*Seed*Time	0.7319	2.08	6	74	0.0654
Annual Grasses					
F.Treatment	0.9525	0.25	2	10	0.7843
Seed	0.9290	0.84	1	11	0.3790
F.Treatment*Seed	0.9242	0.41	2	10	0.6745
F.Treatment*Time	0.4827	2.20	4	20	0.1062
Seed*Time	0.8493	0.98	2	11	0.4074
F.Treatment*Seed*Time	0.2049	6.04	4	20	0.0023
Perennial Forbs					
F.Treatment	0.9871	0.22	2	34	0.8020
Seed	0.9997	0.01	1	35	0.9266
F.Treatment*Seed	0.9605	0.70	2	34	0.5043
F.Treatment*Time	0.9504	0.29	6	68	0.9391
Seed*Time	0.7868	3.16	3	35	0.0366
F.Treatment*Seed*Time	0.8985	0.62	6	68	0.7113
Perennial Grasses					
F.Treatment	0.8558	3.45	2	41	0.0412
Seed	0.9365	2.84	1	42	0.0992
F.Treatment*Seed	0.9120	1.98	2	41	0.1515
F.Treatment*Time	0.9323	0.49	6	82	0.8162
Seed*Time	0.9185	1.24	3	42	0.3068
F.Treatment*Seed*Time	0.9260	0.54	6	82	0.7799
Bare ground					
F.Treatment	0.9947	0.11	2	40	0.8993
Seed	0.7198	15.96	1	41	0.0003
F.Treatment*Seed	0.9003	2.21	2	40	0.1224
F.Treatment*Time	0.8890	0.81	6	80	0.5668
Seed*Time	0.8637	2.16	3	41	0.1080
F.Treatment*Seed*Time	0.9395	0.42	6	80	0.8624

Figure 9 a&b. Results of multivariate analysis for fertility impacts on annual forbs 9- and 14- months post-treatment, respectively.

A



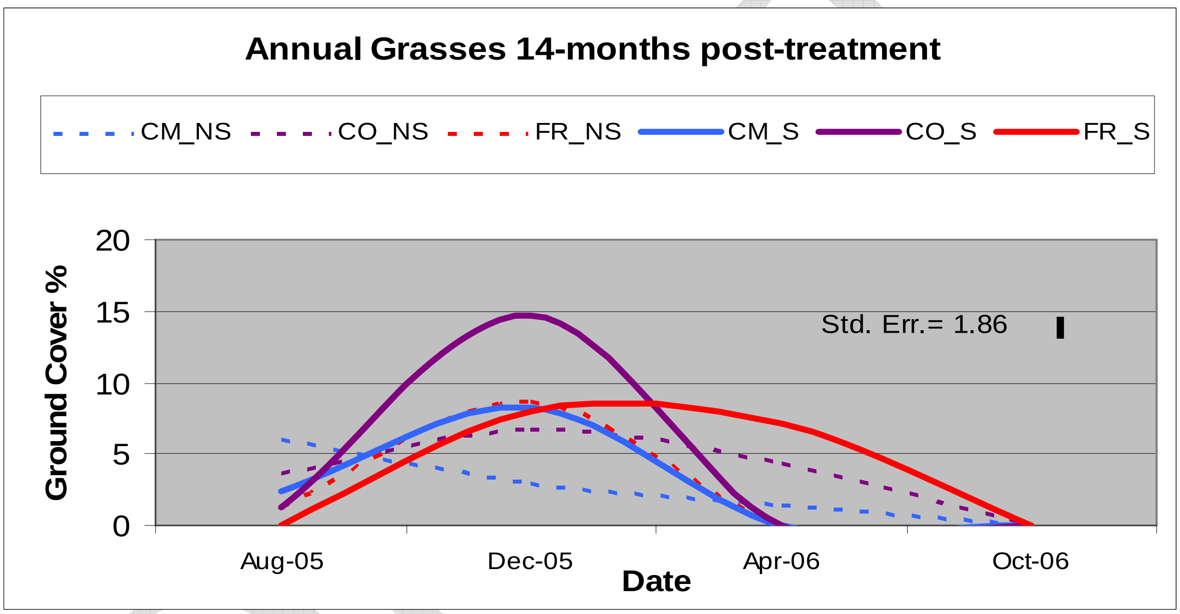
B



<u>Annual Grasses</u>

Annual grasses were not found in any treatment by the October, 2006 survey (Figure 10). The interaction Fertilizer Treatment*Seed*Time was significant at 0.0023 level. This anomaly is due to the interaction Fertilizer Treatment*Seed changing through time in different ways for at least two of the Fertilizer Treatment*Seed combinations. All treatment combinations ended in zero annual grass presence. The combinations compost-seed (CM_S), control-seed (CO_S), and fertilizer-no seed (FR_NS) ended with zero annual grass components in the community earlier (Apr-06) than the rest of combinations. Data shows no evidence of benefits for annual grasses from any of the fertilization-seed combinations. This site had a minimal annual grass population at the beginning of the trial.

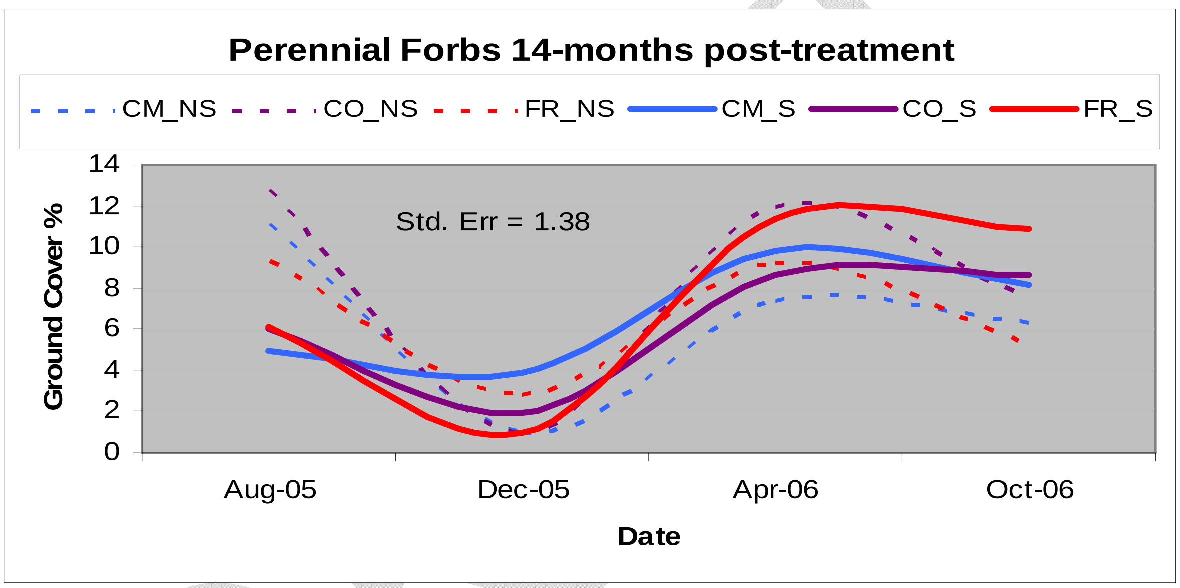
Figure 10. Results of multivariate analysis for fertility impacts on annual grasses 14- months post-treatment,.



Perennial Forbs

For the October 2006 analysis, perennial forbs showed significance only for the interaction "Seed*Time" at the 0.0366 level (Fig. 11). This indicates that the effects of seeding changes over time. In August 2005, the three treatments with seed presented significantly lower perennial forb ground cover than the treatments without seed. In December 2005, the Compost/Seed treatment had the highest ground cover of perennial forbs followed by the Fertilizer/No Seed treatment. However, perennial forb species represented within this analysis were made up primarily of naturally occurring diversity with no indication of perennial forb species included in the seed mix appearing in the data transects. In April 2006, all treatment plots showed increases in perennial forb composition, but none showed statistically significant increases. It is believed that the parabolic nature of the curve is an indication of naturally occurring variation within the system and little or no influence of fertility or seeding on the perennial forb component of the community.

Figure 11. Results of multivariate analysis for fertility impacts on perennial forbs 9- and 14- months post-treatment, respectively.

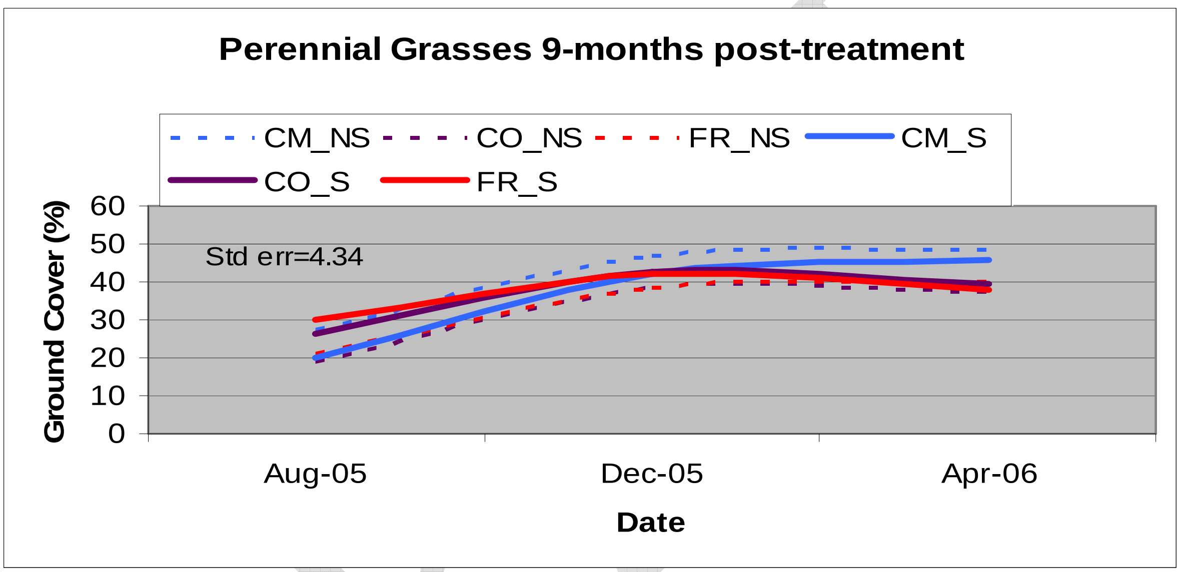


Perennial Grasses

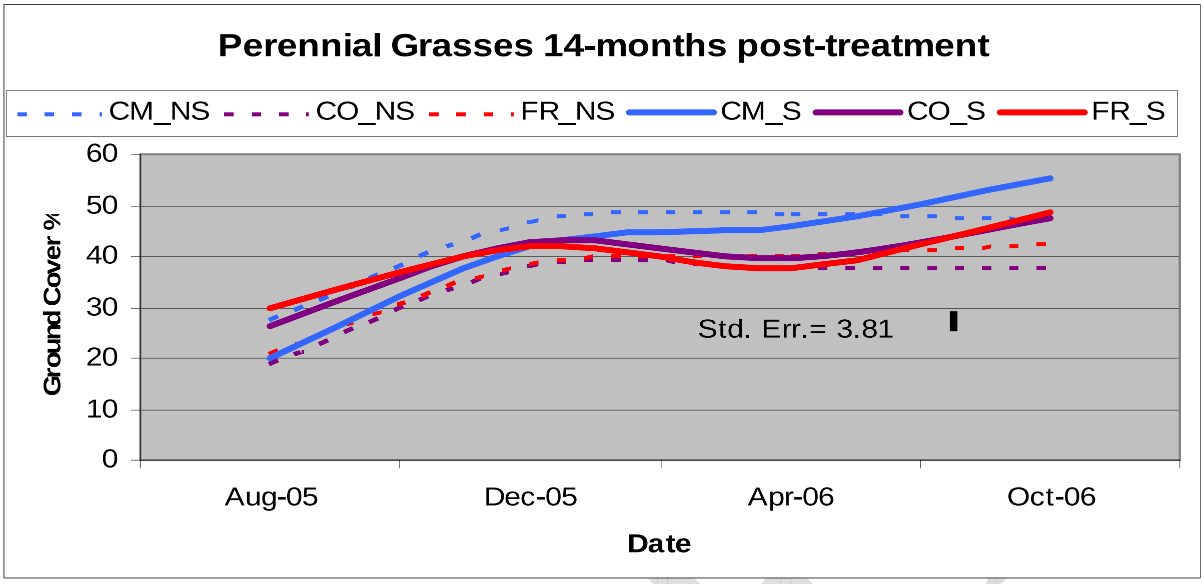
Seed effect and Fertilizer treatment effects are significant at 0.099 and 0.041 respectively for perennial grasses (Table 8; Figure 12 a&b). The significantly higher perennial grass cover of seeded treatments is clear at the end of the 14-month post-treatment data collection. The significantly higher perennial grass ground cover for the compost treatment in April and October 2006 compared to fertilizer and control treatments is the main reason for the significant difference between treatments. The three seeded treatments show increasing perennial grass cover trends from April to October 2006, and they suggest that may continue increasing instead of a seasonal cycle. In contrast, the non seeded treatment reached a maximum ground cover at 9-months post-treatment and remains flat for subsequent assessment periods. The consistent increase in perennial grasses treated with compost provides some indication that, for this experiment, compost may be showing a beneficial effect.

Figure 12 a&b. Results of multivariate analysis for fertility impacts on perennial grasses 9- and 14- months post-treatment, respectively.

A



B

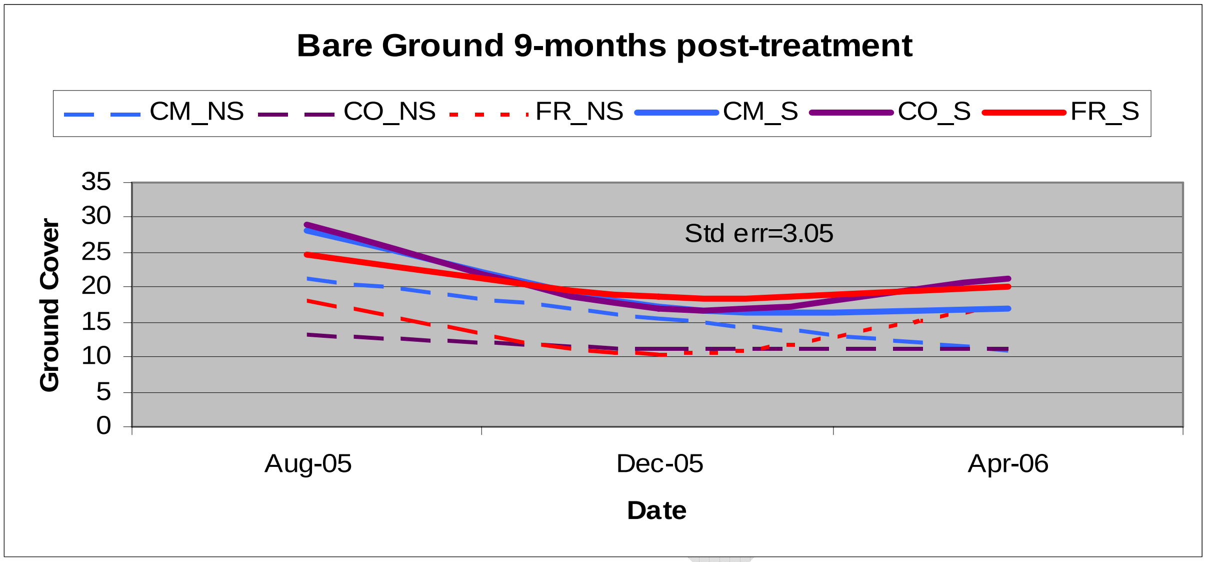


Bareground

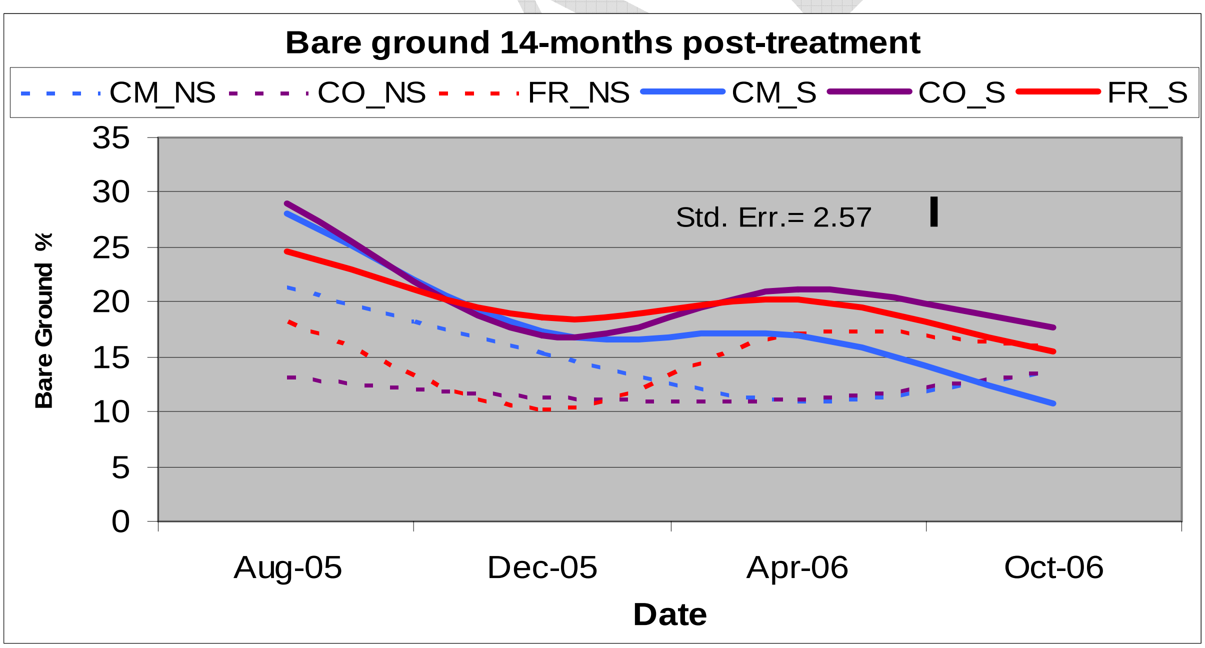
The effect of "Seed" shows a highly significant effect on percentage of bare ground at 0.003 (Figure 13 a&b). Ground percentage of seeded treatments was moderately higher for fertilizer- and control-seeded plots than non seeded treatments, but all seeded treatments show a continued downward trend for bare ground, especially during the second year. In comparison, the non-seeded plots all show upward or flat trends in the bareground cover class. The combination compost-seed (CM_S) had the highest bare ground reduction for the reporting time with a decrease from 28% to 11%. The October 2006 data point shows a significantly lower bareground percent than all other treatments. The slow progression of bareground decrease reflects the time necessary for the establishment of a healthy perennial grass stand with expanding basal crowns reducing open-space between plants.

Figure 13 a&b. Results of multivariate analysis for fertility impacts on bareground 9- and 14- months post-treatment, respectively.

A



B



Inclusion of Seed with Fertility Treatments

This section is currently being reanalyzed with Oct. 2006 data included. The following narrative does not include the Oct. 2006 data set and may change based upon further analysis.

Though not specifically designed to evaluate the additional benefits of inclusion of seed into the fertility treatments, this experiment has provided some useful secondary output that can be used in development of restoration practices for military training lands. It has been questioned as to the validity of including seed into restoration activities. Based upon the results from this experiment, seeding appears to be validated as a beneficial practice. However, this is a limited data set and further, more specified experimentation needs to be undertaken to fully expound on the practice of re-seeding. Nevertheless, the results do indicate some value of seeding as opposed to no-seed treatments.

Figure 14 illustrates the fact that little bluestem is consistently and significantly more prevalent in seeded treatments regardless of fertility treatments imposed. Little bluestem is a common native species found on Ft. Hood and provides a useful deterrence to the natural and accelerated erosion events. Secondly, it is a good surrogate supporting the benefits of perennial bunchgrasses to combat erosion processes. Increases in perennial grasses for Fort Hood vegetation communities should decrease the levels of sediment in overland flows leading to sedimentation in local streams and reservoirs. Further, Figure 15 shows an indication that seeded treatments demonstrate a continued downward trend in percent bareground as compared to non-seeded plots. This relationship is not currently statistically significant; however, continued assessment of this experiment should provide a more thorough understanding.

Figure14. Results of multivariate analysis for inclusion of seed in fertility analysis

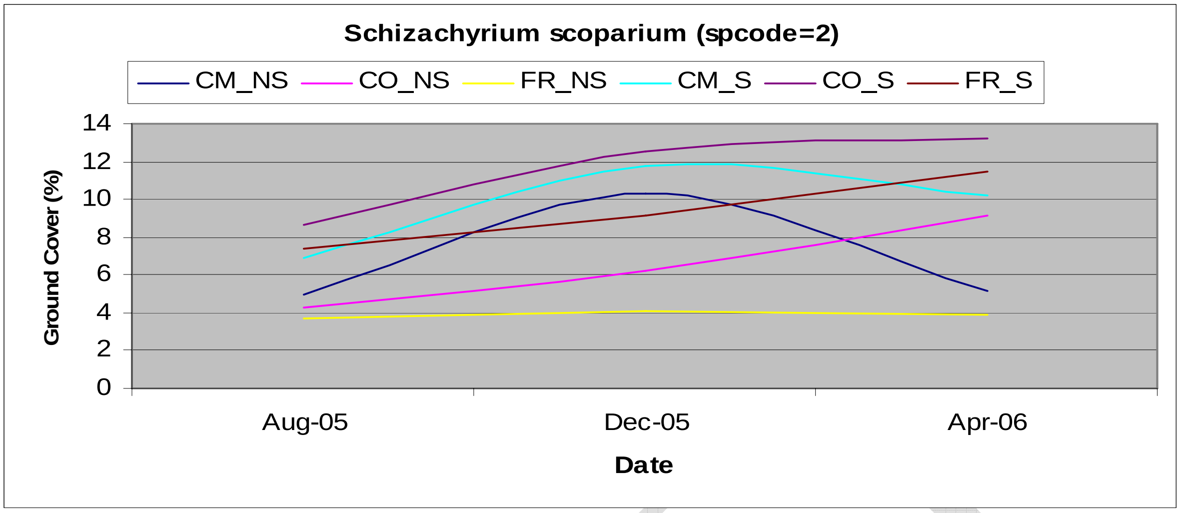
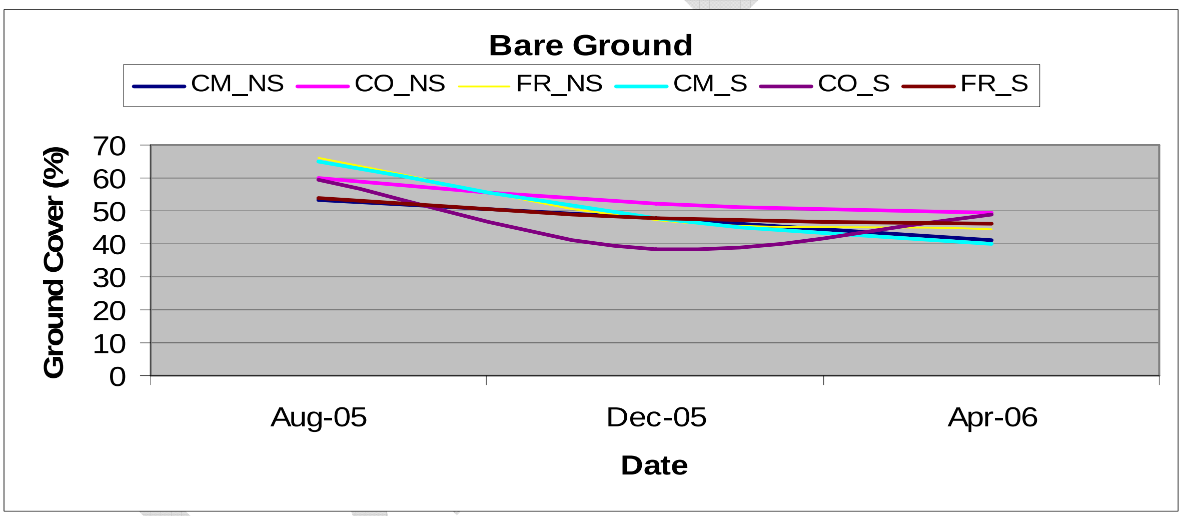


Figure 15. Results of multivariate analysis showing continued downward trend of bareground for seeded treatments compared to no-seed treatments.



Water Quality Results for Compost Program

Storm Runoff Nutrient Concentrations from Field Scale Compost Applications

Nutrient concentrations measured in storm runoff from field scale (over 50 acres) compost applications have not exceeded EPA regulated or recommended levels. The Fort Hood Revegetation Initiative aims to enhance seedling emergence, survival, and vegetative growth through fertility treatment applied as composted dairy manure. Long-term improved vegetation will protect Fort Hood's training areas from erosion and Lake Belton from sedimentation. Placing large scale compost applications requires thought and consideration. All composted manure applications have been located on up land areas that do not drain to streams leading directly to Lake Belton. The applications are thus buffered from Fort Hood streams by large riparian areas, small ponds, and or PL566 structures.

Concerns over nutrient loss in storm water runoff from these applications prompted the installation and operation of automated water sampling equipment down-slope to collect storm water runoff samples for analysis. A total of five monitoring stations have been installed and operated to determine if nutrient concentrations present in storm water runoff exceeds EPA regulated or suggested levels. Nitrate nitrogen ($N\text{-}NO_3$) concentrations are regulated in United States surface waters by the EPA and must not exceed 10 mg/L which is potentially toxic to humans. Orthophosphate phosphorus ($P\text{-}PO_4$) does not exhibit toxic effects and therefore is not regulated by EPA. Phosphorus eutrophication however leads to secondary biological effects that may impact water quality. Rough guidelines based on biological response in different regions have been developed for dissolved reactive phosphorus. These differ greatly but in general waters discharging into streams that do not lead to a lake should have $P\text{-}PO_4$ levels less than 0.1 mg/L. Waters discharging into a stream leading directly to a lake should have concentrations less than 0.05 mg/L, and waters discharging directly into a lake should have concentrations less than 0.025 mg/L.

To date, none of the monitoring stations placed downstream from large scale compost applications at Fort Hood have reported nutrient concentrations in storm water runoff exceeding EPA regulated or suggested levels for nitrate nitrogen or orthophosphate phosphorus (See figures 16-20, note that full scale represents EPA maximum regulated or generally recommended nutrient concentration for surface waters).

Figure 16. Nutrients in runoff from 75 acre demonstration (TA51)

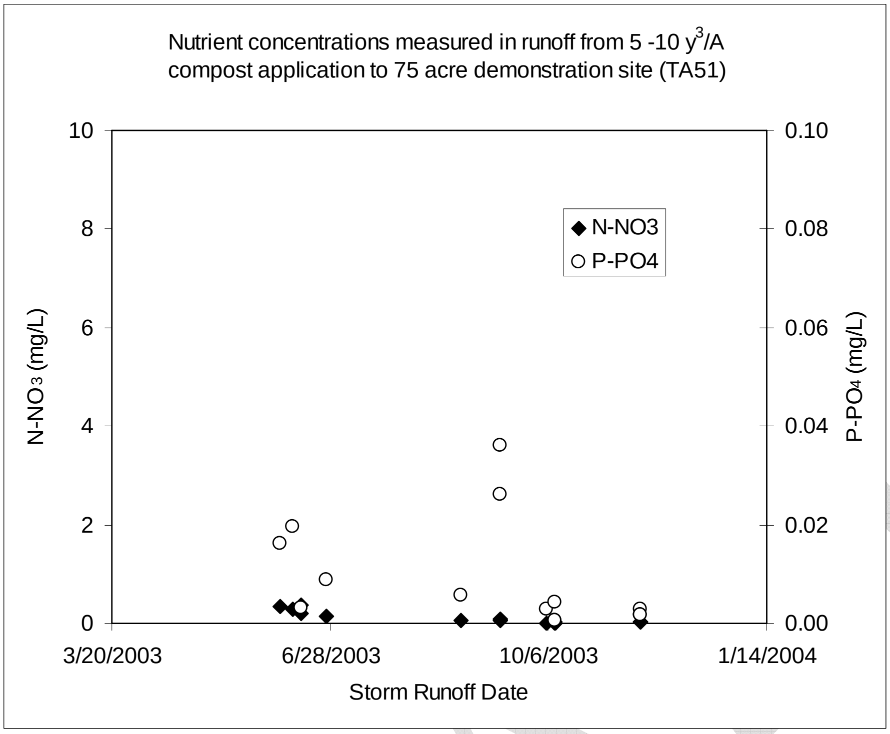


Figure17. Nutrients in runoff from 100 acre plot (TA51)

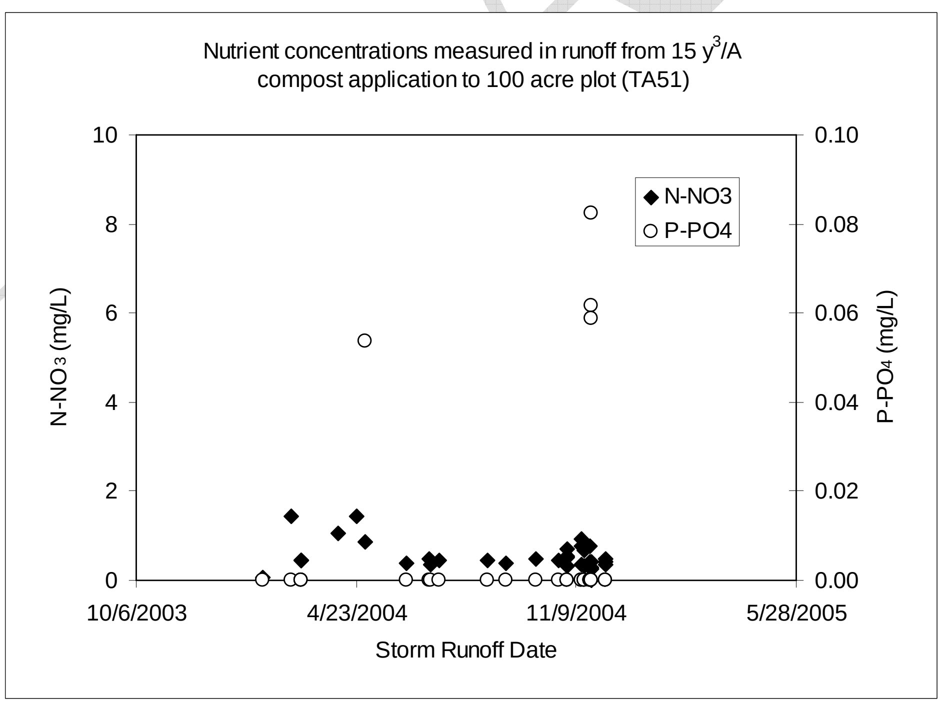


Figure 18. Nutrients in runoff from 75 acre plot (SCR66)

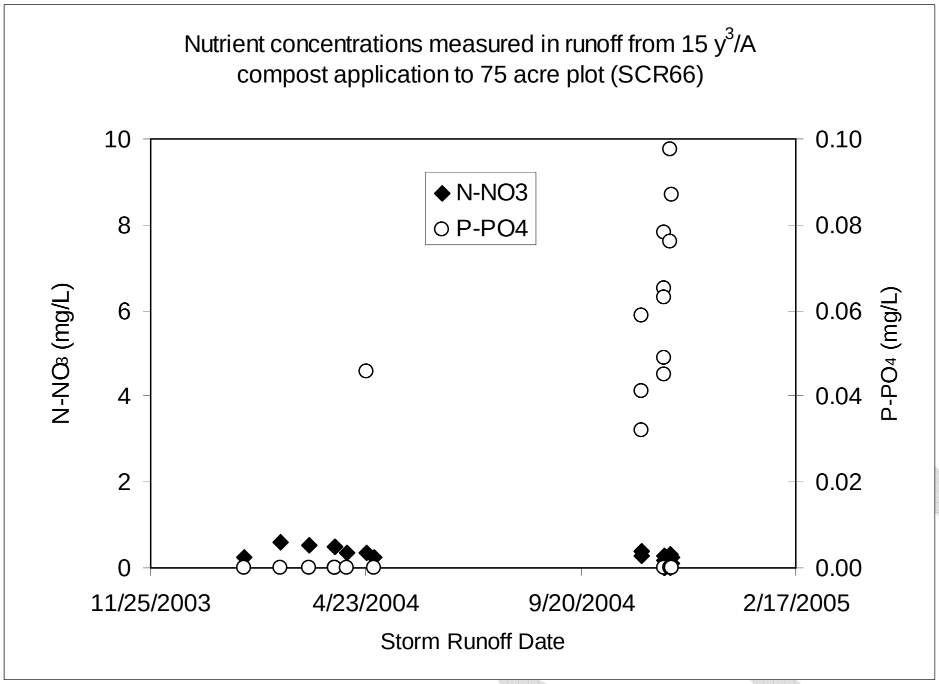


Figure 19. Nutrients in runoff from 165 acre plot (TA44)

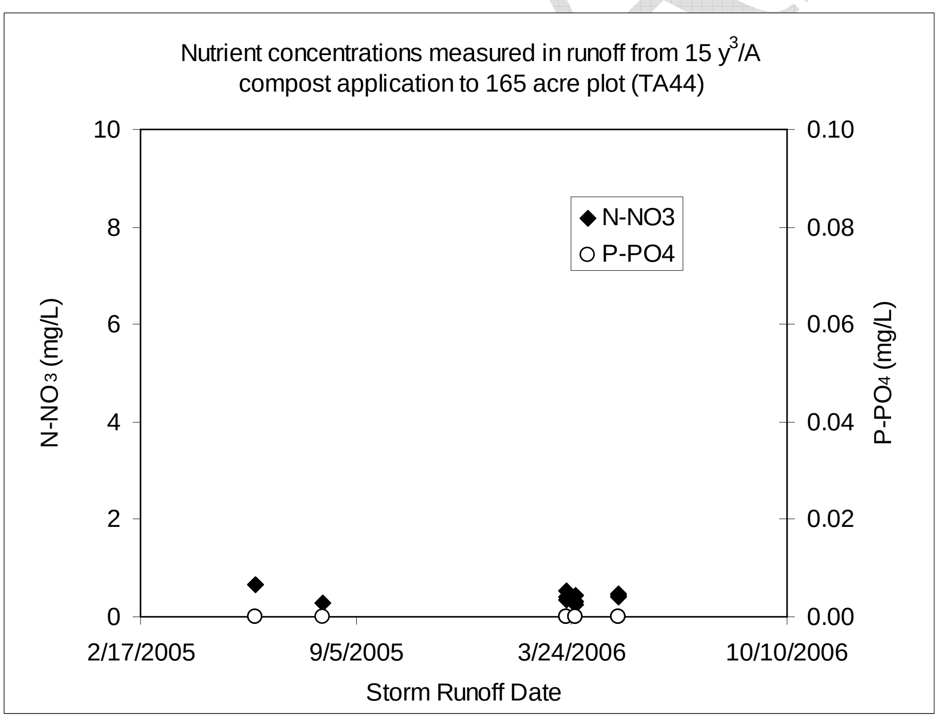
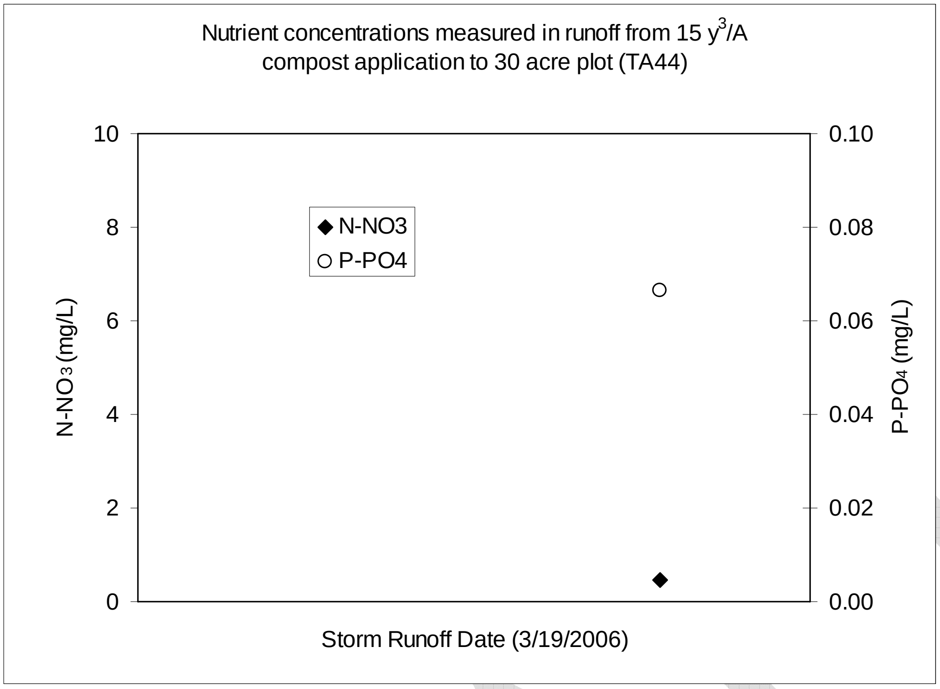


Figure20. Nutrients in runoff from 30 acre plot (TA44)



Storm Runoff and Nutrient Loss from Small Instrumented Plots

Nutrient concentrations measured in edge-of-field storm runoff from small bermed plots exceed EPA regulated or recommended levels for waters discharging directly to a stream (Table 3). These data therefore require special consideration. The Fort Hood Revegetation Initiative aims to enhance seedling emergence, survival, and vegetative growth through fertility treatment applied as composted dairy manure. BREC installed five 0.75 acre micro-watersheds and instrumented them with automated equipment to determine storm water runoff volumes and associated nutrient loss in the runoff. Four levels of composted dairy manure were applied including; 0 y^3/acre (control), 15 y^3/acre, 30 y^3/acre, 60 y^3/acre and 90 y^3/acre.

Concerns over nutrient loss in storm water runoff from composted dairy manure applications prompted the investigation of compost rates appropriate for field application. To date, BREC has adopted a general rate of 15 y3/acre based on compost nutrient analysis and commonly used agronomic nutrient rates. Nutrient analysis indicates the average Bosque composted dairy manure source, when applied at 15 y^3/acre, is roughly equivalent to applying 200 pounds of nitrogen and 100 pounds of phosphorus. Additionally, approximately 50% of the total is available for plant uptake during the first year, 20% the second year, and less than 10% per subsequent year. Because of this slow release factor, it is important to determine the maximum application rate before nutrient loss becomes a pollution issue so that optimum compost spreading rates can be utilized. Spreading the material over large areas requires considerable time and expense. Applying higher rates, containing immediately unavailable nutrients with slow release potential, may be and effective use of the material.

To date, none of the monitoring stations placed downstream from large scale compost applications at Fort Hood have measured nutrient concentrations in storm water runoff exceeding EPA regulated or suggested levels for nitrate nitrogen or orthophosphate phosphorus (Figures 16-20, note that full scale represents EPA maximum regulated or generally recommended nutrient concentration for surface waters). Results from edge-of-field small plots should be evaluated differently. High nutrient concentrations in runoff from the plots are diluted by additional storm runoff, sorbed to soils, or biologically uptaken in their overland journey to channelized streams and downstream water bodies. The large areas surrounding the small plots act as large riparian buffers to streams. Considering this, large area compost applications should not be placed adjacent to major streams and should be located in upland areas providing a large buffer zone.

Table 3. Fort Hood Compost – small plot (0.75 acre microwatershed), edge of field study. Precipitation, runoff, and nutrient loads.

	Event #	Event # 1	Event # 2	Event # 3	Event # 4	Event # 5	Event # 6	Event # 7	Event # 8	Event # 9	Event # 10	Event # 11	Event # 12	Event # 13
	Date	Jan. 27-28, 2005	Jan. 30-31, 2005	Feb.1, 2005	Feb. 6, 2005	Feb.23, 2005	Feb. 24, 2005	Feb. 26-27, 2005	Mar. 2, 2005	Mar. 21, 2005	Mar. 26, 2005	Apr.10, 2005	May 28, 2005	June 3, 2005
Control (FHC02)	N-NO_3 loading (kg)	0.113	0.039	0.034	0.071	0.065	0.182	0.000	0.081	0.249	0.030	0.036	0.010	0.002
	P-PO_4 loading (kg)	0.019	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	Runoff (mm)	13.19	6.00	5.64	3.23	11.32	23.33	12.98	12.87	30.65	3.76	2.82	1.34	0.16
	Precipitation (mm)	25.91	16.26	9.65	5.33	19.81	29.72	17.53	17.78	44.45	12.19	16.00	32.00	12.19
$15y^3$/acre (FHC04)	N-NO_3 loading (kg)	4.728	0.696	0.508	0.000	0.560	1.142	0.000	0.399	0.343	ISV	0.002	ISV	NMR
	P-PO_4 loading (kg)	1.161	0.390	0.488	0.000	0.314	0.459	0.677	0.375	0.405	ISV	0.004	ISV	NMR
	Runoff (mm)	11.70	7.59	10.95	2.81	12.56	25.31	20.27	13.94	29.22	2.40	0.19	0.14	NMR
	Precipitation (mm)	25.91	16.26	9.65	5.33	20.07	30.48	19.05	18.54	44.20	12.45	16.76	32.00	NMR
$30y^3$/acre (FHC03)	N-NO_3 loading (kg)	PCA	PCA	PCA	PCA	6.070	1.477	0.714	0.555	0.368	0.016	ISV	0.019	0.002
	P-PO_4 loading (kg)	PCA	PCA	PCA	PCA	1.704	1.082	0.881	0.488	0.626	0.071	ISV	0.068	0.006
	Runoff (mm)	12.99	11.60	8.96	3.48	14.77	23.62	16.48	12.31	26.47	2.03	0.99	3.22	0.32
	Precipitation (mm)	25.91	16.26	9.65	5.33	20.07	30.48	19.05	18.54	44.20	12.45	16.00	32.26	12.70

Key:

PCA: Pre-Compost Application

ISV: Insufficient Sample Volume

NMR: No Measurable Runoff

Appendix C – Bathymetric Review of Sedimentation Structures & Cowhouse Creek

BATHYMETRIC SURVEY OF FORT HOOD SEDIMENT RETENTION PONDS AND ACOUSTIC SEDIMENT PROFILING OF COWHOUSE REACH; BELTON LAKE, TEXAS

FY-2006 Status Report

Project Leader
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Staff:
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In cooperation with
U.S. Department of Agriculture
Natural Resources Conservation Service
And
U.S. Department of the Army

August 22, 2006 31, 2006

Prepared By

Jason McAlister

Introduction

Integrated Training Land Management (ITAM) and U.S. Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) have installed numerous sediment retention ponds to mitigate training area erosion on Fort Hood Military Reservation. These structures have a limited lifespan as they fill with eroded sediment. Determining the functional life of each retention pond is important to land managers. The objective of this survey was to determine the current capacity each of Fort Hood's 27 sediment retention structures, and to gain information relative to the expected longevity of each structure. Successive surveys (as requested) will be conducted to determine temporal change in retention structure holding capacity.

Additionally, Fort Hood land managers, NRCS-USDA, and other parties were interested in quantification of sediment deposition in the Cowhouse arm of Belton Lake. Recent increases in delta formation at the confluence of Cowhouse Creek and Belton Lake have caused concern to many involved in conservation activities on Fort Hood. The objective here was to determine the distribution, thickness, and volume of sediment at the confluence of Cowhouse Creek and Belton Lake.

Traditional methods of surveying water resources are limited to small and moderately sized lakes due to the physical limitations of transecting these water bodies with cable or rope. Resolution of volumetric estimates in these types of survey is poor. Survey of range lines is typically the method employed. These methods require a substantial amount of manpower and time. A limited number of points can be sampled as the cost per sample is high.

Blackland Research and Extension Center has developed and implemented hydrographic survey/mapping techniques to determine the current capacities and longevity of Fort Hood's sediment retention structures, as well as provide current volumetric analysis of sediment deposition at the confluence of Cowhouse Creek and Belton Lake. A shared objective of both undertakings is to use sediment accumulation data to determine, long-term, the effectiveness of erosion reducing conservation practices implemented on the Fort Hood Military Reservation.

The survey methodology uses a hydro-acoustic system coupled with a Differential Global Positioning System (DGPS) to collect geo-referenced water and/or sediment depths. Collected data sets are then used for generation of a sub-surface digital terrain models (DTMs) from which volumetric analysis can be conducted. Periodic surveys allow Fort Hood resource managers to further implement and/or better target erosion mitigating strategies.

The combination of the GPS with the hydro-acoustics provides an accurate method of lake mapping when combined with the sampling methodology we used. This system of bathymetric mapping also provides a repeatable sampling technique for calculating volumetric data without the need to establish permanent benchmarked reference sites. The GPS records the geographic coordinate of the point where the acoustic depth sounding unit records water and/or sediment depth. A Geographic Information System (GIS) provides the means by which the data can be visually projected, interpolated, and modeled to locate depth contours and yield volumetric data. From the data (depth and corresponding location) derived from a depth sounder and GPS, we have determined current capacities of the sediment retention structures, as well as calculated the remaining capacity to date.

Additionally, through the utilization of dual-frequency sediment profiling, and geo-referenced probing, we have successfully mapped the sediment distribution and thickness in the confluence area of Cowhouse Creek and Belton Lake.

The methodology employed by TAES/Blackland Research and Extension Center, and described hereafter, is intended to be used as a way to gather and supplement data relevant to sedimentation and deposition occurring in or around Fort Hood military training lands. These survey techniques proved useful to our project mandates by 1) estimating current storm water capacity of sediment retention structures on Fort Hood, and 2) determining the distribution, thickness, and volume of sediment at the confluence of Cowhouse Creek and Belton Lake. It is anticipated this data may be utilized to construct a baseline to which future data collection may be compared.

Survey of Sediment Retention Structures (PL-566/DB-GSS)

Executive Summary

Blackland Research and Extension Center (BREC) in cooperation with Fort Hood's Integrated Training Area Management (ITAM) group, has conducted bathymetric survey of 27 Fort Hood sediment retention ponds, and a detailed sedimentation survey at the confluence of Cowhouse Creek and Belton Lake. The objective was to determine the current capacity of each structure, and to gain information relative to the expected longevity of each structure. Reduction in holding capacity and or current life of structure was derived from comparison of engineering specifications and capacities determined by this survey. Results are included in tabular format on page 7 of this report. Successive surveys (as requested) will be conducted to determine temporal change in retention structure holding capacity.

Background

Integrated Training Area Management (ITAM) is responsible for 27 flood control/sediment retention structures on the Fort Hood Military Reservation in Central Texas. These structures, originally contracted by United States Department of Agriculture/Natural Resource Conservation Service (USDA-NRCS), impound between 20 and 200 acre feet of water and vary from 2 to 15 acres in surface area. Situated on military training land, these structures are managed for stormwater retention (with sediment retention in mind). Management goals require a thorough knowledge each retention structure's characteristics, including capacity.

Since the initial construction of the sediment retention structures, siltation, partially caused by military training/maneuvering has altered the storage capacity of these ponds (Fig. 1). Proper management of these structures requires that current storage capacity be determined. Because of relative size, access to, and number of retention structures to be surveyed, conventional surveying techniques would be extremely laborious.

Figure 2**: Silted Retention Pond**

With this in mind, Blackland Research and Extension Center/Texas Agricultural Experiment Station (BREC/TAES) has carried out an alternate method of surveying Fort Hood's sediment retention structures by using a hydro-acoustics system with a Global Positioning System to collect site specific water depth data. Modeling the data in GIS yields subsurface terrain characteristics and water retention capacity estimates that can be produced both efficiently and accurately. We were able to obtain enough depth data to generate highly detailed sub-surface digital terrain models for each retention structure and calculate the current storage capacity specific to each structure. Thus, enabling us to achieve two goals – realize the current capacity of each sediment retention pond, and to determine the expected longevity of each structure. Follow-up survey of these sediment retention structures will enable ITAM to determine temporal changes in the capacity of the structures, and address these changes accordingly.

Methodology

When the sediment retention ponds on Fort Hood were originally constructed, engineers estimated an initial surface acreage and stormwater retention capacity. These estimates were based on post-excavation topography, as well as the elevation of three features: lowest ungated outlet (LUO), principal spillway crest (PSC), and emergency spillway crest (ESC). For the purpose of our efforts it was important to know, as precisely as possible, each retention structure's current surface area at capacity. Full capacity was determined to be the maximum surface area the retention structure occupies when the waters surface is at the LUO. To achieve this, a geo-referenced 350mm aerial photo of Fort Hood (acquired February 2003) served as a field guide and base for digitizing the current lake boundary in a GIS. From the aerial photo, boundaries were interpreted based on geomorphic or vegetative cues.

At the survey site, electronics to include depth finder, transducer, and GPS were calibrated. The GPS unit was turned on so that it could acquire satellites. Time to acquire took up to 10 minutes, depending on satellite availability. GPS was set to acquire only Differential GPS (DGPS) signal through the use of Wide Area Augmentation System (WAAS), significantly improving accuracy of data collection. Following the acquisition of

WAAS and the calibration of the transducer, the system was considered ready for data collection.

The actual survey procedure was initiated at the principal spillway of each retention structure. The water level of the structure at full capacity or LUO had to be determined. This was done by measuring from the pond's surface to the top of the LUO on the spillway structure. If current survey scenario represented pond at partial capacity (water level was below LUO), this measure was to supplement the depth point data in order to reflect full capacity of retention structure.

Transects were driven perpendicular and parallel to the retention structure's primary impoundment from bank to bank as close as possible to current shoreline. A simple grid pattern was run with distance between grid transects estimated at 10 meters or less; thus to ensure the most accurate representation of sub-surface terrain as possible. Shallow areas were surveyed as completely as possible without risking damage to the submerged transducer. Randomly, for the purpose of quality assurance throughout each survey, water depths displayed on the depth sounding system were validated against manual depth soundings.

Data collected from each pond survey contained the locations and depth for each sounding location and were imported into a database table. Geographic coordinates of data were converted to UTM with a precision of six decimal places. Data sets were supplemented with spillway adjustment measurements as necessary for true representation of full capacity at LUO. Database files containing a sequential identification number, UTM coordinates, and depth for each sounding were converted, filtered, formatted, and prepared for transfer to the GIS.

Many of the records contained depths, but the longitude and latitude coordinates were absent. This was the result of collecting depth data at a faster rate than the GPS could geo-locate. The data were filtered for unmatched data pairs and downsized to ensure some uniformity of size across data sets. All finished data sets averaged approximately 3000 data points (geo-referenced depth readings) per retention structure.

The database files containing survey data were used to create an ArcGIS point coverage using the Spatial Analyst and 3D Analyst extensions. The coverage was converted to North American Datum 83 Zone 14, and projected using meters as the unit of projection.

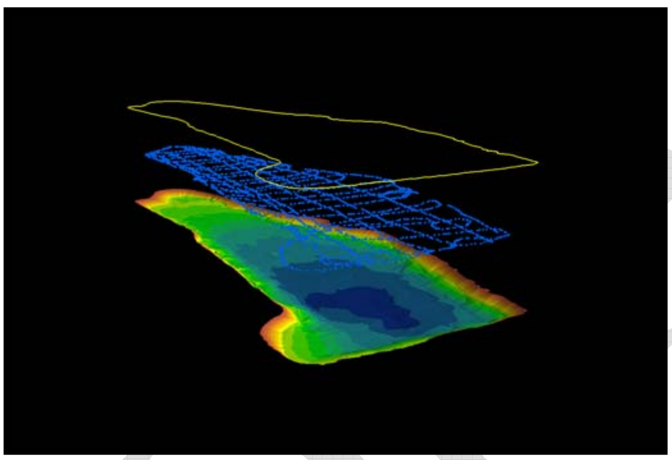


Figure 3: **Global Positioning System and SONAR data overlain/merged to create bathymetric model**

The digitized pond boundary coverage of the LUO capacity was merged with depth data to create a triangulated irregular network or TIN (fig. 2). A TIN represents a surface as a set of irregularly located points (in our case, depth data), linked to form a network of triangles with z-values (depth measurements) stored at the nodes. The input features used to create a TIN remain in the same position as the nodes or edges in the TIN. This allows a TIN to preserve all of the precision of the input data while simultaneously modeling the values between known points. With this, we are able to predict unknown values for any geographical point data (i.e. areas that are inaccessible by boat). This method proved to be the best suited for modeling of Fort Hood’s sediment retention structures.

Once the TIN model was created, it was viewed and manipulated in stereo display (3-dimensional model) to enable discovery of any anomalous depth soundings. While collecting soundings the depth recorder will, from time to time, generate some incorrect soundings. The most common causes for this are air bubbles or debris in the water column, submergent vegetation, and temperature inversions. Any sequential sounding points that transect a horizontal distance greater than 10 meters were eliminated. As well, any compounded depth points were eliminated. The 2-D surface area and 3-D volumetric capacity of the finished subsurface digital terrain models were then calculated using the 3D Analyst extension Volume/Area command.

Data Summary

Throughout FY-06, water levels in Fort Hood's sediment retention structures have remained too low to permit an effective follow-up (post-FY04) data collection. Given low occurrence of training maneuver disturbance during this time period, it is expected that previously collected data is representative of current (FY-06) pond capacities. Some engineering/design information has surfaced in the interim to supplement existing knowledge, and has been incorporated into the data table on the following page.

Conventional wisdom tells us that over time and function, the original surface area and capacity has been diminished. Because of deviations from original engineering plans, as well as poor resolution data used for post-excavation estimates, in some cases data show retention structures have been overbuilt. In those cases where current capacity exceeds engineering criteria, remaining capacities are valued at 100%. Where pond levels are too low to permit effective bathymetric survey, current capacity values are calculated as a percentage of planned 25-year functional life expended (indicated by yellow background in table 1).

Table 1: **Estimated Capacities of Fort Hood Sediment Retention Structures**

RETENTION POND	COORDINATE X	COORDINATE Y	EST. DATE CONST.	PLANNED CAPACITY (AC.FT.)	CURRENT CAPACITY (AC. FT.)	PLANNED SURFACE ACRES AT LUO	SURFACE ACRES AT LUO	EXPECTED CAPACITY (25YR.)	REMAINING CAPACITY
41A	610571.03	3450580.37	1999	150.00	126.41	15.00	10.42	72.0%	84.3%
41B	612307.94	3450689.91	1993	44.30	17.72	5.60	3.68	48.0%	40.0%
41C	608859.28	3450450.20	1995	50.70	39.30	6.50	4.71	56.0%	77.5%
41D	610137.99	3451174.87	--------	--------	29.83	--------	6.22	--------	--------
41F	609608.62	3450423.53	1995	19.35	32.12	3.20	3.79	56.0%	100.0%
42B	610823.73	3454516.35	2000	40.00	45.26	5.70	4.55	76.0%	100.0%
42F	611737.67	3452223.61	--------	25.26	16.20	5.07	4.70	--------	64.1%
42G	613308.20	3453369.69	1999	36.09	17.60	4.85	2.79	72.0%	48.8%
42H	610228.43	3454859.33	2000	14.70	3.53	7.00	7.00	76.0%	24.0%
43C	605799.81	3446391.72	1996	48.70	94.58	7.00	6.33	60.0%	100.0%
43D	606384.68	3446618.62	1997	6.60	2.38	0.65	0.60	64.0%	36.0%
44C	606401.75	3450649.23	1997	147.40	54.54	21.40	15.10	64.0%	37.0%
44G	607851.18	3451370.41	1996	54.70	58.44	7.00	6.28	60.0%	100.0%
44H	608551.36	3451513.62	1996	35.30	29.65	6.96	6.46	60.0%	84.0%
44I	606154.38	3449554.52	1995	55.00	24.20	13.10	6.83	56.0%	44.0%
45A	606169.03	3455209.15	1995	11.00	10.83	2.65	2.18	56.0%	98.5%
45B	606472.17	3455026.75	--------	64.00	37.86	5.60	5.82	--------	59.2%
45D	604168.81	3453522.96	1999	23.30	18.20	4.73	3.48	72.0%	78.1%
45F	605820.45	3453577.16	--------	59.00	33.32	7.80	6.61	--------	56.5%
45G	605364.03	3452962.41	1995	36.20	47.54	5.23	4.96	56.0%	100.0%
45H	605897.99	3452817.35	--------	29.00	14.59	6.40	3.69	--------	50.3%
46B	607688.25	3455005.90	1993	46.00	23.92	13.70	13.50	48.0%	52.0%
46C	608850.81	3455240.20	--------	--------	24.29	--------	5.47	--------	--------
46D	608655.52	3454321.09	1993	76.00	47.44	11.60	10.43	48.0%	62.4%
46E	608270.02	3453400.25	1993	66.00	34.32	4.30	4.29	48.0%	52.0%
46F	608727.44	3453097.70	1993	65.00	12.27	4.20	3.87	48.0%	18.9%
STARNE'S #2	607119.65	3450993.00	1996	74.00	29.60	14.20	7.84	60.0%	40.0%

ACOUSTIC SEDIMENT PROFILING OF COWHOUSE REACH; BELTON LAKE

Executive Summary

Belton Lake was formed following deliberate impoundment on March 8, 1954. Presently, Belton Lake supplies Fort Hood, Killeen, and other areas with water. The drainage area above the dam was 3,560 square miles. Fort Hood's Integrated Training Area Management (ITAM) had an interest in sediment accumulations at the confluence of Cowhouse Creek and Belton Lake. The goals of this survey were to determine the distribution, thickness, and volume of sediment in the specified area to date.

A hydrographic survey of the Cowhouse Reach of Belton Lake using a dual frequency (28/200 kHz) echo sounding system was conducted in fall/winter of 2005. Digital echo sounder profiles were obtained on predetermined planned lines in order to provide reasonable coverage of the area of interest. Navigation was provided using a Trimble GeoXT Global Positioning System (GPS) with real-time differential correction. Sediment profile data was analyzed and edited in HyPack hydrographic software, and then exported to ArcGIS 9.1 for further interpolation, isopach mapping, and redundant volumetric analysis.

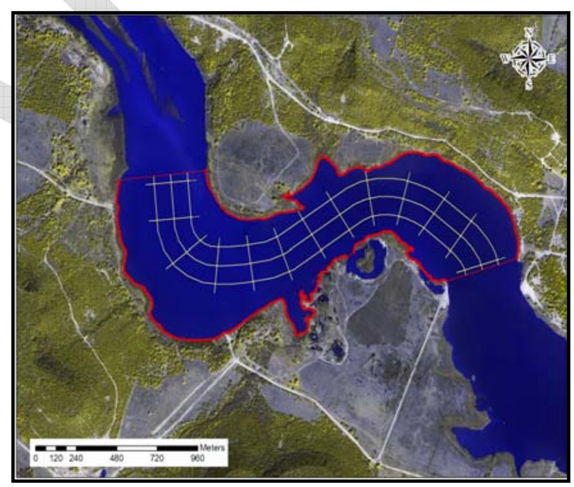


Figure 4: Satellite view of Belton Lake's Cowhouse Reach: Yellow lines are planned survey lines completed during the fall of 2005.

Geographic Information System spatial modeling revealed a total survey area of 340 acres. Within this area, analysis indicated a mean sediment thickness of 2.5 feet, with heavier deposits (up to 8 feet) primarily in the area of delta formation. In total, subsurface digital terrain modeling revealed a total of 1.3 million yd^3 of unconsolidated sediment deposited within the survey area.

Background

Belton Lake and Belton Dam are on the Leon River, part of the Brazos River basin, three miles north of Belton in northwestern Bell County (at 31°07' N, 97°28' W). The project is owned by the United States government and operated by the United States Army Corps of Engineers, Fort Worth District. Construction began in July 1949; the main structure was completed in April 1954, and deliberate impoundment began on March 8, 1954. In 1966 the reservoir had a capacity of 210,600 acre-feet and a surface area of 7,400 acres at the top of the conservation storage space (elevation 569 feet above mean sea level). The reservoir provided 887,000 acre-feet of flood-control storage capacity. The drainage area above the dam was 3,560 square miles.

Fort Hood Land Managers had an interest in conducting a detailed sedimentation survey of the area in proximity to the confluence of Cowhouse Creek and Belton Lake for the purposes of 1) determining the distribution, thickness, and volume of sediment in the specified reach, and 2) using sediment accumulation data to determine, long-term, the effectiveness of sediment reducing conservation practices being implemented on the Fort Hood Military Reservation.

Methodology

Hydrographic survey of Belton Lake's Cowhouse Reach was conducted using a Knudsen Engineering, Ltd. Model 320 B/P dual frequency (28/200 kHz) Echo Sounding System. This system recorded echo sounder profiles geo-referenced to output from a GPS receiver in digital format which was converted to digital image formats for analysis. The 200 kHz acoustic impulse provides approximately 1 cm vertical resolution and is used primarily to acquire detailed bathymetric (depth) data. The 28 kHz acoustic impulse can penetrate up to 10 meters of fine-grained lacustrine sediment to provide an indication of sediment thickness. Thus, this system provides data necessary to produce a detailed bathymetric maps and sediment thickness maps from a single survey.

The KEL 320 B/P Echo Sounding System was mounted on a small shallow draft boat approximately 6 feet in length. Although a little precarious to operate with the array of equipment on board, the small size did prove useful, as most waters were extremely shallow. The system can operate in water depths as shallow as 0.67 m. Data collection / sediment mapping of the Cowhouse Reach was accomplished by maneuvering the boat along a planned network of survey lines. Primary survey lines were those running cross-channel, or bank to bank. Additionally, survey lines were run perpendicular to cross channel lines to serve as an additional validation of depths where survey lines intersect.

Figure 5: Two - man pontoon style bass boat modified to accommodate one surveyor and instrumentation

Reasonable acquisition of low frequency data was somewhat difficult in depths of less than 2.5 meters. Therefore, additional data validity checks were accomplished by probing the sediment with a sounding pole. Locations of these samples were geographically referenced and depths recorded simultaneously though HyPack software.

Echo sounder profile data was analyzed and edited in HyPack hydrographic software. This software package provided an interface from which digital record of depth and echogram may be compared, edited, and modeled. Edited data files were then exported to ArcMap 9.1 for further interpolation, contouring, and redundant analysis. Final volumetric computations were conducted independently (in each software package respectively) for comparison.

In short, depth data was georeferenced along survey lines and output as an x,y,z (vertical and horizontal coordinates) data file. This data was then plotted and compared to digital echogram records, thus allowing elimination of anomalous or false readings. Once edited, interpolation between soundings was performed. This involved using one of several algorithms and or statistical analysis available to solve for unknown areas between survey lines. From interpolation of know data points, a grid of georeferenced elevation points was achieved for each frequency of the echosounder. More specifically, two digital terrain models were developed; one representing the water surface to post-impoundment sediment, and the other representing water surface to pre-impoundment alluvium.

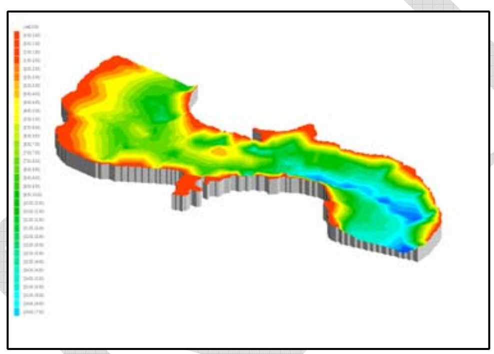


Figure 6: Pre-Impoundment Surface -- digital terrain model representing surface before lake inundation.

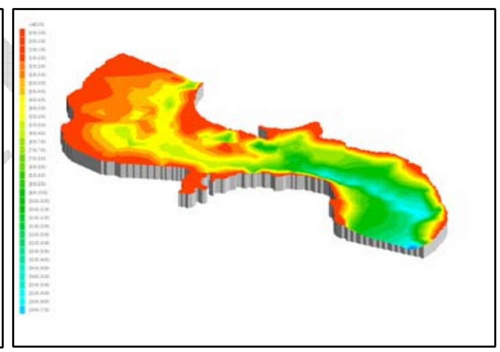
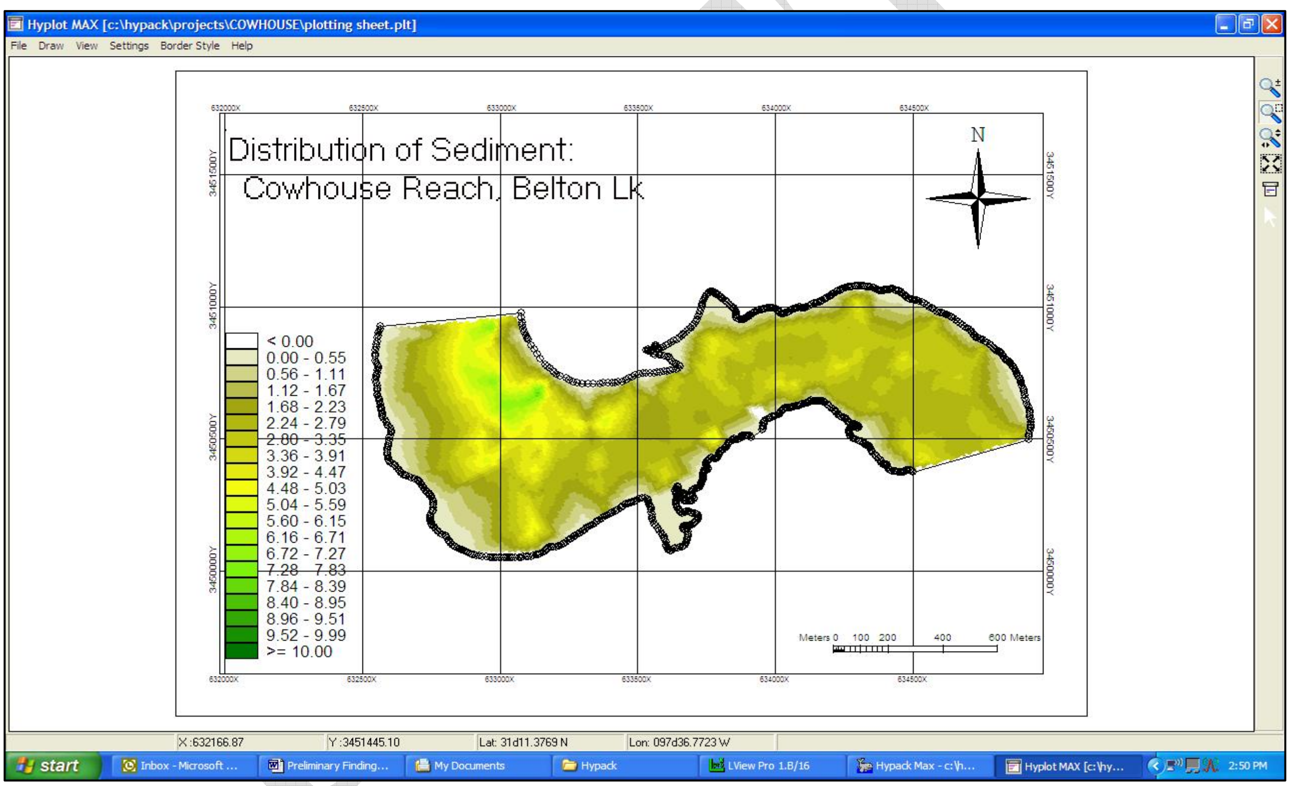


Figure 7: Post-Impoundment Surface -- digital terrain model representing water to sediment interface.

Data Summary

GIS spatial modeling revealed a total survey area of 340 acres. Within this area, analysis indicated a mean sediment thickness of 2.5 feet, with heavier deposits (up to 8 feet) primarily in the area of delta formation. In total, subsurface digital terrain modeling revealed approximately of 1.3 million yd^3 of unconsolidated sediment deposited within the survey area (Fig. 7).

Figure 7: Map of Sediment Distribution



Appendix D – Detailed Regulatory Review

Regulations and Policies that Guide Environmental Management Practices of Military Training Lands in the United States

Texas Agricultural Experiment Station / Texas Water Resources Institute
1500 Research Parkway, Suite 240A, College Station, TX 77843-2118

In cooperation with
U.S. Department of Agriculture
Natural Resources Conservation Service
And
U.S. Department of the Army

November 2006

Prepared By

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Introduction

To understand the range of water quality protection activities now underway at Fort Hood, it is helpful to provide an overview of the federal laws and agency regulations that guide environmental work at military bases and installations. The purpose of this paper is to summarize some of the key policies and statutes that drive ecological programs at military installations throughout the United States.

The fundamental mission of Fort Hood is to conduct readiness training and provide combat-ready forces to deploy and fight worldwide. The primary use of Fort Hood is for military training. It is essential that military activities at Fort Hood comply with federal and state regulations pertaining to the natural resources and the environment.

As stated in Army Report 200-1, "Fort Hood lands and vegetation are managed to provide maximum sustained yields and to protect the water resources of the installation, adjacent communities, and the State of Texas. The land must produce adequate resources for the perennial military training mission, habitat for several endangered species, and recreation for the Fort Hood Community."

Federal Regulations

The National Environmental Policy Act (NEPA) requires federal agencies to evaluate the environmental impacts of land-use management actions at the installation and to consider alternative practices. The intent of NEPA is to protect, restore and enhance the environment through well-informed federal decisions. When major projects are implemented that have the possibility of causing environmental degradation, NEPA provisions may require that the Army develop an environmental assessment as well as an environmental impact statement or a record of environmental consideration. To help federal agencies comply with NEPA, the federal government established the Council for Environmental Quality (CEQ). The CEQ has issued Regulations for Implementing the Procedural Provisions of NEPA (Title 40 CFR Parts 1500-1508).

To comply with NEPA, the Army has developed several regulations and guidance documents including the following:

- Environmental Protection and Enhancement (AR 200-1)
- Environmental Analyses of Army Actions, Title 32 CFR Part 651 (AR 200-2)
- Natural Resources—Land, Forest and Wildlife Management (AR 200-3)
- Cultural Resources Management (AR 200-4).

Title 32, Part 651 of the Code of Federal Regulations requires that the Army integrate environmental reviews concurrently with other Army planning and decision-making actions to avoid delays in accomplishing the mission of the military.

Management actions at military installations must comply with several federal acts intended to protect such resources as water, air, and endangered species. The Clean Water Act (CWA) requires states to develop plans to address and clean up sources of water pollution. The Safe Drinking Water Act (SDWA) establishes numeric standards that must be met in public drinking water supplies to ensure there is not a threat to human health. Military regulations prohibit Army personnel from knowingly discharging any pollutant into the ground-water or surface water on any base. In areas where wetlands may be present, regulations of the U.S. Army Corps of Engineers govern how wetlands must be dredged and filled. If a military base features a storm sewer, these installations have to develop and implement a storm sewer management program. The Endangered Species Act is meant to ensure that the actions of federal agencies do not jeopardize threatened and endangered plant and animal species.

In general terms, the Army policy is to manage installations on an ecosystem basis that emphasizes how such resources as waters, lands, soils and vegetation are interrelated. Often, the goals of Army environmental policy include (among other criteria) maintaining surface water quality, soil productivity, and the biodiversity of plant species.

Department of Defense Regulations and Programs

In 1960, the Sikes Act (the Natural Resource Management on Military Lands Act) was enacted. The Sikes Act requires that "The Secretary of Defense shall carry out a program to provide for the conservation and rehabilitation of natural resources on military installations." The act mandates that the Secretary of each military department (i.e., the Army) will prepare and implement an integrated natural resources plan (INRMP) for each military installation in the United States. These plans must provide for the conservation and rehabilitation of natural resources on military bases including the sustainable use of natural resources. Before an INRMP survey is developed, natural resources planning level surveys need to be carried out.

In 2003, the Department of Defense enacted directive 3200.15 that articulates the need to manage training lands and ranges in an environmentally sustainable manner. The directive describes how environmental considerations should be incorporated into the overall management of military bases and training areas. The Department of the Army published *The Unit Leader's Handbook for Environmental Stewardship* in 1994. The handbook provides guidance troops in the field can take to protect the environment, conserve resources and promote natural resources stewardship.

In 2005, the Army Sustainable Range Program (SRP) was created through Army regulation 350-19. The United States Army Environmental Center provides technical and managerial support for SRP activities about such issues as the carrying capacity of training lands, vegetation species that most able to tolerate training activities, and related issues.

The SRP includes two major components—the Range and Training Land Program (RTLP) and Integrated Training Area Management (ITAM). ITAM provides Army range officers with the capability to manage training lands by integrating sound land-management practices and environmental requirements to support troop training requirements. The ITAM program is the Army's formal strategy for focusing on the sustained use of military lands used for troop training and testing. The Army's ITAM strategy is to manage its lands in a sound manner to ensure no net loss of training capabilities in order to support current and future mission and training requirements (Fort Hood ITAM report, 2006). ITAM provides Fort Hood with guidance so that the installation can comply with the Endangered Species Act, the Clean Water Act and federal regulations regarding wetlands protection. ITAM sponsors workshops and working group meetings to provide technical support for the development and use of geographic information system. ITAM has also developed learning modules that guide users about how to characterize natural resources and trends associated with military training operations.

The Headquarters Department of the Army organizes the work of ITAM into several components: Land Conditions Trends Analysis (LCTA); Training Requirements Integration (TRI), Range and Training Land Assessment (RTLA), Land Rehabilitation and Maintenance (LRAM), and Sustainable Range Awareness (SRA). The RTLA program provides methodologies to assess how military training operations may affect water quality and biological conditions at military training lands and is responsible for collecting and analyzing tabular and spatial data about land conditions on military bases. LRAM is designed to develop procedures to prevent the long-term adverse effects of military training on the environment. LRAM combines preventative and corrective land rehabilitation, repair and maintenance strategies to protect environmental quality. TRI is a decision support system that integrates requirements for land use with natural and cultural resources management processes. TRI integrates the installation training and testing requirements for land use with the installation's natural resources conditions. SRA is the component of ITAM that provides environmental stewardship training by providing educational materials and information resources to troops and other personnel who are involved with land management at military installations.

In 2006, the Army Installations and Environment program described a new strategy to fully integrate environmental protection with military training and troop readiness. The effort, titled "Sustain the Mission: Secure the Future," is meant to transition the Army from merely complying with environmental regulations to developing a mission-oriented approach based on the principles of sustainability. In practical terms, the strategy means the Army will enhance the natural environment while simultaneously meeting future mission requirements, safeguarding human health, and improving the quality of life.

Cooperative Agreements between the Defense Department and Other Federal Agencies

The Defense Department works with other federal agencies to carry out its environmental responsibilities at Fort Hood. The United States Army Environmental Center (USAEC) and the United States Department of Agriculture Natural Resources Conservation Service (NRCS) have entered into an interagency agreement that provides support for

LRAM programs. The agreement can be used to fund land maintenance projects at military installations and NRCS field offices can consult with military staff at local bases and offer assistance to help manage LRAM projects. Since 1996, the Fort Hood, the Range Training Land Assessment program have been carried out by NRCS staff who report to the base's ITAM manager. The program focuses on establishing the viability of best management practices (BMPs) and developing improved strategies to restore and sustain rangelands at the base. Through this collaborative effort, NRCS and the Army have identified and mapped the spread of highly-erodible soils throughout the lands at the base. Two of the most effective BMPs that have been implemented at Fort Hood were developed by NRCS and the Texas Agricultural Experiment Station's Blackland Research and Extension Center at Temple. These practices, installing small check dams near gullies and soil ripping, reduce runoff and promote infiltration. The USAEC provides support for conservation programs at military installations.

In addition, the Defense Department cooperates with other federal agencies in regards to environmental stewardship at Fort Hood. The Fort Worth District of the United States Army Corps of Engineers provides contractor support for the INRMP and administrates wetlands permits and management at the base. Universities are now working with the Corps to carry out environmental and water quality studies at Fort Hood. Participating institutions include the Texas Agricultural Experiment Station, Texas Cooperative Extension, Tarleton State University, and the University of Texas at Austin. In addition, the Army often works with the U.S. Fish and Wildlife Service, state wildlife agencies, and such non-profit organizations as the Nature Conservancy to jointly develop and refine INRMP planning documents.

Environmental Issues and Policies Specifically Related to Fort Hood

Environmental management at Fort Hood is organized and coordinated among four main agencies. The Directorate of Plans, Training, Mobilization, and Security (DPTS) Range Control program is in charge of the maintenance of range lands and the development of master plans. The ITAM Range Control program supervises activities of LCTA, LRAM, TRI and SRA. The Directorate of Public Works (DPW) Environmental Division manages water resources, natural resources, air quality and wildlife (among others). DPW is in charge of several programs related to natural resources, including the implementation of conservation efforts as well as the management of endangered species and wildlife.

High-priority environmental concerns that may affect water resources include the following (2004):

- Reducing erosion from tank trails, stream crossings, and hilltop access trails.
- Constructing and maintaining erosion control structures.
- Reestablishing and maintaining vegetation to minimize erosion.

Some of the ways in which training has adversely affected the ecosystem near Fort Hood include the loss of vegetation and subsequent increases in the amount of bare ground and erosion as well as declines in water quality and water supplies.

The overall goal of the Fort Hood LSMP (2004) is to develop and implement a plan to sustain the natural resources at Fort Hood so that land resources can continue to be used for military training in the future. The guiding principle of LSMP is to balance land uses with the capacity of natural resources. Through the plan, sediment runoff and erosion will be reduced, thus improving downstream water quality in receiving waters.

Similarly, the 2006 Fort Hood ITAM report describes the need to lessen sediment runoff from the base since so much of the facility features highly-erodible soils. Strategies to protect water quality by limiting sediment runoff include locating roads, trails, and hillside access points at locations where erosion is less likely to occur; and improving road surfaces at stream crossings. To address erosion and water quality concerns, ITAM initiated the "Training Out Area Program" in 2000. In simple terms, this program defers training programs and grazing activities on certain geographic areas for up to a year to allow for the establishment and recovery of range vegetation at these sites.

The 2006 INRMP for Fort Hood has the overall goal of ensuring that the vegetation, soil and water resources should be preserved to facilitate realistic military training. Some of the objectives set forth in the INRMP are to minimize erosion and land degradation that may result from military training and grazing cattle on the base and maintaining vegetative cover to minimize erosion. Related to water resources, the goal of the 2006 INRMP is to identify and restore degraded aquatic habitats and to prevent water quality degradation. To reach these goals, the 2006 INRMP recommends such strategies as the assessment and monitoring of surface waters; data gathering to track water quality trends, and learning more about groundwater flows and water quality in karst aquifer systems.

In the past, the Army and other Defense Department agencies have prepared and analyzed NEPA documents after these plans have been developed. However, the 2006 INRMP for Fort Hood was developed concurrently with NEPA analysis in order to make this process as cost-effective and timely as possible. Developing an environmental assessment and NEPA analysis at the same time assures that these processes are fully integrated with the tasks of developing plans to manage and protect such natural resources as fish and wildlife, rangelands and forests. The goal of the 2006 INRMP for Fort Hood is to "maintain the ecological integrity of the landscape and ensure there is not net loss in the capability of Fort Hood training lands to support the military mission."

Fort Hood operates under an industrial stormwater permit regulated by the Texas Commission on Environmental Quality and a general permit. The Fort Hood Directorate of Public Works is required to file a permit application that includes a stormwater management program. The stormwater program must address such issues as public education, pollution prevention and strategies to control pollutants in runoff.

Summary

This document provides a brief overview of how federal regulations and programs affect environmental operations at military training installations. Obviously, the Army has to meet the requirements of several federal laws and statutes to protect water quality and other natural resources while carrying out its core mission of military preparedness. At the same time, the Army and other military organizations have developed well-thought-out strategies and management plans to achieve the cross-purposes of military training and the sustained management and use of natural resources. Finally, there is a role for universities and other agencies to work with the Army to provide the needed science and research to better understand complex environmental issues and provide solutions to these challenges.

Appendix E - Additional Literature Resources

Fort Hood Bibliography

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Appendix F - Annual Report of APEX Modeling Activity at Fort Hood, Texas

Annual Report of APEX Modeling Activity at Fort Hood, Texas

Watershed description

The Shoal Creek watershed (22.5 km^2) is located in the northwest corner of Fort Hood. The dominate soil types within the watershed include Brackett, Eckrant, Topsey and Slidell (Figure 1). Figure 2 is the soil map retrieved from Soil Survey Geographic (SSURGO) database.

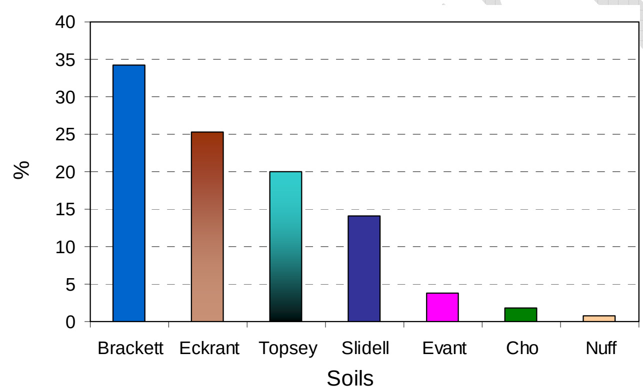

Figure 1. Percentage of dominant soil map units (%) within Shoal Creek

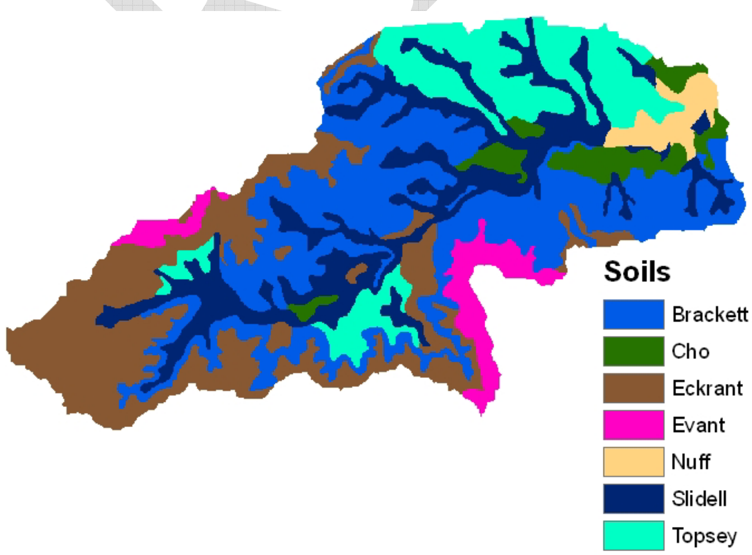

Figure 2. Shoal Creek Soils (retrieved from: http://soildatamart.nrcs.usda.gov/Survey.aspx?County=TX099)

Historically the area was covered with tall grass prairies and small mountain ranges; however, the vegetation cover has been changed over the past five decades. Heavy artillery traffic from training activities has disturbed soils and largely denuded the land of vegetation. Therefore, intensive rainfall (Figure 3) poses severe erosion potential. The prairie areas received the maximum impacts from tracked and wheeled vehicular traffic. Over 63 km of eroding gullies were mapped within this area as of 2001. The Blackland Research and Extension Center (BREC) began collecting water quality and quantity data in this watershed from 1997. The average annual precipitation (1997-2005) for the area is 760 mm (Figure 3). Two BMPs implemented at Shoal Creek are contour ripping of the soil profile (approximately 27% of total area) and gully plugs placed within gully systems (Table 1 and Figure 4).

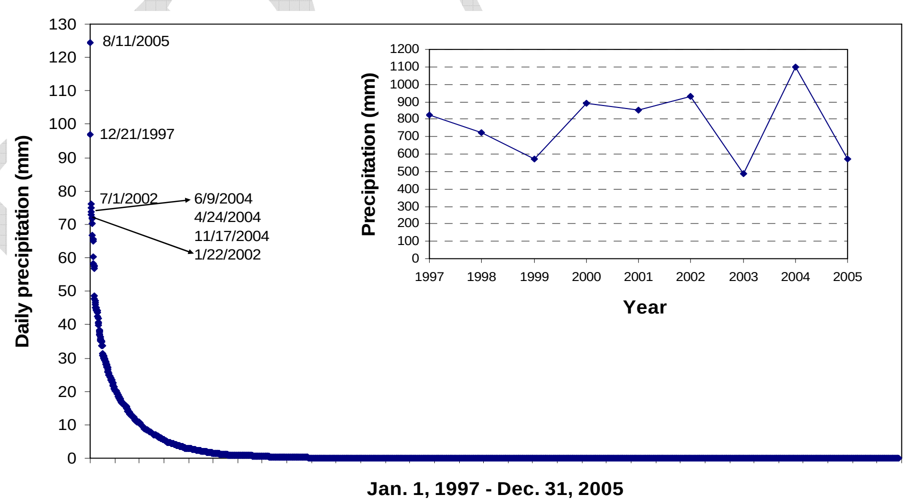

Figure 3. Precipitation in Shoal Creek Watershed

Table 1. Watershed treatment with monitored flow and sediment available

Pre-BMP	BMP	
	Deep ripping	Gully plug
Apr. 1997-Nov. 2001 (no observation for 1999 due to laptop missing)	11/15/2001	135 installed from 7/2002 76 installed from 6/2004

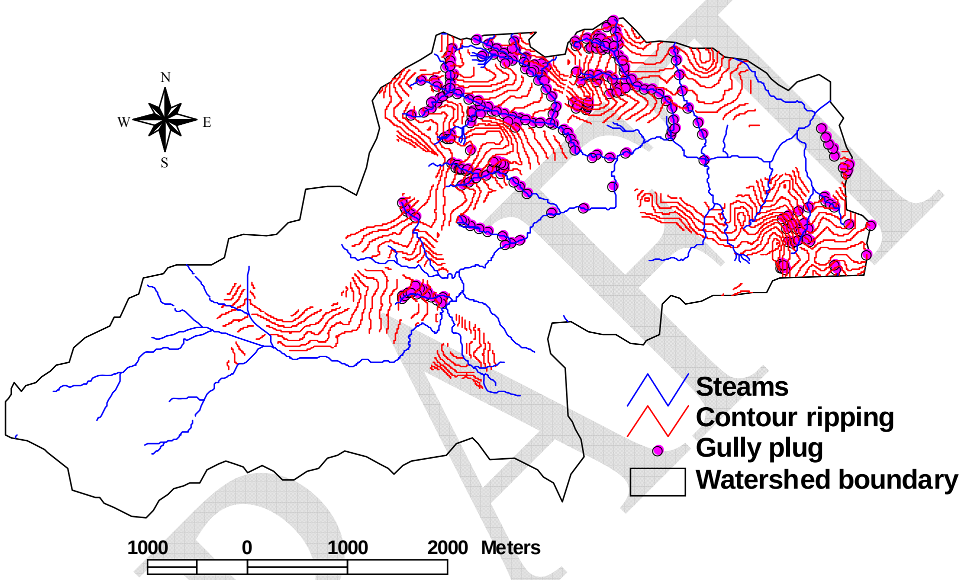

Figure 4. BMP placements in Shoal Creek watershed

APEX simulation

The APEX model is based on state-of-the-art technology taken from several mature and well tested models. The development history was reported by Gassman, et al. (2005). It was developed for use in whole farm/small watershed management. The model was constructed to evaluate various land management strategies considering sustainability, erosion (wind, sheet, and channel), economics, water supply and quality, soil quality, plant competition, weather and pests (Williams and Izaurralde, 2006). Management capabilities include irrigation, drainage, furrow diking, buffer strips, terraces, waterways, fertilization, manure management, lagoons, reservoirs, crop rotation and selection, pesticide application, grazing, and tillage. The model operates on a daily time step (some processes are simulated with hourly or less time steps) and is capable of simulating hundreds of years if necessary. Farms may be subdivided into fields, soil types, land scape positions, or any other desirable configuration.

Constructing APEX subarea file

Each subarea is homogenous in climate, soil, landuse (operation schedule), and topography. Therefore, the heterogeneity of the watershed is determined by the number of subareas. Watershed delineation for Shoal Creek was conducted based on a 10 m DEM using the SWAT interface (AVSWATX). Originally, the watershed was delineated into 29 subbasins/subareas (1.4 -174.0 ha) (Figure 5). In general, the average upland slope is steeper in the upper watershed than in lower watershed. In this preliminary study, the watershed was further divided into 50 subareas manually based on the contour ripping placements (Figure 6). The 10 m DEM is not detailed enough to be used in the SWAT interface to identify all the gullies/channels. There are places where gully plugs were actually placed, but no channels were identified. With some of the gully plugs being as close as 10 m (Figure 4), at this stage it is not realistic to determine the drainage area and channel information for each gully plug based on the GIS data and GIS tool currently available. BREC is developing a new APEX GIS interface. We plan to use this interface and treat the gully plugs like small reservoirs with no permanent storage. Due to the limitation, only preliminary results are presented here.

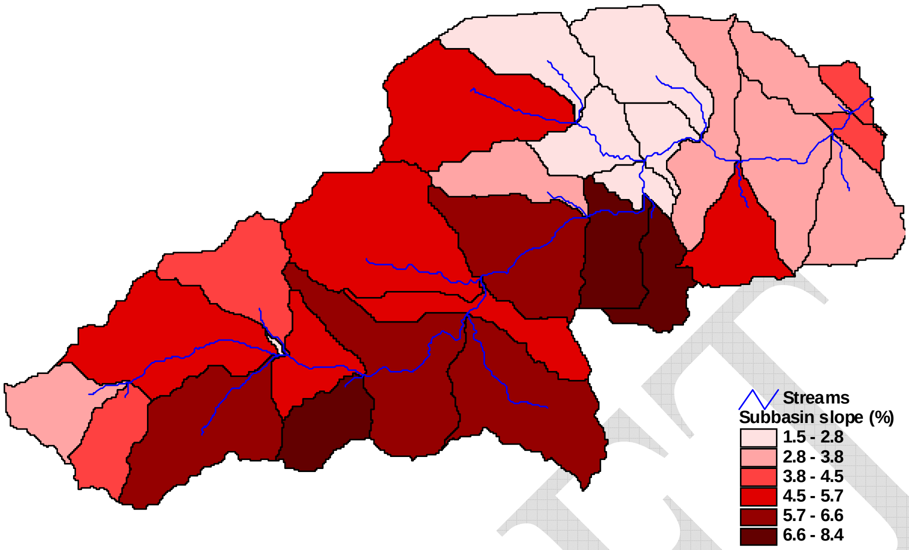

Figure 5. Subbasin average upland slope in Shoal Creek watershed

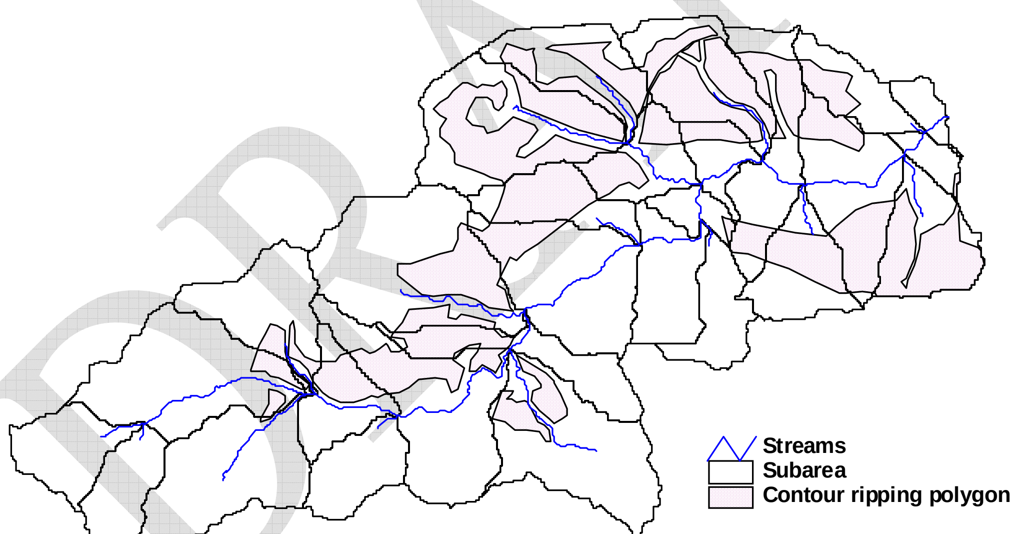

Figure 6. Subareas in Shoal Creek watershed

Modeling results

Model calibration and validation

There were 25 daily storm events observed during the pre-BMP (1997-2001) period. The NRCS average moisture condition runoff curve number (CN2), the curve number retention parameter index coefficient, the sediment routing travel time coefficient (parm(45)), and RUSLE C factor exponential residue coefficient (parm(46)) were calibrated in APEX using the first 13 events (Apr. 1997- Apr. 2000) of surface flow and sediment yield. They were adjusted until the R^2 vaules were > 0.6 and the percentage errors between the observed and predicted daily average values were < 10%. The calibration process for the pre-BMP period resulted in a CN2 value of 89 and a curve number retention parameter index coefficient of 2.8. The calibration also resulted in a parm(45) value of 5.0 and a parm(46) value of 1.4, both within the APEX recommended ranges. The remaining 12 events (Jun. 00 - Feb. 01) were used to validate the model.

The observed and simulated average event values of surface flow and sediment yield at the watershed outlet are compared for both the calibration and validation periods in Table 2 and Figure 7. The R^2 values are > 0.75 for the calibration period and > 0.50 for the validation period. Daily event series of precipitation and observed vs. predicted outlet flow and sediment yield are plotted in Figure 8. APEX reasonably captured the daily event trend of observed flow and sediment yield. Although explicit standards for model evaluation were not established, Adeuya et al. (2005), Chung et al. (1999) and Ramanarayanan et al. (1997) used the criteria of $R^2 > 0.50$ to assess if the model results were satisfactory. APEX's performance can be judged acceptable for the event based comparisons of observed vs. predicted flow and sediment yield.

Table 2. Observed and predicted surface flow and sediment yield summary statistics based on daily event values.

	Daily event	Observed		Predicted		R^2
		Mean	SD	Mean	SD	
Calibration (13 events)	Surface flow (mm)	14.40	14.36	13.07	9.64	0.77
	Sediment yield (Mg ha^{-1})	1.09	1.09	1.20	1.19	0.76
Validation (12 events)	Surface flow (mm)	13.68	7.02	13.39	8.51	0.61
	Sediment yield (Mg ha^{-1})	0.89	0.64	0.59	0.39	0.50

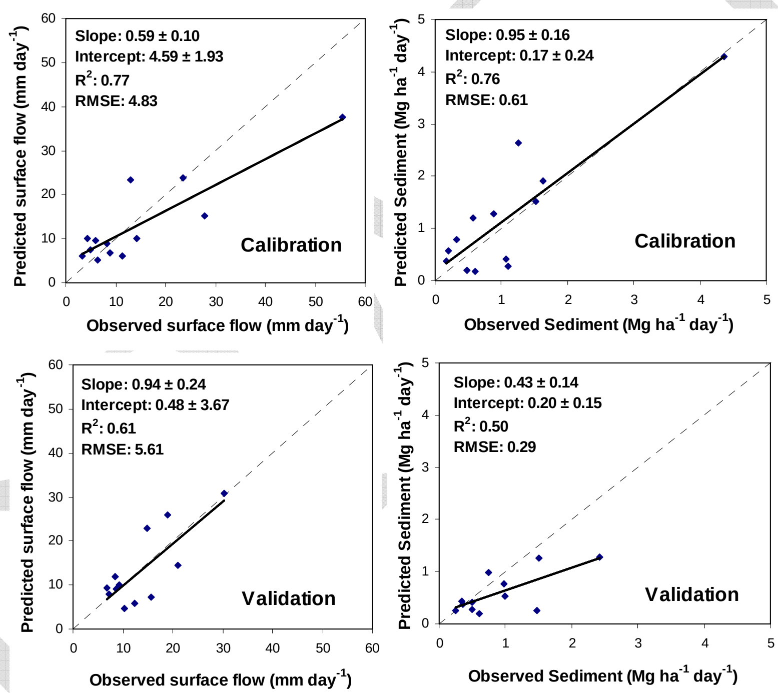

Figure 7. Regressions of simulated vs. observed event flow and sediment yield for calibration period (Apr. 1997- Apr. 2000) and validation period (Jun. 00 - Feb. 01). RMSE (root mean squared error) = $\sqrt{\sum_{i=1}^{n}(O_i - P_i)^2/n}$, where O_i and P_i are observed and predicted values on event i.

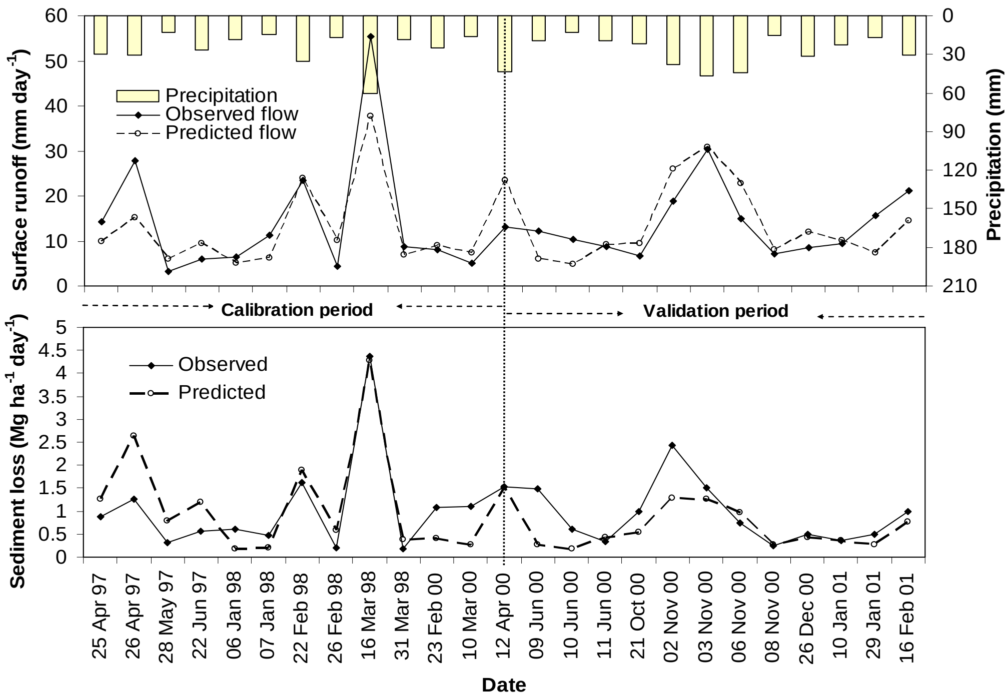

Figure 8. Daily precipitation, and observed vs. predicted event flow and sediment yield in Shoal Creek watershed outlet (Apr. 1997 – Feb. 2001).

BMP effectiveness

The gully plugs cannot be fully represented in APEX simulation at this stage because current GIS limitations. The BMP effectiveness was examined by running a continuous simulation of the calibrated model through 2005 without considering the presence of BMPs; therefore, the differences between predicted and observed values for the post-BMP period are the benefits of BMPs. As of 2005, there were 36 observed events for the post-BMP period. Comparing observed and simulated values showed that surface runoff was reduced by 344.8 mm (108%) and the sediment yield was reduced by 35.8 Mg ha^{-1} (395%) (Table 3). The contour ripping and gully plugs reduced average annual surface flow by 27% and sediment yield by 99%. The time series of observed (with BMPs) and predicted (with BMP condition) surface flow and sediment yield are plotted in Figure 9. During large rainfall events, the outlet surface flow and sediment yield were significantly reduced due to BMPs practices.

Table 3. Benefits of contour ripping and gully plugs in Shoal Creek watershed

Period (11/01 – 03/05)	**Surface flow**	**Sediment yield**
Observed total for post-BMP	318.2 (mm)	9.05 (Mg ha^{-1})
Predicted total if without BMP	663.0 (mm)	44.85 (Mg ha^{-1})
Total reduction	108.3 (%)	395.4 (%)
Average annual reduction	27.1 (%)	98.8 (%)

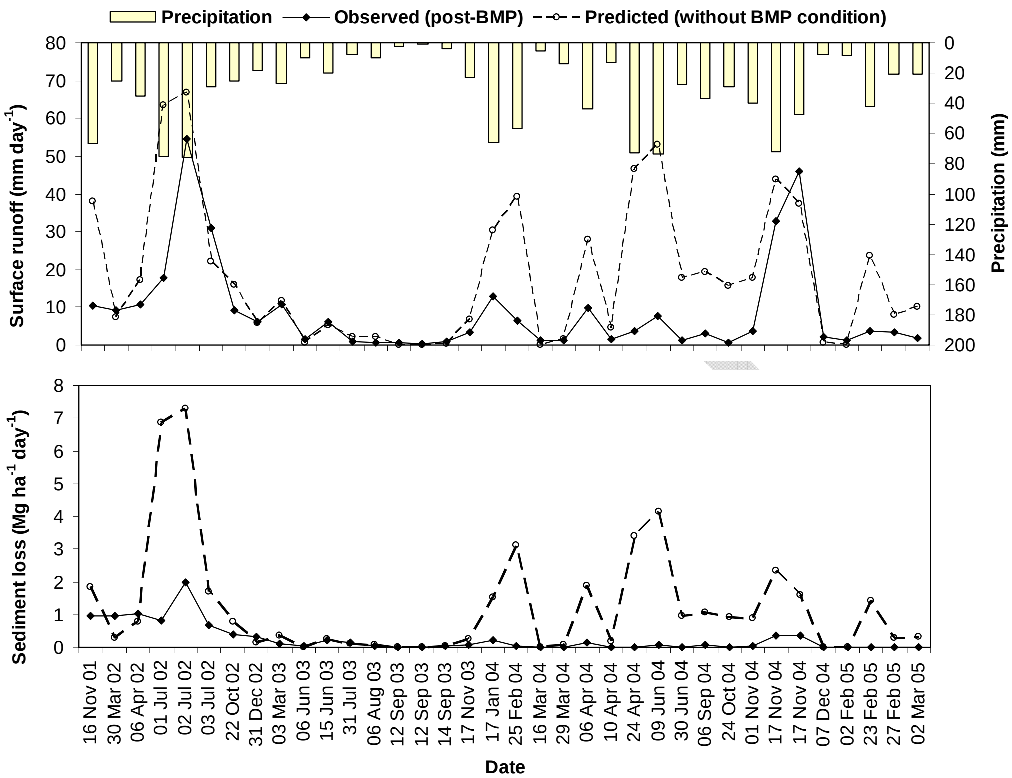

Figure 9. Daily precipitation, and observed (with BMPs) vs. predicted (without BMPs) event flow and sediment yield in Shoal Creek watershed outlet (Nov. 2001 – Mar. 2005).

The benefit of contour ripping alone was examined by running APEX with and without contour ripping. From 2001 to 2005, the contour ripping (approximately 27% of total area) reduced average annual surface flow by 8.5% and sediment yield by 8.2%.

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