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ARMY CRITICAL AREA REVEGETATION ESTABLISHMENT STRATEGIES (ARMY CARES)

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ARMY CRITICAL AREA REVEGETATION
ESTABLISHMENT STRATEGIES (ARMY CARES)

1. Purpose.

a. This Public Works Technical Bulletin (PWTB) identifies and develops new and improved Army Critical Area Revegetation Establishment Strategies (Army CARES) that provide for sustainable management of military lands to ensure sustainability for future use, minimize military impacts to natural and ecosystem processes, and prevent and/or reduce soil erosion for improved water quality.

b. All PWTBs are available electronically (in Adobe Acrobat portable document format) through the World Wide Web at the National Institute of Building Sciences' Whole Building Design Guide web page, which is accessible through the following link:

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

2. Applicability. This PWTB applies to all U.S. Army facilities engineering activities.

3. References.

a. Executive Order (EO) 13423, Strengthening Environmental, Energy, and Transportation Management, 24 January 2007.

b. Army Regulation (AR) 200-1, Environmental Protection and Enhancement. Department of the Army (DA), 21 February 1997; revised 13 December 2007.

c. AR 200-3, Natural Resources – Land, Forest and Wildlife Management. DA, 28 February 1995; revised 20 March 2000.

d. EO 13148, Greening the Government Through Leadership in Environmental Management, 21 April 2000.

e. Commander's Guide: Army Environmental Management Systems (EMS), Version 2, 2007.

4. Discussion.

a. AR 200-1 provides guidance on complying with environmental laws and regulations. Specifically, it addresses environmental and natural resources conservation issues and further supplements Federal, state, and local environmental laws for preserving, protecting, and restoring the quality of the environment. This Army Regulation also integrates pollution prevention, natural resources, and the National Environmental Policy Act (NEPA) into the Army Environmental Management System (EMS). The regulation requires installations to provide stewardship in the preservation, protection, and enhancement of their natural resources for future land-use sustainability.

b. AR 200-3 sets forth policy, procedures, and responsibilities for the conservation, management, and restoration of land and natural resources consistent with the military mission and in consonance with national policies on environment quality and protection. The regulation provides for the conservation, management, and utilization of soils, vegetation, water resources, forests, and other natural resources existing on military lands.

c. This PWTB provides information and planning guidance on revegetation strategies for critically disturbed and degraded areas on military lands. Specifically, this document presents "lessons learned" (through successes and failures) encountered at major installations to share the benefits of experience gained through field applications of critical area revegetation strategies.

d. Land reclamation is an integral part of sustainable development, which aims to reconcile military training with environmental preservation. The goal of this PWTB is to discuss state-of-the-art technology dealing with various aspects of land reclamation, and provide land managers with options for restoration projects and challenges facing them in critical area revegetation strategies.

e. Appendix A describes Army critical revegetation establishment strategies (Army CARES).

f. Appendix B addresses the "why and how" of planting considerations, vegetation considerations/selection, and planting methods.

g. Appendix C discusses the installation experience and lessons learned at Fort Bragg, NC.

h. Appendix D discusses the installation experience and lessons learned at Fort McCoy, WI.

i. Appendix E presents a study of Vetiver grass *(Vetiveria zizanioides).*

j. Appendix F summarizes the U.S. Army CARES program and provides a consolidated, bulleted listing of the lessons learned.

k. Appendix G lists references and Appendix H lists acronyms and abbreviations used in this document. A table of conversions from the inch-pound system of measure to the international system is also provided.

5. Points of Contact (POCs).

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APPENDIX A

ARMY CRITICAL AREA REVEGETATION ESTABLISHMENT STRATEGIES (ARMY CARES)

Erosion Problems — Background

The U.S. Army manages more than 12.6 million acres of land on approximately 120 major installations across the United States (Boice 1996). These acres represent almost one-half of the total 25 million acres under the management of the Department of Defense (Rubenson et al. 1992). In addition, more than 1 million acres of mostly state-owned lands are used by the Army National Guard.

Large blocks of these lands, with varied natural, geographic, topographic, and climatic terrain, act as "classrooms" for Soldiers' learning and training in realistic environments. This training provides the tools necessary to defend the United States within and beyond its borders. However, this security comes at a cost. Severe land disturbance and degradation can result in accelerated erosion, sedimentation, nonpoint source (NPS) pollution, adverse impacts on aquatic and terrestrial species habitat, and impaired quality of surface waters.

Research, study, and demonstration for the Army have resulted in techniques and technologies that can be used for the reclamation, restoration, and rehabilitation of military-impacted training and testing lands at Army installations.

Definitions: Critical Areas, Critically Disturbed Areas, or Degraded Areas

The terms "critical areas," "critically disturbed areas," and "degraded areas" are used interchangeably in this document. They all refer to highly erodible or critically eroding areas that have, or are expected to have, excessive erosion potential on military lands (Figure A-1). These areas usually cannot be stabilized by establishing vegetation with the customary conservation treatment and management practices. Also, if left untreated, these areas can cause severe erosion or sediment damage. Examples of such areas include: steep slopes, highly erodible soils, denuded or gullied areas, and intense-use sites such as bivouac sites, assembly areas, drop zones (DZs), and wheeled- and tracked-vehicular maneuver corridors.

The direct effects on these sites include removal of vegetation, disturbance of soil profile, and soil compaction. These effects may cause increased surface erosion and sedimentation (Curtis 1971; Gilley et al. 1977), changes in surface hydrology (Babb et al. 1985; Garn 1985), reduced aesthetics at the site (Brotherton 1989; Nieman and Meshako 1990), impaired water quality, and NPS pollution. Furthermore, these sites are where vegetation is difficult, if not impossible, to re-establish with the usual and customary planting methods. Critical areas include areas with soils that are highly erodible, droughty, excessively wet, or very acidic or alkaline. Long or steep slopes, slopes immediately adjacent to water bodies or wetlands, fill areas, and areas subject to concentrated flows are also problematic.

Figure A-1. An example of severely eroded land due to military operations.

Land disturbance or degradation can be referred to as "severe" if it results in the complete loss of native soil and vegetation, and/or if it disrupts or destroys natural hydrological features. On military lands, severe disturbances are normally most significant on local rather than watershed scale, but may have far greater impacts on water quality and quantity, wildlife habitat, and other attributes than some much larger scale disturbances. The occurrence of locally severe disturbances is a typical phenomenon on military lands as heavier and faster mobile weapon systems roam these lands under all weather conditions.

Research has shown that it is not uncommon for 5% of a disturbed watershed area to contribute to over 80% of erosion and sediment production. Thus, barren and "idle" critically disturbed areas, though small in land size, are a major source of erosion and sediment production on Army training and testing lands (Figure A-2). Erosion from erodible hill slopes, unimproved roads and trails, and intense-use training areas is a significant contributor of NPS pollution of surface waters.

Degradation (e.g., gullies, slope instability, ruts, and dust) impedes tactical maneuver operations and accomplishment of training objectives. Years of military training have resulted in loss of topsoil and damaged protective vegetative cover. This has in many cases caused progressively accelerated degradation of the land resulting in loss of training area, training realism, clean water quality, and terrestrial and aquatic species habitat. Loss of vegetative cover for wildlife habitat and soil stabilization also means loss of tactical concealment for a realistic training environment. As a result of these conditions and at a time of increased national environmental awareness, installation land managers are faced with growing environmental responsibilities and greater land rehabilitation and maintenance problems than ever before.

Figure A-2. View of Lorraine Road before restoration measures were implemented.

Figure A-3. This gully at Kelley Hill, Fort Bragg, started at the stormwater outfall.

Nevertheless, not all land degradation and soil erosion/sedimentation problems are a direct cause of military training impacts. For example, the gully shown in Figure A-3 started at a stormwater outfall. It measured 95-ft across and 45-ft deep before restoration measures were implemented (Gary Hollon, Soil Conservationist, Environmental Management Division, Fort Benning, pers. comm. 2008). The culvert inlet erosion shown in Figure A-4 shows a similar problem. Although the origin and cause of concentrated flow may be damage by tracked- or wheeled-vehicular traffic, placement of riprap around the culvert is not an appropriate solution. Critically eroded and degraded areas on Army training and testing lands are among the most chronic and aesthetically displeasing sites.

Figure A-4. Riprap placed around this culvert inlet is not the appropriate solution to the erosion problem.

Soil erosion results in the loss of huge amounts of valuable topsoil, and this eroding soil accumulates in down-slope forested areas, streams and creeks, and other surface waters where it is unwelcome, terribly destructive, and prohibitively expensive to remove. Erosion is thus a double disaster: a vital resource disappears from where it is desperately needed only to settle where it is equally unwanted. The National Research Council (NRC 1993) reported that $18 billion is lost to soil erosion just in fertilizer nutrients, which in turn results in eutrophication problems in downstream surface waters. According to the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS), almost $27 billion is lost each year in productivity on cropland and pasturelands. An additional $17 billion is estimated annually for off-site environmental costs (e.g., increased water treatment) due to erosion.

On Army installations, degraded and critical areas present atypical land management problems that require unique land restoration and revegetation solutions. The fact that these areas have lost almost all topsoil provides a further challenge, since it places constraints on the revegetation technology that can be implemented for the rehabilitation of critically eroded lands.

It has been stated that revegetation in areas where precipitation is less than 230 mm (4 in.) per year is a difficult if not impossible task (Plummer et al. 1968). Wallace et al. (1980) claim that only 2 years in 6 have precipitation suitable for revegetation to be successful in the northern regions of the Mojave Desert. On Army and Federal lands located in these arid lands, climatic conditions present additional challenges for seed germination and plant establishment. Since efforts focused on developing effective and exhaustive revegetation strategies for arid lands of the desert southwest have been abundantly reported elsewhere (Winkel et al. 1999; Bainbridge et al. 1998; Roundy et al. 1995; Hall and Anderson 1999; and others), this PWTB does not address revegetation for arid lands.

APPENDIX B

U.S. ARMY CARES – THE WHY AND HOW OF PLANTING CONSIDERATIONS, VEGETATION CONSIDERATIONS/SELECTION, AND PLANTING METHODS

It is impossible to avoid military-related land disturbance, but measures can be taken to diminish impacts. Soil erosion on Army training lands can result in natural resource losses that diminish the land's capacity to support training activities. Degradation such as gullies, channels, slope instability, ruts, and dust impede tactical maneuver operations and the accomplishment of scheduled training goals and objectives. Loss of vegetative cover for wildlife habitat and soil stabilization also means loss of tactical concealment for a realistic training environment. Army planners and decision makers realize that training land resources are limited and must be protected through environmentally sound conservation and land management planning. This is especially true in view of the fact that acquisition of new lands is becoming increasingly difficult because of urban sprawl and funding constraints.

Army installation land managers are confronted with more difficult training land restoration and maintenance problems than ever before. Greater demands are being placed upon them as force modernization programs using more mobile and faster weapon systems operate over larger areas.

Resulting loss of vegetative cover from military impacts and subsequent accelerated erosion degrades the natural landscape, reduces soil productivity, and increases the difficulty of establishing and maintaining vegetation. As a result of these conditions and at a time of increased national environmental awareness, the Army is examining ways to develop optimal management practices and innovative critical area revegetation establishment strategies (Army CARES) to control erosion more effectively and efficiently on its training lands.

Vegetative Control for Training Land Restoration and Maintenance (LRAM)

Selection of a suitable LRAM technology for military lands is a particularly difficult task because special requirements for training compatibility must be taken into account. Mission-compatibility requirements include: durability for use by tactical vehicles; spatially unimpeding terrain for one set of training requirements and rolling terrain for conditions such as tactical concealment islands; harder and stabilized surfaces that impede dust generation for vehicular and tactical maneuver operations; softer and smoother DZs for a safer landing terrain for parachutists.

Among the two mostly commonly used (structural and biological) erosion control options, vegetative control measures offer the preferred choice. Vegetation helps in significant reductions in soil loss, is environmentally friendly, promotes healthier ecology, improves water quality, and is "nature's way" of bio-filtering sediments and NPS pollution. A few of the numerous advantages of vegetation are that it:

- retards stormwater runoff flows,
- aids in stormwater harvesting by increasing infiltration,
- improves soil water-holding capacity,
- reduces overland runoff volumes,
- improves soil structure, and
- enhances soil organic matter content through decay of plant residue.

If the plant's canopy protects the soil above from erosive forces of falling rainfall, the root system below provides "nature's best engineered" anchoring mechanism by reinforcement from long and fibrous roots (Figure B-1), thereby contributing to soil stability. Figure B-1 shows a 7-ft-long fibrous root system of native bluestem grass that is found almost all over the United States. During research on Vetiver (see Appendix E for details), a growth of over 3 ft in 12 weeks was observed in the root system of a Sunshine variety tested in Champaign, IL and Sunshine, LA. Vetiver plants grown on a sandy loam hilltop in Thailand exhibit an exposed root system of Vetiver measuring over 25-ft-deep into the earth.

Establishing vegetation on critically disturbed training areas, steep slopes, and highly erodible bank slopes is very difficult to achieve and maintain. These soils are historically low in organic matter, and concentrated flow velocities tend to dislodge both soil and vegetation growth before it is established. Alternate "innovative" techniques and technologies, such as the planting of Vetiver, blue stem, and willows, that provide for soil-vegetation reinforcement to reduce runoff flow and volume are needed to successfully establish vegetation.

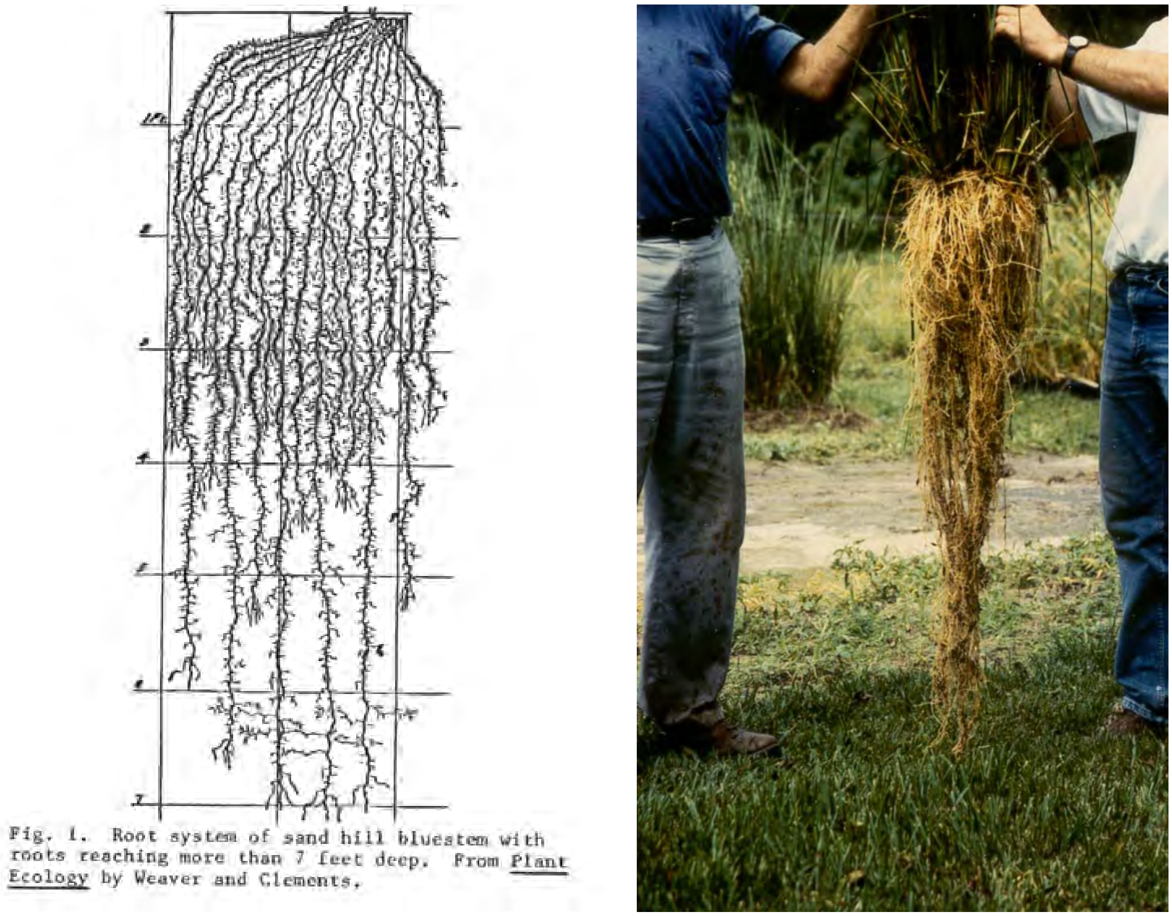

Figure B-1. Root system of (left) sand hill bluestem and (right) Vetiver grown in Champaign, IL. (Source for bluestem drawing is Weaver and Clements 1938.)

Technical Objective

The main objective of this work was to identify and develop new and improved Army CARES strategies that provide for management of military lands to ensure sustainability for future use, minimize military impacts to natural and ecosystem processes, and prevent and/or reduce soil erosion for improved water quality.

Approach

The development of this Army CARES document included conducting site assessments, establishing goals and standards, determining site preparation requirements, selecting species, selecting vegetation techniques, selecting conservation practices, determining planting times, and lessons learned. This appendix includes the following major sections:

1. Planning considerations

2. Vegetative considerations

3. Vegetation selection

4. Planting methods

Planning Considerations

Rehabilitation and maintenance of Army lands include such planning considerations as: (1) needs assessment and technology selection, and (2) adaptive management and planning, which are described briefly in the following sections.

Needs Assessment and Technology Selection that is Mission-Compatible

Guidance should be developed to identify critical-area erosion problems, assess needs, and select appropriate technologies to successfully establish vegetation that is Army-unique and mission compatible. Because many standard critical area erosion controls and revegetation practices simply would not be adequate or acceptable for use under military training conditions, conventional restoration practices would need to incorporate special Army requirements to produce adaptive, modified, or innovative technologies that meet those special needs. For example, restoration of upland eroded and gullied areas by using riprap in waterways and constructing sediment retention basins, though a practice in agriculture and forestry applications, is mission-incompatible in DZs. Rocks or hard materials and standing water are not permissible on DZs because they can potentially increase the hazard of possible drowning or injury to parachutists.

Incorporate Principles of Adaptive Management and Planning in Army CARES

Army CARES strives to be mission-compatible and to use principles of adaptive management and planning. Adaptive management and planning strategies involve a decision-making process based on trial, monitoring, and correction, rather than off-the-shelf standard solutions. Instead of using "standard" revegetation practices, principles of adaptive management should be used for critical-area revegetation practices that could be modified as technical knowledge improves and training requirements change. In other words, adaptive planning and management constitutes an approach that responds quickly and effectively to unique or changing military training or land restoration challenges at a particular site rather than responding primarily to pre-defined guidelines and procedures.

Vegetative Considerations

As noted in Appendix A, establishing vegetation in climatic regions where annual precipitation is less than about 230 mm (4 in.) is difficult if not impossible (Plummer et al. 1968). This PWTB describes revegetation efforts and lessons learned mainly on Army installations located in the southeast and mid-western states. The Army installations located in these southeast and mid-western states usually have (at least) adequate precipitation to accommodate germination through plant establishment.

Role of Vegetation in Army Training Area Stabilization

The most efficient and cost-effective form of erosion control is prevention. The environmentally friendly, aesthetically pleasing, and natural method of erosion control is through the use of vegetation. Vegetation protects the soil from the erosive energy of falling raindrops. It also shields the soil surface from the scouring forces of overland flow, reduces runoff flow velocity, and acts as a filter for sediment, thereby reducing sedimentation of downstream forest lands and surface waters. Properly established vegetation, besides protecting disturbed areas from erosion, also absorbs nutrients and removes contaminants through the soil–water–plant uptake mechanism.

Vegetation helps stormwater harvesting through increased infiltration and replenishment of soil moisture lost through evapotranspiration. Decayed plant litter and roots provide a valuable source of soil organic matter. This also helps increase soil water-holding capacity, improve soil structure, and condition the soil.

Vegetation has been and still is "nature's food basket" for humans, animals, and wildlife. Other vegetation advantages are given on page F-1. Vegetation establishment is relatively inexpensive to achieve and tends to be self-healing. It is often the only practical, economic, and long-term solution for the stabilization of disturbed areas on military lands.

Briefly, the major effects of vegetation may be summarized as:

- Interception. Foliage and plant residue absorbs rainfall energy and prevents soil erosion and compaction.

- Restraint. Root systems physically bind or restrain soil particles while above-ground residue filters sediment runoff.

- Retardation. Above-ground residue increases surface roughness and slows down runoff velocity.

- Absorption. Root systems absorb and assimilate nutrients through soil-water-plant uptake.

Factors Influencing Selection of Vegetation for Army CARES

Factors that influence the selection of vegetation species and their planting strategies generally depend on geography, topography, soil characteristics, and the nature and extent of soil disturbance. Brief descriptions of these factors are given below.

Geography

The physical location of the military training area in need of restoration will determine its climate, precipitation, and geology. These factors cannot be changed or modified, so the selection of plant species will mostly depend on plant species that are native or adapted to that geographical area. It is possible to successfully grow almost any kind and type of vegetation in tropical regions where rainfall is abundant and distributed fairly uniformly throughout the year. However, land managers at Fort Irwin, CA, have little choice in the selection of planting species in the dry Mojave Desert other than to select species that are native or well-acclimatized to the region.

Topography

Physical features of the disturbed area such as terrain, slope, and aspect are among the significant factors influencing the type of vegetation that can be established at the site. In some instances, the slope and aspect may be the limiting factors in species selection (grass, shrubs, and trees). For example, hedge grasses may be the only choice for steep slopes like the one shown in Figure B-2. The steeper the slope, the more difficult it is to establish vegetation and manage equipment and manpower.

Figure B-2. Hedge grasses may be the only choice of vegetation on steep slopes.

Soils and soil limitations

It is possible to change and condition the structure of soils, but not the texture. Soil characteristics such as texture, structure, organic matter, fertility, and chemistry (acidity, alkalinity) influence the selection of planting species and the steps required for their establishment. Liming applications help increase pH and improve soil structure. Coarse sandy soils are usually nutrient deficient and, even after precipitation, lose moisture rapidly in surface layers necessary for seed germination. Clay and loamy clay soils have low permeability and impede infiltration, thereby increasing overland flow velocity and runoff volume. Lacking emergence vigor, small-seeded perennials are often confronted with a dry crust in clay soils. Tailor the selection of vegetation species and planting seed mixtures in accordance with prevailing soil characteristics in the area to be revegetated.

Soil disturbance and degree of land degradation

Establishing vegetation on critically disturbed training areas, steep slopes, and highly erodible bank slopes is difficult to achieve and maintain. Soils are historically low in organic matter, and concentrated flow velocities tend to dislodge both soil and vegetation growth before it is established. The plant species selected for critically disturbed areas may not be significantly different than those used for less disturbed sites for the training area. It takes patience and several years to establish a good and healthy stand of perennials, and that may not be possible either unless aggressive, diligent, and faithfully consistent maintenance measures are undertaken. Overseeding, liming, and fertilizer applications must be performed after planting for the following couple of years until a good stand is achieved. Seeding, liming, and fertilization rates for these critical sites also should be higher than normal.

In cantonment areas where a neat appearance is desired, use grasses that respond well to frequent mowing and other types of intensive maintenance. The determining factor for species selection will be the geographic area. For most parts of eastern and mid-western states, the most likely choice for quality turf may include fescue, Kentucky bluegrass, Bermudagrass, centipedegrass, zoysiagrass, and Bahiagrass. Consult the county’s Cooperative Extension System office for the best choices.

For many Army-unique training areas, the vegetation’s longevity, durability, and low maintenance are particularly important features. Preferred grass choices may include bluestem species, Bermudagrass, redtop, and crownvetch. Again, consult the local Cooperative Extension System office for suitable choices.

Vegetation Selection

A diversity of vegetation can be grown on almost all military lands because of their variation in both soils and climate. However, for practical, economical, and long-term stabilization of disturbed sites, species selection should be made with care. Many common plants are inappropriate for soil stabilization because they do not protect the soil effectively or because they are not quickly and easily established. Plants that are preferred for some sites may be poor choices for others; a few can become troublesome pests.

Planting grass species for stabilization of disturbed areas may be classified based on:

- their growth characteristics: cool or warm season grasses, or
- their longevity: annuals or perennials.

The above criteria are not mutually exclusive; rather, the class of grass species belonging to annuals or perennials may also belong to either cool or warm season grass species, but not to both.

Selection of Planting Species Based on Seasonality

Seasonality must be considered when selecting species. Grasses and legumes are usually classified as warm or cool season species. Cool season plants produce most of their growth during the spring and fall, while being relatively dormant during the hot summer months. Therefore, fall is the most appropriate time to plant them. Warm season plants green up late in the spring, grow most actively during the summer, and go dormant at the first frost in fall. Spring and early summer are preferred planting times for warm season grasses and legumes.

Selection of Planting Species Based on Their Longevity

Temporary seeding

Temporary seeding is the establishment of a temporary vegetative cover on disturbed areas by seeding with appropriate rapidly growing annual plants. Species used for temporary seeding grow rapidly and die in the same growing season. Because these species are short-lived and usually do not survive more than 1 year, they are also called annuals. Temporary seeding is recommended for all disturbed areas that will not be seeded with perennials for a period of 30 days to 1 year.

Annuals added into a mixture of permanent vegetation are called a "nurse" crop. Nurse crop annuals germinate and grow rapidly. They provide quick temporary cover to the slower growing perennials during their early stages of establishment. Using annuals as a nurse crop is a good practice, particularly on severely disturbed and difficult sites where the establishment of perennials is likely to be slow or uncertain. When planted as a single species for establishing immediate cover, the planting species are annuals and the process of their planting is called temporary seeding.

Permanent seeding

Establishing vegetation by seeding perennial grasses for long-term surface protection is called permanent seeding. Planting species used for permanent seeding germinate and grow slowly, taking several months or years to establish a good healthy stand. Planting species used for permanent establishment are seeded in mixtures with annual species to protect the slow growing seedlings of permanent grasses.

Cool and Warm Season Annual Grasses for Temporary Seeding

Temporary seeding of annual plant species is the most common and appropriate erosion control treatment due to the frequent disturbance of many sites during active training periods. Annual plant species generally exhibit rapid establishment, survive for a growing season, and require less establishment costs than permanent seeding or sodding. Annual species such as ryegrass, millet, crimson, clover, and hairy vetch exhibit good reseeding capabilities and provide quality wildlife foods during periods of low food availability.

Salient features of some commonly used cool season and warm season annuals and perennials are given below. Complete descriptions of their botanic and agronomic characteristics can be found in standard books on the subject.

Annual ryegrass

Ryegrass is a cool season annual. It used for temporary cover or as a nurse crop for germination of permanent stands. It provides dense cover rapidly, but may be beneficial in areas that are to be permanently stabilized. Annual ryegrass is highly competitive and, if included in mixtures, it will crowd out most other species before it matures in late spring or early summer, leaving little or no lasting cover. It can be effective as a temporary seeding, but, if allowed to mature, the seed volunteers and seriously interferes with subsequent efforts to establish permanent cover. Winter rye (grain) is preferable in most applications. Optimum seeding times are early spring or fall. Use a seeding rate of 120 lb/acre for temporary cover and 20 lb/acre in mixes.

German millet

German millet is a warm season annual grass, useful for temporary seeding and as a nurse crop. It is better adapted to sandy soils. Normal seeding time is spring and early summer.

Sudangrass

Sudangrass is a warm season annual and is available in two varieties: common and small-stemmed. Only the small-stemmed varieties of sudangrass should be used. Like German millet, it is useful for temporary seeding and as a nurse crop. The grass is well-adapted to soils higher in clay content. Seed for common sudangrass is not always available, but other small-stemmed types may be used. As with all warm season grasses, optimum seeding times range from spring through summer.

Winter rye (grain)

Winter rye, also known simply as rye, is a cool season annual. It is usually superior to other winter annuals (wheat, oats, crimson clover, etc.) both for temporary seeding and as a nurse crop in permanent mixtures. It has more cold-hardiness than other annuals and will germinate and grow at lower temperatures. By maturing early, it is less competitive during the late spring period, a critical time in the establishment of perennial species. Rye grain germinates quickly and is tolerant of poor soils. Including rye grain in fall-seeded mixtures is almost always advantageous, but it is particularly helpful on difficult soils and erodible slopes or when seeding is late. Overly thick stands of rye grain will suppress the growth of perennial seedlings.

Rye is the most common small grain used for temporary cover or nurse crop for soil stabilization and erosion control. It performs well on dry, infertile, acid, and sandy soils. It may be seeded in fall for winter ground cover. By maturing early, it offers less competition during the late spring season period, a critical time in the establishment of perennial species. This makes it an excellent candidate to use as a nurse crop. Rye grain germinates quickly and is tolerant of poor soils. Do not use more than 20 lb/acre in nurse crops; otherwise, it may suppress the growth of perennial seedlings.

Weeping lovegrass

Weeping lovegrass may be grown as a summer annual or short-lived perennial. It is a rapid-growing, warm season, bunch grass introduced from East Africa. It is easy to establish by seed, germinates rapidly, and grows quickly. These qualities make it an excellent choice for erosion control and stabilization of disturbed lands.

Warm Season Perennials for Permanent Seeding

Warm season perennials initiate growth later in the spring than do cool season species and experience their greatest growth during the hot summer months. The following grasses have proven the most useful for soil stabilization.

Bermudagrass

Bermudagrass is an aggressive sod-forming long-lived warm season perennial that spreads by stolons (underground stems) and rhizomes (underground runners). It is adapted to a wide range of well-drained to excessively drained soils. The grass is very drought-resistant, has considerable salt tolerance, and can be used successfully on disturbed lands. It is well-adapted for deep sandy soils. Common bermudagrass is not recommended for general use because it quickly becomes a pest, spreading rapidly both vegetatively and by seed. However, given the nature of Army lands, it may be the best choice for training areas where establishing other vegetation is difficult.

Bermudagrass is an excellent choice for Army-unique erosion problems because it spreads vigorously. It achieves its best growth when temperatures are above 75°F. Bermudagrass grows on a wide range of soils from heavy clays to deep sands.

Bahiagrass

This warm season perennial grass can tolerate dry, acid, low-fertility soils. Bahiagrass produces a fairly dense sod. The grass species is well-suited for the revegetation of Army-unique land because it can withstand vehicular traffic and its growth characteristics are adapted to a wide range of soil and climate conditions. Like Bermudagrass, Bahiagrass may be the best choice for the restoration of critically disturbed Army training and testing lands.

Centipedegrass

Centipedegrass is a creeping perennial that is well-adapted to sandy, acidic soils. It tolerates low fertility and requires little maintenance. Thus it is very well suited for use on military lands. Centipedegrass spreads by stolons and survives well in well-drained, medium- to coarse-textured soils. Again an excellent choice for the revegetation of training disturbed lands because it thrives in soils that are infertile and acidic. It can be established both from seed or sprigs. The best planting months are early spring through summer.

Little bluestem

Little bluestem is a medium height grass with coarse stems and basal leaves. As a warm season grass it begins growth in late spring and continues through the hot summer until the first killing frost. It is easily mistaken for common broom sedge. Little bluestem has very flat bluish basal shoots. Plants are green, but often purplish at the base of the stem, and the entire plant has a reddish cast after frost. Leaves are smooth but frequently are covered with hair at the base next to the sheath. Leaves tend to fold with maturity. Seed head clusters are about 3-in. long. The cluster stems are hairy. Plant height varies from 18 in. on droughty sites to 3 ft on deep, fertile soils. It has a robust, fibrous root system that can grow over 7-ft deep in the soil.

Little bluestem is one of the most widely distributed native grasses in North America. It will grow on a wide variety of soils, but is very well adapted to well-drained, medium to dry, infertile soils. The plant has excellent drought and fair shade tolerance, and fair to poor flood tolerance. It grows preferentially in soils with pH 7.0 and slightly higher. Whenever geographical conditions allow, consider planting bluestem in all of your soil stabilization conservation practices because it is native and possesses highly desirable erosion control characteristics.

Cool Season Perennial Grasses for Permanent Seeding

For much of the country, the most effective times for planting perennials generally extend from March through May and from late August through October. Outside these dates the probability of failure is higher, except areas that receive appreciable precipitation during the hot summer months of July and August.

Cool season perennials produce most of their growth during the spring and fall and are more cold-hardy than most warm season species. Descriptions of the species recommended for vegetating disturbed soils follow.

Tall fescue

Tall fescue is a cool season grass. It is a robust, long-lived, deep-rooted bunchy grass that may have short rhizomes or stolons and is one of the most widely used species for erosion control. It is well adapted to a wide range of soils, but does not perform well during droughts. It thrives in full sun to partial shade and is easy to establish. If seeded in the fall, it provides stabilization early in the first growing season. Because of Tall Fescue's bunchy growth habit, it is best used in mixtures. It does not fill in well where areas are damaged by disease or weather; however, short rhizomes enable individual plants to expand substantially in thin stands.

A number of new varieties of tall fescue are becoming available, but their higher cost over the old standby is seldom justified solely for purposes of stabilization and erosion control. Tall fescue tolerates a wide range of seeding dates, but typically it is most dependable when planted in the fall. Liberal fertilization and proper liming are essential for prompt establishment of Tall Fescue, but once firmly in place it can tolerate minimal maintenance almost indefinitely. Seeding rates may vary from 100 lb/acre for erosion control to 250 lb/acre for lawns. In view of its agronomic and growth characteristics, it is highly recommend for soil stabilization and erosion control of military-unique disturbed training lands.

Kentucky bluegrass

Kentucky bluegrass is a cool season, long-lived perennial that produces a dense, shallow root system. The grass becomes dormant in summer since its growing season is spring and fall. It is used widely throughout the United States as a lawn grass. Because of its shallow root system, it is not a good choice for erosion control. It can be used with Tall Fescue or Bluegrass perennial grasses.

Redtop

Redtop is a very tough cool season perennial grass. It grows well under a wide variety of soil and moisture conditions. It can survive on very acid soils and poor, clay soils of low fertility. It can be successfully established on military lands because it is tolerant to low fertility, droughty, and acid soils. The grass species can be used as a mixture with other perennials and annuals on difficult soils such as dry and stony slopes. It may be planted from early spring through summer. Redtop is seldom seeded alone except as temporary turf. It is most commonly used in mixtures at a seed rate of 3 lb/acre.

Perennial ryegrass

Perennial ryegrass is a cool season perennial, but is short lived. It can be used as a winter annual instead. It is effective when seeded in late summer or early fall as a winter cover crop for other perennial grasses and legumes. It is a bunch grass that helps slow overland storm runoff velocities and can be used for controlling erosion. It is an excellent selection in situations when rapid establishment is desired for disturbed-area stabilization and temporary cover. Perennial ryegrass may be seeded early summer through fall. If used as a single species for temporary cover, use a seeding rate of 120 lb/acre.

Annual Legumes

Like grasses, legumes may be annuals or perennials and are generally planted in mixtures with permanent grasses.

Alfalfa

Alfalfa is a cool season annual, well-suited to a wide range of soil conditions. It has a high nutrient value and should be used in a mixture with sod grasses for erosion control.

Red clover

Red clover is a relatively short-lived perennial that is best suited to moderate temperatures and adequate moisture. Red clover is easy to establish with no-till methods and should be seeded in a mixture with perennial grasses for soil stabilization and erosion control.

Annual lespedeza

Annual lespedeza is a warm season, self-reseeding annual legume that is tolerant of low fertility and is adapted to a range of climate and soil conditions. It is an excellent nurse crop in the spring, filling in weak or spotty stands the first season without suppressing the perennial seedlings. It is often seeded with *Sericea lespedeza*. Annual lespedeza can heal damaged areas in the perennial cover for several years after initial establishment. Two varieties of annual lespedeza are generally available: Kobe and Korean. Compared with Korean lespedeza, the Kobe variety performs better on sandy soils.

The preferred seeding dates for annual lespedeza are in late winter to early spring. Mixed with fall seedings, some seeds remain dormant over the winter and germinate the following spring. However, it is more effective to overseed with lespedeza in late winter or early spring. Annual lespedeza may be grown alone or in mixes as a nurse crop. Recommended seed rate is 25–40 lb/acre if planted alone or 15 lb/acre when used in mixtures.

Perennial Legumes

Crownvetch

Crownvetch is a deep-rooted, cool season perennial legume with spreading rootstocks, adapted to cool slopes (north and east exposures). It is useful on steep slopes and rocky areas that are likely to be left unmowed. Crownvetch requires a specific rhizobium inoculant, which may have to be obtained by special order. It can be seeded in the spring or fall.

Crownvetch spreads from rhizomes and will form a dense cover. It has been used for soil stabilization and as an ornamental for many years. It has a wide range of climatic adaptations, but its performance has been superior on well-drained soils. Crownvetch is tolerant of both low pH and low fertility soils. However, it is highly responsive to lime, phosphorus, and potassium. Crownvetch is particularly adapted to road bank stabilization and erosion control.

Crownvetch is winter hardy and drought resistant, which makes it best for training area stabilization. It provides high quality food for ruminant animals and serves as a wildlife food and cover plant. Seeding in spring is most successful. Crownvetch often takes 2 to 3 years to establish a dense stand. A companion grass such as Perennial ryegrass or Redtop needs to be mixed into initial planting, and seeding in spring is most successful.

Sericea lespedeza

Sericea lespedeza is a warm season perennial legume, with widely branched roots that penetrate soil 3 ft or more. The plant will grow on a wide range of soils from sandy, acidic, or infertile, to well-drained, deep soils of medium-to-coarse texture. *Sericea lespedeza* is a deep-rooted, drought-resistant perennial legume, adapted to most soils with the exception of poorly drained soils. It is long-lived, tolerant of low-fertility soils, pest-free, and it fixes nitrogen. It can be a valuable component in most low-maintenance mixtures. *Sericea lespedeza* is a slow starter and should not be expected to contribute much to prevention of soil erosion the first year; however, it strengthens rapidly and persists indefinitely on suitable sites. Seedings that include *Sericea lespedeza* require mulch and should include nurse plants such as German millet, Sudangrass, or Annual lespedeza. "Scarified" (roughened) seed should be used for spring seeding of *Sericea lespedeza* because it germinates more readily. Unscarified seed is recommended for fall-seed mixtures because many of the seeds will lie dormant over winter and germinate early the next spring.

Planting Methods

Strategies in Vegetative Stabilization

Vegetative strategies include varying degrees of treatment requirements, such as the following:

1. Maintenance of existing vegetation through application of soil amendments – To achieve a healthy stand, apply lime and ferti-

lizer each year by broadcasting on existing vegetation that is sparse and spotty.

2. Overseeding without seedbed preparation — Overseed entire area of existing vegetation if the stand is inadequate and sparse throughout by using a no till drill or similar equipment. Lime and fertilize the entire project area by broadcasting. Use application rates at 50% of the normal rates for the project site.

3. Seeding using seedbed preparation, fertilization, and mulching of annual or perennial grass is described in the following sections.

Seeding

Seeding is by far the fastest and most economical method that can be used with most plant species. However, some grasses do not produce seed and must be planted vegetatively. Seedbed preparation, liming, and fertilization are essentially the same regardless of the method chosen.

Apply all seeds with a drill, cultipacker, or similar equipment. Plant small seed grains no more than 1 1/2 in. deep. Small seeded perennials such as Kentucky Bluegrass, Bahia, and Bermuda should be planted no more than 1/4 to 1/2 in. deep. However, large seed grains such as corn, sorghum, and wheat may be planted up to 2 in. deep in sandy soils. Areas that fail to establish satisfactory vegetative cover will be seeded as soon as areas are identified or at least during the following seeding season.

Except for the use of annuals for temporary cover, single species grass plantings are not recommended for Army land restoration. This is because single species plantings of annul grasses seldom establish a healthy plant establishment. For establishing permanent vegetation, always use a "nurse" crop in a mixture of one or more perennial grasses. General seeding rates for most commonly used annuals and perennials are available from local USDA NRCS offices. Contact the local County Extension Service representative for the selection of planting materials, seeding rates, planting times, and lime and fertilizer requirements.

Seeding Methods

Uniform seed distribution is essential. This is best obtained using a drop spreader, conventional grain drill, cultipacker seeder, or hydraulic seeder. The grain drill and cultipacker seeders (also called grass seeders) are pulled by a tractor and require a clean, even seedbed.

On steep slopes, hydroseeding may be the only effective seeding method (see Hydroseeding section later in this appendix). Surface roughening is particularly important when preparing slopes for hydroseeding. In contrast to other seeding methods, a rugged and even trashy seedbed gives the best result.

A "sod seeder" (no-till planter) is used to restore or repair weak cover. It can be used on moderately stony soils and uneven surfaces. It is designed to penetrate the sod, open narrow slits, and deposit seed with a minimum of surface disturbance. Fertilizer is applied in the same operation.

Seedbed Preparation

Seed germination is highly dependent on good seed-soil contact. The soil on a disturbed site must be modified to provide an optimum environment for germination and growth. At planting, the soil must be loose enough for water infiltration and root penetration, but firm enough to retain moisture for seedling growth. Tillage generally involves disking, harrowing, raking, or similar method. Lime and fertilizer should be incorporated during tillage.

Surface Roughening

A rough surface is especially important for seeding sloped areas. Contour depressions and loose soil surface helps retain lime, fertilizer, and seed. A rough surface also reduces runoff velocity and increases infiltration.

Soil Amendments

Lime and fertilizer application

Liming is almost always required on disturbed sites to raise the pH of acidic soils, reduce exchangeable aluminum, supply calcium and magnesium, and improve soil structure. Whether there is a need or not, lime is relatively inexpensive and acts as a soil conditioner. Even on the best soils, some lime and fertilizer application is required. Suitable rates and types of soil amendments should be determined through soil tests. Limestone and fertilizer should be applied uniformly during seedbed preparation and mixed well with the top 4 to 6 in. of soil. In the absence of lime and fertilizer requirements for a project, use the rates listed in Table B-1 as a general guide. Use 10-20-20 granular fertilizer at the rate of 80-160-160 lb/acre of nitrogen, phosphorous, and potassium, respectively.

Mulching

Mulch is essential for all seeded areas, especially on difficult sites. The steeper the slope and the poorer the soil, the more valuable mulch becomes. It creates a micro-climate for seed germination by reducing evaporation, preventing soil crusting, and insulating the soil against rapid temperature fluctuations. Also, it prevents erosion by protecting the surface from raindrop impacts and reducing the velocity of overland flow. Grain straw (wheat, oats, barley, rye) is the most widely used and one of the best, most cost-effective mulches available (Figure B-3).

Mulch anchoring

To prevent displacement after spreading, mulch must be anchored immediately by a crimper or similar equipment. Anchoring with bulldozer cleats is most effective on sandy soils; however, this practice often causes undue compaction of the soil surface, especially in clayey soils. Thus, anchoring with bulldozer cleats is not advisable on soils other than sandy soils.

Table B-1. Liming and fertilizer requirements for seeding critical and difficult areas.

pH Test	Recommended Application of Fine Granular Agricultural Lime
below 4.2	3 ton/acre
4.2 to 5.2	2 ton/acre
5.2 to 6	1 ton/acre

Figure B-3. Grain straw mulch applied at 4,000 lb/acre.

Hydroseeding

On steep slopes, hydroseeding may be the only effective seeding method. Hydroseeding is recommended on slopes greater than 3:1 or on narrow sites such as road shoulders (Figure B-4).

Hydroseeding is the process of spraying seed, mulch, and other materials that have been mixed with water, usually in one pass. Wetted materials make excellent contact with the soil surface. Other materials such as tackifiers, fertilizer, lime, or other soil amendments can be added to the mixture. Mulch provides temporary protection to allow seed to germinate and plants to establish. The most common mulch materials are straw, wood fiber, and cellulose.

Surface roughening is particularly important when hydroseeding. A roughened slope will provide some natural coverage for lime, fertilizer, and seed; therefore, the surface should not be compacted or smoothed. Fine seed bed preparation is not necessary for hydroseeding operations; large dirt clods, stones, and irregularities provide cavities in which seeds can lodge. For more detailed information on hydroseeding, consult PWTB 200-1-65, “Proper Selection of Hydroseeding Mixtures and Components to Promote Rapid Revegetation of Disturbed Department of Defense Lands.”

Figure B-4. The hydroseeding process sprays seed, mulch, and other materials that have been mixed with water.

APPENDIX C

INSTALLATION EXPERIENCE
FORT BRAGG, NORTH CAROLINA

Background

Fort Bragg, "Home to the Airborne and Special Operations Forces", is west of Fayetteville in south-central North Carolina (Figure C-1). It is the largest airborne facility in the world. Fort Bragg occupies some 161,000 acres of land area that stretches into 6 counties and includes 20 DZs, a multi-purpose range complex (MPRC) in Range 63, 4 impact areas, 82 ranges, 16 live-fire maneuver areas, 2 Army airfields, and a large and extensive network of tank trails and secondary roads.

Fort Bragg's climate is hot in summer and moderately cold in winter. Annual average precipitation is 45.6 in. and a snowfall of 3.2 in. (USDA 1981) is distributed fairly uniformly throughout the year. The driest months of the year are November through January with approximately 2–3 in. of rainfall per month. The wettest month of the year is August with an average rainfall of 5.7 in. Most of the rainfall occurs during the summer months.

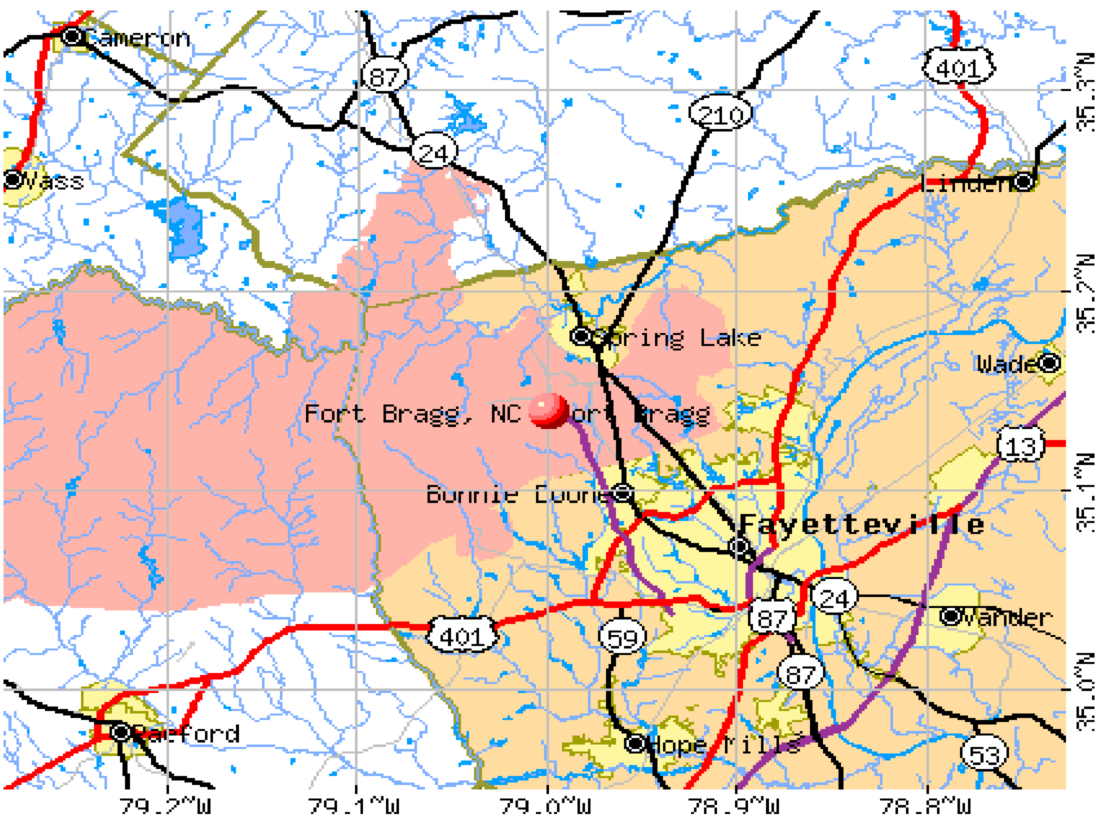

Figure C-1. Fort Bragg is west of Fayetteville, NC.

Geology and Soils

The installation is located in the geologic region known as the Sandhills. Its topography may be characterized as gentle to moderate hilly rolling terrain. Uplands are dominated by clayey gravels and sands of the Middendrop Formation, overlain on ridges and hilltops by looser sands of the Pinehurst Formation.

Fort Bragg soils are sands and loamy sands that are composed of nearly level to moderately steep, well-drained, moderately well-drained, and excessively drained soils that have brittle loamy or clayey subsoils, or that are sandy throughout (USDA 1984).

Revegetation Efforts

Accelerated soil erosion and sedimentation of surface waters have been the most pervasive NPS pollution problems at Fort Bragg. The Land and Heritage Conservation Branch of the Construction Engineering Research Laboratory (CERL) started an aggressive "Army CARES" program at the installation to research, investigate, and demonstrate new and innovative revegetation strategies for training land restoration. This program ran from the mid-1990s through 2003.

Preliminary and several follow-on site assessments were performed for the purpose of categorizing sites into groups according to an approach that used needs assessment, identification, and prioritization as a set of criteria reflecting the complexity of erosion conditions, topography, slopes, soils, land use, vegetation, type of design or technical specifications required, and the kinds of labor and equipment needed to accomplish the work to be performed at the site.

Based on these assessments, it was concluded that prospective solutions to training land problems would entail the use of standard and modified agricultural conservation techniques, biotechnical applications, and innovative and adaptive technologies that use combinations of geosynthetic and conventional materials. During a period of almost 8 years, alternate methods have been tested and evaluated at Fort Bragg for:

- restoration of major DZs;
- improvements of degraded Preachers Road, Longstreet, and McKellers Road tank trails;
- installation of concrete and at-grade stream crossings at Salerno, Range 63, and elsewhere;

- erosion control for the road shoulder at McKellers Road;
- stabilization of tank firing positions in Range 63 (MPRC); and
- construction of a new helicopter landing pad in the Sicily DZ.

The results of these training-area restoration and rehabilitation efforts and lessons learned from these efforts are described briefly in the following sections.

Revegetation and Restoration of Salerno Drop Zone

The objective of pilot tests at Salerno DZ was to test various concepts and procedures for erosion problem identification, needs assessment, and technology selection under actual field conditions. A test was conducted to evaluate concept validity, procedural practicability, and the overall effectiveness of their use in erosion control management on Army training lands.

Selection of a suitable erosion control technology for restoration of DZs is a particularly difficult task because special requirements for training compatibility must be taken into account. Land restoration at military DZs presents several unique and atypical technology selection challenges. Safety considerations require that DZs be kept clear of woody vegetation. The maintenance procedures to achieve this condition often contribute to concentrated runoff and erosion. Developing sufficient land area for operations often requires extension of DZ boundaries into areas with steeper slopes. Such areas receive concentrated overland flow and are highly susceptible to gully development. Solutions to erosion control problems must be carefully selected to be compatible with unique training-related constraints. For example, hard structures and standing water bodies are not compatible with airborne operations and thus not permitted in DZs.

Sandy soils and heavy rain events were compounding the erosion/ sediment and severe land degradation problem at Salerno DZ. The erosion and concentrated runoff had produced gullies as large as 30-ft wide by 20-ft deep (Figure C-2). This was resulting in both the land's incapability to support training and the loss of real training areas. In addition, runoff from the site carried sediment into downslope forest lands, streams, and wetlands which caused a serious NPS pollution concern for Fort Bragg.

Fort Bragg's general approach has been to keep all of its 20 or so DZs free of woody trees and shrubs for the safety of parachutists. Almost all of the seven major DZs (e.g., Salerno, Sicily, Normandy, Holland, St. Mares Eglise) were bare and devoid of all vegetation (Figure C-3). Soil erosion forming deep and wide gullies was not only resulting in NPS pollution and sedimentation of downslope forestlands and stream and creeks, but many sections of training areas had been abandoned and taken out of training for fear of injury to parachutists dropping into the deep gullies and severely degraded areas.

Figure C-2. Concentrated runoff and erosion produced these gullies at Salerno DZ, Fort Bragg, NC.

Figure C-3. Salerno DZ in December 1995 before restoration, showing the normal practice of keeping the drop zone free of all woody and grassed vegetation, which resulted in severe erosion and degradation.

Recent efforts by the local USDA NRCS for land restoration and stormwater runoff control at Sicily DZ followed a traditional conservation approach of using riprap in drainage ways and the construction of a downstream sediment basin. This approach, though effective and durable in farming and forestry operations, was not only extremely costly, but also mission-incompatible. It was in clear violation of the Army requirement that there should be (a) no rocks or hard objects, and (b) no standing water on DZs. The Fort Bragg training community took the riprap waterway so seriously that the USDA NRCS agency was asked to remove it immediately from the DZ.

Design Considerations

Needs Assessment and Technology Selection

Preliminary and follow-on site assessments were performed (as discussed above) for the purpose of identifying, prioritizing, and categorizing areas into groups according to needs requiring land restoration and rehabilitation treatment. Based on these decisions, it was decided to level and grade all areas of all DZs, followed by seeding for vegetation establishment. In view of rolling topography and to slow down stormwater runoff flow velocities, the construction of broad-base level terraces was made integral to all restoration efforts. Following is a brief description of the technology selected, its major components, and the results and lessons learned from field implementation of the selected technology.

Technology Selection

Establish permanent vegetations by planting native grasses using an annual as a nurse crop. Major components in establishment are:

- <u>Earth work</u>: grade and level all project area.
- <u>Earth terraces</u>: install broad base earth terraces to control erosion/sediment and to harvest onsite stormwater runoff.
- <u>Subsurface drainage</u>: install sub-surface drainage to convey all 10-yr design storms off-site within 24 hr.
- <u>Turf</u>: seed, lime, fertilize, and mulch all project area.

- Improve perimeter roads: improve and stabilize perimeter dirt roads; provide frequent stabilized waterbars and water turn-outs to prevent concentrated runoff.

- Repair and maintenance (R&M): provide post-construction R&M immediately to terraces and stormwater drainage system, and overseed, lime, and fertilize the project area during the next year, as needed.

Technology Implementation

Land restoration and revegetation on the 640-acre Salerno DZ was started in 1996 and completed in 1999, with work done in several phases. Depending on project funding each year, areas ranging from 30- to 180-acre tracts were graded and seeded. All work was performed through construction contracts awarded by U.S. Army Corps of Engineers (USACE) Savannah District. CERL developed and prepared "Engineering Construction Designs" and performed all quality assurance/ quality control (QA/QC) work during project construction.

Land restoration and revegetation work was first performed on a 120-acre area in the southeast corner of Salerno DZ (Figure C-4). The work was completed in 1997. Following is a description of the major components of this revegetation effort as implemented in the field.

Figure C-4. Salerno DZ, southeast corner; deep and wide gullies posed safety issues for parachutists.

Earth Work and Terrace Construction

A 3340-ft-long broad-base bottom terrace was first constructed on the contour along the perimeter road. This terrace also served as a temporary erosion control measure. Additional temporary erosion control measures were neither installed nor required by the North Carolina Department of Environment and Natural Resources. Following the construction of the bottom terrace, all 120 acres of the project area were leveled and graded by the contractor using bulldozers (Figure C-5).

To reduce erosion, three additional terraces were constructed on the hillslope at varying levels by shortening the length of slope and conveying the water onto a non-erosive grade to a stable outlet. Terraces were built level with closed ends (no outlets). Shallow and flat-grassed waterway channels were constructed to convey runoff water toward the outlets (Higginbottom Terrace Intake Risers) at non-erosive flow velocities.

The terraces were: a minimum 48-in. high from channel to ridge; a front slope of not less than 12 ft; front and back slope no steeper than 6:1; and a minimum 2-ft wide at the top and level at the ridge. Each terrace had each end closed or blocked with the same cross-section turned uphill until it met with existing ground contour. The lengths of these terraces were 2400, 2700, and 2860 ft, respectively. Terraces were compacted with vibratory sheepsfoot compactors or vibratory self-propelled steel drum rollers. All terraces were built in layers not to exceed 8 in.; each terrace lift was compacted to conform to at least 95% of laboratory maximum density.

Figure C-5. Earth work including leveling, grading, and terrace construction at Holland DZ, Fort Bragg, NC.

Stormwater Runoff Control

A subsurface storm drainage system was installed all over the project area to comply with the Army requirement of no standing water at DZs. This storm drainage system, using non-perforated plastic pipes, was designed to convey all stormwater off-site within 24 hr for a 10-yr design storm.

Gradient Channel — Grassed Waterway

Broad channels — 16 in. deep and no steeper than 10:1 gradient, a minimum of 30 ft across in width, running along the entire terrace system — were constructed to collect storm runoff from the contributing area. The longitudinal slope of the channel was such that, when runoff occurs, the flow travels overland to the grassy waterway and is then directed from both sides of the ditch toward the lowest point near the Higginbottom intake.

Higginbottom terrace inlet risers, 12 in. in diameter, were installed (Figure C-6) to direct filtered stormwater into the subsurface drains. Approximately 2 cu yd of round and washed DOT NC #57 gravel was hand-placed around each Higginbottom to filter trash and keep it from entering the subsurface drain system (Figure C-7). All stone used was circular in shape (no sharp ends) to avoid injury to Army parachutists.

Figure C-6. Higginbottom riser installation at Normandy DZ, Fort Bragg, NC.

Figure C-7. Installed Higginbottom terrace inlet riser with gravel piled around it.

Underground Pipe Drain System

Nonperforated subsurface plastic conduits, with a diameter of 12 in., were installed 3-ft deep in the ground to carry the stormwater runoff from terraces onto the woodlands off the project area (Figure C-8).

Figure C-8. Subsurface stormwater drainage system.

Turf — Permanent Seeding

Seedbed preparation

Before seeding, the project area was plowed and loosened to a depth no less than 4 in. (Figure C-9). Areas to be seeded were dressed to a smooth, firm surface (Figure C-10).

Figure C-9. Plowed area.

Seed mixtures

Table C-1 lists the permanent seed mixture used to establish the DZs. The seed mixture was shown to be good not only for seeding areas on DZs, but also for successful seeding of all disturbed lands at the installation. Fort Bragg now uses this seed mix as their standard for seeding requirements. All seeded areas were limed and fertilized at rates based on soil tests. Agricultural fertilizer having a nitrogen, phosphorous, potassium ratio of 10-20-20 was applied at the rate of 800 lb/acre, which provided a nutrient equivalent of 80 lb of nitrogen, and 160 lb each of phosphorous and potassium, respectively.

Figure C-10. Smooth, firm area to be seeded.

Table C-1. Seeding rates for Fort Bragg, North Carolina.

Seed Mixture	Fall Seeding pure live seed (PLS) Rate (lb/acre)	Spring Seeding PLS Rate (lb/acre)
Bahia grass	50	50
Bermuda grass	10 (unhulled)	10
Apallow Lespedeza	30	30
Kobe Lespedeza	05	05
Millet	20	--
Grain Rye	--	50
Total	115	145

Agricultural lime was applied at the rate of 1 ton/acre. Lime and fertilizer were applied by broadcast and disked into the ground to a depth of not less than 4 in. Lime application was required to be Standard Ground Agriculture Limestone or approved equivalent, or lime slurry having a minimum calcium carbonate equivalent of 90%, ground to such fineness that at least 90% will pass through a 10-mesh sieve and at least 50% will pass through a 60-mesh sieve.

Straw mulch

Grain straw mulch was applied by blow-type mulch spreader at the rate of 4,000 lb/acre (Figure C-11). Mulching was begun on the windward side of relatively flat areas, or on the upper part of a steep slope, and continued uniformly until the area was covered.

Figure C-11. Grain straw mulch applied at 4,000 lb/acre.

Lessons Learned

Land restoration and revegetation operations were performed, evaluated, and demonstrated at Salerno, Normandy, Holland, and St. Mere Eglise DZs, each 640 acres in size (Figures C-12 and C-13).

Following are the conclusions and lessons learned from DZ restoration and revegetation efforts:

1. When the concept of seeding DZs was presented to Fort Bragg in 1995, land managers were skeptical. They had never seeded any of their 20 DZs, so the concept of seeding was a departure from past practice. Fort Bragg's main question/concern was the safety of parachutists in that a grass surface might be harder than a soft, sandy surface on legs and knees of dropping parachutists. CERL responded with a proposal to try seeding a small 120-acre area to find out the response from the real customer, the parachutists. Response from the trainers and trainees was very, very positive. The green, smooth surface was not only gentle on landing, but also provided great visuals and aesthetics (Figure C-14).

2. Through the practice of revegetation on the four major and most-used drop zones covering more than 2500 acres, it was demonstrated that the cost of restoration using vegetative measures ($3,000 per acre) is far less than conventional methods ($22,000 per acre) employing mission-incompatible structural controls of riprap, grassed waterways, and sediment basins that were used by the local USDA NRCS.

Figure C-12. Salerno DZ before restoration.

Figure C-13. Salerno DZ after restoration.

Figure C-14. Salerno DZ — Lush green vegetation established on sandy soils.

3. The demonstrated practice of revegetation combined with terraces and a subsurface drainage system provides advantages such as on-site stormwater harvesting, erosion/sediment control, little or no maintenance, and attractive and green aesthetics. Realizing the advantages of this demonstrated technology, and the confidence in terrace-revegetation practices, Fort Bragg purchased their own terracing machine (Figure C-15). Using in-house labor for terrace construction and seeding, their revegetation costs have come down substantially compared with those of commercial contractors.

4. It has been observed that a sub-surface drainage system may not be necessary in several instances. Thus, it was not installed in subsequent practices at Fort Bragg. The terrace-vegetation technology worked successfully, and no complaints were received from the training community regarding standing water or other issues on DZs.

Figure C-15. Using in-house labor for terrace construction and seeding, Fort Bragg's revegetation costs have come down substantially compared with commercial contracting costs.

5. If seeding times occur during dry or inadequate rainfall periods, germination and plant establishment were noted as poor and sparse. In such situations, it was necessary to use overseeding, liming, and fertilization during the next season to achieve desired plant establishment.

6. As routine R&M operations, trash and dead vegetation need to be removed and gravel cleaned around Higginbottom intakes.

7. A cost-saving lesson about specification of vegetation planting requirements was learned during this technology demonstration. Most contracts specify that contractors must guarantee a certain percentage seed emergence and plant establishment success (e.g., 90%). To ensure against possible requirements to return and reseed due to germination and plant establishment problems, contractors may increase their cost estimates up to three times the actual costs of planting. If installation land managers are willing and able to fix any bare areas showing poor or sparse vegetation by overseeding during the next year using in-house resources, then substantial savings can be realized in total project cost.

Tank Trail and Road Improvements

Repair and maintenance of tank trails and secondary roads present formidable problems on military lands. Fast-moving tracked and wheeled vehicles operating in arid and semi-arid regions create dust problems that obscure visibility for following vehicles and result in hazardous driving conditions. Besides airborne dust during dry months, other problems such as impassable roads, eroded trails, and washed-out road shoulders make military training costly and also result in downtime. The surface conditions can become so precarious that sometimes Army tanks are needed to tow out other Army tanks that become stuck in rutted roads and trails. No cost-effective and durable methods are available for the repair and upkeep to secondary roads and trails at Army installations.

The Problem

In addition to a network of hundreds of miles of secondary roads, Fort Bragg has miles of tank trails at the installation. Trails running through wooded areas often have trees so close to the trail edge that adequate drainage ditches cannot be constructed for surface runoff. Drainage and runoff control over the trails is a widespread problem. No drainageway crossings exist or they are inadequate. Over the years, grading and reshaping have been the only R&M. Continuous use and grading has worsened the problem to the extent that sections of trails have ruts several feet deep, making them so bad that even tracked vehicles cannot pass over them. The severely degraded sections of tank trails must be abandoned and paved road shoulders used instead. This shifts the problem to another area because the road shoulders are not designed to handle tank and tracked traffic. In addition, erosion from trails and secondary roads are the main sources of sedimentation of forested woodlands and NPS pollution of surface waters.

Technology Selection and Evaluation

A series of tests and evaluations were conducted on selected sections of 4-mile-long Preachers Tank Trail. The tests involved evaluation of various methods for surface and subsurface stabilization: geosynthetic materials, borrow, cellular confinement systems (geoweb), and crush and run gravel.

The following four treatments were tested:

1. Fill, compact, and grade selected section of the tank trail with sandy borrow material. Raise the trail surface a minimum of 18 in. above adjacent ground contour.

2. Fill, compact, and grade selected sections of the tank trail with sandy borrow material. Compact the final fill with 6-in. thick layer of crush and run gravel material.

3. Fill, compact, and grade selected sections of the tank trail with sandy borrow material. Install geosynthetic fabric and fill 8-in. deep cellular confinement systems (geoweb) with crush and run gravel, followed by another 6-in. thick compacted layer of borrow fill.

4. Fill, compact, and grade the entire 3 miles of McKellers Road with sandy borrow material. Install 8-in.-deep cellular confinement cells (geoweb) over geosynthetic fabric. The cells were filled with crush and run gravel material, followed by another, 6-in. thick layer of crush and run gravel.

Parts of the road shoulder in steep slope grade sections were stabilized with 6-in. riprap. Sections of road shoulders with gentle and level grades were seeded and hydromulched. Check dams were installed to reduced slope length and slow down flow velocities.

Lessons Learned

1. Treatment #3 (sandy soil fill, followed by geoweb installed over geosynthetic fabric and filled with locally available crush and run gravel) was observed to be the most effective method for the stabilization of tank trails.

2. All newly constructed and upgraded tank trails must be raised a minimum of 18-24 in. above the natural ground contour.

3. Tank trails must have a center crown (Figure C-16).

4. Treatment #3 is the most expensive in initial construction costs. However, this is the preferred choice because of low or little post-construction R&M costs.

Figure C-16. Preachers Tank Trail.

5. Treatment #1(fill and compact with sandy material) is not recommended at all because, though it seems less expensive, it will not last. Treatment #2 is recommended where the tracked vehicular traffic is expected to be light and infrequent.

6. Treatment #4 is considered the best choice for new construction and future improvements of heavily traversed secondary roads.

7. Recommend using 4- or 6-in. geoweb cellular confinement systems as most cost effective and easy to handle and install. We used 8-in. systems because they were brought back to Fort Bragg from Gulf War 1 and, thus, were free of cost for a useful application (after being cleaned and checked for non-native seeds).

8. Tank trail road shoulders should be stabilized using riprap channels on steep slopes, whereas stabilization by vegetation can be successful in situations where slopes are mild or flat.

9. Following successful results, a 2-mile section of McKellers Tank Trail at Fort Bragg was stabilized the next year using Treatment #4. This project was also constructed through the USACE Savannah District (Figure C-17). CERL researchers devel-

oped construction design specifications and performed all QA/QC work.

Figure C-17. Revegetated 2-mile section of McKellers Road.

10. Installations usually lack both financial as well as manpower resources. Most, if not all, training area stabilization efforts often fail, not because the technology was inadequate or improperly implemented. Rather, minor post-construction repairs were not performed resulting in major catastrophes such as utter project failures and NPS pollution problems.

11. Vegetation is not a panacea to all erosion problems. Because of the nature of sandy soils, steep slopes, and potential erosion problems, vegetation did not work in some of the projects at Fort Bragg.

12. As shown in Figure C-18, the failure on the right could have been avoided if immediate repairs had been made at the very start of the problem. The main reason for this wash out is that check dams were not provided to break down long, steep slopes to reduce concentrated flow velocities.

Figure C-18. McKellers Road — Adequate checkdams and in-time repairs would have prevented a complete washout.

APPENDIX D

INSTALLATION EXPERIENCE
FORT MCCOY, WISCONSIN

Introduction

Fort McCoy is in west-central Wisconsin, between the communities of Sparta and Tomah, and approximately 35 miles east of the city of La Crosse. The installation is host to the Wisconsin Army National Guard Mobilization and Training Equipment Site (MATES), and serves as a Regional Training Center that annually supports the year-round training of more than 120,000 military personnel.

Climate and Precipitation

The climate of Fort McCoy is humid continental. Spring is a mixture of warm and cold periods. As spring advances precipitation increases, usually reaching its peak in June. Summers are warm with autumn arriving in mid-September and often lingering into November. Winters have periods of cold and snow. The total annual mean precipitation is 28.04 in., 65% of which (17.9 in.) usually falls in May through September (USDA 1981). The average seasonal snowfall is 39.3 in.

Topography and Soils

Total land area of Fort McCoy is approximately 60,000 acres. The installation topography is gently sloping to very steep. Soils are generally well drained to excessively drained sandy. Permeability of these sandy soils is rapid. Typically the surface layer is 4- to 6-in.-deep sands, has low available water capacity, and dries fast following rain. Most of the soils have a moderate to very severe susceptibility to erosion.

Problem Description and Selected Technology for Land Restoration

The factors described above (inadequate precipitation during growing season, topography, soil type, and high erosion potential) make vegetation establishment difficult at Fort McCoy. Aggravating the natural causes, years of military training have damaged the protective vegetative cover, which has caused progressively accelerated degradation of the land in some cases, resulting in losses of training area, training realism, clean water quality, and wildlife species habitat. As a result of these conditions and at a time of increased national environmental awareness, installation land managers were looking for new and improved technologies to protect and preserve soil and water natural resources and to provide and maintain sustainable training lands. Toward achieving this end, Fort McCoy's Directorate of Plans, Training and Mobilization and Security was developing and implementing their Training Area Recovery Plan (TARP) during the late 1980s.

According to TARP, two to four training areas are withdrawn from use. During the first year, all training is prohibited while the area is being cleared of debris and obstacles and the land is restored. During the second year, training is restricted to foot traffic while the area is recovering. Bivouacs, establishment of fighting positions, wheeled and tracked vehicle movements, and overnight occupation of those areas is not permitted. At the end of the 2-year cycle, the training areas are made available again for general training.

CERL initiated the "CARES" program in 1991 to supplement TARP efforts and to investigate and develop new and improved land restoration practices for training area restoration. The objective of the pilot test was to test concepts and procedures for erosion problem identification, needs assessment, and technology selection under actual field conditions. The test was conducted to evaluate concept validity, procedural practicability, and the overall effectiveness of their use in erosion control management on Army training lands.

Technology Selection and Implementation

The first step in technology selection consisted of problem identification and needs assessment. During initial field visits, it immediately became evident that the main reason hindering vegetation establishment was the nature of sandy soils and their shallow thickness (4–6 in.). As one may observe, sand surfaces on ocean coasts quickly dry as soon as the tide recedes. Nevertheless, the soil layer below the sand surface holds a great deal of moisture. The situation at Fort McCoy is similar.

Soon after rainfall ceases, the process of evaporation dries the surface of sandy soils quickly. Because sand has larger pore space than clay soils, the capillary process that pulls up subsurface water breaks down. This results in available moisture in the subsurface, though the upper few inches of soil surface loses all moisture.

All perennial grasses and most conventional nurse crops have small seeds and must be seeded not less than 0.25-0.50 in. below ground because they lack the vigor to emerge if planted too deeply. Even if some seed does germinate, young and tender emerging seedlings are unable to withstand damage from blowing sand, typical of Fort McCoy conditions.

Figure D-1. Fort McCoy, WI, March 1992 before restoration.

The Technology

If an environment retains soil surface moisture long enough to allow germination and provide the emerging young seedlings with protection from sandblasting, then vegetation establishment would be successful even under Fort McCoy-typical conditions (Figures D-1 and D-2).

Figure D-2. Fort McCoy, WI, October 1992 after restoration.

Corn and sorghum are usual agricultural crops for food and feed in Wisconsin. They are large seed crops that are planted a couple of inches deep into the ground. This is in the layer that retains moisture for some time after rains because of capillary breakdown above. It takes barely 2-3 weeks for germination and seedling establishment. Seedlings can withstand sandblasting far better than can those of perennial grasses.

It was decided to plant native perennials in combination with corn and/or sorghum as nurse crops for the pilot test.

Field Implementation

Two sites were selected for pilot testing and evaluation. The sites were located in different areas, but had similar sandy soil characteristics. Sites were disked to loosen soil and the seedbed was prepared by leveling and grading using conventional agricultural practices. All of the seeding operations were performed by the in-house civilian work force and were completed in early March 1992. Corn and sorghum were planted at a depth of 2 in. using a seed drill. Following corn/sorghum seeding, native perennials were again drill planted at a shallow depth of approximately 0.50 in. All seeded areas were fertilized, limed, and mulched per Turf Specifications of the USDA SCS, Monroe County, Wisconsin.

Results and Lessons Learned

1. Seed germination was better than expected at both sites. The corn and sorghum seedlings effectively provided shelter from exposed sandblasts to emerging grass sprouts. While the grass seeds were still in germination process, the established corn/sorghum seedlings helped to preserve soil moisture by preventing/reducing evaporation due to blowing winds. No competition for moisture utilization occurred between corn and perennials because they were seeded at two different soil depths – corn/sorghum at 2 in. and perennials at less than 0.50 in.

2. Pictures taken during October of the same year (Figures D-3 and D-4) show an excellent stand of nurse crops and perennials.

3. Corn cobs and sorghum heads provided a good source of food for area deer and wildlife during the winter.

4. Dead stalks of corn and sorghum proved to be a welcome source of organic matter that is always deficient in sandy soils on military training lands.

Figure D-3. A stand of corn stalks and perennial grass.

Figure D-4. Example of successful vegetation.

5. It is possible to have less than desirable establishment of perennial grasses during the first year due to overgrowth of large seed nurse crops like corn, sorghum, and millet, etc. Overseeding of natives followed by lime and fertilization applications at one-half the normal rates is recommended during the next year for achieving a healthy and sustainable vegetative stand.

6. Use healthy, native plant communities with sod-forming abilities to protect installation lands from training disturbances.

To conclude, all disturbed sites should be seeded as soon as practical using a combination of perennials and large-seeded agricultural crops. Native, sod-forming plant communities should be reseeded in all disturbed areas that would not be landscaped and routinely maintained. If straw mulch is used, weed-free straw should be used to avoid introduction of invasive or noxious weeds.

APPENDIX E

STUDY OF VETIVER GRASS — VETIVERIA ZIZANIOIDES (LINN)

Background

The local official (Mike Materne) of the USDA SCS planted Vetiver grass during the spring of 1990 at Fort Polk, LA. However, the local County Extension Service representative vehemently disapproved it, arguing that introducing an exotic plant to Fort Polk might create an uncontrollable obnoxious weed problem. He was surprised and "even overjoyed" (NRC 1993), however, to find that native grasses came crowding in behind hedges formed by Vetiver (see details later in this appendix).

Vetiver, a native of South East Asia and India, is a tropical grass species that grows well in hot and humid regions of the world. In the United States, the plant has been known to exist for over 150 years. The Boucard brothers of Leaky, TX, are perhaps the most advanced and largest growers of Vetiver. They have grown Vetiver commercially for the past several decades on over 100 acres for extracting oils used by the perfume industry.

Plant Taxonomy

Family – Graminae (poaceae); Subfamily – Panicoidesa; Tribe - Andropogonidae; Generic Name – *Vetiveria zizanoides*

Slope Stabilization and Erosion Control Characteristics of Vetiver

Agronomic and erosion control characteristics of the plants are described in the National Research Council (1993) book entitled *Vetiver Grass – A Thin Line against Erosion*. Vetiver has a profusely fibrous root system and stiff stalks. It is an excellent grass species that forms contour hedges for steep slope stabilization. When fully established, it forms hedges several feet tall and more than 3-ft wide that have been described in the literature by several names (e.g., "botanical dams," "bioterraces," and "miracle grass").

The Vetiver species planted at Fort Polk by USDA SCS professionals was obtained from a local retired farmer, Eugene LeBlanc of Sunshine Village, LA. For lack of information on the origin of this species, it is referred to in this report as the "Sunshine" variety.

Results of USDA SCS plantings at Fork Polk showed that contour hedges formed by Vetiver slowed down and held back runoff that would have otherwise eroded soils downslope. The vegetative terraces formed by the plant were not barriers in the sense of a wall. Rather, they were like tight porous filters laid across the slope: they slowed down the runoff, but did not physically dam it up. Shallow runoff seeped through the hedge; deeper runoff poured through the upper stiff stalks. In this way, runoff neither ponded nor concentrated, but stayed spread across the slopes. The eroding soil from upslope carried with it seeds of native grasses that established vegetation in the soil held back behind Vetiver hedges.

Objective

Following the successful disturbed area stabilization results achieved by the USDA SCS at Fort Polk, it was decided to expand the field testing of Vetiver to other Army installations. Since the Vetiver grass is inherently a tropical plant, it was decided to field-test it in the warm and humid climates of the south and southeastern states. The main objectives of this research were:

1. To demonstrate whether the plant had the propensity to become an invasive and uncontrollable weed problem, and

2. To document the geographical range for its agronomic survival.

Procurement of Parent Materials

Search for the plant material revealed immediately that Vetiver seedlings were not available in desirable quantities for planting at several installations. To meet project requirements, the following sources/vendors were contracted to propagate parent material for field planting at selected sites:

- USDA-Plant Material Center (PMC), Baton Rouge, LA

- USDA-PMC, Columbus, GA

- Eugene Le Blanc, Sunshine, LA

- Gueric and Victor Boucard, Leakey, TX.

The material obtained from Louisiana was the Sunshine variety. Source of the Vetiver material obtained from the Boucards of Leakey, TX, could not be ascertained. Vetiver material received from the USDA-PMC, Columbus, GA, was propagated from germplasm obtained from India and is designated as the "India" variety in this PWTB.

Vetiver Propagation and Field Planting

Vetiver material obtained from the Boucards was raised in field nurseries (Figure E-1). The seedlings (supplied by the USDA-PMC researchers and Eugene LaBlanc) were planted in 6-in. diameter nursery pots and grown over winter in heated greenhouses for a period of 4–6 months. During this time the plants produced 4–6 healthy tillers (Figure E-2). Vetiver crowns were removed from the pots and the dead portion of the lower roots was cut (Figure E-3. Cutting lower roots off Vetiver tiller.) prior to planting in the field. Pot-grown seedlings were planted 4-in. deep in rows. Spacing between plants was 12 in. Two tablets, weighing 21 grams each, of slow release fertilizer of 20:10:5 (N_2, P_2O_5, K_2O) were placed approximately 4 in. away from the freshly planted seedlings. No supplemental water was applied after planting. Table E-1 lists where the Vetiver cultivars were planted at various locations.

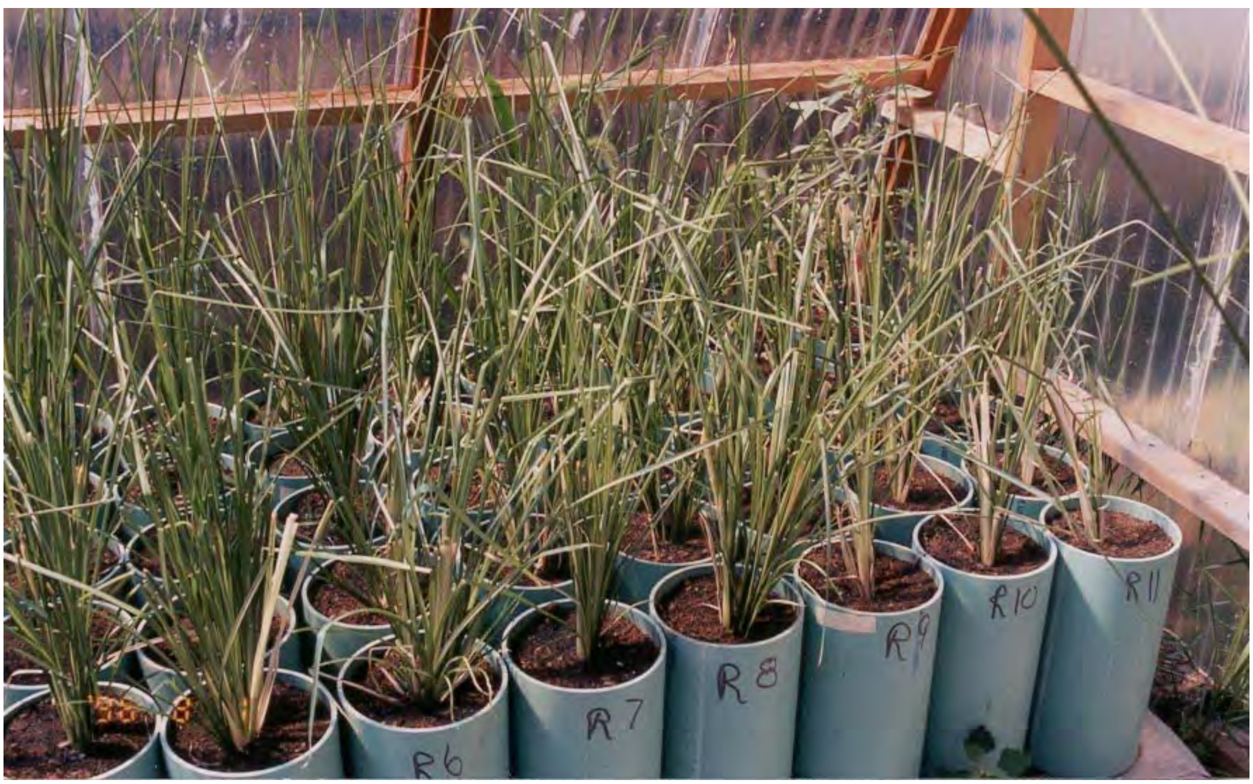

Figure E-1. Seedlings planted in 6-in. diameter nursery pots.

Figure E-2. Vetiver tiller.

Figure E-3. Cutting lower roots off Vetiver tiller.

Table E-1. Vetiver field demonstration sites.

	Site	State	State Abbreviation	Variety
1	A-P Hill	Virginia	VA	Sunshine
2	Champaign	Illinois	IL	Sunshine
3	Camp McCain	Mississippi	MS	Sunshine
4	Camp Shelby	Mississippi	MS	Sunshine
5	Fort Bragg	North Carolina	NC	India/Sunshine
6	Fort Benning	Georgia	GA	Boucard, TX
7	Fort Campbell	Kentucky	KY	India/Sunshine
8	Fort Chaffee	Arkansas	AR	Sunshine
9	Fort Hood	Texas	TX	Sunshine
10	Fort Leonard Wood	Missouri	MO	Sunshine
11	Fort Polk	Louisiana	LA	Sunshine
12	Fort Sill	Oklahoma	OK	Sunshine
13	Fort Stewart	Georgia	GA	Boucard, TX/India
14	Lubbock	Texas	TX	Sunshine
15	McAlester	Oklahoma	OK	Sunshine
16	Manhattan	Kansas	KS	Sunshine
17	Pine Bluff	Arkansas	AR	Sunshine
18	Red River	Texas	TX	Sunshine

Results

Plant Growth Characteristics

Approximately 50,000 plant seedlings obtained from Leakey, TX, were planted at Fort Benning, GA and Fort Stewart, GA, during June-July 1994. The contractor delivered the field grown seedlings as single stems. Not a single plant survived at either location. The actual cause of 100% mortality could not be ascertained. It seems likely that tender singular stems died during the 5-7 day transit period because of excessive heat stress in confined trucks during hot weather.

The following year, seedlings of the India variety, provided by the USDA-PMC, Columbus, GA, were planted at Fort Bragg, Fort Campbell, and Fort Stewart. Fort Stewart has good soils and abundant rainfall. The plants grew fast and, within 4 months of transplanting, started producing flowers. Fearing that they may have another Kudzu at hand, the land managers at Fort Stewart demanded immediate destruction of all plants. Efforts to convince them to let some of the plants survive till seed maturity did not succeed and all plants were destroyed.

Plant establishment was remarkably astounding at all locations (Table E-1, above). However, the Vetiver did not perform well at several Army installations during subsequent years. This may be due to fertilizer application at planting time and nutrient deficiency during the following years.

Under greenhouse controlled environments, the Sunshine variety grown in nutrient rich soil with adequate water exhibited rooting depth equal to its above-ground height. Vetiver grew roots amazingly fast. As shown in Figure E-5, the roots measured over 3-ft long in a short 12 weeks. Greenfield (1993) reported root growth of over 7 ft in 3 months. The roots grew almost straight down; indicating that the plant may not be invasive by spreading latterly from stolons or rhizomes.

At one Fort Campbell site, the India variety was planted on the banks of a nonperennial stream in a wooded area. The soil at this site was sandy loam and extremely nutrient rich. The plants grew to over 13-ft tall (Figure E-6) in just one summer. This substantiates Vetiver as a wetland plant, as indicated by its name "zizanioides" or riverside. The number of tillers counted at this site ranged between 17 and 32 erect stems.

Vetiver planted on sandy loam sites at Fort Campbell grew over 7-ft tall (Figure E-6) and produced profound clumps during its first year of planting. However, most of the plants did not survive the cold winter. During the few years after planting, most of the plants had died due to cold winters and the remaining few were taken over by native species, indicating the plant does not like competition.

Figure E-4. Vetiver roots shown to grow in excess of 3 ft in a period of 3 months.

Figure E-5. Vetiver in rich soil (left) and sandy loam soil (right) at Fort Campbell, KY.

Figure E-6. India (left) and Sunshine (right) varieties of Vetiver in sandy loam at Fort Bragg, North Carolina.

At the other extreme, India and Sunshine varieties of Vetiver were planted in almost pure sandy soils at Fort Bragg as shown in Figure E-7. The plant growth was not as robust as those planted at Fort Campbell. It is encouraging to note that Vetiver is the only plant species still surviving while all efforts to establish natives have failed at that site.

At locations where the India variety was planted side-by-side with the Sunshine variety, results show that the India variety grows taller and produces stronger robust stems. The Sunshine variety grows shorter and produces a bushy plant structure (Figure E-7).

Figure E-7. Sunshine variety planted at ERDC/CERL in Champaign, Illinois.

Karyotypics (cytogenetics) of Vetiver

If Vetiver were a triploid, then it would be sterile and could be introduced on Army lands without any environmental concerns. Karyotypic (chromosome counting) testing performed at the University of Purdue, West Lafayette, Indiana, showed that both cultivars of India and Sunshine had a chromosome number of $2n = 2x = 20$ (Figure E-8). This testing confirmed that the plant is diploid and capable of producing mature seed. This finding led to a check of seed viability.

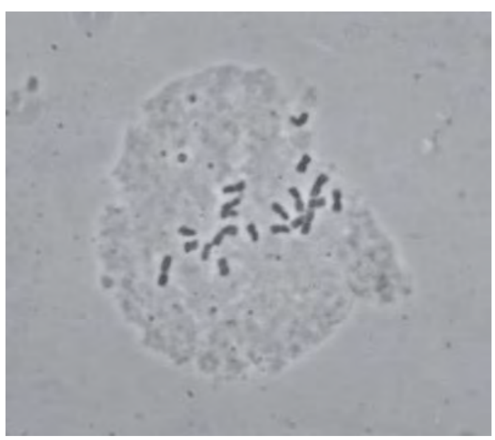

Figure E-8. Sunshine diploid chromosomes.

Seed Viability and Germination

Fort Polk experience showed that the Sunshine variety flowered only occasionally, producing few inflorescences (flowers) that did not produce mature or fertile seed because no growth was ever observed by Mr. LeBlanc who has been growing this cultivar for most of his life. Nevertheless, when the Sunshine variety was grown at ERDC/CERL and at Fort Bragg, more plants than expected started flowering in late August and produced mature seed. Observations were more alarming with the India variety. The entire population flowered at all locations where planted and produced mature flowers (Figure E-9). Flowering of the India variety starts late August and continues through October. Flowers and seed heads were purple and over 2-ft long. No birds have been seen eating the seed, and all seed is shed over the ground by the time winter arrives.

Mature inflorescences were collected from both Sunshine and India varieties. The seed heads were sent to Purdue University for seed viability and germination testing. The total numbers of seeds in each inflorescence were counted and approximately 400 seeds selected for seed germination under controlled laboratory conditions. Seed numbering and germination test data are given in Figure E-10 and

Table E-2Table E-3.

Figure E-9. Flower heads of India variety Vetiver.

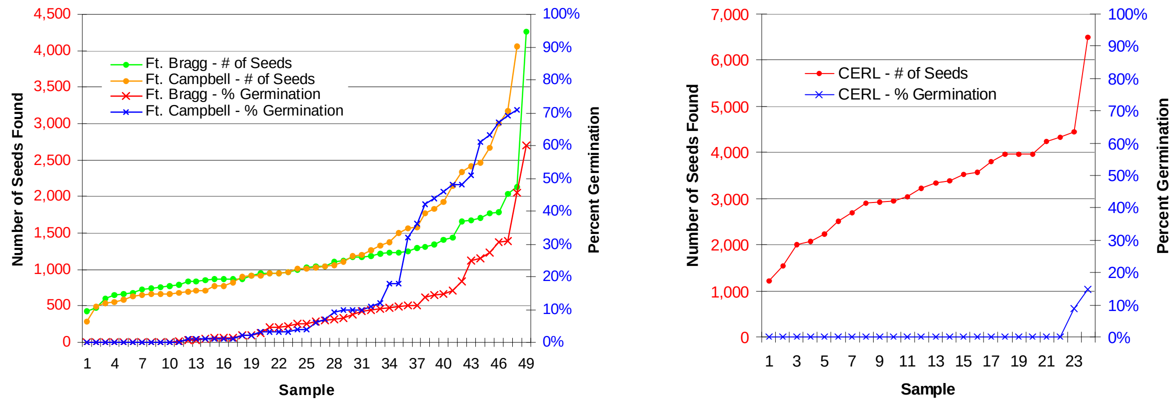

Figure E-10. Number of seeds in each inflorescence and germination results for (left) India variety and (right) Sunshine variety.

Table E-4 shows the number of seeds tested over a 4-week period, and the Vetiver propagation and spreading characteristics were monitored very closely to prevent it becoming invasive. Plants stayed where planted at all installations. Though the seeds have been found fertile and able to germinate under laboratory-controlled conditions, the plant seemed to be sterile under actual field conditions. A major reason for confidence in Vetiver's sterility and it not becoming invasive is that it has been grown for over 150 years in the United States and no spreading has been observed in literature.

Geographical Range for Vetiver Survival

As shown in Table E-1, the Vetiver was planted at 16 Army installations and on 2 private land sites. All of these sites are located within the mid-eastern parts of the United States. No effort was made to field-test Vetiver survival in the mid-western states because of low amounts of annual rainfall in these locations. The Vetiver planted did not survive past a few years at any installation; either it was overtaken by natives or did not survive cold winters.

The Vetiver is a tropical plant and does not perform well in colder climates. As stated elsewhere in this PWTB, the Boucards have been growing Vetiver successfully for commercial production for several years in Leaky, Texas, which is located at latitude 30 degrees north. Therefore, it may be safely concluded that the upper limit for Vetiver survival is approximately latitude 30 north or warmer climates.

Table E-2. Seed fertility and germination results* — India variety.

Fort Bragg. NC - Year 1995

Sample #	# Found	# of Fertile	# Germinated	% Germinated
40845	1,340	408	58	14%
40846	970	296	178	60%
40847	1,780	400	110	28%
40848	1,710	400	26	7%
40849	4,260	400	18	5%
40850	1,170	400	18	5%
40851	1,120	400	20	5%
40852	1,670	400	45	11%
40853	840	400	55	14%
40854	780	400	5	1%
40855	1,220	400	0	0%
40856	680	400	30	8%
40857	2,130	408	41	10%
40858	1,100	400	28	7%
40859	1,400	400	122	31%
40860	870	400	59	15%
40861	1,020	400	25	6%
40862	640	400	6	2%
40863	920	400	40	10%
40864	430	400	44	11%
40865	600	400	99	25%
40866	870	400	1	0%
40867	740	400	8	2%
40868	1,440	400	42	11%
40869	1,310	400	63	16%
40870	1,040	400	75	19%
40871	670	400	0	0%
40872	2,040	400	45	11%
40873	480	400	22	6%
40874	870	408	0	0%
40875	1,660	400	5	1%
40876	870	400	3	1%
40877	1,230	408	23	6%
40878	1,040	400	4	1%
40879	950	408	0	0%
40880	1,240	400	0	0%
40881	720	400	33	8%
40882	1,770	408	8	2%
40883	850	400	0	0%
40884	790	400	123	31%
40885	1,170	408	12	3%
40886	950	400	3	1%
40887	1,000	0	0	0%
40888	1,290	400	102	26%
40889	1,230	408	39	10%
40890	1,180	0	0	0%
40891	940	400	0	0%
40892	840	400	0	0%
40893	750	408	186	46%

Fort Campbell, KY - Year 1995

Sample #	# Found	# of Fertile	# Germinated	% Germinated
51160	556	6	0	0%
51161	1,573	79	3	4%
51162	770	50	1	2%
51163	665	94	2	2%
51164	952	143	1	1%
51165	766	244	7	3%
51166	653	11	1	9%
51167	626	5	0	0%
51168	690	4	0	0%
51169	1,330	126	13	10%
51170	534	120	1	1%
51171	496	120	76	63%
51172	1,006	13	0	0%
51173	289	152	2	1%
51174	683	172	2	1%
51175	1,263	2	0	0%
51176	2,668	93	1	1%
51177	589	269	3	1%
51178	718	159	0	0%
51179	1,771	326	59	18%
51180	3,171	400	72	18%
51181	667	400	12	3%
51182	915	400	16	4%
51183	1,027	400	12	3%
51184	814	400	24	6%
51185	1,372	60	0	0%
51186	2,415	15	0	0%
51187	1,571	400	284	71%
51188	703	280	90	32%
51189	4,062	400	192	48%
51190	1,006	28	2	7%
51191	905	400	168	42%
51192	963	400	276	69%
51199	910	29	0	0%
51200	1,825	400	144	36%
51189	666	400	176	44%
51190	2,337	400	244	61%
51191	2,142	400	204	51%
51192	3,006	400	268	67%
51193	1,500	400	192	48%
51194	1,036	400	40	10%
51195	1,203	0	0	0%
51196	2,462	40	0	0%
51197	1,181	400	44	11%
51198	941	400	40	10%
51199	1,052	400	12	3%
51200	1,109	400	48	12%
51201	1,920	400	184	46%

* Lab testing performed by: Indiana State Seed Commissioner, Purdue University, West Lafayette, Indiana 47907

Table E-3. Seed fertility and germination results* – Sunshine variety.

US CERL - Champaign, IL - Year 1994

Sample #	# Found	# of Fertile	# Germinated	% Germinated	Comments
40820	3,970	1	0	0%	
40821	4,330	0	0	0%	All appeared sterile, or empty
40822	4,230	0	0	0%	All appeared sterile, or empty
40823	3,960	0	0	0%	All appeared sterile, or empty
40824	6,500	0	0	0%	All appeared sterile, or empty
40825	1,220	0	0	0%	All appeared sterile, or empty
40826	4,442	0	0	0%	All appeared sterile, or empty
40827	2,230	0	0	0%	All appeared sterile, or empty
40828	3,230	0	0	0%	All appeared sterile, or empty
40829	2,080	0	0	0%	All appeared sterile, or empty
40830	2,010	0	0	0%	All appeared sterile, or empty
40831	3,800	0	0	0%	All appeared sterile, or empty
40832	1,550	0	0	0%	All appeared sterile, or empty
40833	2,950	0	0	0%	All appeared sterile, or empty
40834	2,700	0	0	0%	All appeared sterile, or empty
40835	3,330	0	0	0%	All appeared sterile, or empty
40836	3,380	0	0	0%	All appeared sterile, or empty
40837	3,580	400	36	9%	
40838	3,960	1	0	0%	
40839	3,040	0	0	0%	All appeared sterile, or empty
40840	2,520	43	0	0%	
40841	2,920	4	0	0%	
40842	3,520	68	10	15%	
40843	2,890	0	0	0%	All appeared sterile, or empty

* Lab testing performed by: Indiana State Seed Commissioner, Purdue University, West Lafayette, Indiana 47907

Table E-4. Weekly seed germination pattern* – India variety.

Fort Bragg, NC - Year 1995

Sample #	# of Seeds	# Tested	Week 1	Week 2	Week 3	Week 4	Total Germ.	% Germ.
40845	1,340	408	16	7	14	21	58	14%
40846	970	296	52	55	71	0	178	60%
40847	1,780	400	38	19	29	24	110	28%
40848	1,710	400	5	4	13	4	26	7%
40849	4,260	400	7	4	5	2	18	5%
40850	1,170	400	3	5	3	7	18	5%
40851	1,120	400	8	4	2	6	20	5%
40852	1,670	400	11	14	7	13	45	11%
40853	840	400	18	14	9	14	55	14%
40854	780	400	2	0	1	2	5	1%
40855	1,220	400	0	0	0	0	0	0%
40856	680	400	6	4	11	9	30	8%
40857	2,130	400	10	10	9	12	41	10%
40858	1,100	400	9	7	4	8	28	7%
40859	1,400	400	30	29	32	31	122	31%
40860	870	400	17	16	14	12	59	15%
40861	1,020	400	7	7	6	5	25	6%
40862	640	400	0	2	0	4	6	2%
40863	920	400	9	9	12	10	40	10%
40864	430	400	16	11	12	5	44	11%
40865	600	400	25	22	21	31	99	25%
40866	870	400	0	0	1	0	1	0%
40867	740	400	0	3	2	3	8	2%
40868	1,440	400	5	13	12	12	42	11%
40869	1,310	400	10	15	20	18	63	16%
40870	1,040	400	12	16	27	20	75	19%
40871	670	400	0	0	0	0	0	0%
40872	2,040	400	11	6	14	14	45	11%
40873	480	400	7	7	6	2	22	6%
40874	870	408	0	0	0	0	0	0%
40875	1,660	400	0	0	4	1	5	1%
40876	870	400	1	0	2	0	3	1%
40877	1,230	408	6	4	5	8	23	6%
40878	1,040	400	2	1	0	1	4	1%
40879	950	408	0	0	0	0	0	0%
40880	1,240	400	0	0	0	0	0	0%
40881	720	720	9	9	7	14	39	5%
40882	1,770	408	0	5	3	0	8	2%
40883	850	400	0	0	0	0	0	0%
40884	790	400	26	36	34	27	123	31%
40885	1,170	408	1	4	3	4	12	3%
40886	950	400	0	3	0	0	3	1%
40887	1,000	408	0	0	0	0	0	0%
40888	1,290	400	23	30	24	25	102	26%
40889	1,230	408	11	12	5	11	39	10%
40892	840	400	0	0	0	0	0	0%
40893	750	408	46	46	46	48	186	46%

* Lab testing performed by: Indiana State Seed Commissioner, Purdue University, West Lafayette, Indiana 47907

Conclusions

Due to environmental concerns, the introduction of an exotic plant like Vetiver on U.S. Army lands is a serious matter unless it is proven that the plant will not become invasive. Seed viability and germination tests have shown that Vetiver does produce viable seeds that germinate under controlled laboratory environments. However, 5–7 years of field plantings of Vetiver on several Army lands have demonstrated that Vetiver seed does not germinate and establish plants under actual field conditions. Results have also shown that Vetiver is a passive plant that does not do well with competition from native species. Chances that it will ever become invasive to native grasses are small. However, these results may not be taken as conclusive. More research is needed to determine the behavior of the plant under more humid and warmer climatic conditions of the deep southeastern United States. In these southern states, how the plant will respond if planted in fertile wetlands is also uncertain. For example, Sunshine Vetiver is known not to flower or produce mature seed under Louisiana conditions. However, the same plant did flower and produce mature fertile seed when planted at Champaign and Fort Bragg. Before promoting the use of Vetiver in the United States, the risks associated with this plant must be carefully examined with further research, even though initial research results from these studies indicate that the plant is not an aggressive colonizer.

APPENDIX F

U.S. ARMY CARES – SUMMARY

This appendix summarizes Appendixes A–E. Concluding ideas are described in one or two sentence bullets accompanied by photographs for visual illustration when appropriate. Unless otherwise stated, all photographs were taken at Fort Bragg, Fort McCoy, or Fort Benning during field implementation of erosion, sedimentation, and revegetation practices. Lessons learned from these exercises are also reiterated briefly.

Major Sources of Nonpoint Source Pollution

Figure F-1 shows serious land disturbance from tracked and wheeled vehicular traffic at MPRC Range 63, Fort Bragg. Barren, hilly terrain would suggest huge amounts of erosion. However, all this estimated and apparent soil loss does not end up in downslope surface waters. It is true that disturbed areas contribute to sediment loading of downslope forest lands, wetlands, and streams and creeks on Army lands. However, the small open, barren areas and road shoulders of improved and unimproved roads and trails are the significant contributors of sediment and NPS pollution. This is because roads and trails are usually built on high ground. Concentrated runoff from roads and trails results in big washouts and gullies that transport large quantities of sediment and NPS downgrade.

Figure F-1. Major sources of NPS pollution on Army installations are land disturbance from tracked and wheeled vehicles (left) and concentrated runoff from roads and trails (right)

Advantages of Revegetation

- Vegetation can indeed restore disturbed Army lands. It may not stop a hillside from slumping, but it can keep the soil on site and, over time, retard most surface erosion.

- Hedging of deeply rooted perennials, such as bluestem and Vetiver, are indeed capable of catching eroded soils and building up terraces behind them for stabilizing steep slopes.

- Incorporating deep-rooted, tall-growing perennials (bluestem, switchgrass, Vetiver) to provide bioterraces for slope stabilization and in concealment island applications seems to be the most promising of all their future uses.

- It may be an exaggeration to say that Army CARES technology is the missing ingredient in disturbed area land restoration. Rather, the prime cause of continuing problems may very well be lack of funding and manpower resources for R&M at the installations. Range Control personnel are always reluctant to use LRAM funds beyond areas that are used for training activities, but not all erosion problems are training-related. For effective installation-wide erosion control problems, land managers and decision makers must initiate or facilitate soil conservation programs such as TARP, especially resources (both funding and manpower) for post-implementation R&M.

Disadvantages of Revegetation

- Vegetation cannot solve all LRAM problems. Poor planting establishment can result from ignorance, lack of post-planting R&M, or simple items that were ignored.

- Vegetation, at least in drier climates, does need care during the period immediately after planting. Although it eventually requires little or no care and is self-healing, sometimes the vegetation must initially be helped to establish. This is especially true in marginal lands where overseeding, liming, and fertilizing may be needed to help the sparse plantings get through their establishment phase.

- A steepness limit (vertical or 45-degree grade slopes) probably exists beyond which establishing vegetation may be impractical for reasons of logistics such as equipment and manpower resources.

- Hedges or strips of tall grasses across the terrain present an excellent environment for concealment islands, but at the same time, the stiff stalks of 3-ft wide hedges (at the base) may be painful to crawl through.

Other advantages and disadvantages are described in the following sections.

Basic Principles of Army CARES

1. For Army CARES to be effective, it is imperative that provisions for soil conservation planning and erosion control measures be made before rather than after damage has occurred. These planned measures, when conscientiously and faithfully applied, will result in reduced erosion and minimum environmental degradation.

2. Select technology that is mission compatible. Adaptive management and planning involves a decision-making process based on trail monitoring and correction, rather than off-the-shelf standard practices. Many standard conservation practices simply may not be adequate or acceptable under typical military land-use conditions; conventional LRAM practices need to be adapted or modified to meet mission-compatibility requirements. For example, use of riprap for waterways and check dams is a standard practice in agriculture and forestry. Nevertheless its use in DZs is mission incompatible due to safety considerations.

3. Plan the development of Army CARES to fit the particular topography, soil, and natural/native vegetation of the site. Long, steep slope stabilization of sandy roads and trails by establishing vegetation may not be as effective as a riprap channel to prevent scouring and frequent R&M (Figure F-2).

Figure F-2. Tank trail improvements to McKellers Road, Fort Bragg show Army CARES implementation that fits the particular topography, soils, and natural/native vegetation of the site.

4. Secondary roads, trails, and other training areas with steep slopes, erodible soils, and soil with serious limitations for the intended land use should not be used before first overcoming limitations through sound planning. For instance, long steep slopes can be broken by benching, terracing, waterbars, or diversion ditches (turnouts) and thus will not become an erosion problem or transfer the problem downgrade.

5. Apply LRAM practices as soon as possible to stabilize disturbed areas immediately. If permanent vegetation cannot be established, provide cover by seeding annuals. The idea is to keep the soil covered with temporary or permanent vegetation at all times when training activities are over an extended period. Temporary vegetation can be most effective where or when it is not practical (for continuing training or measures for permanent vegetation) to establish permanent vegetation (Figure F-3). Such temporary measures should be used immediately after training exercises are over if a delay is anticipated in establishing permanent vegetation. Temporary vegetation serves several purposes including immediate protection to the otherwise bare soil, which is susceptible to erosion. Vegetation reconditions the disturbance-impacted infertile soil by adding organic matter to dead matter decay.

The stories on the above project sites and others described in this PWTB are the same. At the onset, problems at each site were insignificant. Continued delay and deferment for repairs resulted in problems getting out of hand (see Figure F-4).

Summary of Lessons Learned

- Monitor repairs — It is critical that installations have a program in place for monitoring and making necessary repairs immediately to prevent costly expenditures or even Notices of Violation later. Of course this is easier said than done because installations just do not have the funds for R&M, except for LRAM funding under the Integrated Training Area Management program.

Figure F-3. Stabilize disturbed areas immediately by establishing temporary vegetation.

- Correct the problem at the source — Even with monitoring, installing control measures will not be effective unless controls are first implemented where the runoff is originating. In all such situations, control measures must first be installed upland before attempting to control erosion downgrade. Two effective methods for retaining or restraining sediment on site are:

  (a) filtering runoff as it flows through the area, and
  (b) impounding the sediment-laden runoff for a period of time so that the soil particles settle.

  Standard practices include the use of riprap or similar type check dams and sediment basins, respectively. Both of these practices are expensive and sometimes may conflict with the mission. Both objectives can be realized by establishing vegetative hedgerows, also known as contour hedges, as shown in Figures F-5 to F-8.

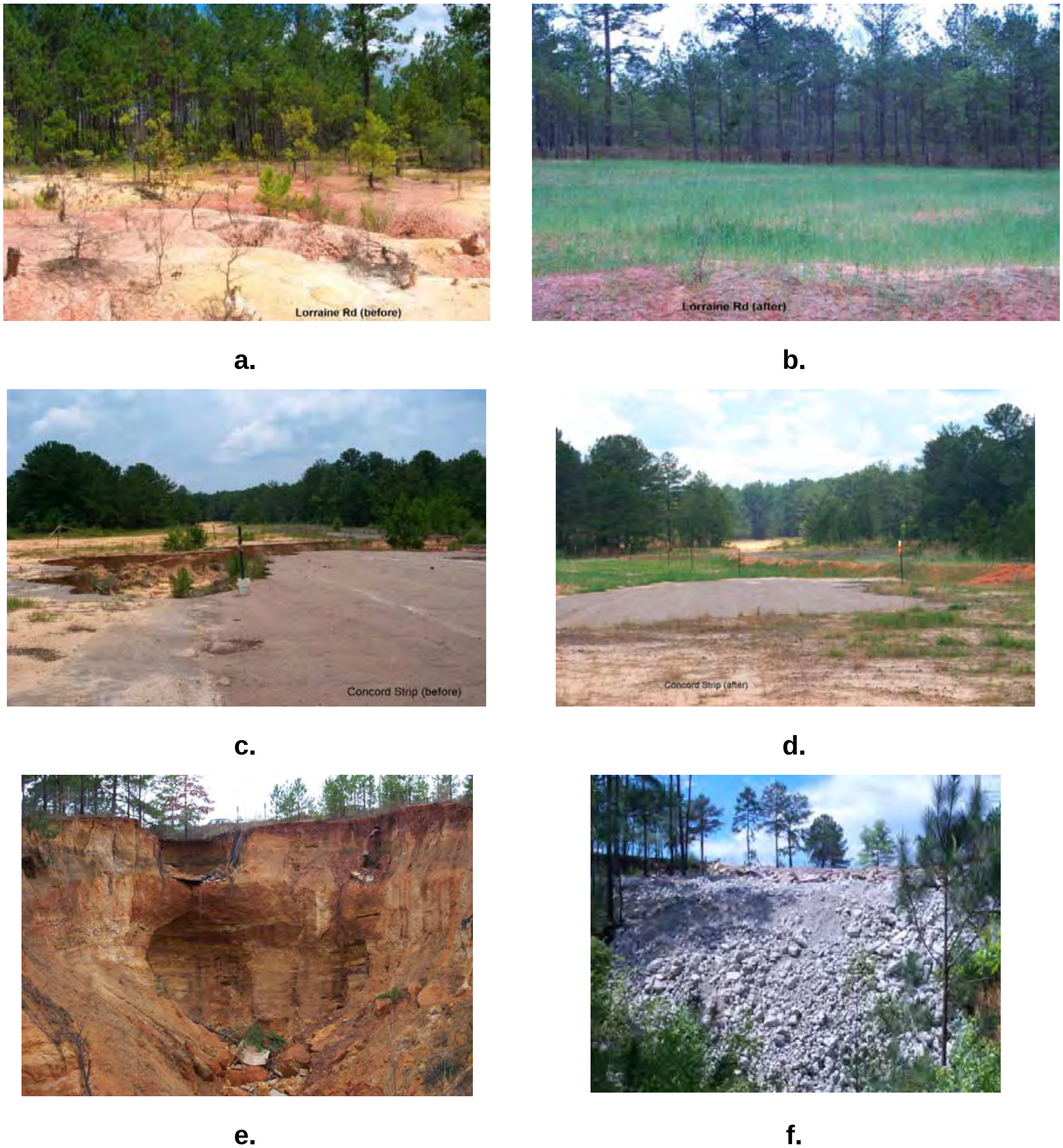

Figure F-4. Examples of delayed or deferred conservation (erosion) problems at Fort Benning that resulted in serious degradation and restoration costs: Lorraine Road, before/after (a/b); Concord strip before/after (c/f); and Kelley Hill gully, before/after (e/f).

Figure F-5. For establishing perennials in difficult sandy soils, use large grain (corn, sorghum) as a nurse crop. It conserves moisture and provides microclimate.

Figure F-6. Often hydroseeding may be the only Army CARES option for seeding steep slopes and narrow, long road shoulders.

Figure F-7. In surface runoff and sediment problems, attack the source (origin, left) before implementing control measures (right) because it pays to "nip the evil in the bud."

(**Source:** www.blm.gov/.../MINERALS__REALTY__AND_RESOURCE_PROTECTION_/bmps.Par.3023.File.dat/O_Ch13_Erosion_Control.pdf)

Figure F-8. Vegetative contour hedges act as bio-terraces, and are unparalleled in stormwater harvesting; they are cost-effective, self-healing, mission compatible, visually appealing, and an excellent choice for concealment islands.

- Take prompt action — Satisfactory stabilization and erosion control requires a complete vegetative cover. Even small breaches in vegetative cover can expand rapidly and, if left unattended, can allow serious soil loss from an otherwise stable surface. A single heavy rain is often sufficient to greatly enlarge bare spots, and the longer repairs are delayed, the more costly they become. Prompt action will keep sediment loss and repair costs down. New seed lings should be inspected frequently and maintenance performed as needed. If rills and gullies develop, they must be filled in, re-seeded, and mulched as soon as possible.

- Plan initial support — Many planting and biotechnical projects fail from neglect. Vegetative measures require care during the establishment period (from 1 to 3 years after planting of perennials). Contingency plans, and funds to implement them, should be part of project specifications. Vegetation measures are weak, ineffective, and vulnerable when first installed, but become progressively stronger, more effective, more adaptable, and self-perpetuating over time.

- Check causes for failure — Even with careful, well-planned seeding operations, failures can occur. When it is clear that plants have not germinated, examine the cause of failure and take corrective actions before attempting to reseed. Reseeding without corrective action means the same problem of inadequate germination may reoccur. Figure F-9 shows problems related to post-construction neglect of routine R&M. Rill erosion occurred during early stages of plant establishment. Had the cause of failure been investigated and necessary repairs completed, this otherwise successful project could have been saved altogether.

Figure F-9. Many revegetation failures can be traced to simple neglect, e.g., failure to construct check dams (left) or rill erosion (right).

- Minimize contractor follow-up — A final lesson learned that proved valuable during restoration of Fort Bragg DZs was simply: "Do not ask for guaranteed plant establishment from commercial contractors in seeding contracts." The contractor was asking a minimum of three times the price for guaranteed establishment to cover the cost for equipment mobilization and reseeding. The cost was based on the assumption that the contractor may have to come back to the job site three times to achieve required plant establishment. The Government was paying three times the actual cost of seeding as an added insurance. We stopped the requirement for guaranteed establishment and took it upon ourselves to reseed and fertilize the areas that failed to establish a good stand. This practice resulted in significant savings (approximately $1.25 million) over 2,500 acres of seeded lands over four DZs (Salerno, Holland, Normandy, and St. Mere Eglise).

- Follow lime and fertilizer protocol — Consider consistently applying lime and fertilizer by broadcast in future years. Following this "universal law" in conservation planning should establish and maintain a healthy vegetative stand at every installation.

Note that, while vegetative control measures are not a panacea for all erosion problems (Figure F-10), if proper establishment, monitoring, and maintenance measures are undertaken subsequent to installation, vegetative measures are the most effective, cost-effective, and aesthetically pleasing solution. Native vegetation can be a challenge to establish and maintain in disturbed soils, however. In such conditions, bio-engineering and/or structural control measures should be considered.

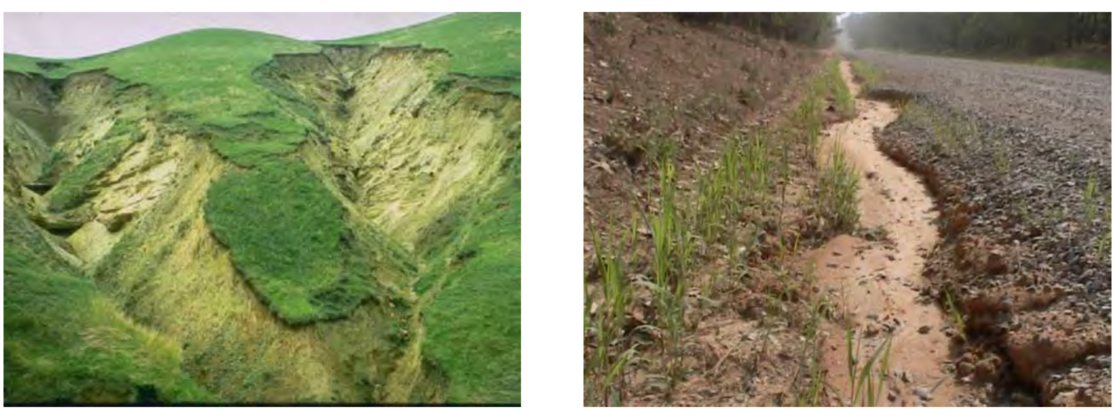

Figure F-10. Vegetative control measures are not a cure-all for all erosion problems, e.g., Fort Bragg gully erosion (left) and McKellers Road erosion, Fort Bragg (right).

APPENDIX G

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APPENDIX H

ACRONYMS AND ABBREVIATIONS

Term	**Spellout**
AR	Army Regulation
CARES	Critical Area Revegetation Establishment Strategies
CERL	Construction Engineering Research Laboratory
DA	Department of the Army
DC	District of Columbia
DOT	Department of Transportation
DZ	drop zone
EMS	Environmental Management Systems
EO	Executive Order
ERDC	Engineer Research and Development Center
HQUSACE	Headquarters, U.S. Army Corps of Engineers
LRAM	Land Restoration and Maintenance
MATES	Mobilization and Training Equipment Site
MPRC	multi-purpose range complex
MUSLE	modified universal soil loss equation
NEPA	National Environmental Policy Act
NPS	Nonpoint Source
NRC	National Research Council [Canada]
NRCS	Natural Resources Conservation Service
PLS	pure live seed
PMC	Plant Material Center
POC	point of contact
PWTB	Public Works Technical Bulletin
QA/QC	quality assurance/quality control
R&M	Repair and Maintenance
RUSLE	Revised Universal Soil Loss Equation
SCS	Soil Conservation Service
TARP	Training Area Recovery Plan
USACE	U.S. Army Corps of Engineers
USDA	U.S. Department of Agriculture

Unit Conversion Factors

acres	4,046.873	square meters
cubic yards	0.7645549	cubic meters
degrees Fahrenheit	(F-32)/1.8	degrees Celsius
feet	0.3048	meters
inches	0.0254	meters
pounds (lb)	0.45359237	kilograms
tons (2,000 lb)	907.1847	kilograms