Fort Hood Grazing Lease – Draft Programmatic Environmental Assessment

October - 2019

US Army Corps of Engineers®
Fort Worth District

Prepared by: U.S. Army Corps of Engineers – Regional Planning & Environmental Center – Fort Worth District

Table of Contents

Finding of No Significant Impact (FNSI)
Programmatic Environmental Assessment for a Grazing Lease at FORT HOOD, TEXAS

The National Environmental Policy Act of 1969 (NEPA) requires federal agencies to consider potential environmental impacts prior to undertaking a course of action. NEPA is implemented through regulations promulgated by the Council on Environmental Quality (CEQ) (40 Code of Federal Regulations [CFR] Parts 1500–1508) and within the United States (U.S.) Department of the Army (Army) by 32 CFR Part 651, *Environmental Analysis of Army Actions*. In accordance with these requirements, Fort Hood prepared an Environmental Assessment (EA), which is incorporated by reference, to consider environmental effects that could result from implementation of the Preferred Alternative, which is to issue the Central Texas Cattleman's Association (CTCA) a five-year grazing lease (2020-2025) permitting up to 2,000 animal units (AUs) on Fort Hood, Texas annually.

1.0 TITLE OF ACTION

Programmatic Environmental Assessment for a Grazing Lease at Fort Hood, Texas, dated October 2019.

2.0 BACKGROUND INFORMATION

The Environmental Division, Directorate of Public Works (DPW) at Fort Hood, Texas, has prepared an Environmental Assessment (EA) analyzing the potential environmental impacts resulting from authorizing use of Fort Hood rangelands for cattle grazing for the next five years (2020-2025).

The attached Environmental Assessment, which is hereby incorporated by reference, was prepared in accordance with the National Environmental Policy Act (NEPA), the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA (Title 40 Code of Federal Regulations Parts 1500–1508), and the Department of the Army Procedures for Implementing NEPA (32 Code of Federal Regulations Part 651).

The U.S. Army Garrison Fort Hood, Texas (Ford Hood) has an estimated on-post population of 68,448 and is located in Central Texas, approximately 60 miles from both Austin and Waco, adjoining the cities of Killeen, Copperas Cove, and Gatesville. Fort Hood is located in Bell and Coryell counties, with the majority of its training lands in Coryell County.

Fort Hood occupies approximately 342 square miles or 218,823 total acres. It is one of the largest armor posts in the United States and is home for approximately twenty percent of the active Army.

Approximately 196,797 acres of this land is range and training land. Approximately 32,525 acres is used for maneuver training area and 62,272 acres is used for range live-fire area.

Since 1942, Fort Hood has continuously renewed a grazing lease allowing previous land owners to graze cattle on training lands. The Central Texas Cattleman's Association (CTCA) was formed by these landowners to manage their cattle grazing rights on Fort Hood.

3.0 DESCRIPTION OF THE PROPOSED ACTION

The Proposed Action is to implement the renewal lease for cattle grazing in accordance with the Modified Combination Strategy, a Grazing Management Plan (GMP) that identifies a sustainable stocking rate for each of the eight Grazing Management Units (GMUs) on Fort Hood, Texas. The proposed action includes specified annual stocking rates for each of the GMUs. The proposed action does not prescribe use of rotational grazing and would not authorize construction of any permanent features anywhere on Installation lands.

Fort Hood training lands have been divided into eight GMUs based on geographic configuration, potential barriers to cattle movement between areas, and training uses. The Eastern Training Area, West Fort Hood, and Western Maneuver Area are each divided into north and south GMUs, while North Fort Hood and the Live Fire and Impact Area are managed as whole GMUs. Due to the lack of fencing and other barriers within GMUs, stocking rates would be managed on a GMU basis.

4.0 ALTERNATIVES

A total of six alternatives were considered as meeting the purpose and need; however, only four were carried forward for further analysis. Each alternative used a distinctly different method to calculate stocking rates for each GMU based on the amount of consumable perennial vegetation.

No Action Alternative (Alternative 1)

The CEQ regulations and Title 32 CFR Chapter V Part 651 (Environmental Analysis of Army Actions AR-200-2) require that a No Action Alternative be evaluated. Analysis of the No Action Alternative assists in our understanding of the anticipated impacts of the proposal and the severity of those impacts. It allows for a comparison to be made of future environmental conditions, both with and without implementation of the proposed plan. The No Action Alternative must be considered for comparison purposes, while other alternatives to the proposal may be eliminated from consideration. The No Action Alternative includes any actions or changes that would occur, regardless of any proposed alternative.

Under the No Action alternative, the installation would re-issue a five-year lease under the same terms and conditions as the current grazing lease (2015-2020). This lease authorized up to 2,000 AUs to be grazed annually within seven GMUs. Two GMUs are considered swing space and are only authorized for grazing use when other areas of the installation have been deferred because of poor rangeland conditions or training use.

25% Harvest Efficiency (Alternative 2)
Under this alternative, the Natural Resource Conservation Service (NRCS) standard method to determine stocking rates on privately owned rangelands was used. This conservative method is known as 25% Harvest Efficiency, which assumes that if 50 percent of forage present in a pasture is left ungrazed, there would be adequate soil cover and residual forage to maintain ecologically healthy rangelands. Of particular note, this alternative does not specifically factor in training utilization of rangelands and assumes that all other land uses are not contributing to loss of forage or soil erosion. Under this alternative, a total of 2,338 AUs could be stocked annually, Installation-wide. The same terms and conditions of the existing lease would be carried forward except for the modified stocking rate.

Combination Strategy (Alternative 3)
Under this alternative, the Grazing Use Model developed specifically for Fort Hood was used to calculate the stocking rate of each GMU. This alternative accounts for training utilization of each GMU and has specific thresholds and management levels based on historic and future training utilization of that GMU when compared to the available forage amount calculated under the most recent forage inventory. Under this alternative with erosion rate less than 1 in each GMU, a total of 1,544 AUs would be stocked annually, Installation-wide. (However, it should be noted that there is a standing Installation-wide policy that states that if the calculated soil erosion indices for all GMUs under the alternative are calculated to be less than 1, then a minimum 2,000 AU stocking rate should be set.)

Modified Combination Strategy (Alternative 4) – Preferred Action Alternative
The Preferred Action Alternative stocking rate was calculated by considering the stocking rate calculated in Alternative 3 and adjusting those stocking rates to achieve 2,000 AUs to meet the Installation-wide minimum when soil erosion indices are below 1 in all GMUs. Under this alternative, the CTCA would be authorized to graze up to 2,000 animal units (AUs) annually Installation-wide between 2020 and 2025. The terms and conditions of the existing lease (2015-2020) would be carried forward to this lease except that the stocking rate for each GMU would be changed to the following:

- Western Maneuver Area – North: 370 AUs
- Western Maneuver Area – South: 237 AUs
- West Fort Hood – North (Northeast and Northwest managed as one GMU): 85 AUs
- West Fort Hood – South: 109 AUs
- Eastern Training Area – North: 293 AUs
- Eastern Training Area – South: 147 AUs

- North Fort Hood: 9 AUs
- Live Fire and Impact Area: 750 AUs

5.0 SUMMARY OF ENVIRONMENTAL EFFECTS

The analysis of the potential environmental impacts are documented in the EA. Table FNSI-1 provides a summary of the potential impacts to environmental and socioeconomic resources that would result from implementing the Preferred Alternative (Alternative 4). Impacts from the No Action alternative would be comparable to the existing condition for all resources. For Alternative 2 and 3, the impacts described in FNSI-1 would be very similar except that as the stocking rate increases, the impacts would also be expected to increase and vice-versa. However, impacts from implementing any of the alternatives would not rise to the level of significant.

Cumulative Impacts were also analyzed for past, present and foreseeable future projects. The analysis considered activities within the Areas of Interest (AOI), which is defined as Bell and Coryell counties. The proposed project location is located throughout the eight GMUs on Fort Hood; therefore Fort Hood projects were included in the cumulative impacts for this AOI.

For each potential environmental impacts detailed below the cumulative impact is also addressed.

TABLE FNSI-1

Summary of Environmental / Socioeconomic Impacts from the Preferred Alternative

Valued Environmental Component	Potential Environmental Impacts Resulting from the Preferred alternative	Mitigation Measure to Minimize Impacts Resulting from the Preferred Alternative
Land Use and **Visual Resources**	Stocking rates would be maintained in the Live Fire and Impact Area at the established maximum. The overall AU stocking rate would be unchanged; however, some GMUs have a slight increase in stocking rate while others have a decrease. There is a slight chance of increased training disruptions as more cattle are stocked; however, it would not rise to the level of significant. Since the annual stocking rate would remain unchanged Installation-wide, the existing condition for visual resources would be maintained.	**None** **None**
Air Quality and **Greenhouse Gas**	There would be no change from the existing condition since the annual stocking rate is not changing.	**None**
Noise	Grazing does not contribute to noise levels above ambient conditions; therefore, grazing would have no beneficial or adverse impact on noise.	**None**

Valued Environmental Component	Potential Environmental Impacts Resulting from the Preferred alternative	Mitigation Measure to Minimize Impacts Resulting from the Preferred Alternative
Geology and **Soils**	Stocking rates were calculated to account for potential soil loss from overgrazing. Average soil erosion indices indicate that under this alternative, soil loss from grazing and training activities, combined, is within the acceptable range of soil loss as determined by NRCS and is not considered significant.	**None**
Water Resources	Direct impacts on water quality would continue, but are not likely to increase from the existing condition. Maintaining a sustainable stocking rate would minimize indirect impacts on water quality. Grazing would have no impact on the extent of jurisdictional wetlands.	**None**
Biological Resources	Grazing would continue to have less than significant impacts on the composition and structure of vegetation communities and the suitability of terrestrial and aquatic habitats for wildlife. By maintaining a conservative stocking rate, habitats special status species rely on would be maintained nearly identical to the existing condition. Threatened and Endangered Species, Migratory Bird Treaty Act (MBTA), Special Status Species ESA-listed species (golden-cheeked warbler), migratory birds, and state listed species would continue to be adversely affected by cattle grazing, mainly through removal of grassland cover and attraction of brown-headed cowbirds which parasitize the nests of other bird species. Maintenance of residual forage and a mixture of habitat types across the Installation would not result in take or contribute to decline of any species. Likewise, the rate of parasitism would continue to be monitored and controlled in compliance of the 2015 BO. Continued monitoring of various species across the Installation would continue and could indicate any adverse effects, in which the Installation could respond by reducing stocking rates.	**None** **None**
Cultural Resources	**None**	**None**
Socioeconomics	**None**	**None**
Energy/Utilities	**None**	**None**
Transportation	**None**	**None**
Airspace	**None**	**None**

Valued Environmental Component	Potential Environmental Impacts Resulting from the Preferred alternative	Mitigation Measure to Minimize Impacts Resulting from the Preferred Alternative
Hazardous and Toxic Substance	**None**	**None**

In terms of cumulative impacts, the Preferred Alternative and No Action Alternative were analyzed for land use, water, soils, air, biological resources, utilities and transportation, noise and hazardous materials and waste. Following review of the alternative actions in combination with other past, present, and reasonably foreseeable future actions within the training lands of Fort Hood, the U.S. Army determined that either no cumulative impacts or no significant cumulative impacts would occur.

6.0 PUBLIC COMMENTS

The EA, including the Draft FNSI, were made available for a 30-day public review and comment period. A Notice of Availability (NOA) of this document was published in the Killeen Daily Herald newspaper on October 7th, 2019. During the 30-day public review and comment period, copies of the EA and draft FNSI were made available at the Killeen Public Library located at 205 East Church Avenue, Killeen, Texas 76543. An electronic copy was also made available at https://home.army.mil/hood/index.php/units-tenants/Garrison-1/DPW/ENV/NOA.

[Summary of Comments Received]

7.0 CONCLUSION

Based on a careful review of the EA, which is incorporated by reference, I have concluded that no significant environmental impacts are anticipated to result from the implementation of the Proposed Action under the alternative analyzed. Therefore, an Environmental Impact Statement (EIS) is not required.

Fort Hood sincerely appreciates the participation of the public in the EA. All public and agency comments are part of the administrative record and have been carefully considered by Fort Hood prior to making final decisions covered under this analysis.

APPROVED:

NANCY SANCHEZ

Environmental Law Attorney

Office of the Staff Judge Advocate

Fort Hood, Texas

BRIAN L. DOSA

Director of Public Works

Fort Hood, Texas

1.0 PURPOSE AND NEED FOR ACTION

1.1 INTRODUCTION

Fort Hood Military Reservation (Fort Hood) became a permanent Installation in 1950, but was initially established as Camp Hood in 1942. The creation of Camp Hood and later expansion to Fort Hood was made possible by the condemnation of private lands by the Federal government, allowing the United States (U.S.) Army (Army) to prepare Soldiers for tank destroyer combat during World War II. In exchange for the condemned land, private land owners received fair market value and a 5-year lease to allow continued grazing of the land. Every five years, the terms of the lease and the effects of grazing are reviewed and a lease may or may not be renewed. The most recent grazing lease was accepted by the Central Texas Cattlemen's Association (CTCA) in 2015.

The intent of this EA is to assess and disclose the known and potential environmental consequences, both beneficial and adverse, of alternative Grazing Management Plans (GMPs). Key issues to be addressed in the EA are the potential effects of alternative GMPs on the sustainability of the landscape, soil quality, water quality, natural resource management, military training activities, and surrounding communities. The EA will help provide an independent, unbiased analysis and comparison of alternatives to the Proposed Action. The EA will assist Fort Hood in deciding how best to implement grazing activities and to assess the direct and indirect environmental effects that may result from alternative GMPs.

This EA is divided into six sections. Section 1.0 provides an introduction to the EA and supporting background material, a description of the Proposed Action and the purpose and need for the Proposed Action, the regulatory framework guiding preparation of the EA, and a record of the public involvement and agency coordination conducted during preparation. Section 2.0 describes the alternatives considered for evaluation, including the No Action Alternative. Section 3.0 describes the existing natural and human environment in the affected area and identifies operational and environmental criteria that will be used to evaluate and compare the alternatives. Section 4.0 discusses the potential environmental consequences of implementing each alternative. Section 5.0 discusses the cumulative effects of past, present, and reasonably foreseeable future actions and the Preferred Alternative for this project. Section 6.0 provides a list of references cited.

1.2 BACKGROUND

Fort Hood occupies approximately 335 square miles of Central Texas in Bell and Coryell counties (Figure 1-1) (Fort Hood 2009a). The Installation is 60 miles north of Austin and 50 miles south of Waco. Fort Hood's infrastructure, power projection capabilities, and state-of-the-art training facilities support upwards of 50,000 active and Reserve Army personnel.

Since 1942, Fort Hood has continuously renewed a grazing lease allowing previous land owners to graze cattle on training lands (Fort Hood 2009b). The CTCA was formed by these landowners to manage their cattle grazing rights on Fort Hood. Providing a lease for continued grazing on training lands is consistent with Fort Hood's "good neighbor" policy and also supports the military mission by maintaining the condition of the training landscape and providing revenue to fund natural resource management on the Installation. The Army recognizes that a healthy and sustainable landscape is required to support the military mission and that properly managed grazing is compatible with the military mission.

Historically, the stocking rates on Fort Hood were determined using the 25 percent Harvest Efficiency method (USACE 2003, Fort Hood 2009b), which the Natural Resource Conservation Service (NRCS) recommends as the standard method to determine stocking rates on privately owned rangelands. This method is generally considered to result in moderate stocking rates, and is based on the premise that 50 percent of forage present in a pasture shall be left ungrazed to provide adequate soil cover and to keep the vegetation stand healthy. In 1996, the Installation-wide stocking rate was set at 3,500 animal units (AU) using this method. In 1997, the NRCS conducted a vegetative resource inventory to determine the ecological health of training lands and to recommend livestock carrying capacities for various vegetation communities on Fort Hood (NRCS 1998). The findings of the vegetative resource inventory indicate that stocking rates were too high on most of the installation and that grazing and training deferments were necessary on all areas void of dense vegetative cover (USACE 2003). The inventory noted extensive rill and gully erosion, poor ecological conditions, and a lack of similarity between existing rangeland conditions and the historical climax plant communities (NRCS 1998). An additional finding of the inventory was that rest from military activities and grazing did not necessarily improve site condition. Despite the findings, the stocking rate was not changed.

In 2000, the Army began preparing an EA to consider modifying the lease stocking rate by reducing stocking rates and incorporating adaptive management, including deferral of grazing, into the GMP, particularly in GMUs where poor ecological conditions and trends away from climax plant communities were recorded. Upon review of the EA, agencies commented that Fort Hood proposed overly complicated grazing management strategies and that stocking rate calculations performed at that time employed inadequate data. As a result, the Army agreed to prepare a Supplemental EA (SEA) to include the results from a forage inventory conducted on the Installation by the NRCS.

In 2001, the NRCS conducted a second forage inventory at Fort Hood, which indicated that productivity of palatable perennial species had declined substantially since 1996 (NRCS 2002a). The observed decline in productivity was attributed to multiyear drought conditions, continuous and heavy grazing, and concentrated military training. In 2002, the NRCS conducted a third forage inventory of the Installation (NRCS 2002b), and the results were incorporated into an SEA prepared by the USACE (2003). The 2003 SEA evaluated several alternative GMPs used to calculate stocking rates based on the observed availability of forage and an evaluation of scheduled military training activities. The SEA identified a preferred alternative that maximized grazing opportunities while minimizing potential impacts on environmental resources and military training activities. The preferred alternative was implemented from 2003 to 2010. During this time, recommended stocking rates have generally been less than 2,000 total AU on an Installation-wide basis.

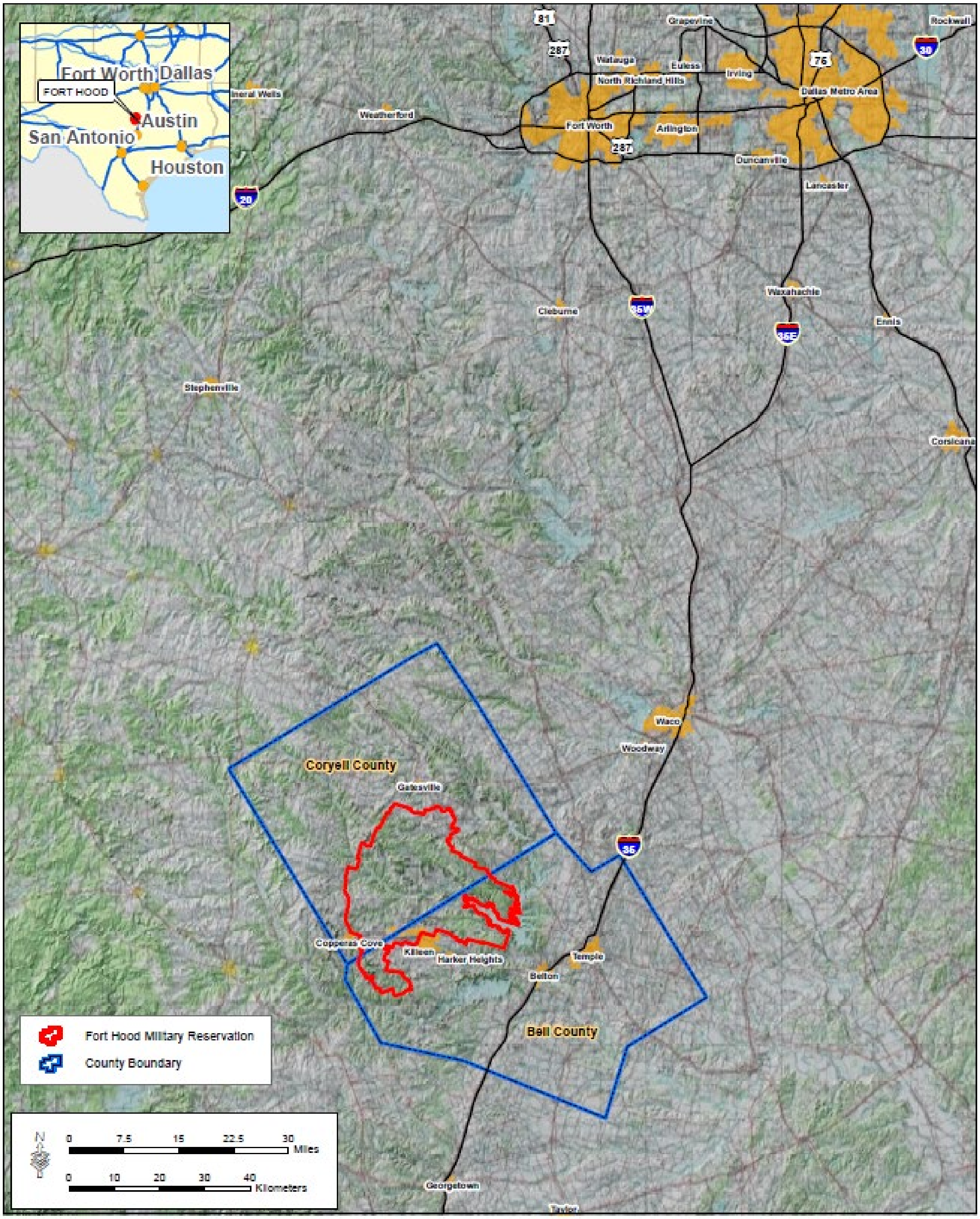


Figure 1-1: Location Map
Fort Hood Military Reservation (Fort Hood)

September 2011

In 2010, the CTCA requested a renewed assessment of vegetation conditions. A new EA was prepared in which three alternatives were assessed including the No Action, a Limited GMP, and an Adaptive GMP. The Limited and Adaptive GMPs proposed stocking rates for only the first two years of the lease and stated that monitoring would dictate the outyears. The No Action was ultimately selected and implemented, which maintained the stocking rate at 2,000 AUs. This EA will utilize updated vegetation inventories to determine if the current stocking rate remains valid or if a modified GMP in warranted based on current conditions.

1.3 PURPOSE AND NEED

The proposed action is to issue the CTCA a 5-year grazing lease with grazing rights to Fort Hood that supports a stocking rate that sustains at a minimum the existing condition of rangelands while not interfering with training activities. The purpose of the Proposed Action is to identify a GMP that provides for sustainable grazing activity while not significantly impacting the environment or Fort Hood's mission. Fort Hood's mission includes providing and maintaining the infrastructure to support strategic power projection and to train Fort Hood units and soldiers; maintaining a quality living and working environment for soldiers, families, retirees, and authorized civilians; and sustaining an effective partnership with surrounding communities (Fort Hood 2009a).

To provide effective training, Fort Hood must manage the training area landscape (i.e., the appearance and natural characteristics of the area) for sustainability, realism, and functionality. Highly eroded soils are unable to sustain vegetation, and the formation of rills and gullies on eroded soils presents a safety hazard to Soldiers and limits tactical maneuverability. Areas that are obviously degraded by previous grazing or training activity detract from the realism of the current training activity. Areas that are stripped of their vegetation no longer resemble the undisturbed lands that might be encountered during real conflicts. Optimum landscape conditions provide sufficient vegetation to provide cover and concealment opportunities.

The landscape condition of training areas can also affect the quality of life for the Fort Hood community. Local communities are connected by the public roadways which traverse the training areas, and the training areas provide multiple recreational opportunities when not being used for military activities. Cattle grazing was part of the local landscape prior to the establishment of Fort Hood and continues to be an important economic and cultural influence on the surrounding communities. Grazing lease proceeds are available to fund a variety of environmental stewardship programs on the Installation, ranging from maintenance of natural resources to preservation of cultural resources. Fort Hood believes that well-managed grazing is compatible with the military mission, and is in support of maintaining both the landscape and Fort Hood's "good neighbor" policy.

The need to support the Army's military mission at Fort Hood remains ever present and includes providing necessary forces and capabilities to support Combatant Commanders in support of National Security and Defense Strategies. Fort Hood is one of the Army's premier training Installations, and providing optimum landscape conditions for the practice of large-scale maneuvers using large numbers of personnel and equipment is necessary to ensure that Army Soldiers are effectively prepared for a variety of potential combat scenarios. The need to support natural resource management at Fort Hood stems from the need to support the military mission.

1.4 COMPLIANCE WITH REGULATORY REQUIREMENTS

The National Environmental Policy Act (NEPA) (Public Law [PL] 91-190, 1969) requires Federal agencies to consider the environmental consequences of all proposed actions in their decision-making process. The intent of NEPA is to protect, restore, or enhance the environment through a well-informed decision-making process. The Council on Environmental Quality (CEQ) was established under NEPA to implement and oversee Federal policy in this process. The CEQ issued the Regulations for Implementing the Procedural Provisions of NEPA (40 Code of Federal Regulations [CFR] 1500-1508, 1993). Army Regulation (AR) 200-2 implements CEQ regulations relating to the Army. These CEQ regulations and AR 200-2 provide for the periodic review of continuing activities to ensure that setting, actions, and effects which may have been previously assessed remain substantially accurate, particularly if changes in operation have occurred or are planned. This document assesses the environmental impacts associated with the implementation of revisions to the grazing program at Fort Hood.

Department of Defense (DoD) Instruction Number 4715.03 "establishes policy and assigns responsibility for compliance with applicable Federal statutory and regulatory requirements, Executive Orders (EO), and Presidential Memorandums for the integrated management of natural resources including lands, airs, waters, coastal, and near-shore areas managed and/or controlled by the DoD." DoD Instruction 4715.03 incorporates the requirements of the Sikes Act of 1960 and the Sikes Act Improvement Act of 1997 (16 United States Code 670), which include the preparation of an Integrated Natural Resources Management Plan (INRMP) in cooperation with the U.S. Fish and Wildlife Service (USFWS) and State fish and wildlife management agencies. The most recent INRMP for Fort Hood was prepared in 2019 and has been approved by the resource agencies.

AR 405-80, 10 October 1997, Section 4-8, Management of Title and Granting Use of Real Property states: "The Department of the Army will not authorize the use of real property, water, or other natural resources when the use conflicts with the goals and intent of overall Federal policy on environmental quality and historical preservation. All actions will comply with applicable Federal and state environmental, historical, and cultural protection requirements as well as any applicable coastal zone management plans, floodplain, and wetland management (see AR 200-2)."

In addition, Army (1999a) Department-Wide guidance on Reimbursable Agricultural/Grazing and Forestry Programs provides general criteria for Installation managers to determine whether such programs can be implemented on the Installation. The guidance states that outleasing and harvesting activities shall be conducted in such a manner as to support mission operations, support conservation compliance, and execute natural resources stewardship (e.g. maintain healthy ecosystems). Below are relevant excerpts from the guidance and the transmittal letter from the Assistant Chief of Staff for Installation Management:

- Reimbursable agricultural/grazing and forestry activities are opportunities for planning and managing the landscape (i.e., the appearance and natural characteristics of the area) to fit the needs of the mission. Outleasing and harvest of forest products shall be conducted in such a manner to support mission operations, support conservation compliance, and execute natural resources stewardship, e.g. maintain healthy ecosystems, sustain biodiversity. (Section 2.a.)

- Installation mission operations personnel (e.g., Installation G-3, Directorate of Plans, Training, Mobilization, and Security staff or equivalent and testing counterparts) shall determine optimum mission landscape requirements (i.e., ecosystem characteristics) in consultation with Installation conservation personnel. (Section 2.b)

- Sustained reimbursable activities "must support the mission" of the Installation. The activity "must not encumber land that is needed for conducting mission operations." The Natural Resource Managers "must coordinate with mission operators to identify opportunities to improve long-term mission access to land, increase training realism, and improve training flexibility." [Section 3.a(5)(a)]

- Installations that conduct these activities must identify how specific reimbursable program activities directly support mission landscape requirements and environmental stewardship in the INRMP or other appropriate planning documents where INRMPs are not required. Reimbursable program activities that obstruct these requirements are not eligible for automatic reimbursement authority. (Section 2.c.)

- Agricultural and forest products shall not be given away, abandoned, carelessly destroyed, used to offset contract costs or traded for services, supplies, or products, or otherwise be improperly removed (except as authorized in 3b(9) and 3c(2)). (Section 3.a(1))

Other laws, regulations, EOs, and guidance documents reviewed in the development of this EA are summarized within Section 3.0, and significance thresholds are provided in Section 4.0 in association with the resources to which they apply.

1.5 PUBLIC INVOLVEMENT/AGENCY COORDINATION

A Public Draft EA and Draft Finding of No Significant Impact (FNSI) was delivered to government and tribal agencies and was made available to the public for review and comment for a period of 30 days (Appendix A). [Summary of public comments will be inserted here prior to the final EA/FONSI is signed.]

2.0 Description of the Proposed Action and Alternatives

This chapter describes and compares the alternatives considered for the management of grazing on Fort Hood. This section presents the alternatives in comparative format, in order to define the differences, between each alternative and providing for a clear basis for choice among options by the decision maker and the public.

2.1 STOCKING RATE CALCULATION

The flow chart presented in Figure 2-1 documents the process by which cattle stocking rates are established on Fort Hood. The process contains three major steps:

1. Selection of a stocking rate calculation method and training related forage reduction factor,
2. Annual forage inventory, and
3. Soil erosion rate estimation.

2.1.1 Selection of Stocking Rate Calculation Method

There are three distinct stocking rate calculation methods that could be used to establish stocking rates for GMUs on Fort Hood. Each of these methods were used to calculate a different stocking rate based on the amount of consumable perennial vegetation.

25% Harvest Efficiency – The NRCS commonly uses this standard method to determine stocking rates on privately owned rangeland. This method is based on the premise that 50 percent of forage present in a pasture shall be left ungrazed to provide adequate soil cover and keep the vegetation stand healthy.

Maintenance Threshold (750 pounds of ungrazed forage residue per acre) – The Texas Cooperative Extension Service states that optimal amounts of ungrazed forage for midgrass rangeland should range from 750 to 1,000 pounds per acre. Selection of a maintenance threshold of 750 pounds of ungrazed forage per acre aims to maintain current rangeland health conditions and to reduce erosion.

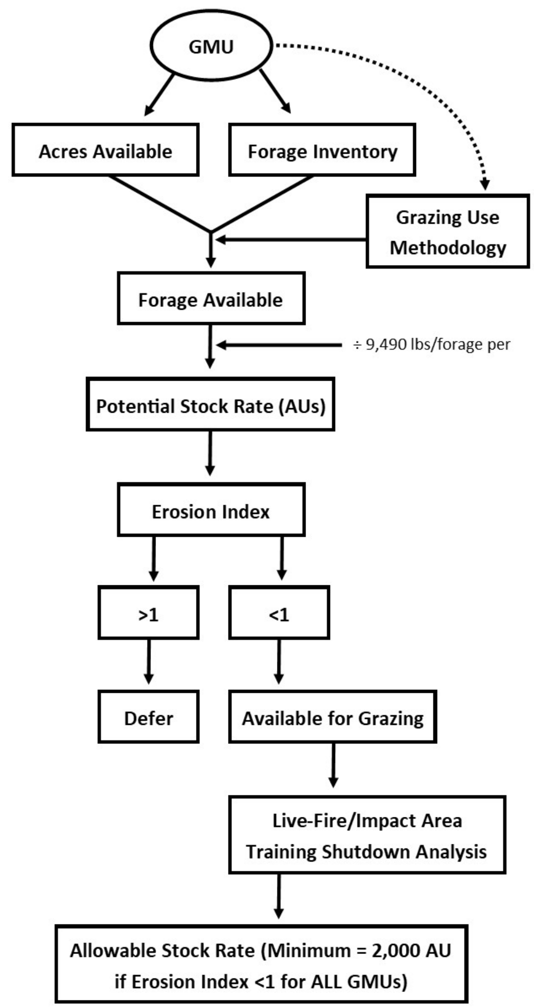


Figure 2-1. Stocking Rate Calculation Process

Conservation Threshold (1,000 pounds of ungrazed forage residue per acre) – Similar to the Maintenance Threshold approach, this strategy retains a greater amount of ungrazed forage to promote an increased rate of rangeland recovery and decrease soil erosion. Cattle stocking rates calculated under this approach would be developed under the limitation that only the volume of forage in excess of 1,000 pounds per acre would be available for grazing.

2.1.2 Forage Inventories

A forage inventory was completed in July 2019 using the same technique as used historically to determine the total available forage within each GMU. The inventory included collecting vegetation data at 70 randomly selected sample locations that were divided proportionately among the GMUs. The sampling technique identified plants within survey transects and categorized them according to forage suitability. This data was extrapolated to develop a prediction of the amount of consumable perennial vegetation in each of the GMUs.

To calculate perennial consumable forage available in a given GMU, the actual grazeable acres were calculated. The forage inventory determined this acreage by using a combination of image classification and analysis by geographic information system (GIS) software on high-resolution aerial photography and bare ground, water, and development layers. Subsequently, the total area of bare ground, water, and developed areas was subtracted from the total acreage in the GMU to obtain a value for grazeable acreage. Between the 2012 and 2019 forage inventories indicate there was a loss of about 7,371 grazeable acres (Table 2-1). The loss of grazeable acres indicates a loss in the overall availability of forage to cattle.

Table 2-1. Change in Grazeable Acres between 2010 and 2019.

GMU	Grazeable Acres (2012)	Grazeable Acres (2019)	Change in Acres
Western Maneuver Area – North	35,045	33,421	-1,624
Western Maneuver Area – South	32,108	29,932	-2,176
West Fort Hood – Northeast	1,468	1,370	-98
West Fort Hood – Northwest	3,856	2,316	-1,540
West Fort Hood – South	9,363	9,005	-358
Eastern Training Area – North	29,182	28,745	-437
Eastern Training Area – South	22,614	21,587	-1,027
North Fort Hood	3,798	3,687	-111
Live Fire and Impact Area	60,500	60,500	0
Total	**197,934**	**190,563**	**-7,371**

Table 2-2 provides a summary of the total annual production (all species types within a sample plot) and the total annual consumable production (only species that cattle consume) for each GMU as indicated in the Forage Inventory Report.

It is important to note, that the forage inventory is a snap shot in time and many factors can affect the actual consumable forage including but not limited to precipitation patterns and temperature during the growing season, establishment or expansion of undesirable/non-consumable species, wildfires, length of growing season, time of year, training intensity, etc.

The assumed forage requirement to support one AU is 9,490 pounds (lbs) of perennial consumable forage per year. The carrying capacity or stocking rate of each GMU is determined by dividing the total perennial consumable forage by a factor of 9,490 lbs of forage per AU per year. Appendix A contains a copy of the most recent completed forage inventory.

Table 2-2. Total Annual Production by GMU based on the 2019 Forage Inventory

GMU	Grazeable Acres	Total Annual Production (lbs/acre/yr)	Total Annual Production (lbs/yr)	Total Consumable Production (lbs/acre/yr)	Total Annual Consumable Production (lbs/yr)
Western Maneuver Area – North	33,421	1121.66	37,486,460	850.27	28,416,569
Western Maneuver Area – South	29,932	450.01	13,469,654	362.98	10,864,606
West Fort Hood – Northeast	1,370	567.36	777,425	327.53	448,801
West Fort Hood – Northwest	2,316	1627.72	3,769,279	1100.73	2,548,940
West Fort Hood – South	9,005	614.63	5,534,860	424.22	3,820,140
Eastern Training Area – North	28,745	562.28	16,162,941	386.88	11,121,128
Eastern Training Area – South	21,587	439.16	9,480,340	210.68	4,548,134
North Fort Hood	3,687	195.08	719,217	92.38	340,569
Live Fire and Impact Area	--	--	--	--	--

2.1.3 Soil Erosion Rate Estimation

The results from the most recent forage inventory were used in the development of estimates of soil erosion in each GMU using the Revised Universal Soil Loss Equation (RUSLE). This methodology is commonly used by the military for assessing erosion on military training lands and as part of Integrated Training Area Management (ITAM) Programs. The RUSLE equation estimates the average soil loss in tons per acre per year based upon the following factors: rainfall-runoff erosivity (R); soil erodibility (K); slope-length (L); slope-steepness (S); cover management (C); and support practice (P). Detailed procedures for RUSLE calculations referenced here are found in Appendix A.

Erosion estimates are compared to acceptable soil loss values that were developed by the NRCS for each soil type found on the Installation. If erosion estimates exceed the acceptable soil loss tolerance limits, grazing must be deferred in that GMU for a period of one year or until estimated erosion rates fall below acceptable limits. None of the GMUs had erosion estimates that exceeded the acceptable limits based on data obtained during the most recent forage analysis (Appendix A).

2.1.4 Final Stocking Rate Selection

A total of 6 alternatives, including the No Action, were identified for consideration. Three sets of stocking rates were calculated using each stocking rate calculation method (harvest efficiency, maintenance threshold and conservation threshold) identified in section 0. These developed the basis for three alternatives. Two additional stocking rates were calculated which followed the process listed but also took into account utilization of each GMU for military training activities.

It is important to note, that the Army has established a minimum Installation-wide stocking threshold of 2,000 AUs per year if calculated erosion indices are below 1 in all GMUs. If calculated erosion indices are below 1 for all GMUs, but the sum of recommended annual stocking rates for each GMU is below 2,000 AU, adjustments to the stocking rates should be applied in appropriate GMUs so that the sum of the annual stocking rates is equal to 2,000 AU. Any GMU with a calculated erosion index greater than 1 shall be deferred from cattle grazing until the GMU recovers and the calculated erosion index is less than 1.

Additionally, there are stocking rate restrictions for the Live-Fire/Impact Area GMU. This GMU is particularly sensitive to training interruptions due to the presence of cattle. Soldiers participating in gunnery practice must stop activities when cattle cross into their line of fire. Either personnel must be dispatched to move cattle out of the way or units must wait until cattle leave their line of fire voluntarily. This often results in significant losses in time available for training. In FY02, there were 419 shutdowns when 750 head of cattle were present in the area; therefore, Fort Hood determine that this is the maximum number of shutdowns that is acceptable. As a result, Fort Hood set a maximum stocking rate of 750 AU in the Live-Fire/Impact Area GMU.

2.2 ALTERNATIVES CONSIDERED IN DETAILED ANALYSIS

It was determined that under all alternatives the terms and conditions of the future lease would remain the same as the No Action, except that the stocking rate would be adjusted based on the results of the July 2019 Forage Inventory.

Under each of the alternatives, the lessee would be responsible for implementing the necessary livestock inventory and herd management practices to ensure that the number of cattle present in each GMU does not exceed the stocking rates as determined in the lease. Grazing would be continuous year-round; rotational grazing would not be implemented. Methods to be used for herd management require Fort Hood’s approval to ensure that they neither conflict with the training mission of the Installation nor are unsafe. Real Property would ensure that the CTCA adheres to agreed stocking rates. Fort Hood retains the right to defer grazing at any time, and grazing would be deferred if impacts on the landscape threaten the military mission.

2.2.1 Alternative 1: No Action (Current Management) Alternative

Under the No Action Alternative, the grazing lease would be renewed for another 5 years without any changes to the stocking rate of 2,000 animal units (AUs); however, the grazeable acres available would decrease by approximately 7,731 acres. The stocking rate for each GMU is listed in Table 2-3. The stocking rate is based on previous forage inventories and rangeland health assessments conducted by the NRCS. These stocking rates represent moderate, sustainable levels of grazing under current climate, training, and management conditions. Cattle may be redistributed among the GMU or grazing may be deferred to avoid substantial impacts on the environment; however, the total stocking rate for the Installation would not exceed 2,000

AU. North Fort Hood and West Fort Hood – Northeast are considered swing space and would not be routinely stocked, but would be used for grazing if temporary deferrals are required in other GMUs. All current terms and conditions of the lease would be carried into the new lease.

To validate whether or not this stocking rate is compatible with available forage resources given the change in grazeable acres, a comparison of forage need to forage availability was completed. The current AU stocking rate was used to calculate the amount of forage needed to sustain the stocking rate for 365 days per year across all grazeable acres in the GMU. It was assumed that the stocking rate is a cow/calf pair, or one AU, which consumes 26 pounds of forage (oven dry weight) per day or 9,490 pounds of forage per year.

Table 2-3. No Action Existing/Proposed Stocking

GMU	Stocking Rate (AU)	Forage Need (AU x 18,980= lbs/forage/yr)	Total Annual Consumable Production (lbs/yr)	% of Annual Consumable Production Remaining	Sufficient Forage Available+
Western Maneuver Area – North	320	3,036,800	28,416,569	89	Yes
Western Maneuver Area – South	394	3,739,060	10,864,606	66	Yes
West Fort Hood – Northeast	Swing space[1]	--	448,801	--	--
West Fort Hood	73	692,770	2,548,940	73	Yes
West Fort Hood – South	109	1,034,410	3,820,140	73	Yes
Eastern Training Area – North	207	1,964,430	11,121,128	82	Yes
Eastern Training Area – South	147	1,395,030	4,548,134	69	Yes
North Fort Hood	Swing space[1]	3,036,800	340,569	--	--
Live Fire and Impact Area*	750	--	--	--	Yes
Total	**2,000**				

* Biomass data was not collected for the Live Fire and Impact Area during the 2019 forage inventory, so it was assumed that the 2005 forage analysis rates remain valid.

+ If the % of Annual Consumable Production Remaining was greater than 50%, it was determined that there is sufficient forage to support the stocking rate and maintain at a minimum "Take Half, Leave Half" management levels. To maintain a 25% harvest efficiency (more conservative rate), at least 75% of the remaining consumable production would be required.

[1] Swing Space: area not routinely stocked, but available for grazing if temporary deferrals are required in other GMUs

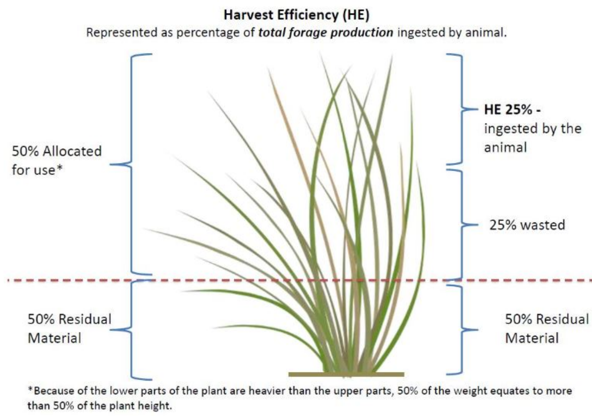
2.2.2 Alternative 2: Harvest Efficiency

Note: This alternative is in reference to Option 1 identified in the Forage Inventory Report.

Under this alternative, the stocking rates were calculated using the 25% Harvest Efficiency method for determining stocking rates was applied to each GMU, except the Live Fire/Impact Area, without regard to potential erosion condition, ecological health, or current land use.

The 25% Harvest Efficiency method is the standard method of calculating stocking rates for private landowners that the NRCS recommends and is considered a conservative method of calculating stocking rates under proper land management. Harvest efficiency applies the old "take half, leave half" rule of thumb, but also recognizes that of the 'Take Half' portion not all of the forage is consumed. Recognizing that some forage is consumed and some is destroyed is a key concept to understanding harvest efficiency.

Figure 2-2. 25% Harvest Efficiency



Total forage production (TFP) includes only the forage (consumable) species in the plant community, and represents all of their above ground annual production, not just the portion above a stubble height. The 'Leave Half' portion (50%) represents post-grazing residual forage. This is the most important part of the old take half, leave half rule of thumb for grazing. The 'Take Half' portion (50%) allocated for use represents the utilization, and includes both consumed and destroyed portions. The 'ingested' portion (25%) represents harvest efficiency, or that portion that is actually ingested by the grazing animal. The 'wasted' portion (25%) represents forage that was utilized but went to waste through trampling, desiccation, manure and urine, bedding, etc.

The forage inventory report determined that if the 25% Harvest Efficiency method is applied to all GMUs without regard to training utilization up to 2,338 AUs could be stocked on Fort Hood (Table 2-4). Although this method does not specifically account for training utilization, the randomization of sample plots inherently accounts for some training use, but may under- or overestimate annual use impacts in some GMUs depending on the level and type of training utilization occurring in the days and weeks prior to the inventory.

Table 2-4. Stocking Rate Using 25% Harvest Efficiency Grazing Use Methodology

GMU	Stocking Rate
Western Maneuver Area – North	749
Western Maneuver Area – South	237
West Fort Hood – Northeast	12
West Fort Hood – Northwest	67
West Fort Hood – South	101
Eastern Training Area – North	293
Eastern Training Area – South	120
North Fort Hood	9
Live Fire and Impact Area	750
Total	**2,338**

2.2.3 Alternative 3: Combination Strategy

Note: This alternative is in reference to Option 4 identified in the Forage Analysis Report.

Under this alternative stocking rate calculations specifically accounted for military training activities that would affect available forage within each GMU. Military training utilization data obtained from Fort Hood Range Control was compared to a scale which has been established for each GMU using baseline range conditions. The Grazing Use Methodology (GUM) model was used to account for the best available data for training area utilization and relative differences in training impacts on vegetation. The GUM was developed specifically for Fort Hood for the 2006 Grazing Management Plan to establish an objective measure of training intensity that can be factored into selecting the appropriate stocking rate calculation method for each GMU (i.e. based on platoon days of training, wheeled versus tracked vehicles). Fort Hood Range Control does not maintain records of military training at the platoon-level. However, records are available for scheduled training area use at larger unit levels. Additionally, specific training areas are used for the same common types of training activities on a recurring basis. For example, much of the tracked-vehicle training occurs in the Western Maneuver Areas. The Eastern Training Areas are used for wheeled vehicle and dismounted infantry training.

The GUM model utilizes a three-category training utilization scale (green, amber, red) to determine the stocking rate calculation methodology and training-related forage reduction factor (FRF) for each GMU. Table 2-5 summarizes the training utilization thresholds established for each GMU.

Table 2-5. Training Utilization Scale.

GMU	Green Range (Harvest Efficiency)	Amber Range (Maintenance Threshold)	Red Range (Conservation Threshold)
Western Maneuver Area – North	0-20%	21-40%	41-100%
Western Maneuver Area – South	0-22%	23-44%	45-100%
West Fort Hood – Northeast	0-100%	N/A	N/A
West Fort Hood – South	0-100%	N/A	N/A
Eastern Training Area – North	0-57%	58-100%	N/A
Eastern Training Area – South	0-45%	46-90%	91-100%
North Fort Hood	0-100%	N/A	N/A
Live Fire and Impact Area	0-100%	N/A	N/A

The training-related FRF is determined by each GMU's Training Intensity Scale. The FRF is the percentage by which the total volume of perennial consumable forage in a GMU identified by the most recent forage inventory is reduced to account for vegetation loss due to military training. The amount of perennial consumable forage is reduced by the training-related FRF. The following FRFs have been assigned to each portion of the Training Intensity Scale:

- Green Range : 10%
- Lower Half of Amber Range: 15%
- Upper Half of Amber Range: 30%
- Red Range: 40%

Table 2-6 shows the training utilization rates for the 2018 training year and corresponds that utilization rate to the training utilization scale and associated FRF as described above. Table 2-7 shows the stocking rate proposed under this alternative.

Calculated erosion indices are below 1.0 for all GMUs but the sum of recommended annual stocking rates for each GMU is below 2,000 A, therefore this alternative would not meet the installation stocking policy guidelines, and Alternative 4 was developed. This alternative was retained for analysis and comparative purposes.

Table 2-6. Forage Reduction Factor for Each GMU Based on 2018 Training Utilization Records.

GMU	2018 Training Utilization (%)	Utilization Range	Forage Reduction Factor	Stocking Rate Calculation Used
Western Maneuver Area – North	43.24	Red	40	Conservation
Western Maneuver Area – South	22.61	Low Amber	15	Maintenance
West Fort Hood – Northeast	23.97	Green	10	25% HE
West Fort Hood – South	34.11	Green	10	25% HE
Eastern Training Area – North	23.97	Green	10	25% HE
Eastern Training Area – South	23.42	Green	10	25% HE
North Fort Hood	67.08	Green	10	25% HE
Live Fire and Impact Area	Set by Installation Policy			

Table 2-7. Stocking Rate Using the Grazing Unit Methodology Model

GMU	Stocking Rate
Western Maneuver Area – North	85
Western Maneuver Area – South	107
West Fort Hood – Northeast	12
West Fort Hood – Northwest	67
West Fort Hood – South	101
Eastern Training Area – North	293
Eastern Training Area – South	120
North Fort Hood	9
Live Fire and Impact Area	750
Total	**1,544**

2.2.4 Alternative 4: Modified Combination Strategy (Preferred Alternative)

The intent of this alternative was to account for the Installation-wide annual stocking rate minimum of 2,000 AU if all calculated erosion indices are below 1.0 for all GMUs but the sum of recommended annual stocking rates for each GMU is below 2,000 AU.

To start, it was determined that some logical variations to the GUM Training Utilization Scale could be applied to the Western Maneuver Area – North and – South. Based on historic values and variables affecting range conditions, it was determined that adjusting the Western Maneuver Area – North down to Amber (Maintenance Threshold) and Western Maneuver Area – South down to a Green Utilization Range (25% Harvest Efficiency) was appropriate. For both areas, utilization has historically hovered within a few percentage points of the threshold breakpoints. This resulted in an increase in 321 AU over Alternative 3.

The second consideration when adjusting stocking rates from Alternative 3 applied to all GMUs, except the two Western Maneuver Areas and the Live Fire/Impact Area. If the stocking rate for the No Action was higher than the 25% Harvest Efficiency, the No Action stocking rate was applied and vice versa. This selection process was applied for these 6 GMUs under the assumption that the GMU can support the stocking rate because at current management levels rangeland health is considered acceptable. For GMUs, where the 25% Harvest Efficiency Rate was applied instead of the No Action, it is assumed that there will be sufficient forage available to support the increased stocking rate. This resulted in an additional 41 AUs being added.

Factors affecting the forage inventory were also considered when determining where increases in the stocking rate should be applied to achieve 2,000 AU. As described previously, the randomization of sample plots inherently capture recent training impacts, which would cumulatively contribute to lower forage availability when coupled with the FRF incorporated into the GUM model. Additionally, the forage inventory was completed at the end of July during the peak of summer. Typically, forage inventories are best completed at the end of the growing season, which typically extends from April 1 to November 1 on the Installation. By completing surveys early, warm season consumables are deteriorating with the warm, dry conditions and the cool season growth has not come in; therefore, it is likely that available consumable forage is actually slightly higher than the current inventory indicates. This increase in available consumable forage should be sufficient to offset the decrease in FRF that is associated with the GUM Model Stocking Rate calculations and to account for the increase over the 25% Harvest Efficiency stocking rate in GMUs where the No Action stocking rate was applied.

The remaining 94 AUs were applied to the Western Maneuver Area – North since this GMU was the only GMU with sufficient forage available to support an increase over the No Action without substantially going over the 25% Harvest Efficiency stocking rate. This stocking rate would result in less AU than under the 25% Harvest Efficiency, but would result in less than 750-pounds per acre of residual forage being left on the landscape in some ecological units.

As part of this alternative, it is recommended that annual erosion surveys be completed to validate that soil erosion indices remain below 1. If erosion indices rise above 1 in any given year, the stocking rate for that GMU should be reduced to the stocking rate from Alternative 3 or deferred for a minimum of one year or until erosion rates fall below 1, whichever is longer. Annual erosion surveys would be most critical in the Western Maneuver Area – North to ensure that training activities and the increase in cattle over the No Action are not adversely affecting rangeland health.

Under this alternative, a total of 2,000 AUs would be stocked annually Installation-wide at the recommended stocking rates per GMU as listed in Table 2-8.

Table 2-8. Stocking Rate to Achieve the Installation-wide 2,000 AU minimum.

GMU	Stocking Rate From Alternative 3	Stocking Rate to Achieve 2,000 AU minimum
Western Maneuver Area – North	85	370
Western Maneuver Area – South	107	237
West Fort Hood – Northeast	12	12
West Fort Hood – Northwest	67	73
West Fort Hood – South	101	109
Eastern Training Area – North	293	293
Eastern Training Area – South	120	147
North Fort Hood	9	9
Live Fire and Impact Area	750	750
Total	**1,544**	**2,000**

2.3 ALTERNATIVES CONSIDERED BUT ELIMINATED FROM FURTHER ANALYSIS

2.3.1 Maintenance Threshold

Note: This alternative is in reference to Option 2 identified in the Forage Analysis Report.

This alternative assessed the stocking rate assuming a minimum of 750 pounds per acre of consumable forage was left on the landscape, in all GMUs, except the Life Fire/Impact Area. This alternative recommended a stocking rate of 1,351 AUs and recommended deferring 1 GMU due to having insufficient forage to meet the residual forage minimum per acre (Table 2-9). This alternative was eliminated from further analysis because it was determined that having a Maintenance Threshold across the board was overly conservative given that range conditions have improved over the last several decades despite higher stocking rates. Additionally, a minimum annual stocking rate of 2,000 AU is required since all erosion indices are below 1.0. There are other alternatives that would more accurately distribute the stocking rate than would occur under this alternative.

2.3.2 Conservation Threshold

Note: This alternative is in reference to Option 3 identified in the Forage Analysis Report.

This alternative assessed the stocking rate assuming a minimum of 1,000 pounds per acre of consumable forage was left on the landscape in all GMUs, except in the Live Fire/Impact Area. This alternative recommended a stocking rate of 1,012 AUs and recommended deferring 2 GMUs due to having insufficient forage to meet the residual forage minimum per acre (Table 2-9). This alternative was eliminated from further analysis using the same rationale as the Maintenance Threshold alternative.

Table 2-9. Stocking Rate Using the Maintenance Threshold.

GMU	Maintenance Stocking Rate	Conservation Stocking Rate
Western Maneuver Area – North	277	85
Western Maneuver Area – South	107	95
West Fort Hood – Northeast	3	0
West Fort Hood – Northwest	38	3
West Fort Hood – South	30	9
Eastern Training Area – North	105	43
Eastern Training Area – South	41	27
North Fort Hood	0	0
Live Fire and Impact Area	750	750
Total	**1,351**	**1,012**

2.4 COMPARISON OF ALTERNATIVES

This section provides a summary of the effects of implementing each alternative that is being considered in detail. Table 2-10 provides a comparison of the stocking rates for each alternative by GMU. Table 2-11 briefly describes the impacts of each alternative on the 3 categories of natural resources where differences between alternatives are most notable.

Table 2-10. Comparison of Stocking Rates for Each Alternative

GMU	Alternatives			
	Alt 1: No Action	Alt 2: 25% Harvest Efficiency	Alt 3: Combination Strategy	Alt 4: Modified Combination Strategy (Preferred Alt)
Western Maneuver Area – North	320	749	85	370
Western Maneuver Area – South	394	237	107	237
West Fort Hood – Northeast	Swing space	12	12	12
West Fort Hood – Northwest	73	67	67	73
West Fort Hood – South	109	101	101	109
Eastern Training Area – North	207	293	293	293
Eastern Training Area – South	147	120	120	147
North Fort Hood	Swing Space	9	9	9
Live Fire and Impact Area	750	750	750	750
Total	**2,000**	**2,338**	**1,544**	**2,000**

Table 2-11. Comparison of Alternatives

Attribute	No Action	Alternative 2: Harvest Efficiency	Alternative 3: Combination Strategy	Alternative 4: Preferred Alternative
Stocking Rate (Total)	2,000 AUs	2,337 AU	1,543 AU	2,000 AU
Duration and Timing	Continuous, Year- round	Continuous, Year- round	Continuous, Year- round	Continuous, Year- round
Animal Performance*	Moderate	Lowest	Highest	Moderate
Meets Purpose and Need	Yes	Yes	Yes	Yes
Compliant with Installation Policy	Yes	Yes	No	Yes
Accounts for Forage Loss from Other Uses	Indirectly	Indirectly	Yes	Yes
Effect on Soil and Watershed	Maintains existing condition	Potential increase in erosion and decrease in overall watershed conditions	At a minimum, maintain existing conditions, but could see decreased erosion and improved watershed conditions	Maintains existing condition
Effects on Biological Resources	Maintains existing condition	Negligible increase	Negligible decrease	Maintains existing condition
Effects on Water Quality and Jurisdictional Wetlands	Maintains existing condition	Negligible increase	Negligible decrease	Maintains existing condition

* Individual animal performance is higher as the density of competing animals decreases because cattle can be highly selective in their forage diet.

3.0 AFFECTED ENVIRONMENT

3.1 INTRODUCTION

This section describes the existing environment that may be affected by the alternative actions considered in this EA. The potentially affected environment generally includes the land area within Fort Hood; however, many resources occurring outside of this geographic boundary could also be affected. For example, water quality could be affected in waterways downstream of Fort Hood. The existing conditions within the area of potential effects are described for each resource. Regional climatic conditions are discussed below; however, an assessment of how alternative actions would affect climate is limited to the assessment of impacts on air quality.

3.2 CLIMATE

Fort Hood lies along the edge of two subtropical climate zones (Nielsen-Gammon 2011). Subtropical climates experience cold winters and hot summers and typically experience the greatest rainfall during the summer months. The subtropical, maritime climate of Texas is predominantly influenced by onshore flow of tropical maritime air from the Gulf of Mexico. The onshore flow is influenced by a decrease in moisture content from east to west and by intermittent seasonal intrusion of continental air from the north. The two subtropical climate zones are classified based on this east-to-west moisture gradient. The climate of Fort Hood exhibits characteristics of both the subtropical sub-humid zone to the west and the subtropical humid zone to the east. Winters are typically cold and summers are typically hot. While precipitation generally occurs in the summer, it can be absent for long periods of time.

Table 3-1 describes the annual and monthly mean temperatures from 2014 through 2018. From January 2014 through December 2018, the three coldest months were January, February, and December with a mean monthly temperature of 46.9, 52.6, and 50.3 degrees Fahrenheit (°F), respectively. The three hottest months were June, July, and August with a mean monthly temperature of 82.0, 85.4, and 85.0 °F, respectively. The highest annual mean temperature was the year of 2017; the lowest mean temperature was 2014. The highest monthly mean was the month of July; the lowest monthly mean was January.

Table 3-1. Monthly and Annual Mean Temperature (°F) 2014-2018

Temperature (°F)													
Year	Jan	Feb	Mar	April	May	Jun	July	Aug	Sep	Oct	Nov	Dec	Annual Mean
2014	46.4	49.3	55.6	66.5	72.1	79.8	82	84.4	78.8	71.5	52.9	51.3	**65.88**
2015	44.9	47.8	57.1	68.1	72.6	80.2	84.9	85.7	80.8	71.6	58.3	52.4	**67.03**
2016	47.6	54.9	62.6	66.8	72.9	81.4	86.3	83.7	79.8	72.4	62.9	52	**68.61**
2017	52.4	60.4	63.9	68.2	73.7	81.4	86.3	83.4	79.1	67.4	62.8	47.4	**68.87**
2018	43.3	50.7	61.9	63.5	77.9	85	87.7	85.7	78.6	67.6	51.1	48.2	**66.77**
Monthly Annual Mean	**46.92**	**52.62**	**60.22**	**66.62**	**73.84**	**81.56**	**85.44**	**84.58**	**79.42**	**70.1**	**57.6**	**50.26**	**67.43***

***This is the Average of the annual Mean Temperatures (average annual temperatures over 5 years)**

Table 3-2 describes the annual and monthly rainfall from 2014 through 2018. The average annual rainfall from 2014 to 2018 was 43.1 inches at Killeen, Texas (Table 3-2) (NOAA NCEI, 2019). Rainfall during this 5 year period was greatest in May, August, and October with an annual monthly average of 6.5, 5.1, and 6.9 inches, respectively. Rainfall typically occurs during isolated, large thunderstorms; thus, amounts of rainfall are primarily singular events and tend to vary substantially among months and years. From 2014 to 2018, rainfall ranged from 0.07 to 18.33 inches in August and from 0.05 to 14.3 inches in October. The minimum monthly average rainfall was 0 inches in July of 2015 and the maximum monthly average rainfall was in August of 2016. The highest annual mean was in 2016, with the lowest annual mean being 2014, with values of 3.95 and 2.48 inches respectively.

Table 3-2. Monthly and Annual Mean Rainfall (in.) 2014-2018

Rainfall (Inches)													
Year	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	**Annual Mean**
2014	0.04	0.2	0.74	1.84	8.02	8.16	1.61	0.11	1.06	4.15	3.64	0.22	**2.48**
2015	3.72	0.95	3.49	3.08	9.2	4.57	0	0.07	1.1	13.3	5.78	2.12	**3.95**
2016	0.32	2.1	3.77	8.84	6.73	3.37	1.02	18.33	0.25	0.05	4.24	1.36	**4.20**
2017	3.5	3.8	4.28	6.76	4.3	3.05	2.24	4.4	3.05	2.9	1.1	1.88	**3.44**
2018	0.43	3.18	3.15	0.96	4.32	0.86	0.69	2.38	6.54	14.3	3.17	6.68	**3.89**
Monthly Mean	**1.6**	**2.0**	**3.1**	**4.3**	**6.5**	**4.0**	**1.1**	**5.1**	**2.4**	**6.9**	**3.6**	**2.5**	**3.59***

***This is the Average of the Annual Mean Rainfall (average rainfall over 5 years)**

3.3 LAND USE

3.3.1 Military Training and Support

Military training and support are the primary land uses on Fort Hood (Fort Hood 2009b). The Installation encompasses approximately 215,000 acres of land area, including nearly 200,000 acres used for military training and more than 15,000 acres used as the Installation's three cantonment areas. There are five main land areas, including North Fort Hood (NFH), the Eastern Training Area (ETAN), West Fort Hood (WFH), the Western Maneuver Area (WMA), and the centrally located Live Fire and Impact Area (LFIA) (see Figure 3-1).

The three cantonment areas are located centrally within NFH and WFH and south-centrally within the Installation. Cantonment areas are essentially urban and contain all facilities related to administrative, command, industrial, maintenance, warehousing, housing, logistical, billeting, and other Installation support land uses.

The Army's only Mission Command Training Center is located at Fort Hood and this facility allows training of brigade, division, and corps formations (Fort Hood 2009b). Coordinated exercises place command and control elements in the field while fire and maneuver actions are replicated using a combination of deployed tactical units and computer-supported war gaming or constructive and virtual reality battlefield simulations. Training lands on Fort Hood easily accommodate a full-scale, modern, digitally equipped heavy battalion task force exercising in multiple scenarios over several weeks at a time.

NFH is the primary site for reserve component training and mobilization and is capable of supporting 12,000 troops in permanent and tent facilities. Land use activities are similar to those of the Main Cantonment Area but are more limited, with most activity occurring during summer training. NFH also includes two auxiliary airfields. When NFH is not being used for training, fewer than 100 personnel reside there.

The Eastern Training Area is divided into a northern unit (ETAN) comprised of Land Groups 1 and 2 and a southern unit (ETAS) designated as Land Group 3. Belton Lake Reservoir divides the two units. ETAN is heavily vegetated and cross-compartmentalized, providing limited value as a mechanized maneuver area. ETAS provides more favorable terrain for mechanized units, but it is only 2.5 to 4 miles wide north to south and 9.5 miles long from east to west. Limited area dictates that ETAN and ETAS are best suited for unit assembly and logistical areas, artillery firing points, and company- and platoon-level mounted and dismounted training. In addition, these areas support engineer, combat support, and combat service support training, while providing locations for amphibious and river-crossing operations.

Land Group 1 is used year-round primarily for tracked vehicle maneuvering. It hosts tanks and Bradley fighting vehicles approximately 28 days per month and additional artillery vehicles approximately 14 days per month. Digging of trenches and fighting positions, construction of obstacles, and use of smoke and pyrotechnics also occur in this land group.

Land Group 2 is used year-round approximately 21 days per month, primarily for wheeled and dismounted military police training. It includes endangered species habitat and has restrictive terrain and vegetation, so training is normally conducted on roads and trails. Only minor digging is conducted in this land group.

Land Group 3 is used year-round for some tracked-vehicle maneuver and dismounted training. Tracked-vehicle training is normally restricted to about 15 vehicles. This land group has most of the Installation’s artillery firing points. Artillery units fire cannon and Multiple Launch Rocket System rockets from this land group weekly, which accounts for additional tracked-vehicle traffic. Some excavation and use of smoke occurs in this area.

West Fort Hood is not used for maneuver training because of its small size and its isolation from the main cantonment area by U.S. Highway 190. This training area includes many restricted areas, including Robert Gray Army Airfield and the Ammunition Supply Point. Designated as Land Group 7, West Fort Hood is used primarily for small mechanized unit and dismounted infantry training and for logistical sites.

The Western Maneuver Area is comprised of Land Groups 4, 5, and 6, and provides training opportunities for large armored and mechanized infantry forces. The training area averages 4 to 6 miles wide from east to west and 19 miles long from north to south. The area features a wide variety of terrain and vegetation characteristics that greatly enhance cross-country, combined arms maneuver. Due to its large, contiguous size, this is the only maneuver area on Fort Hood capable of supporting brigade-level operations.

Land Groups 4, 5, and 6 are heavy, tracked-vehicle maneuver areas. Training with up to 3,000 vehicles is conducted year-round approximately 21 days per month. Digging of vehicle fighting positions, construction of obstacles, and use of smoke and pyrotechnics also occur in these land groups (USACE 2003).

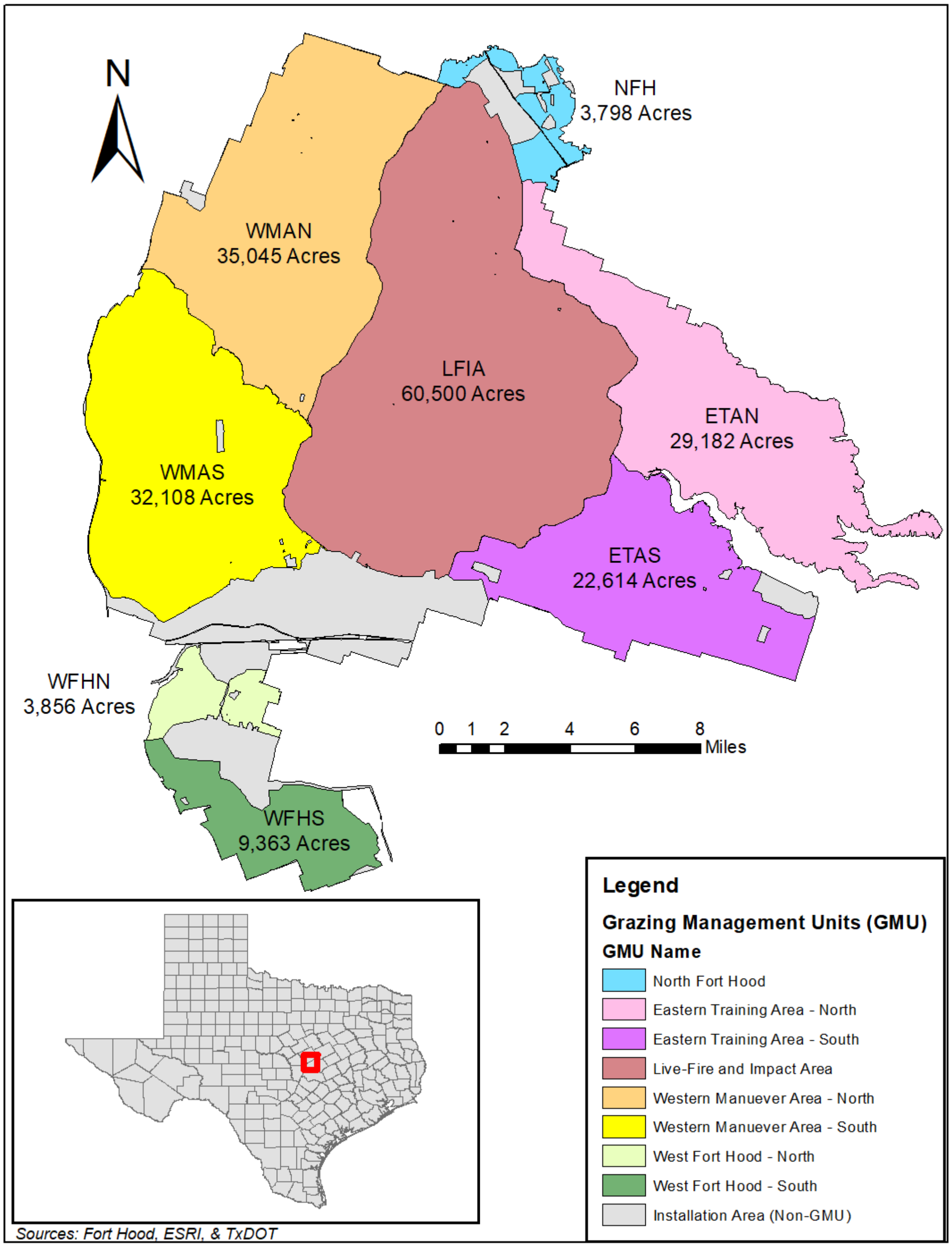


Figure 3-1. Map of Fort Hood Grazing Management Units (GMUs)

The LFIA, in the central portion of the Installation, hosts maneuver training. Individual, crew-served, and major weapons systems up to battalion strength are fired into the area. The area contains more than 80 firing range complexes, all oriented to direct firing at the large impact area in the center of the LFIA. Traffic in the live-fire and impact area consists of vehicles moving to and from the ranges.

3.3.2 Grazing

Fort Hood training lands have been divided into eight GMUs based on geographic configuration, potential barriers to cattle movement between areas, and training uses (see Figure 3-1). The Eastern Training Area, West Fort Hood, and the Western Maneuver Area (WMA) are each divided into north and south GMUs including ETAN, ETAS, Western Maneuver Area North (WMAN), Western Maneuver Area South (WMAS), West Fort Hood North (WFHN), and (WFHS), respectively, while NFH and the LFIA are each managed as whole GMUs. Due to the lack of fencing or other barriers within GMUs, stocking rates are managed on a GMU basis.

3.3.3 Natural Resources Management

Fort Hood's INRMP (Fort Hood, 2019) integrates training land requirements for the military mission and the requirements for maintaining the ecological health of the training areas. Fort Hood's primary purpose is the military mission, and the Installation must provide a quality training facility to serve that purpose. This goal is achieved through implementation of the INRMP and various other plans and programs that support the military mission. Through consultation with the USFWS, the USACE prepared an Endangered Species Management Plan (ESMP) for Fort Hood (Fort Hood, 2019). Fort Hood's ESMP identifies conservation measures to avoid adverse effects of ongoing military activities and other actions, including grazing, occurring on Fort Hood. These measures include limiting the Installation-wide rate of brown-headed cowbird parasitism on Federally listed species to less than or equal to 10 percent, as described in the USFWS's (USFWS, 2015) Biological Opinion of Fort Hood's ESMP. Management actions and other measures implemented under the INRMP and ESMP are discussed specifically in this EA in Section 5.0 as they pertain to the cumulative effects of past, present, and proposed actions in the affected area. However, military training and other land management practices interact with grazing and influence the productivity, composition, and sustainability of the landscape. Thus, each alternative is assessed within the context of these ongoing efforts to minimize the adverse effects of training while managing the landscape for multiple uses, including grazing, maintenance of floral and faunal diversity, and the military mission.

3.4 PHYSIOGRAPHY AND SOILS

3.4.1 Physiography

Physiographic regions are broad-scale subdivisions based on terrain texture, rock type, and geologic structure and history. Based on the USGS's three-tiered classification of the physiographic regions of the U.S. (Fenneman and Johnson 1946), Fort Hood is situated west of the Atlantic Plain division along the southeastern margin of the Interior Plain division. The Atlantic Plain extends inland from the broad continental shelf along the Atlantic and Gulf of Mexico coastlines. The Atlantic Plain is characterized by a series of terraces sloping gently seaward consisting of unconsolidated layers of sand and clay. The Interior Plain spreads across the stable core (i.e., craton) of the North American continent between the Rocky Mountains and the Appalachian Mountains. The craton was formed by the fusion of several smaller continents over 500 million years ago, and tectonic activity on the craton has been limited to areas of uplift along the margins. The Interior Plain was inundated by shallow seas twice during its geologic history, and the relative flatness of the area is a reflection of the deposition and compaction of marine sediments during these periods. The accumulation of marine deposits and subsequent erosion has resulted in layered deposits of limestone, sandstone, and shale, with the residuum of these materials overlying metamorphic and igneous rocks of the craton.

Fort Hood lies within the Great Plains province and Edwards Plateau section of the Interior Plains division (Fenneman and Johnson 1946). The southern and eastern boundary of the Edwards Plateau is defined by the Balcones Escarpment, which is an area of normal faults that rises abruptly from the Gulf Coast Plains forming a plateau to the west. Erosion of the escarpment by eastward-flowing streams has created areas of high relief along the southeast margin of the plateau commonly referred to as “Texas Hill Country”. The bedrock of the Edwards Plateau consists primarily of limestone. Subsequent to periods of uplift, stream erosion has resulted in steep-sided hills, outcrops, and mesas of the underlying bedrock surrounded by broad and relatively flat depositional areas (Figure 3-1).

3.4.2 Soils

There are approximately 40 unique soil series on Fort Hood (NRCS 2009a, 2009b). In general, these soils are well-drained and moderately permeable, but they can vary widely in other characteristics such as depth, parent material, and slope. Approximately 45 percent of the land area on Fort Hood is comprised of shallow or very shallow (i.e., less than 20 inches) soils developed over limestone bedrock. The most common of these shallow soils are the Doss-Real complex, Eckrant-Rock outcrop complex, and Real-Rock outcrop complex (Figure 3-3). Most of these shallow soils are situated on ridge tops, hilltops, and backslopes. Shallow soils that do not include rock outcrops are the only soils on Fort Hood classified as highly erodible. These highly erodible soils occur on the backslopes of hilltops, ridges, and outcrops or on the footslopes just above deep floodplain soils (Figure 3-4).

Approximately 40 percent of the land area on Fort Hood is comprised of moderately deep (i.e: 20 to 40 inches) soils developed over limestone bedrock. The most common of these moderately deep soils is Topsey clay loam, which comprises nearly 20 percent of the Fort Hood land area and is situated on backslopes and footslopes. Other moderately deep soils include Nuff very stony silty clay loam, which is also situated on backslopes, and Evant silty clay, which is situated on summits of broad ridges. Soils in this group are generally well-drained and potentially highly erodible. Soils that are deep to very deep (i.e., over 40 inches) occur over approximately 15 percent of the land area on Fort Hood. These deep soils occur on three major landforms: uplands, terrace deposits, and floodplain sediments. Deep soils formed in uplands include the Slidell silty clay and Cisco fine sandy loam. Deep soils developed in stream terraces include Krum silty clay and Lewisville silty clay. Deep soils developed in loamy and clayey alluvium on floodplains of major streams include the Bosque and Frio soil series. These deep soils are generally not highly erodible, are well-drained, and have moderate to slow permeability.

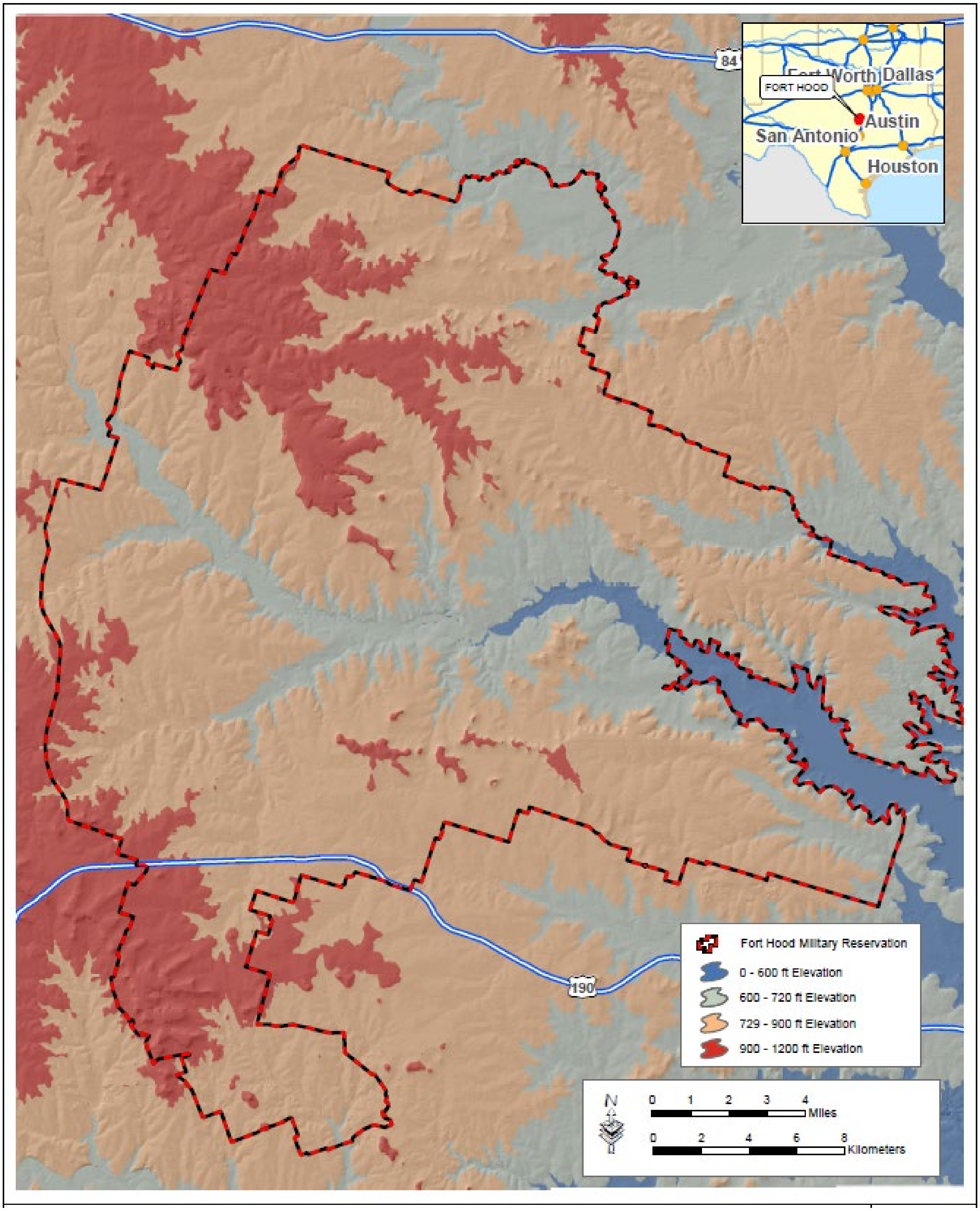


Figure 3-2. Fort Hood Topography

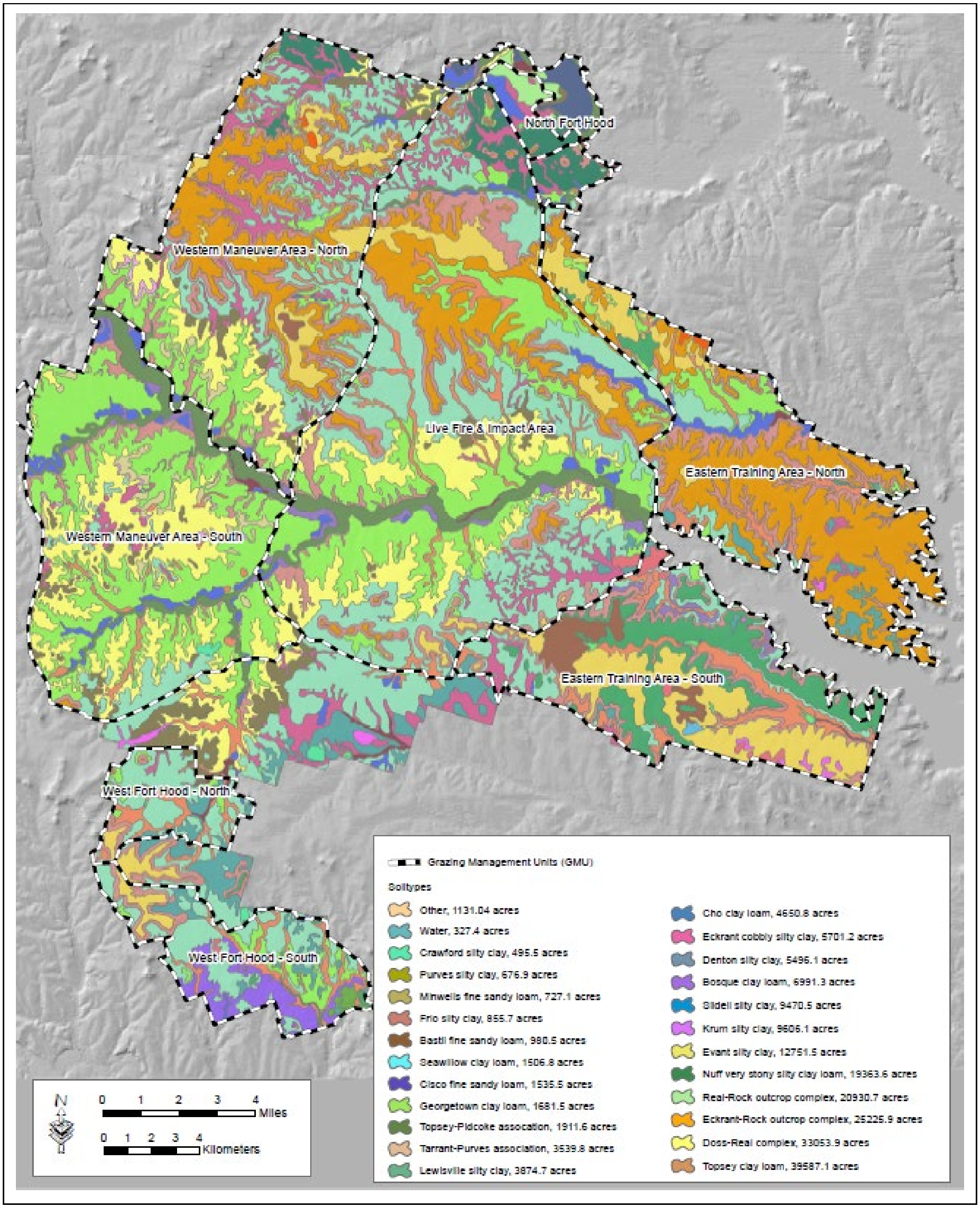


Figure 3-3. Fort Hood Soil Map Units

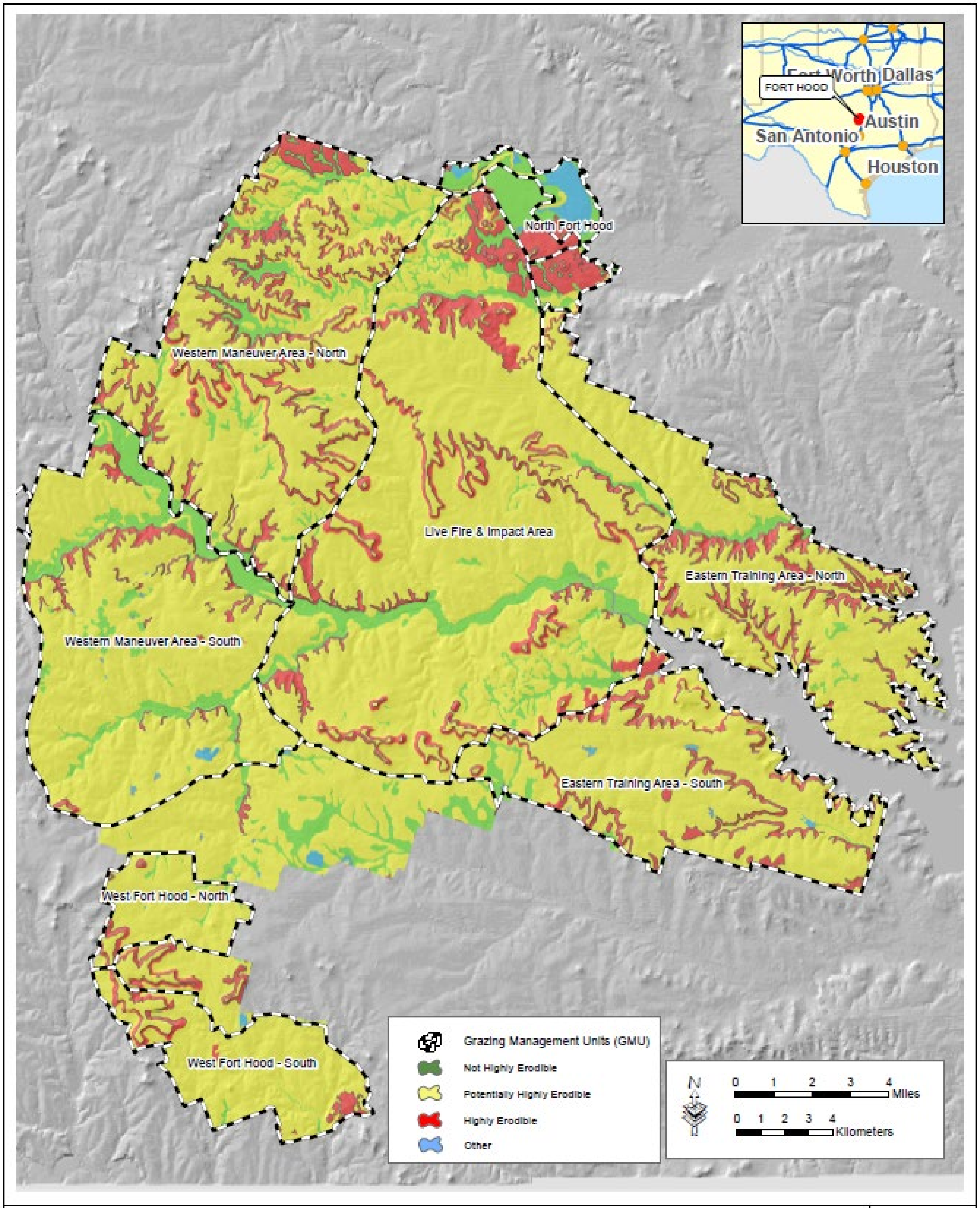


Figure 3-4. Soil Erodibility Map

Although not regulated on military Installations, Prime Farmland, as defined by the U.S. Department of Agriculture (USDA) (Federal Register [FR], Vol. 6, Parts 400-699, January 1, 2001, Section 657.5(a)), is land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber, and oilseed crops and is available for these uses. It could be cultivated land, pastureland, forest, or other land, but it is not urban or built-up land or water areas. The NRCS maintains and monitors a list of Prime and Unique Farmland soils, which produce high value or unique crops, and each state office of the NRCS maintains a list of soils which support Farmlands of Statewide Importance. Approximately 39,000 acres of soils classified as Prime Farmland Soils occur on Fort Hood and include the following soil series: Bastsil fine sandy loam, Bosque clay loam, Crawford silty clay, Frio silty clay, Krum silty clay, Lewisville silty clay, Minwells fine sandy loam, San Saba clay, and Slidel silty clay (NRCS 2009a, 2009b). All of these soils are deep or moderately deep and occur primarily on terraces and floodplains (see Figure 3-3).

3.5 WATER QUALITY AND WETLANDS

3.5.1 Surface Water

As defined by the U.S. Geologic Survey (USGS) (Seaber et al. 1994), Fort Hood lies within three major watersheds trending from northwest to southeast: Leon (#12070201), Cowhouse (#12070202), and Lampasas (#12070203) (Figure 3-5). Cowhouse Creek and the Lampasas River are both tributaries of the Leon River. The Leon River begins approximately 60 miles northwest of Fort Hood and roughly parallels the Installation's northern boundary. Tributaries of the Leon River, including Shoal and Henson creeks, drain northern portions of NFH, the Western Maneuver Area, the LFIA, and the Eastern Training Area. Owl Creek drains northern portions of the LFIA and the Eastern Training Area and merges with the Leon River to form the northern arm of Belton Lake. Nolan Creek, which drains the southern portion of the Eastern Training Area and the main cantonment area, is also part of the Leon River Watershed and merges with this river downstream of Belton Lake. The western arm of Belton Lake is formed by Cowhouse Creek. The Cowhouse Creek watershed includes several tributaries within Fort Hood and drains most of the Western Maneuver Area and LFIA and the northern portion of West Fort Hood. Most of West Fort Hood is within the Lampasas River watershed and this land area is drained by Reese Creek and its tributaries.

The Federal Water Pollution Control Act of 1977 (33 U.S. Code [USC] 1251, as amended), commonly known as the Clean Water Act (CWA), is a comprehensive statute aimed at restoring and maintaining the chemical, physical, and biological integrity of the Nation's waters, including surface water and groundwater. The U.S. Environmental Protection Agency (USEPA) administers the CWA in cooperation with other Federal agencies, states, municipalities, and industries. The Texas Commission on Environmental Quality (TCEQ) is responsible for developing state water quality programs and standards, and maintaining a list of impaired waters. For impaired waters, TCEQ is required to develop a pollutant load reduction plan to correct any cause of impairment. These plans, known as Total Maximum Daily Loads (TMDLs), document the nature of the impairment, determine the maximum amount of a pollutant which can be discharged and still meet standards, and identify allowable loads from the contributing sources.

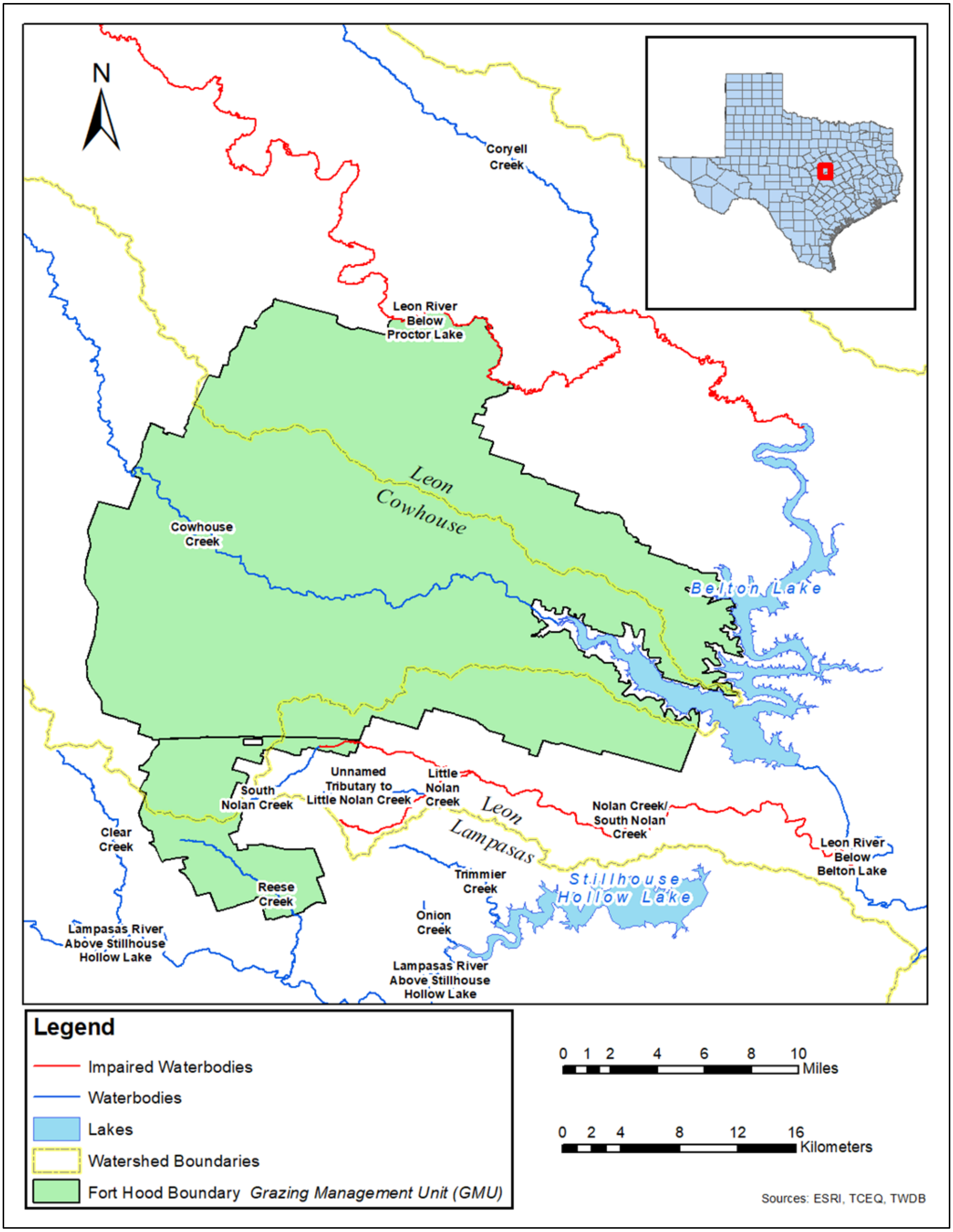


Figure 3-5: Fort Hood Surface Waters

Sections of Nolan Creek, Little Nolan Creek, and the Leon River were determined to be impaired for recreational use by bacterial contamination possibly contributed to by municipal point sources, storm water discharge, agricultural non-point sources, runoff from agriculture, and other non-point sources (TCEQ 2016). Refer to Table 3-3 for more information on these impaired waters that are within or in the watershed proximity of Fort Hood.

At this time, there are no TMDL's in place for any of the impaired waters listed in Table 3-3. All impaired waters that are listed need further review before a TMDL is scheduled or determined.

Table 3-3. Impaired Waters Downstream of or within Fort Hood

Waterbody	Segment	Cause of Impairment	Impaired Use	Potential Sources	Year Listed and Category*
Nolan Creek/South Nolan Creek	1218:Confluence with the Leon River in Bell County to a point 100m upstream to the most upstream crossing of US 190 and Loop 172 in Bell County	*Escherichia coli*	Contact Recreation	PS - Municipal Point Source Discharges; PS - Wet Weather Discharges (Point Source and Combination of Stormwater, SSO or CSO)	2016 5c/5b
Litte Nolan Creek	1218C: Confluence w/ Nolan Creek/South Nolan Creek upstream to headwaters in the city of Killeen, Bell County	*Escherichia coli*	Contact Recreation	UNK - Source Unknown	2016 5b
Leon River Below Proctor Lake	1221: From confluence w/ South Leon Creek upstream to confluence w/ Walnut Creek	*Escherichia coli*	Contact Recreation	NPS - Agriculture; NPS - Non-Point Source; NPS - Permitted Runoff from Confined Animal Feeding Operations (CAFOs); PS - Municipal Point Source Discharges	2016 5c

***Category 5a - A TMDL is underway, scheduled, or will be scheduled. Category 5b - A review of the water quality standards for this water body will be conducted before a TMDL is scheduled. Category 5c - Additional data and information will be collected before a TMDL is scheduled**
****NPS listed by itself in this case generally refers to municipal runoff.**

The U.S. Army Corps of Engineers (USACE) is responsible for administering Section 404 of the CWA. Section 404 regulates the discharge and fill of material into waters of the U.S. (WOTUS). WOTUS are defined in 33 CFR 328.3(a) and include navigable waters and all of their associated tributaries as well as adjacent wetlands. Waters of the U.S., including wetlands, exist across the installation. These resources range from small emergent wetlands associated with ephemeral streams to large, forested wetland complexes adjacent to perennial channels.

3.5.2 Groundwater

The Trinity Aquifer, which extends through parts of 55 counties of north and central Texas, is the only major aquifer beneath Fort Hood (Ashworth and Hopkins 1995). The three major rock formations comprising the Trinity Aquifer, from youngest to oldest, are Paluxy, Glen Rose, and Twin Mountains. The Paluxy formation is a shallow, water-bearing formation consisting of up to 400 feet of predominantly fine- to coarse-grained sand interbedded with clay and shale. The Paluxy formation outcrops on Fort Hood on the rolling lowlands above major creeks. Beneath the Paluxy formation, the Glen Rose formation forms a gulfward-thickening wedge of impermeable marine carbonates consisting primarily of limestone. The Glen Rose formation is exposed within Fort Hood along the bottom of major creeks. The basal unit of the Trinity Group beneath Fort Hood is the Twin Mountains formation, which consists mainly of medium- to coarse-grained sands, silty clays, and conglomerates. The Twin Mountain formation is not exposed on Fort Hood. No major groundwater resources outside the Installation are affected by recharge from within Fort Hood. Recharge that occurs within the Installation affects only the small, shallow groundwater supplies that are confined within the Installation.

3.5.3 Wetlands

Two soil associations occurring on Fort Hood contain soil types that are included on the state and Federal hydric soils lists: Bosque clay loam and Frio silty clays (NRCS 2010). These associations occur over approximately 7,900 acres or 3.7 percent of the Installation; however, hydric components generally comprise 1 to 3 percent of the soil association. Bosque and Frio soils are generally located along the stream banks of the Leon River, Cowhouse Creek, Nolan Creek, and their larger tributaries. Other soils can become hydric, exhibiting anaerobic conditions, as a result of periodic or permanent saturation or inundation.

Wetlands in Central Texas and at Fort Hood are most common on floodplains along rivers and streams (e.g., riparian wetlands), along the margins of lakes and ponds, and in other low-lying areas where the groundwater intercepts the soil (i.e., springs). There are numerous natural springs and seeps occurring on Fort Hood, but most of their locations have not been mapped. Wetland features have been delineated in portions of Fort Hood to determine jurisdictional status under Section 404 of the CWA (33 U.S. Code [U.S.C] 1251, as amended. The delineations have occurred in conjunction with or where construction projects were anticipated. Table 3-4 details the Wetland Type and acreage of the wetlands depicted in Figure 3-6. Figure 3-6 shows the various scattered pockets of wetlands that occur in Fort Hood, as well as the different types of existing streams using Fort Hood delineation data.

Table 3-4. Wetland Acreage within Fort Hood by Watershed

Wetland Type	Acreage
Borrow Pit	9.5
Open Water	507.6
Stock Pond	1.0
Wetland	645.6
Total	1163.7

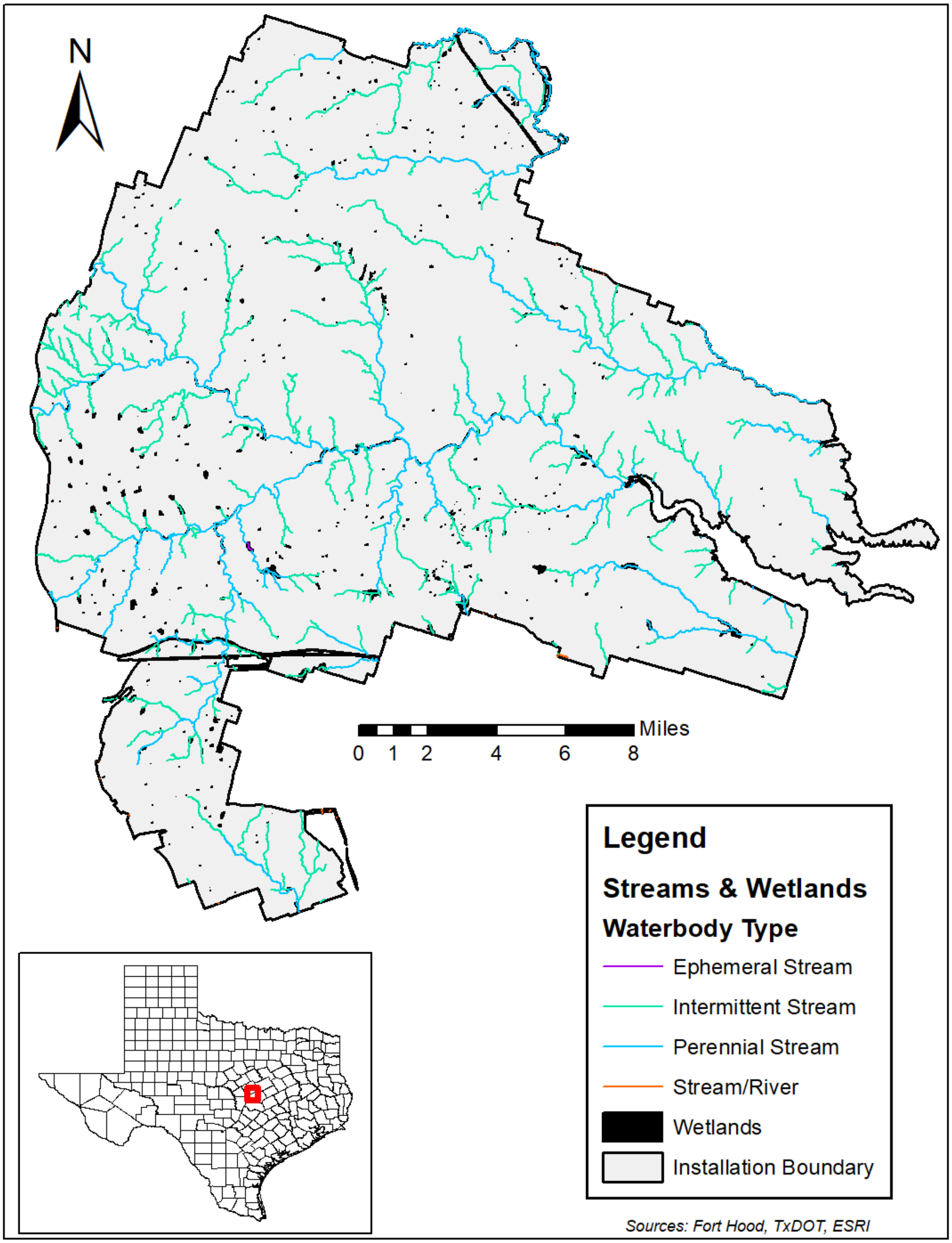


Figure 3-6 Wetland & Streams in Fort Hood

3.6 AIR QUALITY

The Clean Air Act of 1963 (16 USC 470, as amended) provides protection and enhancement of the Nation's air resources. The Federal Conformity Final Rule (40 Code of Federal Register [CFR] Parts 51 and 93) specifies criteria or requirements for conformity determinations for Federal projects, and the USEPA established National Ambient Air Quality Standards (NAAQS) for specific pollutants determined to be of concern with respect to the health and welfare of the general public (USEPA 2015). The rule mandates that a conformity analysis must be performed when a Federal action generates air pollutants in a region that has been designated a non-attainment or maintenance area for one or more NAAQS.

NAAQS are classified as either "primary" or "secondary", and represent the maximum levels of background pollution that are considered safe, with an adequate margin of safety, to protect the public health and welfare. The major pollutants of concern, or criteria pollutants, are carbon monoxide (CO), sulfur dioxide (SO2), nitrogen dioxide (NO2), ozone (O3), particulate matter less than 10 microns (PM-10), particulate matter less than 2.5 microns (PM-2.5) and lead (Pb) (Table 3-5). Areas that do not meet these NAAQS standards are called non-attainment areas; areas that meet both primary and secondary standards are known as attainment areas. Both TCEQ and USEPA consider Bell and Coryell counties as in attainment for all NAAQS (USEPA 2019).

Table 3-5. National Ambient Air Quality Standards (2015)

Pollutant	Primary/ Secondary Standards	Averaging Time	EPA Design Value	Monitored Value	Form
Carbone Monoxide (CO)	Primary	8 Hours	9 ppm	ND*	Not to be exceeded more than once per year
		1 hour	35 ppm	ND	
Lead (Pb)	Primary & Secondary	Rolling 3 month average	0.15 $\mu g/m^3$ [1]	ND	Not to be exceeded
Nitrogen Dioxide (NO_2)	Primary	1 Hour	100 ppb	48 ppb (Travis County)	98th percentile of 1-hour daily maximum concentrations, averaged over 3 years
	Primary & Secondary	1 Year	53 ppb [2]	13 ppb (Travis County)	Annual Mean

Pollutant		Primary/ Secondary Standards	Averaging Time	EPA Design Value	Monitored Value	Form
Ozone		Primary & Secondary	8 hours	0.070 ppm(3)	0.069 (Bell County)	Annual fourth-highest daily maximum 8-hour concentration, averaged over 3 years
Particle Pollution (PM)	$PM_{2.5}$	Primary	1 year	12.0 $\mu g/m^3$	9.6 $\mu g/m^3$ (Travis County)	Annual Mean, averaged over 3 years
		Secondary	24 hours	35 $\mu g/m^3$	20 $\mu g/m^3$ (Travis County)	Annual Mean, averaged over 3 years
	PM_{10}	Primary & Secondary	24 hours	150 $\mu g/m^3$	0 exceedances	Not to be exceeded more than once per year on average over 3 years
Sulfur Dioxide (SO_2)		Primary	1 hour	75 ppb (4)	4 ppb	99^{th} percentile of 1-hour daily maximum concentrations, averaged over 3 years

Units of measure for the standards are parts per million (ppm) by volume, parts per billion (ppb - 1 part in 1,000,000,000) by volume, milligrams per cubic meter of air (mg/m3), and micrograms per cubic meter of air (µg/m3)

* ND = No Data is available for any counties within 50 miles of Bell or Coryell Counties

(1) In areas designated nonattainment for the Pb standards prior to the promulgation of the current (2008) standards, and for which implementation plans to attain or maintain the current (2008) standards have not been submitted and approved, the previous standards (1.5 µg/m3 as a calendar quarter average) also remain in effect.

(2) The level of the annual NO2 standard is 0.053 ppm. It is shown here in terms of ppb for the purposes of clearer comparison to the 1-hour standard level.

(3) Final rule signed October 1, 2015, and effective December 28, 2015. The previous (2008) O3 standards additionally remain in effect in some areas. Revocation of the previous (2008) O3 standards and transitioning to the current (2015) standards will be addressed in the implementation rule for the current standards.

(4) The previous SO2 standards (0.14 ppm 24-hour and 0.03 ppm annual) will additionally remain in effect in certain areas: (1) any area for which it is not yet 1 year since the effective date of designation under the current (2010) standards, and (2)any area for which an implementation plan providing for attainment of the current (2010) standard has not been submitted and approved and which is designated nonattainment under the previous SO2 standards or is not meeting the requirements of a SIP call under the previous SO2 standards (40 CFR 50.4(3)). A SIP call is an EPA action requiring a state to resubmit all or part of its State Implementation Plan to demonstrate attainment of the required NAAQS.

3.7 BIOLOGICAL RESOURCES

3.7.1 Flora

The three physiographic regions associated with Fort Hood's geology and climate are the Edwards Plateau, the Great Plains, and the Balcones Escarpment as discussed in Section 3.4. Several authors have delineated regions of Texas giving varying importance to geology, climate, flora, and fauna. Although the boundaries of these regions vary somewhat depending upon the specific delineation criteria, the three physiographic regions are more or less associated with three ecological regions: Edwards Plateau, Cross Timbers and Prairies, and Blackland Prairie, respectively (Texas Parks and Wildlife Department [TPWD] 2009a). The classification system used here is based on a physiognomic classification conducted by NRCS in 2008. A physiognomic classification distinguishes between vegetation communities based on the general appearance of both the landscape and plant growth forms (e.g., Deciduous Woodland). The species composition and, to some extent, the physiognomic classification of Fort Hood's vegetation communities is the result of regional geology and climate, as well as more local patterns of topography and soil. However, the predominant factor influencing the distribution and composition of vegetation communities on Fort Hood is the history of disturbance related to fire, grazing, and military training.

Fort Hood is situated in the northeastern reaches of the Edwards Plateau, the southernmost extension of the Cross Timbers and Prairies, and just west of the Blackland Prairie ecological regions. Woody and shrub-dominant communities which typify much of the land area on Fort Hood are most closely representative of Edwards Plateau vegetative associations. The grasslands are representative primarily of the mid-grass associations of the Cross Timbers and Prairies areas, with inclusions of species more commonly associated with tall-grass associations of the Blackland Prairie. Historically, frequent natural and man-made fires confined woody vegetation to riparian areas and rocky slopes and hills. As a result of human activities including grazing, reduction and suppression of fires, and training activities, the current vegetation structure and mix of species differ from those historically associated with the region (Fort Hood 2009b).

Three distinct vegetation communities dominated by woody vegetation occur on Fort Hood: Coniferous Forest and Shrub, Deciduous Forest and Shrub, and Mixed Forest and Shrub communities. These communities are found on the rocky slopes and hillsides or mesas and along streams and rivers (Figure 3-7). Small pockets of Coniferous Forest and Shrub are found throughout the Installation and are primarily composed of Ashe juniper (*Juniperus ashei*). Other species found in this community include flameleaf sumac (*Rhus lanceolata*), Texas ash (*Fraxinus texensis*), plateau live oak (*Quercus fusiformis*), a variety of grasses, and broomweeds (*Amphiachyris spp.*).

Deciduous Forest and Shrub was historically more abundant throughout the Installation. This community is composed of broad-leaf trees and shrubs and is found in lowlands and on protected slopes. Tree species representative of this community include plateau live oak, post oak (*Quercus stellata*), pecan (*Carya illinoiensis*), and sycamore (*Platanus occidentalis*). Understory species include Alabama supplejack (*Berchemia scandens*), Texas persimmon (*Diospyrus texana*), saw greenbriar (*Smilax bona-nox*), hairy grama (*Bouteloua hirsuta*), Texas grama (*B. rigidiseta*), prairie-tea (*Croton monanthogynus*), broomweed, silver bluestem (*Bothriochloa saccharoides*), prairie three-awn (*Aristida oligantha*), and mist-flower (*Eupatorium coelestinum*).

The most common vegetation community on the Installation is the Mixed Forest and Shrub Community. In some areas Ashe juniper dominates over either plateau live oak or Texas red oak (*Quercus texana*), and in others the oaks dominate the Ashe juniper. Understory species are a mixture of the previously mentioned communities.

Grasslands are found throughout the Installation, but are most common on rolling uplands between the floodplains and hills or mesas in the LFIA and Western Maneuver Area. Wildfires caused by various training activities, controlled burns, and other forms of brush removal increase the area of grasslands and limit the establishment and expansion of woody vegetation.

Several vegetation resource inventories have been conducted to assess the effects of a variety of actions occurring on Fort Hood on grasslands, including military training and grazing. Conditions observed during the 2019 biomass survey (Appendix A were similar to previous surveys; however, areas with extremely low forage biomass (i.e., less than 500 pounds per acre) were less frequent than in previous surveys. In the Western Maneuver Area and Eastern Training Area, sites that had moderate to high residual biomass (i.e., 1,000 to 3,000 pounds per acre) were generally dominated by King Ranch bluestem (*Bothriochloa ischaemum*), a non-native perennial grass that has high productivity but has only fair grazing value. King Ranch bluestem is considered to have fair grazing value due to lesser volume production, lower palatability, and lower quality when compared to plants with good value, such as little bluestem. In NFH, little bluestem and wooly croton *(Croton capitatus*) dominated. In the West Fort Hood management units, sites were typically dominated by little bluestem.

3.7.2 Fauna

Terrestrial wildlife habitats are closely associated with the vegetation communities described above, but are also influenced by moisture and elevation clines from upland to riparian habitats (USACE 1999, Fort Hood 2009b). Wooded habitats in riparian areas contain the greatest densities of passerine birds, followed by juniper woodland and mixed woodland. The least dense bird populations are found in the grassland habitat. The most widespread and abundant passerine species located on the area is the cardinal (*Cardinalis cardinalis*), which thrives in disturbed areas. Other common species are the mourning dove (*Zenaida macroura*), Carolina chickadee (*Parus carolinensis*), mockingbird (*Mimus polyglottos*), and turkey vulture (*Cathartes aura*).

Common mammal species in the area are the raccoon (*Procyon lotor*), white-tailed deer (*Odocoileus virginianus*), and black-tailed jackrabbit (*Lepus californicus*). Common small mammals include the deer mouse (*Peromyscus maniculatus*), hispid cotton rat (*Sigmodon hispidus*), and eastern wood rat (*Neotoma floridana*).

Reptiles and amphibians at Fort Hood are representative of the eastern, western, and southern U.S. communities. Eastern species present on the Installation include Blanchard's cricket frog (*Acris crepitans blanchardi*), gray treefrog (*Hyla versicolor*), and bullfrog (*Rana catesbeiana*). Western species include the Texas greater earless lizard (*Cophosaurus texanus*), collared lizard (*Crotaphytus collaris*), western diamondback rattlesnake (*Crotalus atrox*), and the western narrow-mouthed toad (*Gastrophryne olivacea*). Southern species include the Texas spiny lizard (*Sceloporus olivaceus*), short-lined skink (*Eumeces tetragrammus brevilineatus*), Rio Grande leopard frog (*Rana berlandieri*), and Texas patchnose snake (*Salvadora grahamiae lineata*).

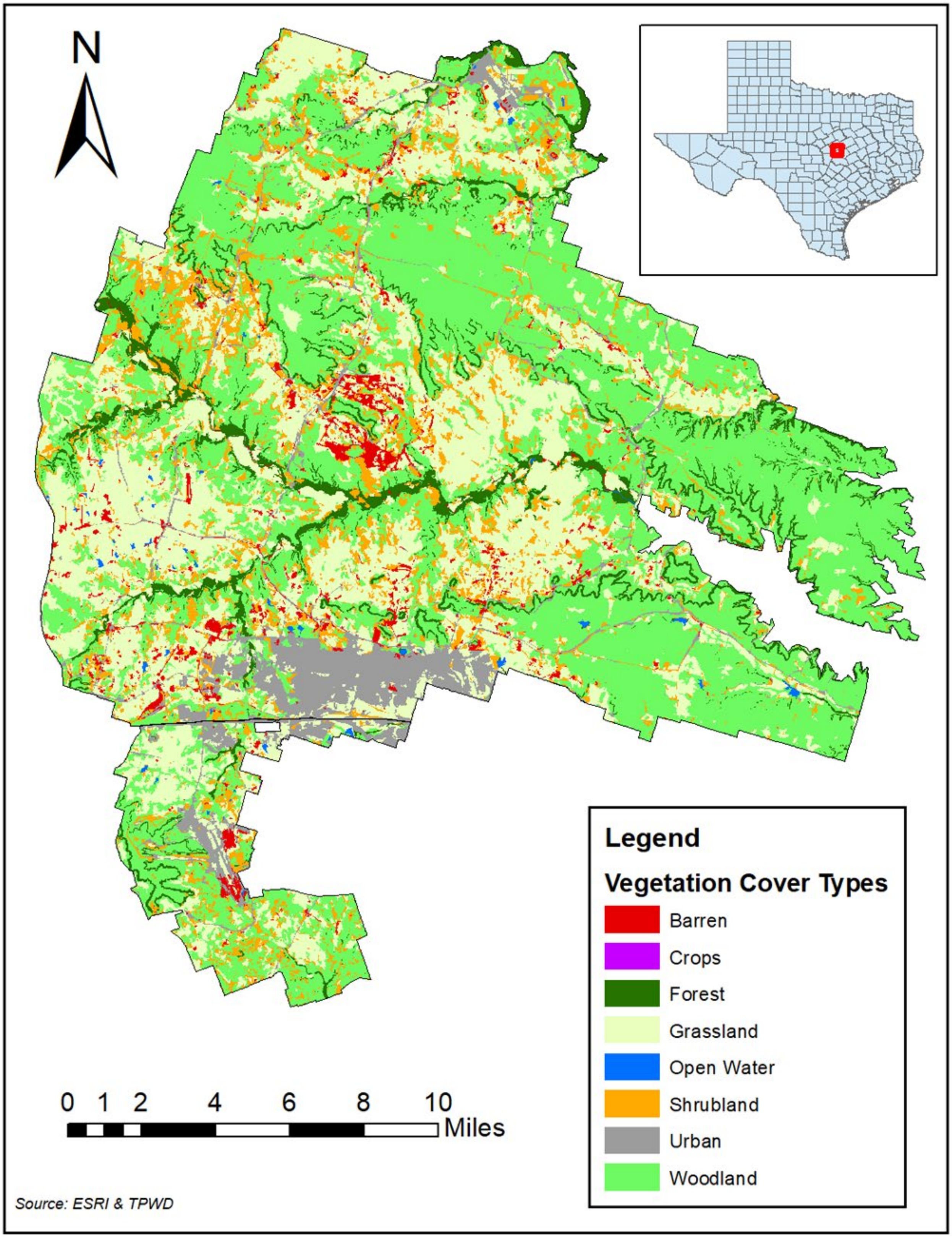


Figure 3-7. Vegetation Land Cover within Fort Hood

Thirty-two species of fish have been documented from the lakes, ponds, and streams on the Installation. The common species are red shiner (*Cyprinella lutrensis*), blacktailed shiner (*Notropis venustus*), and bullhead minnow (*Pimephales vigilax*), with remaining species being members of the minnow (*Cyprinidae*), sunfish (*Centrarchidae*), and Perch/Darter (*Percidae*) families.

3.8 SPECIAL STATUS SPECIES

3.8.1 Listed Species

Special status species include those species for which some protection is afforded under state or Federal regulations or which is not formally protected but monitored due to rarity or sensitivity to anthropogenic activities. The Endangered Species Act (ESA) of 1973 requires that a discretionary Federal action not put into jeopardy the continued existence of a listed species or cause the destruction or adverse modification of their critical habitat. The USFWS maintains and monitors a list of non-marine species considered to be threatened with extinction or in danger of becoming extinct. The USFWS (2011a) and TPWD (2010a, 2010b) each maintain a database of special status species and the counties in which they could potentially occur. The status, preferred habitats, and potential for each of these species to be within the range of potential effects resulting from grazing activities on Fort Hood are presented in Table 3-6.

Species listed as threatened or endangered by the USFWS are protected from harm or harassment by the Endangered Species Act (16 U.S.C. 1531). Migratory birds are afforded special status under the Migratory Bird Treaty Act (MBTA). The Bald and Golden Eagle Protection Act affords additional protection to Bald Eagles (*Haliaeetus leucocephalus*). Potentially affected special status species are described below. Species not afforded protection or official listing, but are important to include for other considerations, designated as Species of Concern, are described in Table 3-7.

3.8.2 Federally Listed Species

The Houston Toad (*Bufo houstonensis*) is known to require a specific forested habitat and has a limited range in Austin, Bastrop, Burleson, Colorado, Lee, Leon, Lavaca, Milam, and Robertson counties; there is no known habitat in Bell or Coryell counties and it is unlikely that this species would occur in the project area (TPWD, 2019a).

The Kretschmarr Cave Mold Beetle (*Texamaurops reddelli*) is a rare mold beetle that prefers to inhabit rotting wood, termite nests, spaces under rocks, in sinkholes, and in caves. It is only known to inhabit 4 caves in the neighboring Travis county (City of Austin, 2019). It is very unlikely this rare species would be present in Fort Hood.

The Smalleye Shiner is known to be restricted to the upper areas of the Brazos River system upstream of Possum Kingdom Reservoir (USFWS, 2016). Fort Hood is not part of the Brazos River system, so it is very unlikely that this species would occur in water bodies within the installation's boundaries.

The Salado Springs Salamander (*Eurycea chisholmensis*) is known to be heavily geographically restricted to a small amount of water bodies in the vicinity of Salado Springs; these water bodies do not occur within Fort Hood and the salamander is not known to exist within Fort Hood (USFWS, 2015 & Fort Hood, 2019). This species is very unlikely to occur within the project area.

Table 3-6. Federal and State Listed Species of Concern

Species	Status*	Preferred Habitat	Potential to be Present in the Action Area
INSECTS			
Kretschmarr Cave mold beetle *Texamaurops reddelli*	FE, SE	Small, cave-adapted beetle found under rocks buried in silt; small, Edwards Limestone caves in of the Jollyville Plateau, a division of the Edwards Plateau	Very Unlikely – Only known to occur in Travis County
MOLLUSKS			
Smooth pimpleback *Cyclonaias houstonensis*	FC, ST	Small to moderate rivers and moderate sized reservoirs over a variety of substrates	Unlikely – Only have occurred on the border of Fort Hood and the Leon River
Texas fawnsfoot *Truncilla macrodon*	FC, ST	Rivers and larger streams	Very Unlikely – Not known to occur within Fort Hood
FISHES			
Smalleye shiner *Notropis buccula*	FE	Medium to large prairie streams with sandy substrate and turbid to clear warm water in the upper Brazos River system	Very Unlikely – Not known to occur within Fort Hood
AMPHIBIANS			
Houston Toad *Bufo houstonensis*	LE, SE	Pine and oak woodlands and savanna with forbs and bunchgrasses present in open areas	Very Unlikely – Not Known to occur within Fort Hood
Salado Springs Salamander *Eurycea chisholmensis*	FT	Surface springs and subterranean waters of the Salado Springs system	Very Unlikely – Not Known to occur within Fort Hood
REPTILES			
Texas horned lizard *Phyrnosoma cornutum*	ST	Open, arid and semi-arid regions with sparse vegetation on friable soils	Likely – Low density, sparse populations have been known to occur within Fort Hood
Timber Ratlesnake *Crotalus horridus*	ST	Moist lowland forests and hilly woodlands or thickets near permanent water sources such as rivers, lakes, ponds, streams and swamps where tree stumps, logs and branches provide refuge	Very Unlikely – Not Known to occur within Fort Hood
BIRDS			
Bald Eagle *Haliaeetus leucocephalus*	ST	Found primarily near rivers and large lakes; nests in tall trees or on cliffs near water; communally roosts, especially in winter	Likely – Species Is commonly seen near the lake; is not known to nest on the installation.
Black-Capped Vireo *Vireo atricapilla*	SE	Found in hardwood scrub habitat that typically exhibits a patchy or clumped distribution with a scattering of live and dead trees	Very Likely – known to inhabit isolated territories in peripheral grassland or within warbler habitat

Species	Status*	Preferred Habitat	Potential to be Present in the Action Area
Golden-cheeked Warbler *Setophaga chrysoparia*	FE, SE	Ashe juniper in mixed stands with various oaks (*Quercus spp.*). Edges of cedar brakes. Dependent on Ashe juniper (also known as cedar) for long fine bark strips, only available from mature trees, used in nest construction	Very Likely – known to have large established populations
Interior Least Tern *Sterna antillarum athalassos*	FE, SE	Sand beaches, flats, bays, inlets, lagoons, islands. Nests along sand and gravel bars within braided streams, rivers; also know to nest on man-made structures.	Unlikely – Migratory visitor but does not nest on the installation.
Piping Plover *Calidris canutus rufa*	FT, ST	Beaches, sandflats, and dunes along Gulf Coast beaches and adjacent offshore islands. Also spoil islands in the Intracoastal Waterway. Algal flats appear to be the highest quality habitat.	Unlikely – Migratory visitor in spring and fall but does not nest on the installation.
White-Faced Ibis *Plegadis chihi*	ST	Prefers freshwater marshes, sloughs, and irrigated rice fields, but will attend brackish and saltwater habitats; currently confined to near-coastal rookeries.	Unlikely – Migratory visitor in spring and fall but does not nest on the installation.
Whooping Crane *Grus americana*	FE, SE	Small ponds, marshes, and flooded grain fields for both roosting and foraging. Potential migrant via plains throughout most of state to coast; winters in coastal marshes of Aransas, Calhoun, and Refugio counties.	Likely – Common migratory visitor
Wood Stork *Mycteria americana*	ST	Prefers to nest in large tracts of baldcypress (*Taxodium distichum*) or red mangrove (*Rhizophora mangle*); forages in prairie ponds, flooded pastures or fields, ditches, and other shallow standing water.	Unlikely – Few sightings ; migratory visitor in the fall
Zone-tailed Hawk *Buteo albonotatus*	ST	Arid open country, including open deciduous or pine-oak woodland, mesa or mountain county, often near watercourses, and wooded canyons and tree-lined rivers along middle-slopes of desert mountains.	Unknown – Possible Migratory visitor

The Interior Least Tern (*Sterna antillarum athalassos*), Piping Plover (*Charadrius melodus*), and Rufa Red Knot (*Calidris canutus rufa*), are not a concern for this project since it is not a wind-energy related project. The Interior Least Tern and Piping Plover are known to occur as a migratory visitor but do not nest on the installation.

Migratory black-capped vireos (*Vireo atricapilla*) historically nested along a grassland/forest ecotone from central Kansas to eastern Mexico during the summer months (USFWS 2007). Breeding has not been recently documented in the northern portions of the historic breeding range. Black-capped vireos nest in early-succession deciduous scrub communities that are typically generated as the result of various disturbances, including wildfire or mechanical removal of woody top growth. Preferred nesting habitat for black-capped vireos includes a wide diversity of hardwoods in patchy, low-growing configuration separated by open, grassy spaces. As high quality habitat ages, it will decrease in quality until it is no longer used; therefore, maintaining habitat for black-capped vireos requires active management. Throughout the range of the species, the black-capped vireo is threatened by cowbird parasitism and by habitat loss from browsing animals, fire suppression, and urban development. Wildfire suppression threatens the black-capped vireo because this species utilizes relatively young deciduous shrub communities that replace the older, single-species juniper stands after a wildfire. *V. atricapilla* is currently federally delisted, but is State Endangered; it is discussed here because it shares a large amount of habitat with the Golden-Cheeked Warbler.

Table 3-7. Species of Concern in Fort Hood

Scientific Name	Common Name	Federal Status	State Status	Status on Fort Hood*
Various species	Cave invertebrates	Not currently listed	--	A
Danaus plexippus	Monarch Butterfly	Under review	--	A
Spilogale putorius interrupta	Plains Spotted Skunk	Under review	--	A
Plethodon albagula	Slimy salamander	Not currently listed	--	A
Myotis velifer	Cave myotis	Not currently listed	--	A
Perimyotis subflavus	Tri-colored bat	Under review	--	A
Croton alabamensis var. *texensis*	Texabama croton	Not currently listed	--	A
Colinus virginianus	Northern Bobwhite	Not currently listed	--	A
Falco peregrinus anatum	American peregrine falcon	DL 1999	Threatened	B
Falco peregrinus	Peregrine falcon	Delisted 1999	Threatened	B
Fusconaia mitchelli	False spike	Under review	--	C
Canis rufus	Red wolf	Endangered	Endangered	C

* Status refers to population status on Fort Hood according to these definitions: (A) Population established on Fort Hood. Recent information documents an established breeding population (even if small) or regular occurrence on the installation. This includes those species for which research and management is ongoing and several endemic cave invertebrates. (B) Recently recorded on Fort Hood, but there is no evidence of an established population. This includes species considered to be transient, accidental, or migratory (e.g., some migrating birds may use the installation as a stopover site during migration to and from their wintering grounds). For some species in this category, further inventory may reveal breeding populations. (C) Not known to occur on Fort Hood.

** Note- This table is sourced from the 2019 Fort Hood Integrated Natural Resources Management Plan (originally Table 4-10) ; any species that had overlap with Table 3-5 were removed.

*** Please refer to the 2019 INRMP for more information regarding Species of Concern.

Golden-cheeked warblers (*Setophaga chrysoparia*) are migratory and breed exclusively in mixed Ashe juniper/deciduous woodlands of Central Texas (USFWS 2011c). Suitable nesting habitat is provided by tall, closed canopy, dense, mature stands of Ashe juniper mixed with deciduous trees and is typically found in relatively moist areas such as steep-sided canyons, slopes, and adjacent uplands or in drier areas of flat topography. The species is dependent upon Ashe juniper bark for nest material and forages on insects gleaned from a variety of tree species. Primary threats to the species throughout its range include habitat destruction by urban development, brush clearing, oak wilt, range wildfires, and nest parasitism from brown-headed cowbirds.

Suitable habitat for black-capped vireos and golden-cheeked warblers occurs throughout much of Fort Hood (Figure 3-8) (Fort Hood, 2019). In 2019, it was estimated that approximately 49,403 acres of suitable golden-cheeked warbler habitat occur on Fort Hood (Fort Hood, 2019). The Fort Hood ESMP designates approximately 8,900 acres of golden- cheeked warbler habitat in the Eastern Training Area as core habitat for the species (Hammer 2011). Activities in the core habitat area are restricted to minimize impacts on the species. In 2011, it was estimated that approximately 22,043 acres of suitable black-capped vireo habitat occurs on Fort Hood (Fort Hood, 2019). Surveys conducted from 1992 to 2005 indicated a steadily increasing trend in the number of golden-cheeked warblers nesting on Fort Hood, but did not indicate a trend in the number of black-capped vireos (Anders and Dearborn 2001).

Oak wilt has been observed on the Installation and its impacts are unknown, but studies are underway to assess the extent and the impacts of this disease. Wildfires on the Installation result from military training activities, primarily in the LFIA, during hot and dry periods when fuel is readily available in the form of dry brush and grass. Such fires have affected both golden-cheeked warbler habitat and that of the black-capped vireo over the past decade.

Brown-headed cowbirds are most abundant near grazing cattle where they feed on insects disturbed by the cattle; however, cowbirds are known to travel up to 5 miles to parasitize nests. Brown-headed cowbirds parasitize nests by removing eggs of the occupant and laying their own eggs in the nest. Occupants of the nest then brood over the brown-headed cowbird's egg. Most species parasitized by the cowbird are unable to differentiate between their hatchling and the cowbird hatchling, and expend energy and other resources raising only the cowbird. However, the golden-cheeked warbler is one of the few species that may either abandon parasitized nests, or successfully raise the cowbird hatchling with a reduced number of its own, reducing but not eliminating the impacts of cowbirds on the species. Cowbird parasitism on the black-capped vireo is a greater concern than on the golden-cheeked warbler because the vireo does not have a natural defense mechanism such as nest abandonment.

Whooping cranes are rare migrants through the Fort Hood area (Fort Hood, 2019). Whooping cranes are a common migratory visitor through Central Texas during spring and fall and have been observed along the shoreline of Belton Lake. Whooping cranes were observed foraging in a borrow pit on Fort Hood in March 2010 (Hammer 2011). This species is not known to nest on the installation.

The Smooth Pimpleback (*Cyclonaias houstonensis*), listed as a Federal Candidate Species, is known to be endemic to the Colorado and Brazos River drainages of Central Texas; this mollusk has only been known to exist in relevance to the project in the Leon River bordering the outside boundary of Fort Hood (Fort Hood, 2019). This species is very unlikely to occur in the project area. Recent genetic studies revealed that smooth pimpleback is synonymous with pimpleback, a wide-ranging species that is very common. These studies have been widely accepted by the relevant scientific community and the Service. Due to being synonymized with pimpleback, smooth pimpleback is not a valid taxonomic entity; does not meet the definition of a species or subspecies under the Act; and, as a result, cannot warrant listing under the Act. See 84 FR 41694.

The Texas Fawnsfoot (*Truncilla macrodon*), occurred in its historical range within the project area, but has not occurred recently and is not known to occur within Fort Hood (USFWS, 2011d & Fort Hood, 2019).

3.8.3 State-Listed Species

The Timber Rattlesnake (*Crotalus horridus*) prefers moist lowland forests, hilly woodlands and thickets near permanent water sources fallen timber provides hiding habitat (TPWD, 2019b). This species is not known to occur within Fort Hood and is not likely to be within the project area (Fort Hood, 2019).

The Texas horned lizard has been documented throughout Fort Hood in low numbers (Webb and Henke 2008, Fort Hood 2009b). The species prefers arid to semi-arid habitats with minimal vegetation cover over friable soils. Threats to the species include fragmentation of habitats; disturbance of habitats, including compaction of soils; predation of prey (i.e., red harvester ants [*Pogonomyrmex barbatus*]) by imported red fire ants (*Solenopsis invicta*) and direct predation by fire ants. This species is known to exist in low density populations within Fort Hood (Fort Hood, 2019).

The American peregrine falcon (*Falco peregrinus anatum*) is a resident of southwest Texas, where it occupies a variety of arid and semi-arid habitats (Cornelius et al. 2007, Fort Hood 2009b). The species was heavily impacted by pesticide use in the late 20th century and was previously listed as Federally endangered; however, bans on pesticide use and reintroduction efforts have led to recovery of the species over most of its range and delisting of the species by the USFWS. The species remains listed as threatened by the TWPD. The species has been anecdotally recorded on Fort Hood, and it is presumed that the species is a transitory migrant in the area. This species has been recorded as a migratory visitor, but is not known to have established populations in Fort Hood (Fort Hood, 2019).

The Peregrine Falcon (*Falco peregrinus*) has a widespread distribution and prefers rocky and steep cliff sides, mountains, and ledges (TPWD, 2013). This species has been recorded as a migratory visitor in Fort Hood, but is not known to have any established populations within the installation (Fort Hood, 2019).

Bald eagles (*Haliaeetus leucocephalus*) winter regularly on Belton Lake and the shoreline along the eastern boundary of Fort Hood (Cornelius et al. 2007, Fort Hood 2009b). Wintering populations vary from two to as many as seven, including adults, subadults, and juveniles. Historically, threats to bald eagles included hunting, habitat destruction, and widespread pesticide use. Laws preventing hunting of the species and outlawing the use of certain pesticides have resulted in a significant recovery of this species, and delisting by the USFWS. The only substantial threat to this species on the Installation is the aerial support for training activities. However, activities near roost sites are heavily restricted when bald eagles are known to be in the area. This species is recorded as recently occurring in Fort Hood and is commonly seen at the Lake, but is not known to nest on the installation (Fort Hood, 2019).

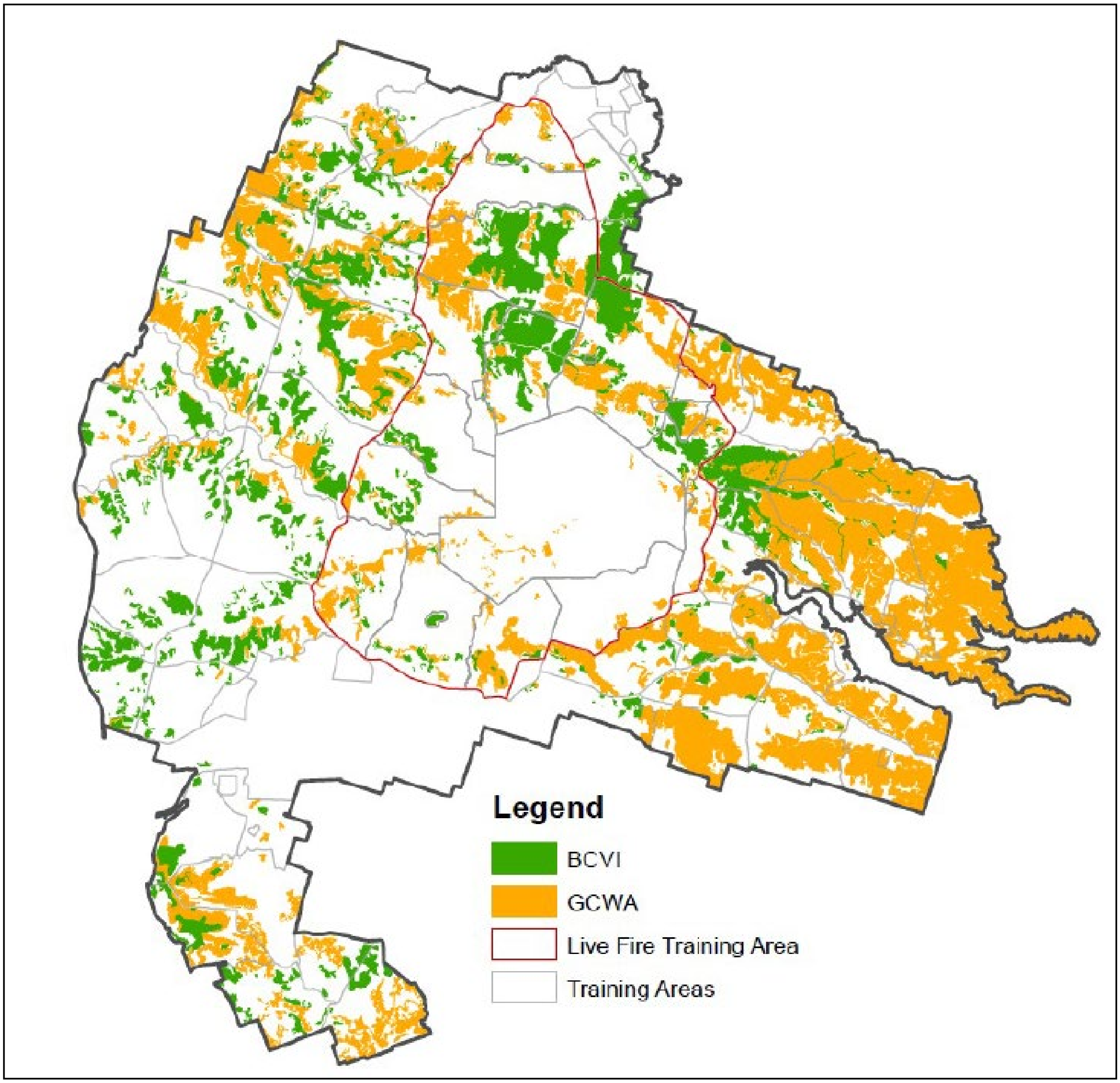


Figure 3-8 Suitable Habitat for *S. chrysoparia* & *V. atricapilla*

The White Faced Ibis (*Plegadis chihi*) prefers freshwater marshes, swamps, ponds, and rivers; this species occurs in Fort Hood as a migratory visitor in the fall and spring (TPWD, 2019c). This species is not known to nest on the installation.

The Wood Stork (*Mycteria americana*) prefers cypress swamps, marshes, ponds, and lagoons but also forages in essentially any standing freshwater; this species occurs as a rare migratory visitor in Fort Hood (Audobon, 2019a).

The Zone-Tailed Hawk (*Buteo albononatus*) prefers river woodlands, desert mountains, and canyons and tends to forage over open country, grassland, and desert; this species is unknown if it occurs in Fort Hood, but is a possible migratory visitor (Audobon, 2019b).

3.8.4 Other Special Status Species

Species listed in Table 3-6 that are not State Listed or are not previously discussed will not be further elaborated upon. For more information regarding these species that are of other conservation concern, please refer to Fort Hood's 2019 Integrated Resource Management Plan.

3.9 CULTURAL RESOURCES

3.9.1 Historical Context

The Central Texas region has been inhabited since about 12,000 years ago when groups hunted large game and collected the plant resources of the region at the end of the last Ice Age (Army 1995). As the climate gradually warmed, small bands of people used a wider range of plant foods. Burned rock deposits provide archaeological evidence of specialized food processing techniques. Later, hunting activities increased and the bow and arrow came into use. Pottery-making techniques were developed and subsequent regional trade networks were established in the area.

Europeans reported encountering Tonkawa Indians in Central Texas in the late 1600s (Army 1995). Little else is known about the Tonkawa people, who may have been displaced by tribes from the plains who had adopted horseback riding. Wild horse herds are likely to have attracted both Anglo-Americans and Comanches to the area. The Wichita Indians, who had a large village at Waco by the early 1800s, hunted in the hill country around Fort Hood, along with the Comanches. In the early 1800s, Phillip Nolan operated in the area rounding up horses for resale in Louisiana. Nolan Creek runs through the Main Cantonment Area of Fort Hood. The Tonkawa, Waco, and Peneteka Commanche were also active in the area surrounding Fort Gates circa 1850.

The Brazos River area, including Bell and Coryell counties, was colonized in the 1830s by Sterling Robertson and was known as "Robertson's Colony" (Army 1995). After Texas became part of the U.S. in 1846, the Army built Fort Gates on the Leon River; Fort Gates was active from 1849-1583. In 1850, Bell County was established from Milam County and the region grew as ranchers grazed cattle and hogs on the open rangeland. In the 1880s, railroad access to the area increased settlement along the railroad route and provided access to regional markets for cash crops such as cotton, which increased in importance through World War I, until its value dropped during the economic decline of the 1920s.

In 1942, Camp Hood was established as a tank destroyer center with 5,630 buildings and 35 firing ranges (Army 1995). Camp Hood was renamed Fort Hood when it became a permanent

Installation in 1951. Since its establishment, Fort Hood has been used as a training location for Army armored units.

3.9.2 Archaeological Resources

Intensive professional archaeological investigations began at Fort Hood in 1949 with the National Park Service (NPS) River Basin Surveys (Army 1999b). Since then, more than 2,200 archaeological sites, approximately evenly divided between prehistoric and historic sites, have been recorded at the Installation. A total of 1,098 prehistoric sites range in age from 12,000 years old to less than 150 years old and include flaked rock scatters, campsites, burned rock features, rock quarries, caves and rock shelters, and rock art. According to the Fort Hood archaeological database, 167 of these sites are eligible for the National Register of Historic Places (NRHP), and 325 are potentially eligible. A total of 1,120 historic archaeological sites include the remains of farms, homes, churches, and cemeteries reflecting Euroamerican occupation of the area. According to the Fort Hood archaeological database, 13 sites are eligible for the NRHP, and 641 sites are potentially eligible (USACE 2003). None of the Fort Hood sites are presently listed on the NRHP (NPS 2011).

A total of 2,214 archeological resources have been identified. This total comprises 1,111 prehistoric archeological resources and 1,103 historic archeological resources. The Fort Hood Archeological Resource Management Series (FHARMS) consists of over 67 volumes and contains a vast amount of archeological and historic data and resource characteristics.

Prehistoric archeological resource assessment has followed the traditional methodology of shovel testing proceeding to Phase 2 National Register testing for NRHP assessments of eligibility. This assessment program prioritized testing of resources based on mission needs particularly in training areas. Table 3-8 summarizes NRHP eligibility assessments for historic and prehistoric archeological sites (Fort Hood Historic Properties Component 2015).

Table 3-8. Archeological Historic Properties at Fort Hood

	Total	Eligible	Eligibility to be assessed	Not Eligible
Prehistoric	1111	200	101	810
Historic	1103	11	29	1063
Totals	2214	211	130	1873

3.9.3 Architectural Resources

Historic architectural resources at Fort Hood include buildings that predate Army ownership of the property and more than 600 primarily temporary buildings constructed during the World War II era (Army 1995). An evaluation of historic buildings at the Installation in 1990 and 1991 identified structures that were eligible for the NRHP, including several that predate the military Installation and one from the World War II era. None of the Fort Hood buildings are presently listed on the NRHP (NPS 2011).

Many of the built resources and landscape elements of Fort Hood are covered under Programmatic Memoranda of Agreement and Program Comments that offer an alternative approach to inventory and evaluation. These Program Alternatives are discussed in SOP 1.2.

Fort Hood has seven NRHP eligible historic landscapes within the cantonment areas including: 1) Capehart-Wherry Family Housing; 2) Headquarters/Ceremonial; 3) the Hood Army Airfield; 4) Killeen Base; 5) the Motorpool Corridor; 6) Railroad and Transportation Corridors; and 7) Unaccompanied Personnel Housing. FHCRM is in the process of finalizing an inventory and assessment of built resources that are not covered under the Program Alternatives. Appendix B contains the Fort Hood building inventory. FHCRM currently manages four built resources as historic properties: Bldg. 53 (Camp Hood Post Chapel), Bldg. 7001 (HAAF Flight Control Tower), Bldg. 7013 (HAAF Paint Hanger), and Bldg. 7027 (HAAF Hanger). FHCRM will continue to define and establish other built historic properties, districts, and landscapes within the constraints of mission requirements and priorities (Fort Hood Historic Properties Component 2015).

3.9.4 Traditional Cultural Resources

At Fort Hood, one traditional cultural place has been evaluated as eligible for the NRHP (U.S. Army 1999b). Fort Hood maintains an informal agreement with the Tonkawa and Comanche tribes regarding the treatment of human remains under the Native American Graves Protection and Repatriation Act (NAGPRA).

The NRHP recognizes that PTRCI could potentially be considered eligible for listing. Three sites have been identified by the Comanche Nation as being of cultural importance to the Comanche people: Sugarloaf Mountain (NRHP eligible), Comanche Trail, and 41BL0146 (NRHP eligible). An additional site, the Leon River Medicine Wheel, on Fort Hood is of religious importance to multiple Native American Tribes. The site was reported during an archeological survey in 1990 and has been used continuously for ceremonial activities since its identification. Access to the location is restricted to Native Americans for traditional observances. FHCRM personnel visit the resource for condition monitoring purposes and the Coordinator for Native American Affairs serves as a point of contact for Native American access (Fort Hood Historic Properties Component 2015).

3.10 SOCIOECONOMICS

Executive Order 12898 (Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations) requires an assessment of environmental effects, including human health, economic, and social effects on minority communities and low-income communities.

Executive Order 13045 (Protection of Children from Environmental Health Risks and Safety Risks) requires an assessment of environmental health and safety risks that may disproportionately affect children.

Seven surrounding cities are partnered with and provide substantial quality of life support to Fort Hood: Killeen, Temple, Belton, Salado, Copperas Cove, Gatesville, and Lampasas (Fort Hood 2009a). Fort Hood’s homepage directs personnel and their families to these areas for various activities which economically drive local service and retail industries, bolster development, and support community growth.

3.10.1 Demographics

The estimated 2018 population of the seven incorporated places partnered with Fort Hood was approximately 302,826 people (USCB, 2018a. Bell County includes four incorporated places near Fort Hood: Belton, Temple, Killeen, and the village of Salado. The estimated 2018 population of these four incorporated places was 22,222; 76,256; 149,103; and 2,351, respectively. Coryell County includes two incorporated places near Fort Hood: Gatesville and Copperas Cove. The estimated 2018 population of these places was 12,237 and 32,658, respectively. Lampasas County includes one incorporated place near Fort Hood, Lampasas, which had an estimated population of 7,909 in 2018.

The Bell County population in 2018 was estimated to be nearly 1.5 times larger than the average of all Texas counties and experienced around 4 times more growth than the average(Table 3-9) (USCB 2018a/b). Coryell County population was estimated to be nearly a third of the average population for all Texas counties in 2018 and experienced a decline in population percentage compared to the average. The Lampasas County population was estimated to be nearly a 10th of the average population for all Texas counties in 2018 and experienced a growth rate approximately 3 times higher than the average for other Texas Counties.

Table 3-9. Bell, Coryell, and Lampasas County Population Estimates and Annual Growth: 2017 to 2018

County	2017 Population	2018 Population	Population Change (%)
Bell	347,851	355,642	+2.2
Coryell	74,883	74,808	-0.1
Lampasas	20,919	21,229	+1.5
Average (Texas)	222,138.95	225,112.5	+0.55

The populations of Bell and Coryell County have higher diversity levels than the State of Texas, while Lampasas County is less diverse (Table 3-10) (USCB 2018c). Bell and Coryell counties have a proportionally larger population of blacks when compared to Texas as a whole; however, the composition of other races is proportionally near or less than the State of Texas average. The population of people of Hispanic origin is relatively low in all three counties when compared to Texas as a whole. The US Census Board defines Hispanic origin as an ethnicity, and states that people with Hispanic origin can be of any race (USCB 2018c).

3.10.2 Employment and Income

Income levels in Bell, Coryell, and Lampasas counties are lower than the national average (USCB 2017a/b) for 2017 (Table 3-11). Lampasas County had the greatest income by household, family, and per capita, while Coryell had the least income by family, household, and per capita. In Bell County, the number of families living below the poverty level was greater than the national average.

Table 3-10. Bell, Coryell, and Lampasas County Estimated Percent Composition by Race 2018

Geography	Race Population Percentage by Race Alone[1] (US Census Board, 2018c (%)					
	White	Black or African American	American Indian & Alaska Native	Asian	Native Hawaiian & Other Pacific Islander	Two or More Races
Bell County	65.8	24.4	1.1	3.3	0.9	4.6
Coryell County	73.6	17.7	1.1	2.1	1.0	4.5
Lampasas County	89.8	4.1	1.3	1.4	0.5	2.8
State of Texas	78.8	12.8	1.0	5.2	0.1	2.0

1: "Hispanic origin is considered an ethnicity, not a race. Hispanics may be of any race."

Table 3-11. Bell, Coryell, and Lampasas County Estimated Economic Characteristics for 2013-2017

Characteristic	Bell County	Coryell County	Lampasas County	State of Texas	United States
Median Household Income (dollars)	52,583	50,865	54,467	57,051	57,652
Median Family Income (dollars)	60,751	57,731	66,662	67,344	70,850
Per Capita Income (dollars)	25,017	21,171	26,405	28,985	31,177
Families Below Poverty Level (percent)	11.3	10.5	8.4	12.4	10.5
People Below Poverty Level (percent)	14.3	13.3	12.0	16	14.6

Fort Hood employs over 35,000 active duty Soldiers and they are complemented by more than 11,900 civilian employees, making Fort Hood the largest single site employer (150,155 total) in the state and directly inserting nearly $24.6 billion annually into the Texas economy in 2018 (TMPC, 2018).

The vast majority of employers are located in Bell County, with the least number of employers located in Lampasas County (Table 3-12) (USCB 2016). Excluding educational services, sectors not reported, and farm-related income, the services sectors are the largest employers and payroll providers in the Bell, Coryell, and Lampasas counties. The largest segments of the services sector were Health Care and Social Assistance, with 26,550 employees and a payroll of more than 1.4 billion dollars, and Professional, Scientific, and Technical Services, with 4,042 employees and a payroll of more than 193 million dollars. Other important sectors included manufacturing, retail trade, and accommodation and food services.

The total farm-related income for Bell, Coryell, and Lampasas counties was approximately 8.7 million dollars in 2017 (Table 3-13) (USDA 2017). The area of land in farm production is greater than 400,000 acres in each county; however, Bell County has the greatest number of farms. This indicates that Bell County has a disproportionate number of small farms. In each county, farms producing cattle and calves account for at least 50 percent of all farms. Livestock and crops are of nearly equal market value in Bell and Lampasas County; however, crops account for a significantly larger proportion of market value in Coryell County.

According to the USDA Census of Agriculture (USDA 2017), many types of livestock farms occur within Bell, Coryell, and Lampasas counties. These include: cattle and calves, poultry and eggs, dairy farms, hogs and pigs, sheep, goats, horses, ponies, mules, burros, and donkeys. The dominant livestock operation is cattle and calves totaling over 110,000 animals. When compared to other Texas counties, Bell, Coryell, and Lampasas counties ranked 125th, 81st, and 135th, respectively in Cattle and Calf market value. In total market value for livestock, Bell, Coryell, and Lampasas Counties ranked 83rd, 107th, and 143rd, respectively compared to other Texas counties. The operators of farms in Bell, Coryell, and Lampasas County were predominantly white in 2017 (Table 3-14) (USDA 2017). The proportion of each race operating farms is either lower than or similar to the proportion of the total population for each county and each race. The largest minority race operating farms is black or African American in Bell and Coryell counties, who operate 2.6, 0.6, percent of farms, respectively; whereas the largest minority race operators in Lampasas county are American Indian or Alaska Natives, who comprise 1.3 % of total operators.

Table 3-12. Bell, Coryell, and Lampasas County Non-Farm Employment and Payroll by Sector for 2016

Sector	Bell		Coryell		Lampasas	
	Employees	Payroll ($1,000)	Employees	Payroll ($1,000)	Employees	Payroll ($1,000)
Agriculture, forestry, fishing and hunting	A	X	U	U	A	X
Mining, quarrying, and oil and gas extraction	159	7941	A	X	B	X
Utilities	285	23468	18	921	A	X
Construction	3739	164209	667	22948	496	18455
Manufacturing	6198	256243	508	24972	644	17843
Wholesale trade	3098	159178	146	4640	62	1751
Retail trade	15194	392428	1887	46923	651	20270
Transportation and warehousing	3318	132047	57	1729	46	1621
Information	1945	122875	86	3158	24	783
Finance and insurance	3380	190592	409	15243	102	4773
Real estate and rental and leasing	1677	65617	135	4467	37	1825

Sector	Bell		Coryell		Lampasas	
	Employees	Payroll ($1,000)	Employees	Payroll ($1,000)	Employees	Payroll ($1,000)
Professional, scientific, and technical services	3186	153978	750	34903	106	4427
Management of companies and enterprises	1373	119501	A	X	B	X
Administrative and support and waste management and remediation services	2922	87389	1759	22390	223	4876
Educational services	2024	53087	B	X	7	58
Health care and social assistance	24863	1360360	1176	37196	511	15380
Arts, entertainment, and recreation	1257	17979	63	659	B	X
Accommodation and food services	12805	181896	1425	18015	403	5358
Other services (except public administration)	4685	104241	613	14907	256	5788

*A = 0 to 19 employees; exact information not disclosed to protect individual businesses
*B= 20 to 99 employees; exact information not disclosed to protect individual businesses
*X= Data not disclosed to protect individual businesses
*U= Data unavailable for sector

Table 3-13. Bell, Coryell, and Lampasas County Farms and Income from Farm-Related Sources for 2017

Farm Characteristic	Bell	Coryell	Lampasas
Market Value of Livestock and Poultry ($)	38,947,000	28,096,000	16,421,000
Market Value of Crops ($)	38,084,000	8,180,000	2,019,000
Per Farm Net Cash Income ($)	3,804	-4,412	-7,686
Farm-Related Income ($)	4,008,000	2,734,000	1,916,000
Total Farm Acreage (ac)	487,052	456,973	469,013

Table 3-14. Bell, Coryell, and Lampasas County Census of Farmer's Race

Race*	Individuals Farmers per County					
	Bell County		Coryell County		Lampasas County	
	Total	%	Total	%	Total	%
American Indian or Alaska Native	24	0.6	33	1.3	25	1.3
Asian	26	0.6	23	0.9	14	0.7
Black or African American	108	2.6	14	0.6	20	1.0
Native Hawaiian or Pacific Islander	7	0.2	10	0.4	1	0.1
White	3,906	94.8	2,392	96.2	1,850	96.0
More than one Race	50	1.2	15	0.6	18	0.9

*Hispanic Origin is not included because the US Census Bureau classifies this characteristic as an ethnicity

3.11 AESTHETICS AND RECREATION

Aesthetics is essentially based on an individual or group of individuals' judgment as to whether or not an object is visually pleasing or would influence the quality of life. The rural character of the Texas Hill Country is largely defined by the vast open vistas created by undeveloped rangelands and agricultural development. The local landforms, including flat-topped steep-sided plateaus, ridges and isolated hills, sloping valley sides, floodplains, and stream courses, are varied and visually interesting. Rocky outcrops are visible at the tops of some of the steeper slopes and add visual interest. Vegetation is visually varied with dense shrub forest, areas of scattered trees and brush, and areas with low grassy or forb ground cover. Moving or standing water along stream channels or in the form of constructed ponds and small lakes is common and also adds visual interest. There are no scenic highways or visually sensitive, Federally protected areas that have views to Fort Hood.

Fort Hood has offered to establish an entirely voluntary program with cooperating nearby landowners known as the Army Compatible Use Buffer. Under this program, landowners would be compensated in exchange for their agreement to maintain the current rural nature of their land near Fort Hood's boundaries (Army 2009).

3.12 UTILITIES AND TRANSPORTATION

The Bell County Water Control and Improvement District (BCWCID) #1 provides potable water and wastewater treatment for most of the communities surrounding Fort Hood, including Fort Hood (BCWID 2011). The BCWCID #1 currently serves a population of 250,000 people and can treat and deliver over 90 million gallons of potable water daily. The district's three wastewater treatment facilities serve the City of Killeen and Fort Hood and have a total capacity to treat 30 million gallons of water per day. The NFH cantonment area relies on wastewater sedimentation ponds that are designed to be expanded to meet the requirements of the additional National Guard troops that are stationed at NFH every summer (USACE 1999). The treatment facilities were constructed in anticipation of heavy use for a few months in the summer, and very low use for the remainder of the year. Electric power and natural gas are each provided to Fort Hood through the Texas Utilities and Electric Company and Lone Star Gas Company, respectively (USACE 1999).

The Installation's principal cantonment area and the adjacent West Fort Hood are bisected by U.S. Highway 190, which is a four-lane controlled access road that flows directly into U.S. Interstate Highway 35 (I-35). I-35 is the main north-south route through Texas and Mid-America from Laredo, Texas to Duluth, Minnesota. Roadways through the Western Maneuver Area and West Fort Hood training areas are open to the public and connect many of the surrounding communities. West Range Road travels the length of the Western Maneuver Area and connects the main cantonment area of Fort Hood to Gatesville and other communities north of Fort Hood. Elijah Road and Antelope Road provide access from West Range Road to the western boundary of the Installation and residential areas associated with Copperas Cove. Two roads bisect the training areas around the West Fort Hood cantonment, Oakalla Road and Maxdale Road; however, there are no major residential or commercial areas south of the Installation.

Cattle are free ranging within the Installation and accidents involving cattle occur on average every 3 weeks (USACE 2003). Over a 39-month period beginning in January of 1997, 54 vehicle accidents were reported, of which 53 involved cattle. All of these accidents involved property damage and seven involved injury. The Installation-wide stocking rate during this period was 3,500 AU.

3.13 NOISE

The primary source of noise exceeding ambient levels is attributed to aircraft use (Fort Hood 2009). Existing airspace agreements allow Fort Hood aircraft a 500-foot floor. The historical use of the study area by approximately 36,000 flight operations monthly has created approximately 30 noise complaints per year. Residential areas and isolated residences, along with farms and ranches, around Fort Hood are the primary sensitive land uses of concern with respect to noise. Most public complaints about Fort Hood activities are caused by aircraft (Fort Hood 2009b). The cause of the complaints is not always a direct effect of the noise heard by the people, but due to the damage done to facilities or structures when livestock are startled by sudden noise.

Operation of military vehicles and use of munitions during training activities also produces noise levels greater than ambient conditions; however, noise from these sources is typically attenuated before reaching sensitive receptors.

3.14 HAZARDOUS MATERIALS AND WASTE

The management and use of compounds regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (7 USC 136, as amended) are performed by the Environmental Management Division (Fort Hood 2009b). The Installation has an Installation Pest Management Coordinator who oversees all activities and maintains an application record. All applicators are certified prior to using pesticides at Fort Hood.

The largest quantities of bulk transported materials are vehicle fuels (i.e., gasoline and diesel fuel) and aviation fuels (Fort Hood 2009b). Additional transported items include other ignitable or flammable materials, corrosives, toxics, and reactive materials such as munitions. These materials are mostly transported in small non-bulk packed quantities.

Hazardous materials are widely distributed throughout the Installation (Fort Hood 2009b). Hazardous materials of interest would depend upon the training activities and the specific locations in which they are planned to occur. Information on Resource Conservation and Recovery Act (RCRA) (42 U.S.C. 6901) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) (42 U.S.C. 9601, as amended) locations within the Installation are available through the USEPA's CERCLA and RCRA databases and registration reports. Additional USEPA-identified sites are listed in the Emergency Response Notifications System Locations database. These and other potentially hazardous materials and hazardous material locations can be identified though the Texas Natural Resource Conservation Commission (TNRCC) Waste Management Section (800-832-8244) databases, including the leaking tanks report and solid waste registration report.

4.0 ENVIRONMENTAL EFFECTS

This section of the EA addresses potential impacts associated with the implementation of the alternatives described in Section 2.0. Impacts on the human and natural environment can be characterized as beneficial or adverse, and can be direct or indirect, based upon the result of the action. Direct impacts are those effects that are caused by the action and occur at the same time and place (40 CFR 1508.8[a]). Indirect impacts are those effects that are caused by the action and are later in time or further removed in distance, but are still reasonably foreseeable (40 CFR 1508.8[b]).

The impact analysis presented in this EA is based upon existing regulatory standards, scientific and environmental knowledge and best professional opinions. Impacts can vary in degree or magnitude from a slightly noticeable change to a total change in the environment. Minimal impacts are impacts that would result in a slightly noticeable or quantifiable change in a resource, but which would not substantially change the value of that resource. A moderate impact is an impact that would result in easily recognized changes in a resource and potentially affect the value of that resource, but would remain less than significant. Significant impacts are those effects that would result in substantial changes to the environment (as defined by 40 CFR 1508.27) and should receive the greatest attention in the decision-making process. The alternatives may create temporary (lasting less than a single grazing season), short-term (up to 3 years), long-term (3 to 10 years), or permanent impacts or effects. Whether an impact is significant depends on the context in which the impact occurs and the intensity of the impact.

The following discussions describe and, where possible, quantify the potential effects of each alternative on each resource. All impacts described below are considered to be adverse unless stated otherwise. Additionally, a quantitative impact analysis was used to describe potential impacts when data were available for the given resource (i.e., soils). Many impacts are qualitative in nature (i.e., impact on cultural resources) and are not quantified.

4.1 LAND USE

Significant effects on land use include substantial interruptions or delays of military training. Any short-term or longer delay of training activities due to direct interaction with cattle or the indirect effect of cattle on the landscape would be considered significant. Support of military training is part of the primary mission at Fort Hood and part of the purpose and need for the Proposed Action. Actions which improve the realism of training activities or result in the long-term stability and sustainability of the landscape are considered beneficial to land use and support the purpose and need of the Proposed Action.

Cattle grazing on Fort Hood has resulted in land use impacts in the form of training delays. Combat Vehicle Crew gunnery proficiency and qualification training – a subset of Fort Hood's primary mission – has been heavily impacted by cattle grazing in the live fire and impact areas. When cattle move within the line of fire, training activities cease until the cattle are removed, even though not required by the lease terms.

In addition to the direct loss of training time, suspending training to clear cattle off the range complex has even greater second-order effects on training. The tempo of range operations is disrupted, combat vehicle crews must stop, attempt to restart systems, and resume the intended rhythm of the training scenario. Since none of the training ranges are fenced, training delays are expected yearly due to the presence of cattle.

Though training and grazing can be compatible land uses in most areas at Fort Hood, the intensive and critical training activities that occur in the Live Fire and Impact Areas require additional restrictions on cattle densities in these areas. Training delays must be minimized in order that soldiers may fulfill the semi-annual requirement to meet Army-mandated qualification standards. .

Fort Hood range managers have set a limit of 750 AUs in the live fire and impact areas. This represents the maximum number that can reasonably be controlled without significant impacts on training. Each alternative incorporates a stocking limit of 750 AU in the Live Fire and Impact Area.

Grazing cattle have less adverse impacts on training in other areas. Where live rounds are not used, damage to cattle is avoided and the need to disrupt training is reduced. In these areas, cattle tend to avoid interaction with most training activities.

No air space or visual resource impacts are expected from any alternative. Additionally, range conditions under any of the alternatives would not be expected to degrade; therefore, there would be no anticipated impact to recreational uses of the land (e.g. hunting and fishing).

4.1.1 No Action Alternative

Stocking rates have been reduced by more than 40% compared to historic rates, and improved land management practices have been implemented, including increased use of fire management, brush control and removal, improved stormwater management practices, and other efforts to mitigate training impacts. Without substantial changes in training intensity, climate, or occurrence of wildfires, the current stocking rate would not result in significant adverse effects on land use, specifically training activities. If future training activities increase or the use changes to that which degrades the rangelands, grazing may need to be deferred. Also, if there is a substantial change in range conditions or forage type because of drought, fire, or an increase in woody vegetation or invasive species, but training intensities do not change, grazing may still need to be deferred.

4.1.2 Alternative 2 – 25% Harvest Efficiency

Grazing under this alternative would have no significant impacts on training because the stocking rate for the Live Fire and Impact Area (LFIA) would be limited to 750 AUs. Under this alternative, stocking rates outside the LFIA would slightly decrease in some GMUs and increase in others. In GMUs, where there is a reduction in stocking rates, delays or obstacles to training activities would also decrease as compared to the No Action. However, in GMUs where the stocking rate increases, more delays in training would be expected, although the level is not anticipated to rise to the level of significant (unacceptable number of training delays). Increased stocking rates would force cattle to forage in areas not previously grazed or only lightly grazed when compared to historic conditions. As cattle graze further from previous sites, there is an increased chance in training and cattle interactions despite the skittish nature of cattle.

The Western Maneuver Area – North and Eastern Training Area North both have proposed stocking rate increases of almost 150% and 40%, respectively, when compared to the No Action. With a stocking rate increase in these two GMUs, there is an increased chance in training delays because of tracked-vehicle collisions with cattle. Cattle injuries and mortality could be higher as a result of falling into constructed trenches or being exposed to pyrotechnic activities.

Impacts on recreational uses of the installation would likely occur from more cattle/recreational user interactions. The alternative is not expected to cause a decline in ecological condition and would therefore not result in any loss in recreational opportunities

4.1.3 Alternative 3 – Combination Strategy

Grazing under this alternative would have no significant impacts on training; similar to Alternative 2, Alternative 3 would also limit the LFIA to 750 AUs. Areas other than the LFIA would use the same stocking rates seen in Alternative 2, with the exception of the Western Maneuver Area – North, and the Western Maneuver Area – South, which would have decreases from the No Action Plan of 73.4% and 72.8 %, respectively. These two areas would have less AUs on them compared to the No Action Plan, and would therefore experience less impacts to land use, as well as a decreased chance of cattle mortality or injury.

4.1.4 Alternative 4 – Modified Combination Strategy (Preferred Alternative)

Grazing under this alternative would have no significant impact on training and is nearly identical to the No Action Alternative's stocking rates. This alternative would see AU increases in the Western Maneuver Area – North and the Eastern Training Area – North of 15.6% and 41.5%, respectively. There would be an AU decrease only in Western Maneuver Area – South by 39.4%. The overall AU stocking rate would be the same as the No Action Alternative and would have similar, non-significant, impacts to land use. There is a slightly higher chance of tracked vehicle collision or other injury of cattle in areas with increased stocking rates.

4.2 PHYSIOGRAPHY AND SOILS

The Farmland Protection Policy Act of 1981 requires Federal agencies to avoid the unnecessary and irreversible conversion of farmland to nonagricultural uses. As discussed in Section 3.4.2, approximately 39,000 acres of Prime Farmland Soils occur on Fort Hood; however, conversion of Prime Farmland Soils for national defense is not regulated and none would be converted to nonagricultural uses as a result of any alternative.

Erosion results in soil loss and occurs naturally across the landscape. Soil loss is typically not a significant impact; however, the indirect effects of soil loss on the sustainability of the landscape and pollution of downstream waterways can be significant. The tolerable soil loss threshold (T) as established by the NRCS (1999) is used in this EA as a significance threshold, such that soil erosion rates greater than T are considered significant. T is defined as the maximum amount of erosion at which the quality of a soil as a medium for plant growth can be maintained. This includes maintaining the surface soil as a seedbed for plants, maintaining the interface between the air and the soil that allows the entry of air and water into the soil and still protects the underlying soil from wind and water erosion, and maintaining the total soil volume as a reservoir for water and plant nutrients.

Erosion losses are estimated by the Universal Soil Loss Equation and the Revised Universal Soil Loss Equation (RUSLE). The T factor is assigned to soils without respect to land use or cover, is used to compare erodibility of soils, and does not directly relate to vegetation response. T factors commonly serve as objectives for conservation farm planning to assist in the identification of cropping sequences and management systems that will maximize production and sustain long-term productivity. Thus, T factors represent the goal for maximum annual soil loss in the context of maintaining the long-term sustainability goal.

Estimated sediment yields were compared to the T listed in the soil survey for each soil type. An erosion index was calculated as the ratio of estimated sediment yield to sustainable sediment yield. An erosion index greater than 1.0 indicates unsustainable conditions and is assumed to result in significant adverse effects. A detailed description of the methods used to estimate soil erosion rates using RUSLE is provided in Appendix A.

Vegetative cover is critical for maintaining natural rates of erosion (Davenport et al. 1998). As the cover of perennial bunch grasses is reduced, the space between plants increases, resulting in reduced retention of organic matter in the soils, reduced infiltration of precipitation, increased evaporation, increased soil temperatures and increased erosion (Hanselka et al. 2001). As vegetative cover is reduced to critical levels, soil erosion begins to increase substantially in response to small decreases in vegetative cover. Erosion rates beyond this threshold increase rapidly and are irreversible, and the landscape becomes unsustainable without implementation of remedial actions.

As discussed in Fort Hood's 2019 INRMP, military training on Fort Hood is one of the primary causes of soil erosion on the Installation. Tracked and wheeled vehicles crush vegetation and disturb soils, which results in reduced vegetative cover and increased erosion. Tracking on wet soils significantly increases these effects. Recovery of the vegetation and the reduction in soil erosion rate depends on the amount of time before the site is disturbed again. Grazing by livestock can slow the recovery of these sites because new growth on the vegetation is grazed before it can produce sufficient root systems to hold the soil and provide sufficient plant cover to reduce erosion. Although levels of vegetative cover return to pre-disturbance levels after a few years without disturbance, several years of recovery and remedial actions may be necessary before climax grass species return to their pre-disturbance abundance.

4.2.1 No Action Alternative

Under the No Action Alternative, soil erosion would continue to occur as a result of both military training activities and cattle grazing. Because the potentially affected soils are not Prime Farmland soils, or otherwise unique and valuable, the direct loss of soil would have a minimal adverse effect on this resource. However, soil erosion rates have indirect impacts on land use, water quality, air quality, biological resources and special status species, cultural resources, socioeconomics, aesthetics, and recreation as discussed in the sections associated with these resources.

Using RUSLE, estimated sediment yield (i.e., soil erosion rates) occurring as a result of the No Action Alternative would be less than significant (Table 4-1) and are within the acceptable range of soil loss as defined by NRCS. This analysis assumes that climate conditions, training intensity, and other factors influencing productivity (e.g., fire, brush control, or other management actions) would remain relatively stable over the long-term. Since this same stocking rate has been implemented for nearly a decade, it is reasonable to assume that the existing condition would be at a minimum maintained throughout the lease term, if training utilization is not increased and there are no significant drought years.

4.2.2 Alternative 2 – 25% Harvest Efficiency

Grazing under Alternative 2 is not expected to have significant impacts on soil in any of the GMUs. This alternative is however, expected to have greater impacts to soils compared to the No Action Alternative. Under this alternative the stocking rate would be increased; however, under this calculation method, training utilization is not a factor to forage availability. Therefore, there is concern, despite the soil erosion indices being within the acceptable range, that rangeland health could slowly deteriorate and previous recovery of rangelands from reduced stocking rates would be negated. This would be particularly susceptible in areas where forage biomass is already low and where more vegetation would be removed than under the existing condition. This is likely to increasing the erodibility of the soil. Overall, since the AU quantity in Alternative 2 is 16% more than the No Action Alternative, it is unlikely that there would be differences in impacts to soils that would rise to the level of significant, but with the history of overgrazing and the short duration of acceptable erosion and soil loss levels, the potential increase in soil loss is notable. See Table 4-1 for a description of the erosion index at each GMU for the alternatives.

Table 4-1. Average Erosion Index by GMU for each of the Alternatives Considered

GMU	Alt 2: 25% Harvest Efficiency	Alt 3: Combination Strategy	Alt 4: Modified Combination Strategy
WMAN	0.64	0.78	0.62 - 0.64
WMAS	0.75	0.71	0.75
WFHNE	0.70	0.70	0.70
WFHNW	0.27	0.27	0.27
WFHS	0.77	0.77	0.77
ETAN	0.80	0.8	0.8
ETAS	0.95	0.95	0.95
NFH	0.03	0.03	0.03

4.2.3 Alternative 3 – Combination Strategy

The effects of this alternative on soil erosion rates would be similar to the No Action Alternative and would be less than significant (Table 4-1). Implementation of the Combination Strategy would promote production of desirable grass species and reduce soil erosion rates over the long-term. If the combined effects of grazing, training, climate, or wildfires result in reduced forage, stocking rates would be reduced and, if necessary, grazing would be deferred to allow rangelands to recover before erosion rates become significant. Alternative 3 would have less, if not comparable, impacts to soils in Fort Hood GMUs to the No Action Alternative since it has approximately 23% less AUs.

.

4.2.4 Alternative 4 – Modified Combination Strategy (Preferred Alternative)

Alternative 4 would have nearly identical impacts to soils as the No Action Alternative. This is because this alternative has the same total AU quantity with only minor changes in AUs in some GMUs. Beneficial practices such as management of invasive flora and controlled burns would continue to provide benefits to vegetation communities in the GMUs. In Table 4-1, the erosion index values would be extremely similar, if not identical to the No Action Alternative.

4.3 WATER QUALITY AND JURISDICTIONAL WETLANDS

Significant impacts on water quality occur when waterbodies are polluted to the extent that they are listed as impaired for designated uses under the CWA, or when an action conflicts with local or regional plans to maintain or achieve TMDLs.

The CWA and Executive Order 11990 (Protection of Wetlands) regulate developments affecting waters of the U.S. and wetlands. Significant effects occur as a result of lost wetland area. No development would occur as a result of grazing; thus, the connectivity of waters of the U.S. and extent of jurisdictional wetlands would not be affected by any alternative.

Grazing livestock can affect water quality both positively and negatively. No matter how good management practices are, there will always be negative effects on water quality, but the extent of water quality impairment is entirely dependent on how good the management is. Grazing livestock negatively affect water quality through erosion and sediment transport into surface waters, through nutrients from urine and feces dropped by the animals and fertility practices associated with high-density stocking and/or poor forage stands. Good management practices for forage production (i.e. maintaining sufficient residual forage) protect the soil surfaces by minimizing erosion and transport of sediment into nearby waterbodies.

The two nutrients of primary concern relating to grazing are nitrogen and phosphorus, both of which are found in manure. The other major water quality concern with grazing livestock is pathogens, which may move from the waste into surface waterbodes or groundwater. Release of nutrients and pathogens from manure deposited on grazing land is influenced by time, temperature, moisture, and other variables. Runoff from grazed land can contain high numbers of indicator pathogens. However, pathogens counts in runoff from grazed lands are typically several orders of magnitude lower than numbers from land where manure is deliberately applied or cattle are concentrated in high densities. Nutrient inputs from grazed lands to surface water come mainly in the form of nitrogen and phosphorus from manure and decaying vegetation. Nutrient impacts on water quality vary considerably in study results, and are dependent on specific site conditions such as precipitation, runoff, vegetation cover, grazing density, proximity of grazing to waterbodies, and period of use. The risk of nutrient enrichment is low in arid rangelands where animal wastes are widely distributed and stormwater runoff volume is comparatively light.

As discussed in Section 3.5 water quality has been significantly affected in the waterbodies surrounding Fort Hood, including Nolan Creek, Little Nolan Creek, and the Leon River. Contact recreation in these water bodies has been significantly affected by high levels of harmful (i.e., fecal coliform) bacteria. Although the most substantial contributors to these adverse effects have been attributed to runoff from municipal areas and concentrated animal feeding operations, the presence of cattle in any number contributes to harmful bacteria and nutrient concentrations in downstream waterbodies (USEPA 2003). Cattle grazing on Fort Hood is a relatively minor source of nutrient and pathogen release (i.e., 2,000± AU distributed over 250,000 acres of the Installation) when compared to listed sources of pollution resulting in impairments to downstream waterbodies. As discussed later in Section 5.0, other ongoing or approved actions (e.g., establishment of TMDLs and implementing Watershed Protection Plans) within the affected watersheds would result in moderate beneficial effects on water quality in these waterbodies and would result in removal of the waterbodies from the list of impaired waters. There are currently no TMDLs established for the 3 impaired waters within or adjacent to Fort Hood.

4.3.1 Alternative 1 – No Action Alternative

Impacts from implementing the No Action would be nearly identical to the existing condition. The stocking rate would not be changed from the lease that has been implemented for the last five years. Under this stocking rate, water quality variations have not been specifically attributed to grazing management. Under this alternative, the impaired portion of Leon River below Proctor Lake would not be affected because cattle would not be routinely stocked in North Fort Hood unless grazing is deferred in another GMU and cattle must be placed in this GMU. If stocking were required in NFH, impacts would be minor and insignificant considering that Leon River runs along the outer boundary of Fort Hood. Little Nolan Creek and Nolan Creek / South Nolan Creek may experience some impacts from runoff in heavy rain events from stocked portions of the Eastern Training Area – South and the LFIA.

4.3.2 Alternative 2 – 25% Harvest Efficiency

Overall impacts to water quality would be similar to the No Action Alternative and at most, marginally higher considering the increases in stocking in the Eastern Training Area – North and in North Fort Hood. Higher stocking rates can potentially contribute more bacteria to the impaired waters during heavy rainfall events in the form of runoff; however, any potential increase would be negligible compared to other sources of pollutants in the watershed and would not cause any non-impaired water body to exceed state limits and would not cause any impaired water body to become worse.

4.3.3 Alternative 3 – Combination Strategy

Impacts to water quality under this alternative would be identical to Alternative 2 in six of the 8 GMUs considering the stocking rates for these GMUs are identical and would contribute the same to impaired waters. However, in both Western Maneuver Areas, the stocking rates would be significantly lower, which would result in less nutrients from manure entering waterbodies in these two GMUs; however, it is unlikely that this decrease would noticeably improve the existing water quality.

4.3.4 Alternative 4 – Modified Combination Strategy

Impacts to water quality with Alternative 4 would be identical to the No Action Alternative considering the total AUs are the same, with minor changes in stocking rates spread out over all 9 GMUs.

4.4 AIR QUALITY

Effects on air quality would be significant if an action results in levels of criteria pollutants greater than NAAQS. The Federal Conformity Final Rule mandates that a conformity analysis must be performed when a Federal action generates air pollutants in a region that has been designated a non-attainment or maintenance area for one or more NAAQS. Bell and Coryell counties are currently in compliance with NAAQS; thus, a conformity analysis is not required. Methane produced by cattle on Fort Hood does not reach levels warranting further analysis and would not substantially contribute to GHG emissions. The alternatives considered do not include any development or additional sources of pollutant emissions.

4.4.1 No Action Alternative

The No Action Alternative would have minimal effects on air quality. Air quality is adversely affected by the suspension of particulate matter, which occurs in areas where fine soils are exposed to wind erosion for prolonged periods. Cattle grazing and training with wheeled and tracked vehicles disturbs and compacts soils and can result in reduced plant cover and consequently exposure of soils to wind erosion. Grazing, in combination with other land management practices, is not likely to result in an increased area of exposed soils relative to historic conditions; thus, impacts on air quality would be less than significant.

4.4.2 Alternative 2 – 25% Harvest Efficiency

Alternative 2 would have similar effects on Air Quality compared to the No Action Alternative. Areas with increased stocking rates such as the Western Maneuver Area – North and the Eastern Training Area – North may have higher rates of erosion, and therefore more exposed soils that may contribute to Particulate Matter being released. Overall, there is an increase of 338 AUs and this is not likely to significantly affect Air Quality in comparison to the No Action Alternative. Additionally, the acceptable soil loss thresholds as set by the NRCS would not be exceeded under this alternative indicating that soil erosion would not be a significant concern with the increase.

4.4.3 Alternative 3 – Combination Strategy

Alternative 3 would have similar effects on Air Quality compared to the No Action Alternative. There is an overall decrease in stocking rates of 466 AUs, but this is not likely to significantly decrease impacts to Air Quality already experienced with the No Action Alternative.

4.4.4 Alternative 4 – Modified Combination Strategy

Alternative 4 would have similar effects on Air Quality compared to the No Action Alternative. The total AUs for Alternative 4 and the No Action alternative are the same; Alternative 4 only shifts the AUs in 5 areas, 2 of which were originally ‘swing spaces’ with an increase of less than 20 AUs.

4.5 BIOLOGICAL RESOURCES

Effects on biological resources would be considered significant if the alternative results in loss of diversity (i.e., extirpation of a species from the area) or substantial, long-term changes in ecological processes such that remedial actions are required. Ecological processes occur at the scale of the landscape and affect the cycling of energy, nutrients, and water on the landscape, which substantially affect the abundance and diversity of flora and fauna. Healthy rangeland is land on which all ecological processes can be sustained indefinitely. Sustainability for long periods can be expected as long as the conditions of the soil, soil moisture, and vegetation remain within a certain range.

The presence of cattle and the impact of grazing on forage availability and vegetation structure has varied effects on habitat suitability in grasslands, riparian zones, and aquatic habitats. In grasslands, cattle can trample nests of ground-nesting birds, affect cover opportunities for birds, mammals, and reptiles, and can reduce forage availability for other herbivores. In riparian habitats, cattle grazing can reduce structural diversity of vegetation resulting in reduced suitability for riparian dependent birds. Grazing affects aquatic habitats indirectly through its effects on soil erosion from upland habitats and through its effects on the filtration and water storage capacity of riparian zones. The presence of cattle can also result in direct effects on aquatic habitats by destabilizing streambanks, disturbing substrates, and suspending sediments in the water. The intensity and scale of these impacts are strongly influenced by the level of grazing that occurs. Management at low to moderate levels would realize these adverse effects, but would be minimally recognizable on the landscape. However, stocking rates that could lead to overgrazing (i.e. management above a moderate threshold given the condition of the range when combined with other outside influences such as precipitation rates, invasion of woody or undesirable species, training intensities, fire, etc.) are more likely to result in ecological changes including loss of floral and faunal diversity and substantial, long-term changes in ecological processes.

Livestock grazing can disturb vegetation through consumption or trampling and can lead to changes in plant species composition (Fuhlendorf and Smeins, 1997; Milchunas et al., 1999). Intensity and duration of the grazing drive the severity of the impact. For example, in the Edwards Plateau of Texas, heavy grazing by livestock for a duration of 45 years caused increased abundance of shortgrasses, whereas taller, more productive midgrasses were more abundant under moderate to no grazing (Fuhlendorf and Smeins, 1997).

Each of the alternatives, relies on maintaining varying levels of residual forage. Maintenance of residual forage promotes increased productivity and improved composition of desirable grasses over the long-term and consequently improve the suitability grassland habitats for wildlife. Maintaining residual forage availability provides direct benefits to forage plants by protecting the plant crown from cold, heat, and insect damage and improves vegetative cover and productivity by improving soil moisture retention and reducing erosion (Hanselka et al. 2001b, Heitschmidt et al. 1998, Thurow et al. 1988, White and McGinty 1999). Maintenance of residual forage also helps to conserve a metabolic reserve of leaf and stem tissue that allows plants to recover from grazing and is the primary factor influencing rangeland recovery from and tolerance of disturbance and drought. Maintenance of minimum levels of residual forage also improves the effectiveness of controlled burns by producing high enough temperatures to kill small shrubs and tree saplings (i.e., less than 2 feet in height) (Menke 1992, Stevens 2010).

4.5.1 No Action Alternative

Grazing would continue to have adverse effects on biological resources but would not result in reduced floral or faunal diversity or substantial, long-term changes in ecological processes. Implementing this alternative would continue to support grassland, shrubland, and woodland communities that are suitable for military training that are tolerant of disturbances related to training, grazing, fire, and climate (i.e., sustainable); and that provides suitable habitats for the greatest diversity of plants and animals. Maintaining this mixture of habitats types will have beneficial effects on some wildlife and adverse effects on others, but will insure a long-term maintenance of overall diversity (Brown 1978, bock et al 1984).

The current stocking rate is the result of past monitoring of rangeland trends and forage productivity and represents a light to moderate level (i.e., within management thresholds) of grazing given current rangeland conditions. The composition and abundance of desirable grasses has not changed substantially since stocking rates were reduced from historic highs to the current levels (Appendix A). Grazing at light to moderate levels can help to sustain this mixture of habitats by promoting increased biomass production and improved composition of desirable grasses (Hanselka et al. 2001b, Thurow et al. 1988), by preventing the accumulation of excessive fuels (Menke 1992, Stevens 2004), by limiting or controlling woody encroachment (Predick and Archer 2009, Reinecke et al. 2011, Sankey 2007, Smiens and Fuhlendorph 2011), and by promoting long-term sustainability of the grassland and resistance to disturbance and climate (Hanselka et al 2001b, Heitschmidt et al. 1998, White and McGinty 1999).

Because cattle tend to concentrate near water, grazing would continue to have adverse effects on riparian and aquatic habitats. Although maintenance of residual forage in grasslands would have long-term beneficial effects on aquatic habitats as a result of reduced soil erosion and water pollution, the direct effects of grazing on riparian and aquatic habitats would continue. Grazing in riparian areas would continue to affect vegetation structure and composition, destabilize stream banks, and disturb substrates. These direct impacts can reduce the suitability of riparian and aquatic habitats by reducing the availability of forage and cover and by reducing water quality. Although many of the adverse effects of grazing on riparian and aquatic habitats would continue, they would not result in a loss of floral or faunal diversity or result in substantial, long-term changes in ecological processes.

4.5.2 Alternative 2 – 25% Harvest Efficiency

Although the 25 percent Harvest Efficiency calculation is deemed a conservative stocking rate (Hanselka et al., 2002) for rangelands, this method does not account for ecological health impacts from training activities. This is the first forage inventory that indicates rangeland health is in acceptable condition for all GMUs under all grazing calculation methods. This was a result of stocking reductions over the last 15+ years. Before stocking rate reductions, the 25% Harvest Efficiency Method was used; however, NRCS reports in 1996 and 2000 indicate that despite using the standard method of stocking rate calculation, overgrazing and intensive military training activities were contributing to excessive erosion and poor ecological conditions.

For the two GMUs that would have increased stocking rates over the No Action, it is anticipated that rangeland health and all biological resources in the GMUs could decline potentially reversing the recovery of rangelands from historic overgrazing. Intensive training use of these two areas has resulted in lower biomass and more loss of perennial vegetation than is actually represented by the calculation methodology. If this stocking rate was implemented, it is likely that there will be less residual biomass available to protect soils from erosion and invasive species establishment; there would be a decrease in desirable perennial species, and a decline in overall ecological health. With decreased ecological health, the suitability of grassland and riparian habitats for wildlife is also expected to decrease.

The impacts of implementing this alternative on the GMUs with decreased stocking rates would maintain at a minimum existing rangeland conditions, but could potentially see improvements by leaving more residual forage. Maintenance or increase of residual forage would promote increased productivity and improved composition of desirable grasses over the long-term and consequently improve the suitability of grassland habitats for wildlife.

Grazing under this alternative could result in adverse impacts to the wildlife on the installation; however, these impacts are not expected to be significant. Grazing throughout the installation would continue to attract cowbirds, however, the trapping program currently being implemented has proven effective at reducing the impacts on endangered birds, therefore other songbird species are expected to receive the same benefit. Other direct impacts of grazing on faunal species, such as trampling of ground-nesting birds or behavioral exclusion of deer likely would occur at the stocking rates in this alternative, similar to the levels that are currently occurring. The current and historical impact of stocking at the 25 percent Harvest Efficiency rate on fauna is insignificant; therefore, it is unlikely that stocking at this rate will result in significant impacts.

4.5.3 Alternative 3 – Combination Strategy

Alternative 3 would have the least adverse effect on biological resources of all the alternatives. This alternative promotes maintaining higher residual forage rates based on the anticipated training utilization of the GMUs.

The adverse effects of grazing on riparian and aquatic habitats would be similar to the no action alternative, but somewhat lessened particularly in the GMUs with reduced stocking rates. Overall there would be less direct adverse impacts from grazing, as the total AUs are less than the No Action Alternative; the beneficial impacts to biological resources from grazing would be similar to the No Action Alternative: Continuous grazing can hasten the encroachment of wood or nuisance flora species in grassland areas.

4.5.4 Alternative 4 – Modified Combination Strategy

Alternative 4 would have very similar effects to biological resources as the No Action Alternative due to their overall stocking rates being the same. There are minor variations in stocking rates in individual GMUs, with moderate stocking rate increases in the Western Maneuver Area – North and the Eastern Training Area – South. Areas of increased stocking rates may have slightly increased adverse effects, but these would be negligible differences compared to the effects of the No Action Alternative.

4.6 SPECIAL STATUS SPECIES

Actions that adversely affect Federally listed species are considered significant if the effects cannot be minimized to a level that avoids jeopardy. TPWD regulations prohibit the taking, possession, transportation, or sale of any of the animal species designated by state law as endangered or threatened without the issuance of a permit. Actions that result in substantial adverse effects on state-listed species, such that local populations become unsustainable or extirpated, would be considered significant.

The MBTA made it illegal for people to "take" migratory birds, their eggs, feathers, or nests. Take is defined in the MBTA to include, by any means or in any manner, any attempt at hunting, pursuing, wounding, killing, possessing or transporting any migratory bird, nest, egg, or part thereof. Actions which result in substantial take of migratory birds, their eggs, or nests; such that local populations become unsustainable or extirpated, would be considered significant.

4.6.1 No Action Alternative

Under the No Action Alternative, adverse effects on special status species would be less than significant. Grazing at any stocking rate is not likely to adversely affect special status species that are suspected to be transient at Fort Hood, including, Whooping cranes, Peregrine Falcons, Piping Plover, Interior Least Tern, and Bald Eagle. The Timber Rattlesnake, which prefers wooded habitats, is also not likely to be affected by stocking rates, but could be adversely affected if damaging fires occur in woodland areas as a result of excessive accumulation of fuels. Continued grazing is not likely to impair aquatic life use of Belton Lake and is consequently not likely to affect the suitability of habitats for bald eagles. The Texas horned lizard, which prefers low vegetative cover, could benefit from the effects of continued grazing on vegetative cover. Any species that have not been recorded in Fort Hood or the vicinity will not be discussed. The likelihood of a special status species occurring in or near Fort Hood is discussed in Section 3.8.

The troglobite fauna in Fort Hood such as the possible Kretschmarr Cave-Mold Beetle would not be affected by current stocking rates. This species may inhabit caves in Fort Hood, although this is very unlikely considering they are currently understood to be restricted to less than 10 caves in Travis County. The primary threat to these species is disturbances which occur within caves or other karst features. Caves and karst features (i.e., landscape formed by layers of soluble bedrock) on Fort Hood have been identified and are protected from human disturbance. Substantial increases in erosion rates that result in deposition of sediments within karst features or substantial increases in woody cover that result in increased evapotranspiration and reduce water flows could adversely affect these species. These impacts are not likely to be substantial with continued stocking at current levels.

At least one state-listed freshwater mussel occurs near Fort Hood, and one other freshwater mussel may also be found on the installation. These mussels are adversely affected by activities that lead to excessive sedimentation or adversely affect water quality. Although cattle grazing can contribute to both sedimentation and water pollution, grazing at sustainable stocking rates can substantially reduce these impacts. Efforts to allow growth of riparian buffers along tributaries and streams, and other land management practices that reduce erosion, help to reduce both sediment and pollutant loads carried into streams by surface runoff. These impacts are not likely to be substantial with continued stocking at current levels.

Migratory birds would continue to be adversely affected by the No Action Alternative. Migratory birds utilize grassland, shrubland, and woodland communities depending on the species and resource use (i.e., nesting or foraging). The effects of cattle grazing and other land management practices would sustain a mixture of these habitat types across the Installation. Grazing and other land management practices would continue to affect the cover conditions of grassland habitats; however, these habitats are not likely to be substantially degraded such that it affects the status of any migratory bird. Cattle can also affect migratory bird populations by attracting brown-headed cowbirds, which parasitize the nests of other species. Adverse impacts on migratory birds would not result in take such that population levels become unsustainable and would not be significant.

One Federally listed species, the Golden-Cheeked Warbler (S. *chrysoparia*) is affected by grazing at any stocking rate because the presence of cattle attracts brown-headed cowbirds. The golden-cheeked warbler and black-capped vireo are both adversely affected by cowbird brood parasitism. As discussed in Section 5.0, the cumulative effects of past and present actions have affected these Federally listed species. The effects of grazing on the Installation, including the effects of brown-headed cowbird parasitism, are assessed in the Fort Hood ESMP (Fort Hood 2019). Fort Hood implements the reasonable and prudent measures to promote the recovery of the two species on the Installation, which include limiting cowbird parasitism to less than or equal to 10 percent, as described in the USFWS's (2015) Biological Opinion of Fort Hood's ESMP. The adverse effects of grazing on golden-cheeked warblers and black-capped vireos would continue at current levels, would not affect the status of the species, and would be less than significant.

4.6.2 Alternative 2 – 25% Harvest Efficiency

As described under the No Action Alternative, light to moderate stocking rates are not likely to substantially affect the suitability of habitats utilized by special status species on Fort Hood, and Alternative 2 is not likely to significantly adversely affect most special status species. There is potential that implementing this alternative could adversely affect the recovery of grassland and other habitats within the two Western Manuver GMUs because of the increased stocking rate over the No Action. This could result in a reduction in these available habitats, although it is not anticipated that the increase in stocking rates would result in a long-term loss of diversity or extirpation of the species from the Installation.

The Smooth Pimpleback is a Federal candidate, but is likely to no longer be a candidate species for listing under the ESA that is currently affected by grazing on Fort Hood. Although these impacts are less than significant, the Army would monitor their listing status and consult with the USFWS if these species become listed in the future. Grazing would continue to attract brown-headed cowbirds and result in parasitism of migratory and Federally listed birds, specifically, the golden-cheeked warbler. However, the rate of parasitism would continue to be monitored and controlled in compliance with the 2015 BO which authorizes grazing under the Endangered Species Management Program. If cowbird parasitism or other adverse impacts to federally-listed species exceed the amount assessed in the 2015 BO, the Army would reinitiate consultation with the USFWS pursuant to the ESA. Therefore, Alternative 2 is not likely to adversely affect Federally listed species.

4.6.3 Alternative 3 – Combination Strategy

Alternative 3 would have similar adverse and beneficial effects to special status species as described in the No Action Alternative. This alternative has a lower overall stocking rate than under the No Action Alternative, meaning there are likely to be less cumulative impacts to special status species. Grazing would continue to disturb habitat utilized by resident and migratory species, but this alternative is not likely to significantly affect the existence or habitat suitability of special status species.

4.6.4 Alternative 4 – Modified Combination Strategy

Alternative 4 would have similar, if not identical effects to special status species as described for the No Action Alternative. This is because these alternatives share the same overall stocking rate, meaning any minor changes in GMU stocking rates are not likely to significantly alter effects to special status species already experienced with existing stocking rates.

4.7 CULTURAL RESOURCES

Cultural resources are subject to review under both Federal and state laws and regulations. The National Historic Preservation Act (NHPA) of 1966 (16 USC 470, as amended) requires the assessment of effects through consultation with the Advisory Council on Historic Preservation. Under Section 106 of the NHPA, consultation with the State Historic Preservation Officer

(SHPO) is required for all Federal actions. The Archaeological Resources Protection Act of 1979 prohibits the excavation, removal, damage, or other alteration or defacing of archaeological resources located on public lands. Fort Hood maintains an informal agreement with the Tonkawa and Comanche tribes regarding the treatment of human remains under the NAGPRA. A significant impact on cultural resources would occur if resources that are eligible for listing on the NRHP are substantially degraded such that they would no longer be eligible for listing.

4.7.1 All Alternatives

Impacts to Cultural Resources would remain not significant. Trampling and erosion from cattle do not typically affect any cultural resources and are comparable, if not less than, the impacts already experienced from tracked-vehicle use. In areas of particular concern, a best management practice to avoid any impacts to important cultural resources will be implemented. The highest stocking rate is 2,338 AUs, under Alternative 2, which is not great enough to significantly impact cultural resources.

4.8 SOCIOECONOMICS

An action would result in significant impact if it causes a permanent population increase beyond the capacity of existing and projected infrastructure and public services, causes the vacancy rate for housing to fall, requiring relocation of existing people, construction of replacement housing elsewhere, or relocation of housing or businesses, or causes a reduction in local income that would affect the surrounding city or county budgets through loss of tax revenue.

There are no significant social impacts due to any of the proposed alternatives.

No impacts related to any of the proposed alternatives are expected to affect environmental justice populations or children since individual resource area impacts described throughout this chapter do not disproportionately affect minority or low-income populations or children. Economic impacts will not be disproportionate because the action affects only a small proportion of regional farm production costs incurred by all producers.

Because economic impacts are evaluated at a regional level, not upon the associated individuals, the most notable economic impacts related to the grazing outlease program are likely to occur under Alternative 3, Combination Strategy, which would decrease the stocking rate by about 25%. Reductions in the stocking rates could affect income and profit for members of the CTCA, but these adverse effects would not extend to the agricultural sector of the economy as a whole and would not be significant. The stocking rate under the No Action and Alternative 4 would remain the same as the existing condition and implementation of Alternative 2 could realize a slight increase for CTCA members, but not of an amount that would significantly contribute to the overall regional economy.

4.9 AESTHETICS AND RECREATION

Significant effects on aesthetics occur when an action results in substantial loss or degradation of the visual qualities of the landscape that are valued by the local culture. Significant effects on aesthetics of rangelands on Fort Hood would include large areas of denuded and eroding soil or substantial encroachment of woody species and loss of grassland vistas.

Significant effects on recreation occur when recreational opportunities are lost or their value is substantially degraded. As discussed in Section 3.9, recreational opportunities on Fort Hood generally consist of hunting, fishing, and water sports on Lake Belton.

4.9.1 No Action Alternative

Under the No Action Alternative, there would be no anticipated change from the existing condition.

4.9.2 Alternative 2 – 25% Harvest Efficiency

Alternative 2 would have similar beneficial and adverse effects to the No Action Alternative, with the possibility of higher adverse impacts considering this alternative has an overall gain of 338 AUs. A higher stocking rate could mean more erosion due to trampling, grazing, and reduced soil stability, which in turn could affect the surrounding natural features such as water bodies and their visual qualities. The increase in AUs is however, not likely to result in a vast increase in adverse effects overall; the only area that may be of concern is the Western Maneuver Area – North since it sees a change from 320 AUs in the No Action Alternative to 749 AUs in Alternative 2. Effects on recreation would be comparable, if not marginally higher than, the No Action alternative.

4.9.3 Alternative 3 – Combination Strategy

Alternative 3 would have similar beneficial and adverse effects to the No Action Alternative, with the possibility of lower adverse impacts considering this alternative has an overall decrease of 466 AUs. A decrease in stocking rates could translate to less erosion due to trampling and grazing, which in turn could provide more beneficial effects to the GMUs. As stated in sections 4.2 and 4.5, moderate grazing can help maintain grasslands, and therefore the visual quality of the land. Effects on recreation would be comparable, if not marginally higher than, the No Action alternative.

4.9.4 Alternative 4 – Modified Combination Strategy

Alternative 4 would have nearly identical beneficial and adverse effects to the No Action Alternative; this is because they share the same AUs overall, whereas Alternative 4 only has minor variations in stocking rates in GMUs. Aesthetics and recreation are likely to experience the same beneficial and adverse effects as described in the No Action Alternative.

4.10 UTILITIES AND TRANSPORTATION

Significant impacts on utilities would occur when an action results in increased use beyond existing or planned capacity or when an action results in reduced access to or availability of utilities. Utilities-based effects would also occur as a result of extending utilities into previously undeveloped areas. Grazing would not increase use or availability of utilities and therefore have no impact under any alternative.

Significant impacts on transportation would occur when an action results in substantial delays or substantially affects safety.

4.10.1 No Action Alternative

Under the No Action Alternative, delays and collisions related to cattle on roadways would be similar to the existing condition and would not be expected to increase in the future. Accidents involving cattle would continue. Signs indicating the presence of cattle on the range and signs indicating locations of frequent crossings minimize the frequency of cattle- related incidents.

4.10.2 Alternative 2 – 25% Harvest Efficiency

Alternative 2 would have similar adverse effects to transportation as the No Action, except that an increase in the stocking rate in some GMUs could result in an increase in delays and collisions. All other GMUs would have stocking rates very close to the No Action and therefore would not be expected to have impacts that were measurably different than under the existing condition.

4.10.3 Alternative 3 – Combination Strategy

Alternative 2 would have similar, but less adverse impacts to transportation than the No Action Alternative considering there is an overall decrease in AUs.

4.10.4 Alternative 4 – Modified Combination Strategy

Alternative 4 would have identical impacts to the No Action Alternative; this is because the overall stocking rate is the same, with minor variations in individual stocking rates within GMUs.

4.11 NOISE

Noise would result in significant adverse effects when the level of noise damages hearing or creates a substantial nuisance or hazard to other activities. Suitable noise levels for the workplace, residential areas, and other designated places have been developed by the Office of Safety and Health Administration and the USEPA; however, noise levels outside the workplace are typically regulated by local government agencies.

Although grazing occurs near residential areas and other noise sensitive locations on and around the Installation, grazing does not contribute to noise levels above ambient conditions; this, there would be no adverse effects on noise if any alternative is implemented.

4.12 HAZARDOUS MATERIALS AND WASTE

Through the RCRA and the CERCLA, the USEPA has developed guidelines for the safe treatment, storage, and disposal of hazardous materials and wastes. Grazing would not result in the treatment, storage, or disposal of hazardous materials or wastes; thus, there would be no adverse effects from these substances occurring as a result of any alternative.

5.0 CUMULATIVE EFFECTS

5.1 IDENTIFICATION OF CUMULATIVE EFFECTS ISSUES

The CEQ defines cumulative effects as "the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions" (40 CFR 1508.7). This section continues, "Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time."

In Section 4.0, this EA identified several resources which would not be affected by the Preferred Alternative: utilities, noise, and hazardous materials and waste. Although other actions would affect these resources, the Preferred Alternative (Alternative 4) would not affect these resources; therefore, there would be no cumulative effects. For the remaining resources addressed in Section 4.0, adverse effects were assessed as minimal and some resources would be beneficially impacted.

5.1.1 Land Use

Land use on Fort Hood has changed to meet the requirements of an evolving military training Installation. As training activities have changed, so have cattle management strategies. These two components have interactively and cumulatively affected land use. As training methods evolve, action areas experience change, and stocking rates must then be adjusted to avoid substantial adverse impacts. The most recent training development plan involves the construction and modification of Installation ranges and is summarized below:

- The 10-year range development plan began in 2010 and includes the construction and modification of 24 ranges within the LFIA and their associated facilities to support changing military training standards. Each project has a specific year associated with its construction. Best Management Practices (BMP) will be followed which utilize stormwater runoff mitigation and low-impact development techniques (Hoganwood 2011).

Stocking rates in the LFIA would not change under any of the alternatives assessed in this EA, including the No Action Alternative, and the range development plan would have a limited effect on forage availability. The use of controlled burns, brush removal and control, and other BMPs would continue to have beneficial effects on the value and sustainability of the landscape for military training.

5.1.2 Water, Soils, and Air

The Hill Country of Central Texas has experienced significant declines in water quality, stream and river geomorphology, and soil stability. On Fort Hood training areas, this combined and cumulative degradation affects the predominantly clayey soils, causing sedimentation in adjacent streams (Cowhouse Creek, Nolan Creek, etc.), consequently affecting Belton Lake and Leon River. These large downstream bodies of water also draw runoff and associated pollutant loads from the adjacent Cities of Killeen, Harker Heights, Belton, and Temple. These declines adversely affect riparian and aquatic environments, and consequently human communities. This degradation can be historically attributed to early cattle management practices, invasive species introduction, and inadequate wastewater treatment facilities. These historic effects have experienced remediation/monitoring from several government-funded programs including, but not limited to, the following:

- The Installation Restoration Program (IRP), established in 1975 to provide guidance and funding for the investigation and remediation of hazardous waste sites caused by historic disposal activities at military Installations.
- The Soil Erosion Inventory compiled in 1998 by Fort Hood and the NRCS to determine erosion tolerance levels on the Installation.
- The Soil Erosion Survey and Rangeland Health study conducted in 2001 through 2002 and 2004 to determine rangeland health and soil stability.
- The TCEQ conducts ongoing water quality surveys producing impairment data which can be used to produce mitigation and quality improvement protocols.

Proposed, present, and future projects which include mitigation efforts and water quality improvement projects are summarized below:

- The Tank Trail Maintenance project improves over 400 miles of tank trails present on Fort Hood. These trails experience significant degradation due to intensive use. Maintenance is required to prevent erosion, sedimentation, and runoff that can impair Cowhouse Creek and consequently Belton Lake or Leon River (Hoganwood 2011).
- The Maneuver Access Structure Program proposal would initiate the Installation of maneuver structures commonly referred to as "gully plugging". These Installations fall under Integrated Training Area Management (ITAM) and reduce sediment influx to Lake Belton which is attributed to constant tank maneuvering. These Installations consist of the placement of rock structures over seasonal water drainages. This slows runoff during heavy precipitation and reduces erosion and consequently sedimentation (Hoganwood 2011).
- Wastewater treatment infrastructure developments at Fort Hood and surrounding cities are in progress or in planning and will meet the demands of a growing population.

All future projects occurring on the Fort Hood Installation have associated contamination risks involving the handling of fuels, oils, volatile organic compounds, and hazardous materials and will be avoided or minimized by use of BMPs. Compliance with wastewater treatment regulations and integration into the current wastewater treatment system will likely be required; thus, any future cumulative effects would be minimized. Current wastewater treatment projects would markedly reduce municipal runoff levels, effectively allowing for natural vegetative filtration to resolve impairments over time.

A large portion of Fort Hood training acreage is considered highly susceptible to erosion (see Figure 3-3). In erosion areas already bare from previous soil activities such as the Western Maneuver Area, overgrazing effects are exacerbated by military vehicle maneuvering. Loss of perennial vegetative cover as a result of heavy training maneuvers has resulted in annual woody encroachment and high erosion rates. These degraded soil communities would stabilize given the combined effects of a residual biomass maintenance program and ongoing revegetation measures to prevent grassland and streamside erosion. A project has been proposed to remove woody plants and brush so that healthy grassland communities which support training operations will return. This project is summarized below:

The U.S. Army, Headquarters III Corps and Fort Hood propose to perform woody species management throughout the western maneuver training areas. The area encompasses the entire west side of the Installation. It is located in both Bell and Coryell counties, although the majority of the area lies within Coryell County. The project footprint is approximately 67,000 acres. The estimated amount of Ashe juniper and mesquite to be removed is approximately 3,000 acres (Hoganwood 2011).

Prior to any vegetation removal, coordination between Directorate of Public Works Natural Resources staff, Range Control, Integrated Training Area Maintenance, and the contractor's staff who would perform the maintenance would occur. The addition of riparian buffer zones in current and future project BMPs will also promote the restructuring of deep and complex root systems which prevent soil loss and stream sedimentation. When combined with the Proposed

Action, the woody species management plan would minimize any cumulative erosion issues through the moderation of grazing activity throughout the Installation.

5.1.3 Vegetation

Central Texas Hill Country grasslands and cross-timbers have historically been altered by several additive and cumulative factors, including poor cattle management during European settlement, an overpopulation of white-tailed deer, and Ashe juniper expansion. In many places, continuous overgrazing and fire suppression has reverted the cross-timber and mid- grass dominant ecosystem to patches of mid-grass separated by large areas of bare soil and short-grass. White-tailed deer over-browsing has affected plant diversity while hoof trails have eroded soil and diverted overland water flow. The expansion of Ashe juniper has substantially lowered the floral species diversity.

During the early decades of the Installation’s history, extensive sodding and seeding of large areas for training purposes added to these stress factors, causing further alteration of vegetation structure. Soil compaction and erosion from both training exercises and cattle movement have been primary factors contributing to these alterations. In recent history, monitoring projects have been initiated in an effort to understand the scope of change in the interest of mitigation. These projects are noted below:

- The Fort Hood Vegetative Resource Inventory (1998)
- The Fort Hood Vegetation Survey Project (2002)
- The study involving tolerance of switchgrass to tracked vehicle disturbance (ongoing)

As a result of these monitoring efforts, Fort Hood has proposed a project to perform maintenance in the form of woody species management (small tree and brush removal) from the entire Western Maneuver Area, which encompasses 67,000 acres on the west side of the Installation, over 10 years.

The Proposed Action, when combined with BMPs involved in the aforementioned project, would give grass time to grow, and reduce the overall impacts on the environment. Therefore, the cumulative effects on the environment under the GMPs assessed in this EA would be less than significant.

5.1.4 Special Status Species

Cumulative impacts on fauna are determined to be significant using standards similar to those used for assessing traditional impacts (See Section 4.2). However, the temporal aspect holds greater weight during cumulative impact analysis due to both a larger time scale (past, present, and future projects), and a capacity for rapid change within native wildlife populations in any given season. In order to preserve current population levels and establish buffers against large-scale and unpredictable events (wildfire, drought, flooding, etc.), the health of any individual species population must be directly tied to range health (i.e, soil, vegetation, water) and its ability to sustain at least current levels of abundance and species richness.

The main species of concern present on Fort Hood is the Federally endangered golden-cheeked warbler. The largest threats to this species, which can be mitigated by Fort Hood activities, are habitat alteration and removal and nest parasitism by brown-headed cowbirds. Projects buffering and preserving the riparian habitats which are frequented by this species have been outlined in previous sections; however, historic and ongoing projects involving parasitic species control have proven effective and can cumulatively interact with proposed action alternatives to avoid or minimize adverse effects:

- A cowbird trapping and shooting program began in 1988 and has since lowered rates of parasitism and consequently raised abundance levels of both endangered passiforms (Hayden et al. 2001).
- The Maneuver Access Structure Program proposal outlined in Section 5.1.2 preserves riparian ecosystems through the prevention of erosion and sedimentation which affects local riparian ecosystems as it is transported to larger permanent water bodies.

Rates of cowbird parasitism would be maintained at rates less than or equal to 10 percent under each alternative assessed in this EA; therefore, adjustment of stocking rates would not result in a change in the effects of grazing on warblers or vireos. Improved riparian ecosystem management would improve habitat for these species, thereby, further minimizing or avoiding adverse effects on these species.

7.0 REFERENCES

Ackerman, C.J., J. Sumner, and T.R. Shirley. Estimation of Forage Mass Using a Visual Obstruction Technique. 2001. Proceedings, Western Section, American Society of Animal Science, Vol. 52, 2001.

Anders, A. D., and D.C. Dearborn. 2001. Population trends of golden-cheeked warblers on Fort Hood from 1992-2001. The Southwestern Naturalist 49(1):39-47.

Andres, B.A., K.L. Stone. 2009. Conservation Plan for the Mountain Plover (Charadrius montanus). Version 1.0. Manomet Center for Conservation Sciences. Manomet, Massachusetts.

Ashworth, J.B. and J. Hopkins. 1995. Aquifers of Texas. Texas Water Development Board Report 345. Texas Water Development Board. Austin, Texas.

Audubon. 2019a. Audubon Guide to North American Birds. Available at: https://www.audubon.org/field-guide/bird/wood-stork

Audubon. 2019b. Audubon Guide to North American Birds. Available at: https://www.audubon.org/field-guide/bird/zone-tailed-hawk

Bell County Water Control and Improvement District (BCWID) #1. 2011. About Us. Available at: www.wcid1.org/aboutus.html.

Bock, C.E., J.H. Bock, W.R. Kenney, and V.M. Hawthorne. 1984. Responses of Birds, Rodents, Vegetation to Livestock Enclosures in a Semidesert Grassland. Journal of Range Management, 37:239-242.

Brown, D.E. 1978. Grazing, grassland cover, and gamebirds. Forty-third North American Wildlife Conference, 43:477-485.

City of Austin. 2019. Wildland Caves. Austin Water Utility. Available at: http://www.austintexas.gov/page/wildland-caves

Cornelius, J.D., T.J. Hayden, P.A. Guertin. 2007. Endangered Species Management Plan for Fort Hood, Texas: FY06-10. ERDC/CERL TR-07-11. Construction Engineering Research Laboratory, U.S. Army Engineer Research and Development Center. Champaign, Illinois.

Crider, F. J. 1955. Root Growth Stoppage Resulting from Defoliation of Grass. USDA Soil Conservation Service Technical Bulletin 1102.

Davenport, D.W., D.D. Breshears, B.P. Wilcox, and C.D. Allen. 1998. Viewpoint – sustainability of pinon-juniper ecosystems - a unifying perspective of soil erosion thresholds. Journal of Range Management, 51(2):231-40.

Department of Public Works (DPW). 2011. Email from Kimberly Musser concerning current and future projects on the Fort Hood Installation. January 31, 2011.

Fenneman, N.M., D.W. Johnson. 1946. Physiographic divisions of the conterminous U.S. USGS. Washington, DC.

Fort Hood. 2009a. Fort Hood Overview. Fort Hood Fact Sheet No. 0703. Prepared by Fort Hood Public Affairs Office. August 19, 2009. Available at: www.hood.army.mil.

Fort Hood. 2009b. Fort Hood Integrated Natural Resources Management Plan. Fort Hood Military Reservation, Killeen, Texas.

Fort Hood USA. 2011. Fort Hood – As Seen From Austin. Available at: FortHoodUSA.org Hammer, M. 2011. Personal Communication/Comment on Draft EA

Hanselka, C.W., L.D. White, and J.L. Holechek. 2001a. Using Forage Harvest Efficiency to Determine Stocking Rate. Texas A&M System Extension, AgriLife Communications and Marketing. Publication E-128. Available at: AgriLifebookstore.org

Hanselka, C.W., L.D. White, and J.L. Holechek. 2001b. Managing Residual Forage for Rangeland Health. Texas A&M System Extension, Rangeland Risk Management for Texans. Publication E-127. Available at: AgriLifebookstore.org

Hassan-Williams, C., and T.H. Bonner. 2011. Texas Freshwater Fishes. Texas State University – San Marcos, Department of Biology. San Marcos, Texas. Available at: http://www.bio.txstate.edu/~tbonner/txfishes/

Hayden, T.J., J.D. Cornelius, H.J. Weinberg, L.L. Jette, and R.H. Melton. 2001. Endangered Species Management Plan for Fort Hood, Texas, FY01-05. Prepared by U.S. Army Corps of Engineers, Environmental Research and Development Center (ERDC)/CERL TR-01-26.

Heitschmidt,R., K.D. Sanders, E.L. Smith, W.A. Laycock, G.A. Rasmussen, Q.D. Skinner, F.C. Hall, R. Lindenmuth, L.W. Van Tassell, J.W. Richardson, R.R. Fletcher, G.W. Borden,

T.R. Harris, D.T. Taylor, B.R. Moline, and W.C. Krueger. 1998. Stubble Height and Utilization Measurements: Uses and Misuses. SB 682-E. Western Regional Resarch. Albany, California.

Hoganwood, K. 2011. Email detailing current and future projects with direct impact on the Fort Hood training areas. Kim Hoganwood is a NEPA Specialist with the Department of Public Works at Fort Hood.

Klute, D.S., L.W. Ayers, M.T. Green, W.H. Howe, S.L. Jones, J.A. Shaffer, S.R. Sheffield, and

T.S. Zimmerman. 2003. Status Assessment and Conservation Plan for the Western Burrowing Owl in the Unites States. U.S. Department of Interior, Fish and Wildlife Service, Biological Technical Publication FWS/BTP-R6001-2003, Washington, D.C.

Loomis. 2010. Draft Mammal Species of Concern. Southern Edwards Plateau Habitat Conservation Plan. Project No. 080801. Austin, Texas. Available at: www.sephcp.com

Menke, J.W. 1992. Grazing and Fire Management for Native Perennial Grass Restoration in California Grasslands. Fremontia, A Journal of the California Native Plant Society, 1992, Volume 20(2):22-25.

National Climate Data Center. 2008. Freeze/Frost Maps. Available at: www.ncdc.noaa.gov/oa/climate/freezefrost/frostfreemaps.html

National Park Service (NPS). 2011. Main.xlsx. Available at: http://nrhp.focus.nps.gov/natreg/docs/Download.html

Natural Resources Conservation Service (NRCS). 1998. Fort Hood Vegetative Resources Inventory. U.S. Department of Agriculture, NRCS

NRCS. 1999. Natural Resources Conservation Service, National Soil Survey Handbook. Title 430-VI. U.S. Government Printing Office. Washington, D.C.

NRCS. 2002a. Final Report to Fort Hood Texas Presenting Findings from the 2001 Soil Erosion Project, the 2001 Rangeland Health Project, 2001 Vegetation Monitoring Project with Presentation of Management Alternatives. U.S. Department of Agriculture, Natural Resources Conservation Service. Gatesville, Texas.

NRCS. 2002b. Final Report to Fort Hood, Texas Presenting Findings from The 2002 Vegetation Survey Project. U.S. Department of Agriculture, Natural Resources Conservation Service. Gatesville, Texas.

NRCS. 2009a. Soil Survey Geographic (SSURGO) database for Bell County, Texas. USDA, NRCS. Fort Worth, Texas.

NRCS. 2009b. Soil Survey Geographic (SSURGO) database for Coryell County, Texas. USDA, NRCS. Fort Worth, Texas.

NRCS. 2010. Texas. From National Hydric Soils List by State. Available at: soils.usda.gov/use/hydric

Nickens, P. 1990. Impacts of Domestic Livestock Grazing on Archeological Resources. In The Archeological Sites Protection and Preservation Notebook: Technical Notes. U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Nielsen-Gammon, J. 2011. Climate of Texas. Office of the State Climatologist Publications. Office of the State Climatologist, Texas A&M University Texas. College Station, Texas. Available at: http://atmo.tamu.edu/osc/library/osc_pubs/

Office of Texas State Climatologist. 2011a. Texas Normals, Means, and Extremes: Waco. Provided by National Climate Data Center. Office of the State Climatologist, Texas A&M University Texas. College Station, Texas. Available at: http://atmo.tamu.edu/osc/norm/

Office of Texas State Climatologist. 2011b. Texas Climate Bulletins: 2005, 2006, 2007, 2008, 2009, 2010. Office of the State Climatologist, Texas A&M University Texas. College Station, Texas. Available at: http://atmo.tamu.edu/osc/tx/

Osburn, A., S. Vetter, R. Hartley, L. Walsh, and J. Brown. 1987. Impacts of Domestic Livestock Grazing on the Archeological Resources of Capitol Reef National Park, Utah. Midwest Archeological Center. Occasional Studies in Anthropology No. 20.

Predick, K. and S. Archer. 2009. PS 64: Does livestock grazing promote woody plant encroachment in drylands? 94th Ecological Society of America Annual Meeting.

Reinecke, R., R. Conner, and A.P. Thurow. 2011 Economic Considerations in Ashe Juniper Control. Texas Natural Resources Server. Texas AgriLife Research and Extension Center. College Station, Texas.

Sankey, T.T. 2007. Woody-Herbaceous-Livestock Species Interaction. Annals of Arid Zone, 46(2):1-28.

Seaber, P.R., F.P. Kapinos, and G.L. Knapp. 1994. Hydrologic Unit Maps. USGS Water Supply-Paper 2294. USGS. Denver, Colorado.

Smeins, F.E., and S.D. Fuhlendorf. 2011. Biology and Ecology of Ashe Juniper. Texas Natural Resources Server. Texas AgriLife Research and Extension Center. College Station, Texas.

Stevens, R. 2004. Fuel Loading, Fuel Moisture are Important Components of Prescribed Fire. Ag News and Views: January 2004. The Samuel Roberts Noble Foundation. Available at: www.noble.org/Ag/news_views/.

Texas Commission on Environmental Quality (TCEQ). 2010a. Draft 2010 Texas 303(d) List (February 5, 2010). Available at: www.tceq.texas.gov.

TCEQ. 2010b. Draft 2010 Texas Water Quality Inventory – Sources of Impairments and Concerns. Available at www.tceq.texas.gov.

Texas Parks and Wildlife Department (TPWD). 2009a. GIS Lab Map Downloads. Available at: www.tpwd.state.tx.us/landwater/land/maps/gis/map_downloads.

TPWD. 2009b. Wildlife Facts Sheets. TPWD. Austin, Texas. Available at: http://www.tpwd.state.tx.us/huntwild/wild/species/.

TPWD. 2010a. Bell County. TPWD Annotated County Lists of Rare Species. Available at: http://gis.tpwd.state.tx.us/TpwEndangeredSpecies/DesktopDefault.aspx.

TPWD. 2010b. Coryell County. TPWD Annotated County Lists of Rare Species. Available at: http://gis.tpwd.state.tx.us/TpwEndangeredSpecies/DesktopDefault.aspx.

TPWD. 2013. Peregrine Falcon. Texas Parks and Wildlife Species Fact Sheet. Available at: https://tpwd.texas.gov/publications/pwdpubs/media/pwd_bk_w7000_0013_peregrine_falcon.pdf

TPWD. 2019a. Houston Toad. Texas Parks and Wildlife Species Fact Sheet. Available at: https://tpwd.texas.gov/huntwild/wild/species/htoad/

TPWD. 2019b. Timber Rattlesnake. Texas Parks and Wildlife Species Fact Sheet. Available at: https://tpwd.texas.gov/huntwild/wild/species/timberrattlesnake/

TPWD. 2019c. White Faced Ibis. Texas Parks and Wildlife Species Fact Sheet. Available at: https://tpwd.texas.gov/huntwild/wild/species/ibis/

Thurow, T.L., W.H. Blackburn, and C.A. Taylor Jr. 1988. Some Vegetation Responses to Selected Livestock Grazing Strategies, Edwards Plateau, Texas. Journal of Range Management, 41(2): 108-114.

Thurow, T.L. 1990. Soil Compaction Evaluation at Fort Hood: Annual Report. Department of Range Science, Texas A&M Univ. Contract#DACA88-89-M-1249.

Thurow, T.L., S.D. Warren, and D.H. Carlson. 1993. Tracked vehicle traffic effects on the hydrologic characteristics of central Texas rangeland. Am. Soc. Agric. Eng., 36:1645- 1650.

TMPC. 2018. Texas Military Preparedness Commission – Fort Hood – Killeen, TX. Office of the Governor. Available at: https://gov.texas.gov/uploads/files/organization/military/2018Hood.pdf

Trimble, S.W., and A.C. Mendel. 1995. The cow as a geomorphic agent - A critical review. Geomorphology, 13:233-53. United States (US) Department of the Army (Army). 1995. United States Army Cultural Resource Management Plan for Fort Hood, Texas, Fiscal Years 1995 through 1999.

Tronstad, R., G. Royle, J. Sprinkle. 2001. RUSLE Applications on Arizona Rangelands. Arizona Ranchers' Management Guide. Arizona Cooperative Extension. Available at: http://ag.arizona.edu/arec/pubs/rmg/1%20rangelandmanagement/11%20rusle01.pdf.

U.S. Army. 1999a. Memorandum - Army Regulatory Guidance for Reimbursable Agricultural/Grazing and Forestry Programs; Assistant Chief of staff for Installation Management, Department of Army.

U.S. Army. 1999b. Management Plan for Treatment of National Register-Eligible Prehistoric Sites on Fort Hood, Texas. Review Draft. Prepared by Prewitt and Associates, Inc., Boyd, D.K., G. Mehalchick, and A.M. Scott for Cultural Resource Management Program.

U.S. Army Corps of Engineers (USACE). 1999. Department of the Army Headquarters III Corps and Fort Hood Environmental Baseline, Fort Hood, Texas. USACE, Fort Worth District. Fort Worth, Texas.

USACE. 2003. Final Supplemental Environmental Assessment for Grazing Outlease at Fort Hood, Texas. December 2003. USACE, Fort Worth District. Fort Worth, Texas.

USCB. 2016. Geography Area Series: County Business Patterns by Employment Size Class. United States Census Bureau. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=BP_2016_00A3&prodType=table

USCB. 2017a. INCOME IN THE PAST 12 MONTHS (IN 2017 INFLATION-ADJUSTED DOLLARS) 2013-2017 American Community Survey 5-Year Estimates. United States Census Bureau. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_S1901&prodType=table

USCB. 2017b. COMPARATIVE ECONOMIC CHARACTERISTICS 2013-2017 American Community Survey 5-Year Estimates. United States Census Bureau. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=ACS_17_5YR_CP03&prodType=table

USCB. 2018a. Annual Estimates of the Resident Population: April 1, 2010 to July 1, 2018. United States Census Bureau. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2018_PEPANNRES&prodType=table

USCB. 2018b. Estimates of Resident Population Change and Rankings: July 1, 2017 to July 1, 2018 - State -- County / County Equivalent. United States Census Bureau. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2018_PEPANNCHG.ST05&prodType=table

USCB. 2018c. Annual Estimates of the Resident Population by Sex, Race, and Hispanic Origin for the United States, States, and Counties: April 1, 2010 to July 1, 2018. United States Census Bureau. Available at: https://factfinder.census.gov/faces/tableservices/jsf/pages/productview.xhtml?pid=PEP_2018_PEPSR6H&prodType=table

U.S. Department of Agriculture (USDA). 1997. National Range and Pasture Handbook. Washington, D.C.

USDA. 2017. Census of Agriculture. 2017 State and County Profiles – Texas. National Agricultural Statistics Service. Available at: https://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/County_Profiles/Texas/

USDA. 2009. 2007 Census of Agriculture: United States; Summary and State Data. AC-07-A-51. USDA, National Agricultural Statistics Service. Available at: www.agcensus.usda.gov.

U.S. Environmental Protection Agency (USEPA). 2003. National Management Measures to Control Nonpoint Source Pollution from Agriculture. EPA 841-B-03-004, July 2003. Available at: water.epa.gov/polwaste/nps/agriculture/agmm_index.cfm.

USEPA. 2010. The Green Book Nonattainment Areas for Criteria Pollutants. USEPA. Available at: www.epa.gov/air/oaqps/greenbk/index/.html.

USEPA. 2015. National Ambient Air Quality Standards (NAAQS). USEPA Office of Air Quality Planning and Standards. Available at: www.epa.gov/air/criteria.html.

USEPA. 2019. Texas Nonattainment / Maintenance Status for Each County by Year for All Criteria Pollutants. Green Book 2019. Available at: https://www3.epa.gov/airquality/greenbook/anayo_tx.html

U.S. Fish and Wildlife Service (USFWS). 1999. Memorandum of Understanding between USFWS, U.S. Army at III Corps and Fort Hood, Texas, Parks and Wildlife Department,

U.S. Department of Agriculture APHIS Wildlife Services, and Central Texas Cattlemen's Association. FWS Number: 1448-20181-99-K951.

USFWS. 2005. A Non-jeopardy Biological Opinion on the Military training and other Activities at the U.S. Army Fort Hood Military Reservation in Bell and Coryell Counties, Texas, and its Effects on the Endangered Golden-cheeked Warbler and Black-capped Vireo. USFWS, Arlington Ecological Services Field Office. Arlington, Texas.

USFWS. 2007. Black-capped Vireo (Vireo atricapilla). 5-Year Review: Summary and Evaluation. USFWS. Arlington, Texas.

USFWS. 2011a. Endangered Species List. Counties Selected: Bell, Coryell. USFWS, Southwest RegionEcological Services. Available at: www.fws.gov.southewst/es/EndangeredSpecies/lists.

USFWS. 2011b. 12-Month Finding on a Petition to List Texas Fatmucket, Golden Orb, Smooth Pimpleback, Texas Pimpleback, and Texas Fawnsfoot as Threatened or Endangered. 50 CFR 62166.

USFWS. 2011c. Species Profile for Golden-Cheeked warbler (Dendroica chrysoparia). Environmental Conservation Online System. Available at: www.ecos.fws.gov.

USFWS. 2011d. 5 Central Texas Mussels Distribution Maps. Southwestern Division. Available at: https://www.fws.gov/southwest/es/Documents/R2ES/5_central_Texas_mussels_Maps_2011.pdf

USFWS. 2015. Salado Salamander Monitoring Final Report. Peter Diaz, Mike Montagne, Randy Gibson. Available at: https://www.fws.gov/southwest/fisheries/txfwco/documents/Salado_Salamander_Monitoring_2015.pdf

USFWS. 2016. Sharpnose Shiner and Smalleye Shiner Fact Sheet. Arlington, Texas Ecological Services Field Office. Available at: https://www.fws.gov/southwest/es/ArlingtonTexas/pdf/Brazos%20Shiners%20Fact%20sheet%202016%20FINAL.pdf

Vermeire, L.T., A.C. Ganguli, and R.L. Gillen. 2002. A Robust Model for Estimating Standing Crop across Vegetation Types. Journal of Rangeland Management, 55:494-497, September 2002.

Webb, S.L., S.E. Henke. 2008. Effects of Military Training on Texas Horned Lizard, Phrynosoma cornutum, Occurrence on Fort Hood, Texas. The Texas Journal of Agriculture and Natural Resources, 21:43-49.

White, L.D. 1997. Do You Have Enough Forage? Texas A&M University System, Agricultural Communications. Publication L-5141. Available at: AgriLifebookstore.org.

White, L.D. and A. McGinty. 2007. Stocking Rate Decisions; Key to Successful Ranch Management. Publication E-152. Texas AgriLife Research and Extension Center. College Station, Texas.

Zara Environmental LLC. 2010. Draft Preliminary Assessment of Rare Mollusk Species of the Southern Edwards Plateau Habitat Conservation Plan Plan Area. Available at: www.sephcp.com.

8.0 Appendices

Draft

Fort Hood Grazing Analysis Report

Prepared for:

U.S. Army Corps of Engineers
Regional Environmental Planning Center
2000 Fort Point Road
Galveston, TX 77550

Date:

September 20, 2019

CYPRESS
Environment & Infrastructure

Table of Contents

I. Introduction

Cypress Environmental Services, LLC (Cypress) was contracted by the U.S. Army Corps of Engineers Regional Environmental Planning Center on behalf of Fort Hood Directorate of Public Works to produce an inventory of forage resources. The inventory involved on-the-ground studies of 70 predetermined sampling locations across Fort Hood and an analysis of the on-the-ground studies to determine recommended stocking rates based on estimates of forage biomass, erosion potential, and military training impacts. The forage inventory was accomplished with teams from Cypress and Freese and Nichols, Inc. between July 16, 2019 and July 22, 2019.

II. Methods

A. Field Surveys

70 sampling locations were identified for the 2019 Fort Hood Forage Analysis. In order to select the appropriate locations for each sampling point, Fort Hood requested that the current inventory reference the sampling locations identified in the 2005 vegetation survey conducted by Texas A&M University and the 2010 Grazing Outlease Management Plan conducted by Gulf South Research Corporation. A meeting with Tim Buchanan, Chief of Natural and Cultural Resources at Fort Hood, was held on July 16, 2019 to confirm the location of each sampling point.

The 2005 vegetation survey included 131 predetermined sampling locations located throughout Fort Hood that were previously used in a 2004 vegetation survey conducted by the Center for Grazinglands and Ranch Management (CGRM) at Texas A&M University. The 2010 Grazing Outlease Management Plan included 77 sampling locations that were divided proportionately between each grazing management unit (GMU) based on the percentage of area of each soil type in the GMUs.

Both surveys were referenced to determine the 70 sampling locations for the 2019 inventory. The sampling locations were randomly selected and divided proportionately among the GMUs. Table 1 shows the number of sampling locations within each GMU.

Table 1: Number of sampling locations within each GMU for 2019 analysis

GMU	Number of sampling locations
Western Maneuver Area – North	20
Western Maneuver Area – South	20
Eastern Training Area – North	8
Eastern Training Area – South	7
West Fort Hood – North West	2
West Fort Hood – North East	3
West Fort Hood – South	9
North Fort Hood	1

Sampling locations in the Live Fire Area were not included within the scope of this inventory.

While conducting the forage analysis, Fort Hood Range Control communicated that Training Area 50 and Training Area 51 were inaccessible during the study window due to troop activities in the area. Training Area 50 and Training Area 51 contained seven sampling locations that were moved into adjacent training areas in the Western Maneuver Area – North and the Western Maneuver Area – South GMUs. These GMUs had the same soil associations as the original point locations. The U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) Web Soil Survey was referenced to confirm that each sampling location was moved to an adjacent area that contained the same soil association. The coordinates for the sample locations evaluated are shown in Appendix A and the sample locations are plotted on the map in Appendix B.

Cypress replicated the same procedure used for the 2005 vegetation survey conducted by CGRM at Texas A&M University (Appendix L). This included following procedures for double sampling contained in Chapter 4 of the USDA NRCS National Range and Pasture Handbook revised in 2003. At each sampling location, GPS coordinates were recorded, and 10 0.25-sq. meter sampling plots were measured at a 5-meter interval in a north direction from the GPS point. A double sampling procedure was used in which plants present within the plots were identified, harvested, and weighed in grams to determine appropriate weight units for each species. The weight units were then used at all plots to estimate the weight of each plant species (in grams) contained within each plot. At each sample location, weights for plants in all 10 plots were estimated and then two plots were clipped, weighed, and recorded to serve as a basis for evaluating estimated weights. A photo was taken in each cardinal direction to show an average view of the vegetation at close range (approximately 5 feet above ground) at the first plot at each sampling location. Sampling location photos can be seen in Appendix N.

B. Biomass Calculations

Estimates for percent air dry material are based on USDA NRCS guidelines presented in the National Range and Pasture Handbook (Exhibit 4-2). Two plots at each sample location were clipped and bagged. The clipped vegetation samples were placed in a drying oven at 65° C for 72 hours to obtain a dry weight. A conversion factor (0.9109) based on a comparison of over 500 'air dry to oven dry' plants was used to convert air dry estimated weights to oven dry weights. The conversion factor is the percent of air-dry weight that is oven dry weight. There was 8.91% moisture in the air-dry samples. Percent current growth estimates are based on knowledge of individual species growth habits in relation to the time of sampling. Weight in grams from the 0.25-sq. meter plots was corrected to pounds (lbs.) per acre. The average weight of the harvested plots from transects was used to derive a correlation coefficient for evaluating the accuracy of estimated weights. Based on the 2005 report, correction of the estimated data is not required if the r^2 value is 0.8 or higher. The correlation coefficient was below 0.8 (r^2=0.7927), therefore; each species was corrected based on the average percent difference between the harvested weight and estimated weight. Biomass calculations by species are presented in Appendix F and sampling location biomass calculations are presented in Appendix G.

III. Data Analysis

A. Stocking Rates

Biomass estimates were used to calculate a set of stocking rates for each GMU. The stocking rates presented in Appendix H are derived from four options for expressing animal units (AU) for the GMUs. All AU values are based solely on consumable vegetation identified in the survey. An AU is considered an average forage requirement of 26 lbs. of dry matter (oven-dry) per day or 9490 lbs. of dry matter per year. The following are the four stocking rate options:

1. Option 1 Harvest Efficiency: 25% of the available forage is consumed across the GMU. This is based on the premise that 50% of the forage present in a pasture shall be left ungrazed. Of the remaining 50%, cattle consume only 25% and drop about half (25 percent) of the grazed forage. This is based on the standard NRCS approach to determining amount of forage available for cattle.
2. Option 2 Maintenance Threshold: Only the volume of forage in excess of 750 lbs. per acre would be available for grazing across the GMU.
3. Option 3 Conservation Threshold: Only the volume of forage in excess of 1,000 lbs. per acre would be available for grazing across the GMU.
4. Option 4 Combination Strategy: Based on physical characteristics and use of the GMU using an approach where the most appropriate of the three thresholds above and the option to defer, if the ecological trend is predicted to be declining or erosion is predicted to be excessive, are assigned to specific areas within the GMU. The specific strategy selected for each unit will be based on best management strategies considering the condition of the range, other land uses for the unit, and the potential for direct conflicts with training activities.

According to the Performance Work Statement, a limit of 750 AUs was established in the Live Fire and Impact Areas to reduce live-fire training interruptions and delays. Based on the 2005 study, the AUs for the four options described above were calculated for each GMU not including the Live Fire Area using the following procedures.

1. Option 1 Harvest Efficiency is the consumable biomass for the grazeable acres in each management unit using a 25% harvest efficiency expressed in AU.
2. Option 2 Maintenance Threshold is based on 750 lbs. per acre threshold residue amount and was calculated based on the consumable biomass for the grazeable acres in each management unit. If forage was greater than 1,500 lbs. per acre, a 25% harvest efficiency was applied to determine the AU. If the forage was between 750 lbs. and 1,500 lbs. per acre, the threshold amount of 750 lbs. per acre was subtracted and a harvest efficiency of 50% was used on the remainder to determine the AU. If there were less than 750 lbs. per acre, 0 AU were determined.
3. Option 3 Conservation Threshold is based on a 1,000 lbs. per acre threshold residue amount and was calculated based on the consumable biomass for the grazeable acres in each management unit. If the forage was greater than 2,000 lbs. per acre, 25% harvest efficiency was used to determine the AU. If the forage was between 1,500 and 2,000 lbs. per acre, the threshold amount of 1,000 lbs. per acre was subtracted and 50% harvest efficiency was used on the remainder to determine the AU. If the forage was less than 1,000 lbs. per acre, 0 AU were determined.

4. Option 4 Combination Strategy where the stocking rates for each GMU are based the most appropriate of Option 1, Option 2, Option 3, and the option to defer if ecological trends are declining or erosion is predicted to be excessive.

Appendix H presents the total animal units allowed per year for each grazing management unit under the four stocking options described above. The acres used in calculating animal unit values for each sampling location are based on the grazeable acres within the ecological site areas used in the 2005 report and are shown in Appendix E. When more than one sampling location fell within the same ecological site, the data from the sampling locations were averaged together. When an ecological site did not contain a sampling location, the site was aggregated with another site based on soil type and habitat. Averaged sampling locations are listed at the end of Appendix E.

B. Military Training Impact

The impact of military training activity was analyzed using the methods documented in the 2005 report. The impact was estimated and incorporated using a training-related forage reduction factor. A forage reduction factor was calculated for each GMU using the Training Intensity Scale created for the 2005 report. The Training Intensity Scale is GMU-specific and is based upon a comparison of military training utilization that occurred in Fiscal Year 2002 and ecological conditions observed during that same period.

Training percent utilization was calculated using training schedule data for January through December 2019 provided by Fort Hood Range Control. Annual utilization was determined by calculating an annual sum of individual days that at least a portion of a GMU was used for military training and then dividing by 365 days.

Training utilization was plotted on the Training Intensity Scale and a training-related forage reduction factor was determined for each GMU. The forage reduction factor is the percentage by which the total volume of consumable forage in a GMU identified by the most recent forage inventory is reduced to account for vegetation loss due to military training. Forage reduction factors are assigned to a range of percent utilization for each GMU. Table 2 shows the Training Intensity Scale for each GMU and the percent utilization ranges assigned to each forage reduction factor.

Table 2: Training Intensity Scale

GMU	10% Forage Reduction Factor	15% Forage Reduction Factor	30% Forage Reduction Factor	40% Forage Reduction Factor
Western Maneuver Area – South	0 – 22%	22 – 33%	33 – 44%	44 – 100%
North Fort Hood	0 – 100%	N/A	N/A	N/A
Western Maneuver Area – North	0 – 20%	20 – 30%	30 – 40%	40 – 100%
Eastern Training Area – North	0 – 57%	57 – 79%	79 – 100%	N/A
Eastern Training Area – South	0 – 45%	45 – 68%	68 – 90%	90 – 100%
West Fort Hood – South	0 – 100%	N/A	N/A	N/A
West Fort Hood – North*	0 – 100%	N/A	N/A	N/A

*West Fort Hood – North includes training for West Fort Hood – North West and West Fort Hood – North East GMUs

C. Revised Universal Soil Loss Equation (RUSLE)

The sediment yield for each sampling location was calculated using the Revised Universal Soil Loss Equation (RUSLE). The RUSLE estimates the average soil loss in tons per acre per year based upon the following factors:

- R – rainfall-runoff erosivity factor
- K – soil erodibility factor
- L – slope-length factor
- S – slope-steepness factor
- C – cover management factor
- P – support practice factor

The RUSLE2 model and USDA NRCS's Web Soil Survey were used to identify the R and K factors which are dependent on location, soil type, and climate. The LS factor was calculated based upon the slope steepness and slope length using Table 3 – Values of the topographic factor, LS, for specific combinations of slope length and steepness from the USDA Agriculture Handbook Number 537 (Appendix M). The P factor is equal to 1 as no contouring and/or stripcropping occurs within the GMUs. Vegetation parameters (biomass, fall height, litter, and canopy cover) were derived from field collected data for Total Perennial Biomass and Perennial Consumable Biomass during the July 2019 vegetation survey. The C factor for each site and management scenario was estimated using Table 10 – Factor C for permanent pasture, range, and idle land. Using Table 10, equations were created that use canopy cover, average fall height, and percent ground cover to estimate C. These equations are:

Canopy cover of less than 25%, any average fall height:

$$C = 0.00005 * \%Cover^2 - 0.0089 * \%Cover + 0.4317$$ *Equation 1*

Canopy cover between 25% and 50%, average fall height less than 20 inches:

$$C = 0.00004 * \%Cover^2 - 0.0067 * \%Cover + 0.3458$$ *Equation 2*

Canopy cover between 50% and 75%, average fall height less than 20 inches:

$$C = 0.00002 * \%Cover^2 - 0.0042 * \%Cover + 0.2513$$ *Equation 3*

Additional equations were not created as none of the site scenarios fell outside of the parameters listed above.

To calculate the percent ground cover (%Cover), RUSLE2's 'Management' template was used with the following assumptions:

- Operation: graze, rotational
- Vegetation: bluestem, old world, established, regrowth after grazing or hay

Additionally, for each sampling location deductions were made in consumable biomass using the corresponding forage reduction factor presented in Table 3. The consumable perennial biomass was not included in the residual biomass number used to calculate the percent cover.

Using these assumptions, the cover material added in lbs. per acre (the "res Biomass" numbers in Appendix I) was converted into a percent ground cover. Based upon data points from the 2005 data, the following equation was created to estimate additional ground cover using residual mass:

$$Additional\ Cover\ \% = 0.0523 * Residual\ \left(\frac{lb}{ac}\right) + 0.183$$ *Equation 4*

The total percent cover for each sampling location was calculated using the following:

$$\%Cover = Rock\% + Litter\% + Additional\ Cover\ \%$$ *Equation 5*

The results from this equation were then input into Equations 5, 6, or 7 for each sampling location depending upon the scenarios and inputs in Appendix I.

Using this to find the C factor, the following RUSLE Equation was used:

$$A = R * K * LS * C * P$$ *Equation 6*

Where A is the sediment erosion in tons per acre per year.

Input parameters for the RUSLE equation and output sediment yield by GMU can be seen in Appendix I and Appendix K, respectively.

To determine weighted averages of erosion for each GMU, the erosion sediment yield as produced by RUSLE was assigned to the ecological sites in the same way biomass was assigned for the stocking option calculations. The sediment yield across ecological sites was then averaged within the associated GMU using the acres of the ecological site as a weighting factor. Therefore, the erosion estimates were weighted according to the area they represent within the GMU.

The T values (acceptable soil loss in tons/acre) obtained from RUSLE2 were weighted in the same way within GMU. The erosion estimates can then be compared to the weighted T values to determine significance of erosion. If the weighted average of the erosion estimate for a GMU is greater than the weighted average for the T value within a GMU, then erosion is occurring at a rate that is greater than acceptable. If the weighted average of the erosion estimate for a GMU is less than the weighted average for the T value within a GMU, then erosion loss could be considered acceptable.

Weighted averages were determined for the 25% Harvest Efficiency, the Maintenance Threshold, and the Conservation Threshold scenarios using the grazeable acres as the weighting factor. The number of acres in each GMU are listed in Appendix D.

IV. Results

The results of the military training impact analysis and erosion analysis are presented before the stocking option calculations because they inform the Option 4 Combination Strategy stocking results.

A. Military Training Impact

The percent utilization based on the 2019 training schedule was highest in the Western Maneuver Area – North GMU with a utilization of 43.24% which resulted in a forage reduction factor of 40%. All GMUs had training utilization rates over 20%. Table 3 shows the training utilization rates and forage reduction factors for each GMU.

Table 3: Percent training utilization and training-related forage reduction factor for each GMU

GMU	% Training Utilization	Forage Reduction Factor
Western Maneuver Area – South	22.61%	15%
North Fort Hood	N/A*	10%
Western Maneuver Area – North	43.24%	40%
Eastern Training Area – North	23.97%	10%
Eastern Training Area – South	23.42%	10%
West Fort Hood – South	34.11%	10%
West Fort Hood – North**	23.97%	10%

*Based on the Training Intensity Scale North Fort Hood has a reduction factor of 10 for the entire range of percent utilization
**West Fort Hood – North includes training for West Fort Hood – North West and West Fort Hood – North East GMUs

B. Erosion Analysis

The calculated sediment yield rates are presented in Appendix J and acceptable soil loss rates are presented in Appendix K. The calculated sediment yield rates for all stocking options across all GMUs did not exceed the corresponding calculated acceptable soil loss rates in any case. Therefore, erosion rates across the GMUs are not estimated to be excessive and will not require deferred grazing.

C. Stocking Options

The calculated stocking rates for each stocking option are presented in Appendix H.

1. Option 1 25% Harvest Efficiency

The total number of AUs for the 25% Harvest Efficiency stocking rate was 2,336.7. The Western Maneuver Area – North had the highest stocking rate of 748.6 AUs and North Fort Hood had the lowest stocking rate of 9 AUs.

2. Option 2 Maintenance Threshold

The total number of AUs for the Maintenance Threshold stocking rate was 1,350.7. The Western Maneuver Area – North had the highest stocking rate of 277.6 AUs, West Fort Hood – North East had the lowest stocking rate of 2.7 AUs, and North Fort Hood didn't contain enough consumable biomass to support stocking any animals while ensuring 750 lbs. per acre of residual biomass.

3. Option 3 Conservation Threshold

The total number of AUs for the Conservation Threshold stocking rate was 1,010.8. The Western Maneuver Area – South had the highest stocking rate of 94.7 AUs, West Fort Hood – North West had the lowest stocking rate of 2.5 AUs, and North Fort Hood and West Fort Hood – North East did not contain enough consumable biomass to support stocking any animals while ensuring 1000 lbs. per acre of residual biomass.

4. Option 4 Combination Stocking Strategy

The Combination Stocking Strategy is selected from the three previous stocking options taking into consideration the erosion analysis and impact of military training. Table 4 shows the results of the three previous stocking options.

Table 4: Stocking results for Option 1, Option 2, and Option 3

GMU	Option 1 25% Harvest Efficiency (AU)	Option 2 Maintenance Threshold (AU)	Option 3 Conservation Threshold (AU)
Western Maneuver Area - South	236.8	106.8	94.7
North Fort Hood	9	0	0
Western Maneuver Area - North	748.6	277.6	84.9
Eastern Training Area – North	293	105.1	43.2
Eastern Training Area – South	119.8	41.4	27
West Fort Hood – South	100.6	29.6	8.5
West Fort Hood – North West	67.1	37.4	2.5
West Fort Hood – North East	11.8	2.7	0
Total	1586.7	600.7	260.8

The selected Combination Strategy stocking options are shown in Table 5. The total number of AUs for the Combination Strategy stocking rate was 1,543. The Eastern Training Area – South had the highest stocking rate of 119.8 AUs and North Fort Hood had the lowest stocking rate of 9 AUs. As stated previously, according to the Performance Work Statement, a limit of 750 AUs was established in the Live Fire and Impact Area to reduce live-fire training interruptions and delays.

Table 5: Option 4 Combination Strategy stocking results

GMU	Option 4	Animal Units
Western Maneuver Area - South	Maintenance Threshold	106.8
North Fort Hood	25% Harvest Efficiency	9
Western Maneuver Area - North	Conservation Threshold	84.9
Eastern Training Area – North	25% Harvest Efficiency	293
Eastern Training Area – South	25% Harvest Efficiency	119.8
West Fort Hood – South	25% Harvest Efficiency	100.6
West Fort Hood – North West	25% Harvest Efficiency	67.1
West Fort Hood – North East	25% Harvest Efficiency	11.8
Live Fire Area	N/A	750
Total		1543

V. Discussion

The recommended stocking rates calculated by the process described in this report are shown in Appendix H. Generally, the results showed similar stocking rate, erosion rate, and stocking option outcomes when compared to the 2005 analysis. The total animal units calculated for all GMUs is 1,543 in 2019 which is 98.5 animal units higher than the total in 2005. The 2005 report noted lower biomass readings due to drought conditions. Climate conditions during the 2019 survey were normal; therefore, an increase in animal units is reasonable.

The NRCS commonly uses the 25% Harvest Efficiency stocking rate as the standard method to determine stocking rates on privately-owned rangeland. This method only considers livestock grazing as a consumer of forage; it does not take into account vegetation loss from other activities such as military training or ecological conditions. This method does not establish a minimum amount of vegetation that should be left to protect rangeland from natural (drought, flood, or wildfire) or anthropogenic (military training) impacts. Implementing this approach on rangeland would require rotational grazing methods which allow pastures periods of rest from grazing and other disturbance. North Fort Hood, Western Maneuver Area – North, Eastern Training Area – North, Eastern Training Area – South, West Fort Hood – South, West Fort Hood – North West, and West Fort Hood – North East have low military training impacts and therefore low forage reduction factors (≤10%) and are candidates for the Harvest Efficiency stocking rate. If ecological conditions decline and/or military training impacts increase, then the Harvest Efficiency stocking rate should be reevaluated.

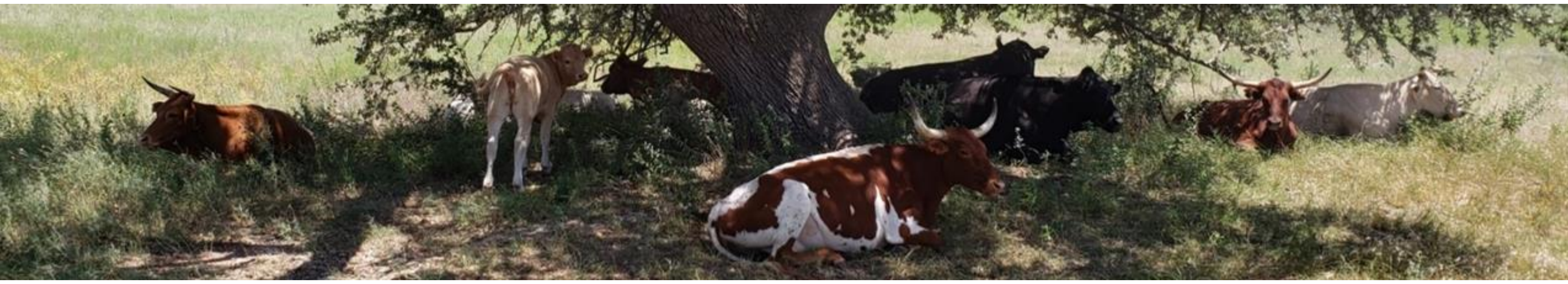
The Texas Cooperative Extension Service states that the optimal amount of ungrazed forage for midgrass rangeland should range from 750 to 1,000 lbs. per acre. Leaving this amount of forage promotes maintenance or possible gradual improvement of rangeland health. Selection of a maintenance threshold of 750 lbs. of ungrazed forage per acre aims to maintain current rangeland health conditions and to reduce erosion. Western Maneuver Area – South has a moderate forage reduction factor (15% - 30%) and is a candidate for the Maintenance Threshold stocking rate. If ecological conditions and/or military training impacts change, then the stocking rate should be reevaluated and changed accordingly.

Similar to the Maintenance Threshold approach, the Conservation Threshold strategy retains a greater amount of ungrazed forage of 1000 lbs. to promote an increased rate of rangeland recovery and decrease soil erosion. Western Maneuver Area – North has the greatest forage reduction factor (≥40%) and is a candidate for the Conservation Threshold stocking rate. If ecological conditions and/or military training impacts change, then the stocking rate should be reevaluated and changed accordingly.

There were a few notable differences between the 2005 and 2019 stocking rates. The differences in stocking rates when compared to the 2005 results for the Eastern Training Area – North and the Western Maneuver Area – North GMUs were investigated and determined to be a result of the change in the number of sampling locations measured in 2005 (131) compared to 2019 (70). In order to account for the decrease in sampling locations, ecological site areas were aggregated by soil type and habitat type to ensure all grazeable acres were represented in the analysis. Aggregating areas led to an increase in size of some ecological sites. Due to the 2005 analysis methodology, this change in ecological site size was unavoidable and impacted stocking rates. However, overall stocking rates are generally similar for 2005 and 2019.

The Combination Strategy stocking options selected for the GMUs are consistent with the final stocking options selected for the GMUs in 2005 except for the Eastern Training Area – North GMU. The Eastern Training Area – North GMU Combination Strategy stocking option was determined as Harvest Efficiency and in 2005 it was determined as Maintenance Threshold. This change is attributed to a decrease in the impact of military training activities on forage availability in the Eastern Training Area – North GMU when comparing the 2005 training activities and the 2019 training activities.

Overall, the findings of this report represent conditions at the time of the field data collections. Conditions may change based on changes in training, rainfall patterns, or wildfires. A biannual or annual survey completed in the same seasons would generate information about forage trends and enable more adaptive management.



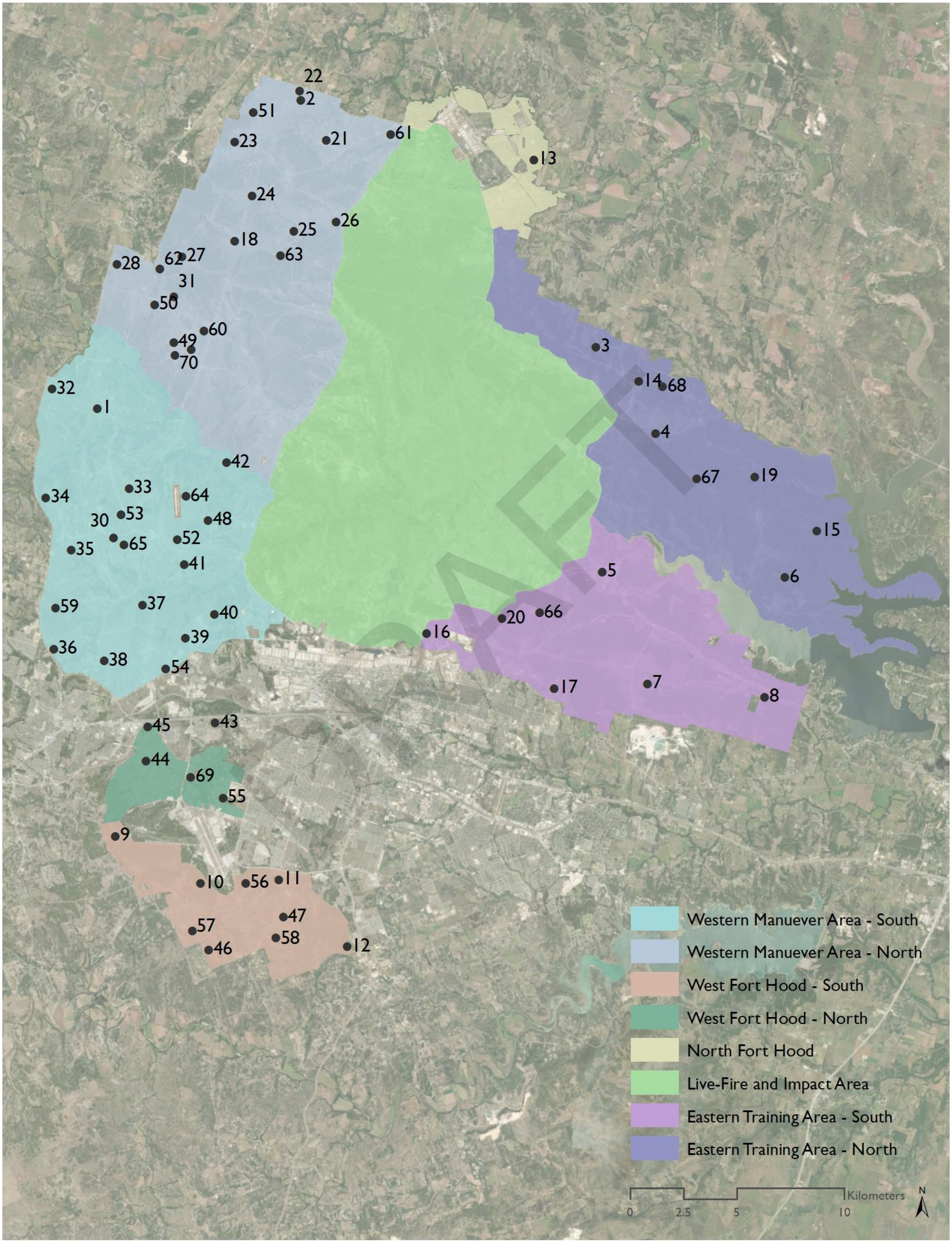
APPENDIX A

Table 2.6. Geographic coordinates for surveyed sample locations. The coordinates are in Geographic Coordinate System, WGS 1984 datum.

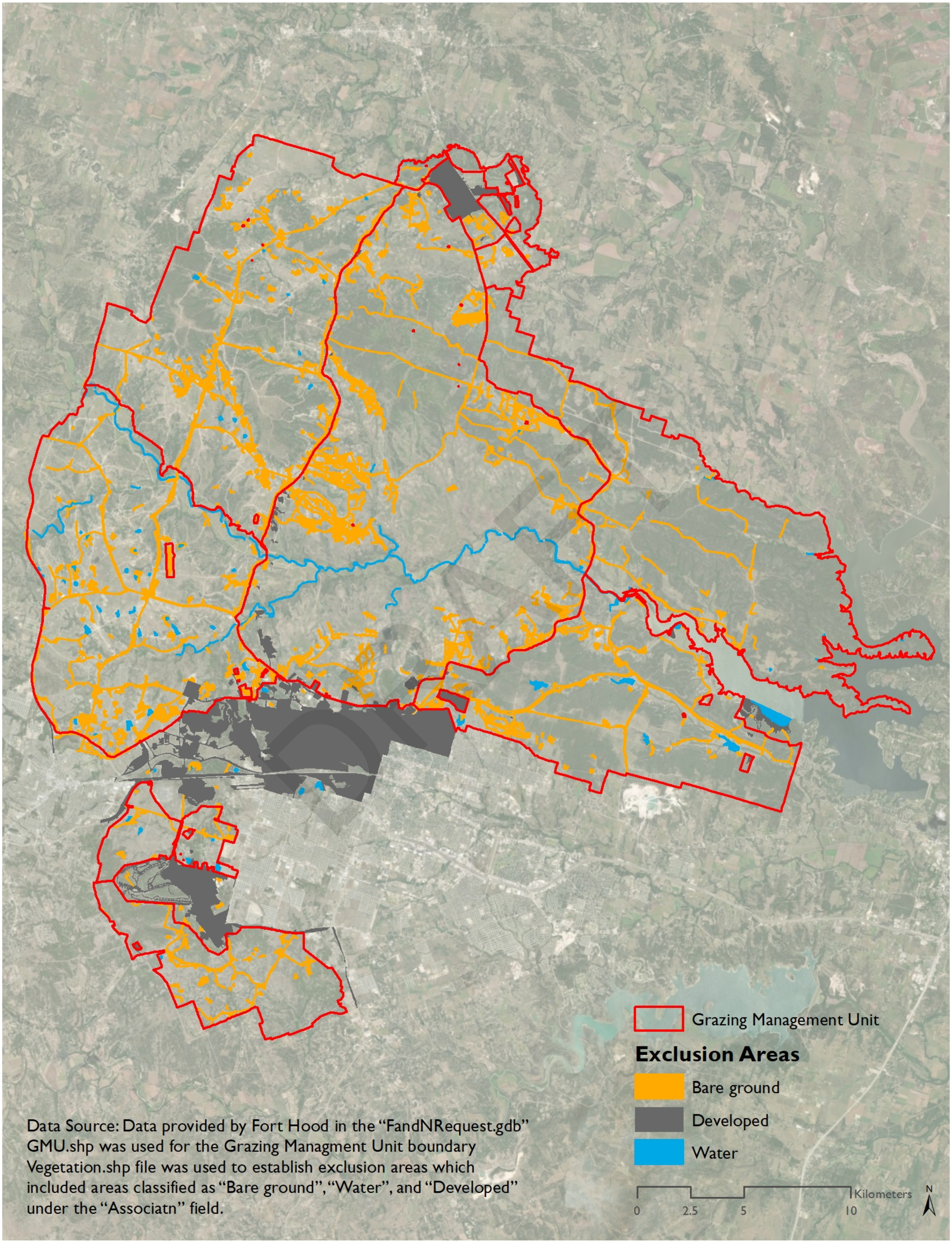
Sample Location ID	Latitude	Longitude
1	31.25336913	-97.87998329
2	31.38169982	-97.77650969
3	31.27442205	-97.63427603
4	31.23742193	-97.60608201
5	31.17957831	-97.63382421
6	31.17528905	-97.54423242
7	31.13181327	-97.61296587
8	31.1249206	-97.55568198
9	31.07276616	-97.87563933
10	31.05198301	-97.83453301
11	31.05280662	-97.79607393
12	31.02394104	-97.76329001
13	31.35423033	-97.6625419
14	31.25950467	-97.61373592
15	31.19451107	-97.52795417
16	31.15529069	-97.7206682
17	31.13090278	-97.65874817
18	31.32280688	-97.81068756
19	31.21802259	-97.55790322
20	31.16087098	-97.68364272
21	31.36452851	-97.76439326
22	31.38547245	-97.77692869
23	31.36455597	-97.8096004
24	31.34169081	-97.80151212
25	31.32638746	-97.78147652
26	31.33001952	-97.76043811
27	31.31670851	-97.83658993
28	31.31403491	-97.86863037
29	31.27750763	-97.83323929
30	31.19880609	-97.8734429
31	31.29992682	-97.84119125
32	31.26208551	-97.90204919
33	31.2193483	-97.86517066
34	31.2161913	-97.90613256
35	31.19386622	-97.89434712
36	31.15236251	-97.90398161
37	31.17005448	-97.8599366
38	31.14682482	-97.87917367
39	31.1556198	-97.83905925

Sample Location ID	Latitude	Longitude
40	31.16547581	-97.82458547
41	31.18667956	-97.83893714
42	31.22938435	-97.81702546
43	31.11963216	-97.82552527
44	31.10431736	-97.85976584
45	31.11862269	-97.85857612
46	31.02396357	-97.83112663
47	31.0370225	-97.79423414
48	31.20514871	-97.82666892
49	31.28069767	-97.84170106
50	31.29667846	-97.85066699
51	31.37694888	-97.7999325
52	31.19745506	-97.84213156
53	31.20835818	-97.86941832
54	31.14297805	-97.8491
55	31.08782726	-97.8224657
56	31.05162416	-97.81245947
57	31.0321292	-97.83895733
58	31.02841219	-97.79803176
59	31.16965141	-97.90254843
60	31.28520037	-97.82669833
61	31.36628167	-97.73270287
62	31.31176058	-97.8477908
63	31.31618553	-97.78837071
64	31.21555858	-97.83748705
65	31.19556152	-97.8682175
66	31.16290829	-97.66505608
67	31.2178618	-97.58637589
68	31.25704237	-97.6019312
69	31.09695965	-97.83806106
70	31.27506983	-97.84127896

APPENDIX B


Western Manuever Area - South
Western Manuever Area - North
West Fort Hood - South
West Fort Hood - North
North Fort Hood
Live-Fire and Impact Area
Eastern Training Area - South
Eastern Training Area - North
0
2.5
5
10
Kilometers
N
DRAFT

APPENDIX C



Grazing Management Unit
Exclusion Areas
Bare ground
Developed
Water
0
2.5
5
10
Kilometers
N
Data Source: Data provided by Fort Hood in the "FandNRequest.gdb"
GMU.shp was used for the Grazing Managment Unit boundary
Vegetation.shp file was used to establish exclusion areas which
included areas classified as "Bare ground", "Water", and "Developed"
under the "Associatn" field.

APPENDIX D

Table 2.9. Number of acres by Grazing Management Unit

Grazing Management Unit	Total Acres	Bare Ground + Water + Developed Acres	Grazeable Acres
Western Maneuver Area - South	32108.86	2176.96	29931.90
North Fort Hood	3798.60	111.82	3686.78
Western Maneuver Area - North	35045.37	1624.85	33420.52
Eastern Training Area – North	29182.15	436.79	28745.36
Eastern Training Area – South	22614.65	1027.21	21587.44
West Fort Hood – South	9363.16	357.97	9005.19
West Fort Hood – North West	2388.37	72.69	2315.68
West Fort Hood – North East	1468.42	98.17	1370.25
Total	135969.60	5906.46	130063.1

The bare ground/water/developed layer assembled for the Grazing Environmental Assessment was used to subtract these areas from the total acreage in the Grazing Management Unit map supplied by Tim Buchanan.

APPENDIX E

Table 2.10. Table showing total acres of each sampling location with an adjusted value of grazeable acres.

Sample Location	Total Acres	Exclusion Acres	Grazeable Acres
1	3248.21	73.49	3174.72
2	4131.90	76.36	4055.54
3	2305.07	53.70	2251.37
4	3437.82	118.54	3319.27
5	2005.71	187.04	1818.67
6	849.34	7.18	842.16
7	2107.46	48.64	2058.81
8	961.73	166.31	795.42
9	162.73	0.99	161.73
10	2358.09	86.36	2271.73
11	353.72	40.06	313.66
12	1666.26	28.71	1637.55
13	3798.60	111.82	3686.78
14	2204.05	40.26	2163.79
15	7720.66	21.56	7699.10
16	1456.35	222.55	1233.80
17	554.73	24.28	530.45
18	602.96	15.07	587.89
19	1254.49	31.92	1222.57
20	14045.77	371.41	13674.36
21	3331.23	130.69	3200.54
23	673.17	38.80	634.37
24	2202.17	92.17	2110.00
27	6388.40	103.77	6284.63
28	3351.35	178.05	3173.30
29	886.60	153.81	732.78
30	2016.84	285.92	1730.92
31	1336.11	151.82	1184.29
32	217.50	1.56	215.94
33	6146.27	440.75	5705.52
35	5432.08	223.83	5208.25
36	519.13	23.12	496.01
37	3569.42	328.18	3241.24
38	846.14	130.62	715.51
39	2358.58	512.27	1846.31
40	5990.76	309.68	5681.08
42	3870.15	165.57	3704.58

Sample Location	Total Acres	Exclusion Acres	Grazeable Acres
44	1662.38	44.16	1618.23
45	905.34	70.91	834.43
46	834.70	41.14	793.56
47	541.25	14.85	526.40
55	647.00	46.12	600.88
56	447.56	14.75	432.81
57	1700.23	101.08	1599.15
58	1769.64	59.03	1710.62
61	2133.69	135.44	1998.24
63	8054.91	263.38	7791.53
66	779.95	7.19	772.76
67	9242.25	150.88	9091.37
68	2172.53	13.01	2159.51
69	199.38	1.71	197.66

*The acreage for the sites in the column on the right were re-assigned to the sites in the column on the left

Site Name	Combined Sites
2	2, 22, 51
24	24, 25, 26
28	28, 49, 50
29	29, 70
30	30, 48, 60
31	31, 62
33	33, 34, 52, 53, 64, 65
35	35, 41, 59
39	39, 54

Grazing Management Unit Abbreviations	
WMAS	Western Maneuver Area - South
NORTH	North Fort Hood
WMAN	Western Maneuver Area - North
ETAN	Eastern Training Area – North
ETAS	Eastern Training Area – South
WS	West Fort Hood – South
WNW	West Fort Hood – North West
WNE	West Fort Hood – North East

APPENDIX F

Table 2.11. Vgetation survey data and per acre biomass calcuations for consumable and non-consumable plant material

Sample Location	*Species Scientific Name*	Category	Percent Current Growth	Percent Air Dry Matter	Percent Ungrazed	Percent Normal Production	Plot 1	Plot 2	Plot 3	Plot 4	Plot 5	Plot 6	Plot 7	Plot 8	Plot 9	Plot 10	Biomass (lbs per acre)
1	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	1.05	0	0	0	0	0	1.52
1	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	2.008	0	0.502	0.251	1.255	0.502	0	0	0.753	2.008	22.51
1	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	0.98	1.96	7.95
1	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0.332	0	0	0	0	0	0	1.03
1	*Castilleja campestris*	ncpf	1	0.65	1	0.9	0	0	0	0.24	0	0	0	0	0	0	0.56
1	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0.7	0	0	0	1.12
1	*Evax prolifera*	ncaf	1	0.9	1	0.9	0	0	0	0.1	0	0	0	0	0	0	0.32
1	*Glandularia bipinnatifida*	ncpf	0.8	0.5	1	0.9	0	0	0	0	0	0.5	0.5	0	0	0	2.25
1	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	1.003	0	3.009	0	0	0	0	0	0	0	6.03
1	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0.756	0	0	2.52	0	0	0	0.756	2.52	9.45
1	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	9.5	0	0	0	1.52	0.38	0.76	0	0	0.38	19.39
1	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	0	0.151	0.22
1	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	0	0	0	0	0	0	0.3	0	0	0.35
1	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0.705	0.235	0	0.47	0.94	0.705	0.47	0.235	0	0.705	3.98
2	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	30.78	0	0	0	11.97	0	0	0	0	77.10
2	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	116.4	0	279.92
2	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	35.28	66.64	0	0	0	0	0	275.73
2	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	13.28	0	0	0	0	0	0	0	0	41.06
2	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	2.2	3.3	0	13.23
2	*Dichanthium aristatum*	cpg	0.75	0.6	1	0.9	0	0	46.75	0	0	17.85	78.2	0	0	0	412.08
2	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	5.25	8.75	0	22.75	0	0	0	17.5	0	45.5	159.92
2	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	6.51	39.06	0	0	0	0	0	0	0	0	65.75
2	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	0	0	4.72	0	5.31	23.34
2	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	17.1	0	0	0	0	0	0	0	0	26.44
2	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	1.67	0	0	0	0	0	0	0	0	1.92
2	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	40.53	0	0	0	0	0	0	32.81	0	30.88	309.60
3	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	1.71	0	87.21	0	70.11	286.82
3	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	42.68	42.68	85.36	85.36	128.04	0	73.72	11.64	116.4	34.92	1492.88
3	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	11.64	0	0	0	0	27.99
3	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	11.76	13.72	0	0	0	0	0	0	0	0	68.93
3	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	3.3	0	0	0	0	7.94
3	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	5.25	0	0	14	0	0	0	0	0	30.86
3	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	30.09	0	0	0	40.12	105.52
3	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0	0	10.02	11.54
4	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0.502	0	1.004	0	0	0	0	0.502	0	0	6.21
4	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	7.76	3.88	0	1.164	19.4	7.76	0	0.776	0	19.4	144.62
4	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	1.96	0	0	0	1.96	0	10.61
4	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0.835	0.501	0	0.334	0.334	0.835	0	5.69
4	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0.33	0	0	0.55	2.12
4	*Digitalis purpurea*	ncaf	0.9	0.4	1	0.9	0	2	0	0	0	0	0	0	0	0	3.21
4	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0.35	0	0.35	0.525	0	0	0	0	0	0	1.96
4	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	0	0	0	0	34.1	0	105.43
4	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	0	0	0	0	10.03	15.07
4	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0.57	0	0	0	0.88
4	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	0	0.3	0.3	0	0	0	0	0	0	0.70
4	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	1.67	0	0	0	0	0	1.92
4	*Panicum virgatum*	cpg	0.55	0.4	1	0.9	0	0	0	0	0	0	1.105	0	0	0	2.90
4	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0	0.658	0	0	0	0	0	0	0	0.57
4	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0	0	0	0	2.2	0.22	22	0	0	44.49
4	*Salvia texana*	ncpf	1	0.6	1	0.9	2.0025	0	0	0.534	0	0	0	0	0	0	5.49
4	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0.235	0	0	0	0	0	0	0.21
4	*Solanum xanti*	ncpf	0.97	0.6	1	0.9	0	0	0	0	0	0	1.5	0	0	0	3.35
4	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	2.065	0	0	0	0	0	7.45
4	*Tetraneuris scaposa*	ncpf	1	0.4	1	0.9	3	0	0	0	0	0	0	0	0	0	4.33
5	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	10.2	0	0	0	0	0	0	0	16.00
5	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	7.76	0	7.76	3.88	1.94	1.164	3.88	63.45
5	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	1.1	0	0.33	0	0	0.22	0	0	0	3.97
5	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0.875	0	0	0	0	0	0	0	1.40
5	*Glandularia bipinnatifida*	ncpf	0.8	0.5	1	0.9	0	0	0	0	0	0	0.5	0	0	0	1.13
5	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	0	5.015	0	10.03	20.06	52.76

5	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	2.52	0	3.64
5	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	9.5	0	0	0.57	0	0	0	0	0.95	0	17.04
5	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	6.58	0	0	0	0	0	0	12.49
5	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0.501	0	0.501	0.835	1.67	0	0.835	0	0.501	0.167	5.77
5	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	3.86	0	0	0	0.193	0.965	0.579	0	16.63
5	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0	0	0	0	0	0.55	0	0	0	1.00
5	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	0	0	0	0	0	0	0.5	0	0	0.90
5	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0.826	2.065	0	0	0	0	0	0	0	0	10.43
6	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	25.65	0	0	35.91	22.23	0	13.68	0	175.80
6	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	65.96	50.44	34.92	58.2	69.84	46.56	31.04	15.52	42.68	27.16	1063.68
6	*Croton texensis*	ncaf	0.3	0.2	1	0.9	1.1	0	0	1.1	0	0	0	0	0	0	5.29
6	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	6.82	0	0	0	6.82	0	0	42.17
6	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	160.48	0	0	30.09	120.36	20.06	20.06	0	0	20.06	557.77
6	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	15.12	0	0	0	0	0	0	0	0	0	21.82
6	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	1.96	2.94	0	0	0	0	0	0	1.96	15.15
6	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0	0	0	0	0	0	16.45	19.74	0	31.08
6	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	0	8.26	0	0	0	29.80
7	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	3.4	6.8	0	0	0	0	0	0	16.00
7	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	7.53	0.753	0	0	0	0	0	0	1.255	0	29.49
7	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	1.164	0	11.64	0	0	2.328	36.39
7	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	1.66	0.996	3.32	3.32	4.98	3.32	0	3.32	1.66	0.996	72.88
7	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0.33	0	0.22	0	0	0	0.33	2.12
7	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	100.3	0	0	10.03	0	0	165.82
7	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0	2.52	0	7.56	15.12	2.52	40.00
7	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0.501	5.01	0	0	0.835	0	0	7.31
7	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0	0	0	0	5.5	0	0	0	0	10.02
7	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0.47	0	0.705	0.47	0	0	1.175	0	2.51
7	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	4.13	0	0	0	0	0	14.90
8	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	1.7	6.8	3.4	10.2	6.8	45.32
8	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	31.04	0	0	2.716	11.64	2.91	3.88	0	0	0	125.50
8	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	1.1	0.33	0	0.22	0	0	0.33	0.55	0.55	7.41
8	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0.875	0.7	0	0.35	0	0	0	0	0	3.09
8	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	0	1.705	0	0	0	0	5.27
8	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	0	0	0	1.77	0	4.12
8	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	10.03	0	0	0	3.009	5.015	0	50.15	0	102.51
8	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0	2.52	0	0	0	0	3.64
8	*Indigofera miniata*	cpf	1	0.3	1	0.9	0	0	0.2	0	0	0	0	0	0	0	0.22
8	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	1.67	0.501	0	0.835	0	3.46
8	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	0	0	0	0	1.23	0	0	0	1.81
8	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0	2.303	0.987	1.645	16.45	0	3.29	0	1.645	22.60
8	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0	0	0.33	0	0	0	0	0	3.3	6.61
8	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	0	0	0	0	0	0	0.5	0	0	0.90
8	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0.705	0	0	0	0	0	0	0	0	0.63
8	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	4.13	4.13	4.13	4.13	4.13	0	0	0	8.26	104.28
9	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	0	0	23.8	6.8	6.8	58.66
9	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	1.05	0	0	1.05	0	0	3.03
9	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	11.76	3.92	2.94	1.96	9.8	11.76	5.88	3.92	0	0	140.52
9	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0	0.15	0	0	0	0	0	0	0	0.27
9	*Convolvulus equitans*	cpf	0.96	0.45	1	0.9	10.98	2.745	0	0	0	0	0	0	0	0	23.21
9	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0.33	0	0	0	0	0	0	0	0	0.79
9	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0.525	0	0	0	0	2.625	1.75	0	0	7.86
9	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	26.32	0	0	0	0	0	0	32.9	0	0	112.43
9	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	3.34	0	0	0.835	3.34	0	0	0	0	8.65
9	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	0	0	0	0	0	0	7.38	0	10.87
9	*Rhus lanceolata*	ncpf	0.2	0.35	1	0.9	0	0	0	0	0	0	0	0	15	0	94.69
9	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	12.78	12.78	6.39	7.455	14.91	2.13	10.65	2.13	4.26	21.3	186.49
9	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	1.175	1.175	0	0	2.09
10	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	0	0	1.05	0	0	0	1.52
10	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	2.51	2.51	2.51	0	0	0.251	0	0.502	0	0	25.61
10	*Bouteloua harista*	cpg	0.6	0.45	1	0.9	0	0	2.865	0.955	0	0	1.91	0	1.91	0	20.67
10	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	2.175	0	0	0	1.45	0	0.725	14.12
10	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	1.225	0	0.175	0	2.24
10	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0	0	3.34	3.85
10	*Panicum hallii*	cpg	0.6	0.4	1	0.9	0	0	0	0	11.05	0	0	0	0	0	26.57

10	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	6.39	10.65	0	0	0	0	0	0	0	0	33.53
11	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	10.04	0	0	10.04	62.08
11	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	23.28	0	34.92	46.56	15.52	27.16	0	0	0	0	354.56
11	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	1.45	5.8	0	23.54
11	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	0	0	5.7	8.81
11	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	3.34	0	0	0	0	0	0	3.85
11	*Panicum virgatum*	cpg	0.55	0.4	1	0.9	0	0	0	0	0	0	0	6.63	0	0	17.39
11	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	0	0	0	0	0	0	3	0	0	5.41
11	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	14.91	27.69	12.78	2.13	34.08	29.82	6.39	17.04	25.56	14.91	364.61
11	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0.235	0	0	0	0	0	0	0.21
12	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	0	0.21	0	0	0	0	0.30
12	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	0	0	0	2.51	0	0	5.02	0	0	23.28
12	*Bouteloua harista*	cpg	0.6	0.45	1	0.9	0	7.64	3.82	1.91	0	0	0	0	0	0	36.17
12	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	4.35	0	0	0	0.725	0	0	0	0	0	16.48
12	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0	0	0	0.03	0	0	0.75	0	0	1.41
12	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	0	1.1	0	2.65
12	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	1.75	0	0	0	0	0	3.5	5.25	0	3.5	22.44
12	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	0	0	1.9	2.94
12	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	0	0	0	0	5.34	1.335	14.45
12	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	21.3	4.26	10.65	10.65	10.65	4.26	10.65	12.78	0	0	167.63
13	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	27.16	0	0.776	0.776	0.776	0	1.94	0.388	0.776	0.776	80.24
13	*Croton capitatus*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	5.5	3.3	5.5	2.2	4.4	50.26
13	*Croton texensis*	ncaf	0.3	0.2	1	0.9	3.3	3.3	3.3	0	0	0	0	0	1.65	0	27.78
13	*Cynodon dactylon*	cpg	0.55	0.5	1	0.9	0	0	0	3	0	0.2	0	0.5	0	0	12.13
13	*Evax prolifera*	ncaf	1	0.9	1	0.9	0	0	0	0	0	0	0	0	0	0.2	0.65
13	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	0	0	0.47	0.42
13	*Solanum xanti*	ncpf	0.97	0.6	1	0.9	0	6	0.5	0	0	2	0	0	0	0.3	19.63
13	*Verbena goodmanii*	ncpf	0.8	0.4	1	0.9	0	0	0	0	0	0	0.2	0	1	1	3.97
14	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	8.55	0	0	0	0	0	0	0	0	15.42
14	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	38.8	62.08	58.2	0	50.44	46.56	62.08	69.84	62.08	1082.34
14	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0.15	0	0	0	0	0	0.3	0	0	0.81
14	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	5.25	5.25	7	0	0	0	0	0	3.5	33.67
14	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	27.28	0	0	0	0	0	0	0	6.82	105.43
14	*Glandularia bipinnatifida*	ncpf	0.8	0.5	1	0.9	0	0	0	0	0	0	0	0	0	10	22.54
14	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	9.5	0	0	0	0	0	0	0	0	14.69
14	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0.835	0	0	0.96
14	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0	0	4.9	2.94	0	0	0	17.31
15	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	20.08	0.753	0.753	0	0	0	0	0	5.02	0	82.26
15	*Carex pseudocyperus*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	0	0.725	0	2.35
15	*Chloris verticillata*	cpg	0.55	0.6	1	0.9	0	0	0	0	0.5	0	0	0	0	0	1.97
15	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.33	0.22	1.1	1.1	0.88	0.22	2.2	2.2	1.1	0	22.48
15	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0.255	0	0	0	0.83
15	*Eragrostis spectabilis*	cpg	0.6	0.45	1	0.9	0	0	0	1	0	0	0	0	0	0	2.71
15	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	100.3	0	0	0	5.015	0	0	158.29
15	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	2.52	0	0	0	0	0	0	0	0	0	3.64
15	*Opuntia engelmannii*	ncpf	0.2	0.1	1	0.9	0	1	0	0	0	3	0	0	0	0	7.21
15	*Panicum hallii*	cpg	0.6	0.4	1	0.9	0	0	0	0	6.63	0	0	0.663	0	0	17.54
15	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	6.195	0	0	0	0	0	22.35
16	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	10.2	0	0	0	0	0	16.00
16	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	15.52	0	37.32
16	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	41.16	13.72	0	0	0	15.68	0	0	0	0	190.89
16	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	5.8	0	0	4.35	0	0	0	0	0	32.95
16	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	2.2	0	0	0	0	0	0	2.2	0	10.58
16	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0	0	10.5	0	16.83
16	*Elymus virginicus*	cpg	0.95	0.6	1	0.9	0	0	0	9	0	0	0	0	0	0	20.50
16	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	13.64	0	37.51	0	57.97	0	0	0	10.23	17.05	421.73
16	*Helianthus maximiliani*	cpf	0.35	0.2	1	0.9	0	13	0	0	0	11	12	0	5	0	84.51
16	*Iva annua*	ncaf	0.35	0.15	1	0.9	148.2	5.7	104.5	180.5	39.9	20.9	3.8	228	17.1	7.6	1169.03
16	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	18.37	0	3.34	11.69	1.67	5.01	11.69	10.02	0	11.69	84.59
16	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	32.81	0	19.3	9.65	15.44	7.72	0	0	252.26
16	*Panicum virgatum*	cpg	0.55	0.4	1	0.9	0	11.05	13.26	39.78	0	46.41	0	0	0	130.39	631.95
16	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	26.32	0	0	0	13.16	6.58	0	0	3.29	13.16	53.69
16	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	14.8	14.8	0	0	0	66.6	0	0	0	154.23
17	*Asclepias sp*	ncpf	0.87	0.4	1	0.9	0	0	0	0	0	0	11	0	0	0	18.24

17	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	54.32	58.2	143.56	124.16	11.64	54.32	19.4	54.32	108.64	46.56	1623.51
17	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	2.2	0	2.2	0	0	0.55	0	0	0	11.90
17	*Desmanthus illinoensis*	cpf	0.7	0.3	1	0.9	0	0	0	0	0	0	2.4	0	1.2	0	5.57
17	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	12.25	0	0	0.875	0	0.875	22.44
17	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	3.41	30.69	0	0	17.05	0	0	0	0	0	158.15
17	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	20.06	0	0	0	0	0	0	40.12	0	0	90.45
17	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	1.9	0	0	0	0	0	17.1	0	0	29.37
17	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	13.16	0	0	0	24.98
17	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0.835	0	0	0	0	0	0	0	0.96
17	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0	3.92	0	0	0	0	0	8.66
17	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	0	0	0	0	13.51	0	0	0	40.13
18	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	3.4	0	0	102	0	0	165.30
18	*Annual forb*	ncaf	1	0.4	1	0.9	8.4	0	0	0	6.3	0	0	0	0	0	21.21
18	*Asclepias viridis*	ncpf	0.87	0.4	1	0.9	0	0	0	0	55	0	0	0	0	0	91.22
18	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	77.6	11.64	3.88	194	3.88	11.64	0	19.4	7.76	19.4	839.75
18	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	8.85	0	0	0	1.18	23.34
18	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	12.6	25.2	0	0	0	25.2	90.90
18	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	1.9	0	0	95	0	0	0	0	0	149.80
18	*Iva annua*	ncaf	0.35	0.15	1	0.9	0	2.85	0	0	7.6	0	95	0	57	57	339.25
18	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	0	12.39	0	0	0	44.69
18	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	7.4	0	0	0	0	0	0	0	0	0	11.86
19	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	6.8	0	0	17	1.02	0	0	0	0	0	38.93
19	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	19.4	0	0	0	0	0	46.65
19	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0.996	0.332	0	0	3.32	14.37
19	*Croton texensis*	ncaf	0.3	0.2	1	0.9	5.5	5.5	1.65	0.55	0.33	0	0	0	0.22	0	33.07
19	*Glandularia bipinnatifida*	ncpf	0.8	0.5	1	0.9	0	0.5	0	0	0	0	0.2	0	0	0	1.58
19	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	12.6	2.52	0.756	0	0	0	0	0	0	0	22.91
19	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0.57	0	0	0	0	0	0	0	0.88
19	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	0	0	0	0.246	0	0	0	0	0.36
19	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0	6.58	9.87	32.9	0	0	0	0	1.645	43.80
19	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0.55	0	2.2	22	0.55	0	11	8.8	3.3	88.18
19	*Solanum xanti*	ncpf	0.97	0.6	1	0.9	0	0	0.5	0	0	0	0	0	0	0	1.12
19	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	41.3	0	1.239	4.13	0	0	0	0	1.239	0	172.81
20	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	7.76	0	0	0	0	0	18.66
20	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	3.92	0	0	0	0	0	0	10.61
20	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0.835	0	0	0.96
21	*Aristida oligantha*	cag	0.7	0.6	1	0.9	0	5.02	0	0.251	0	5.02	0	2.51	0.502	0.502	42.68
21	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	5.02	0	0	0	2.51	0	0	0	0	0	23.28
21	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	1.75	0	0	0	0	0	0	0	0	2.81
21	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	0	14	0	0	0	0	0	0	0	16.29
22	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	3.4	0	0	0	0	5.33
22	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	10.26	0	0	0	0	0	0	0	5.13	27.76
22	*Aristida oligantha*	cag	0.7	0.6	1	0.9	0	0	0	0	0	0	0	0	12.55	5.02	54.32
22	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	50.44	0	0	0	0	0	85.36	7.76	0	345.23
22	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	7.25	0	0	0	23.54
22	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	2.2	0	0	2.2	0	0	10.58
22	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	17.5	5.25	0	0	0	5.25	7	56.11
22	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	40.92	37.51	0	0	0	0	242.49
22	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	42.84	0	0	0	0	0	0	0	0	0	61.81
22	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	49.4	20.9	39.9	17.1	22.8	0	3.8	7.6	17.1	276.10
22	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	82.25	0	13.16	39.48	0	0	0	0	256.09
22	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	35.07	0	0	0	0	0	0	16.7	0	6.68	67.29
22	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0	0	0	0	2.94	0	0	6.49
22	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	19.3	30.88	21.23	3.86	0	0	0	0	223.60
22	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	155.49	0	0	0	0	0	110.76	0	0	0	523.86
22	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	0	0	16.52	0	0	59.59
23	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	97	0.776	0	0	65.96	0	46.56	50.44	108.64	46.56	1000.23
23	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	29.4	5.88	0	0	0	95.45
23	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0	0	0	0	0	0	0.3	0	0	0.54
23	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0.35	3.5	0	0	6.17
23	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	16.45	0	0	0	0	0	31.23
23	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0.167	0	0	5.01	5.96
23	*Salvia texana*	ncpf	1	0.6	1	0.9	0	1.335	18.69	0	0	0	0	13.35	0	0	72.23
24	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	10.2	0	0	85	0	0.34	0	0	0	0	149.84

24	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	59.85	0	0	0	18.81	0	11.97	163.46
24	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	27.16	38.8	31.04	0	27.16	174.6	174.6	97	77.6	38.8	1651.50
24	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0.22	0	0	0	0	0	0	4.4	11.11
24	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0.175	0	0	0	0	0	0.28
24	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	0	2.36	0	0	0	5.49
24	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	30.09	0	0	1.003	0	30.09	20.06	0	30.09	167.33
24	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	7.56	0	0	0	0	0	0	0	0	0	10.91
24	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	26.6	7.6	0	15.2	0	0.38	0	0	0	0	76.96
24	*Iva annua*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	2.85	0	0	4.41
24	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0	0	3.34	3.85
24	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	0	0	0	0	24.78	89.39
25	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	1.255	0	2.008	0	1.757	1.255	1.255	0	0	23.28
25	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	15.68	0	0	0	0.98	0	0	0	0	3.92	55.68
25	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0.045	0	0	0	0	0	0	0	0	0.08
25	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	0	0.33	0	0.79
25	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0.875	1.05	0.875	0	0	4.49
25	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	0	0	0	5.9	1.18	16.48
25	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	1.26	0	0	0	1.26	0	0	0	0	3.64
25	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	1.9	0	0	2.94
25	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0.334	0	0	0	0	0.38
25	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	0	6.69	6.69	6.69	0	0	0	0	0	57.92
25	*Oenothera macrocarpa*	ncpf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	0	2.46	3.55
25	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	0	0	4.92	0	0	0	0	0	7.24
25	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	11	0	0	0	0	0	0	0	0	0	20.04
25	*Rudbeckia fulgida*	ncpf	0.2	0.15	1	0.9	0	0.795	0	0	0	0	0	0	0	0	2.15
25	*Salvia texana*	ncpf	1	0.6	1	0.9	8.01	0	0	0.801	0	0	0	0	2.136	0.801	25.43
25	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0.47	0	0.705	0	0	0	1.05
26	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	0	3.15	0.63	0	3.15	0	10.00
26	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	1.255	0.753	5.02	0.502	0	0	0	0	0	0	23.28
26	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	3.88	1.94	1.94	0	0	18.66
26	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	3.92	0	10.61
26	*Bouteloua trifida*	cpg	0.65	0.45	1	0.9	0	0	0	0	0	0	0	0	0.382	0	0.95
26	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0	6.64	0	0	0	0	0	20.53
26	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0.334	0	5.01	0	1.67	0	0	0	0	3.34	20.75
26	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	1.1	0	0	0	0	0	2.65
26	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	3.5	0	2.1	1.75	0	1.75	0.875	0	15.99
26	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	1.764	0	0	0	0	0	0	0	0	0	2.55
26	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0.57	0	0	0	0	0.88
26	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0.302	0	0	0	0.453	0.755	0.755	0	0.453	3.02	8.28
26	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	0	0	0	0	0	0	0	0	3	3.49
26	*Salvia texana*	ncpf	1	0.6	1	0.9	0.801	1.335	0	0.801	0.801	0	1.335	0.801	0	0	12.71
26	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0.47	1.175	0	0	0	0	1.47
26	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0.826	0	0	0	0	0	2.98
26	*Tetraneuris scaposa*	ncpf	1	0.4	1	0.9	0	0	0	0	0	0	0	1.5	0	0	2.16
27	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	31.04	46.56	15.52	62.08	58.2	77.6	19.4	15.52	3.104	0	791.23
27	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	31.36	0	0	84.84
27	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.55	0	0	0	0	0	0	0	0	0	1.32
27	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	1.7	0	0	0	5.52
27	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	7	0	0	0	0	0	0	0	0	0	11.22
27	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	5.04	0	0	0	0	0	0	0	0	0	7.27
27	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	3.8	0	0	0	0	0	0	0	5.87
27	*Linum berlandieri*	ncpf	1	0.4	1	0.9	4.53	0	0	0	0	0	0	0	0	0	6.54
27	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	3.34	0.334	0	0	0	0	0	0	0	0	4.23
27	*Sida actua*	ncpf	0.81	0.2	1	0.9	0	0	1.175	0	0	0	0	0	0	0	1.05
27	*Toxicodendron radicans*	ncpf	0.3	0.2	1	0.9	0	0	0	0	0	0	12	0	0	0	28.86
28	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	20.4	125.8	0	0	0	0	229.29
28	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	1.71	0	0	0	6.84	17.1	0	0	0	46.26
28	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0.251	20.08	17.57	25.1	15.06	12.55	0	0	0	0	280.16
28	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0.388	0	50.44	15.52	27.16	27.16	290.18
28	*Croton texensis*	ncaf	0.3	0.2	1	0.9	1.1	0.55	0	0	1.65	0.55	2.2	1.65	0	0	18.52
28	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	5.25	0	0	0	3.5	0	0	0	0	0	14.03
28	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	0	0	0	0	0	0	0	52.08	0	0	75.14
28	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	0	0	0	0	6.82	0	21.09
28	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	2.95	1.77	0.885	0	0	1.77	0	0	0	0	17.16

28	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	2.52	0	0	0	0	0	0	0	0	0	3.64
28	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0.95	0	0	22.8	0	0	36.72
28	*Linum berlandieri*	ncpf	1	0.4	1	0.9	4.53	0	0	0	0	0	0	0	0	0	6.54
28	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	3.34	0	0	3.85
28	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	2.13	0	0	0	0	0	0	0	0	0	4.19
28	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	1.175	0	0	0	0	0	0	0	4.7	5.23
29	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0.34	0	0	0	0	0	0.53
29	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	3.42	0	0	0	0	6.17
29	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	42.68	97	73.72	46.56	15.52	19.4	23.28	34.92	54.32	116.4	1259.62
29	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	35.28	0	0	11.76	0	0	0	0	0	127.26
29	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.55	0	0	0	0	0	0	0	0	0	1.32
29	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0.875	0	5.25	5.25	0	5.25	7	0	37.88
29	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	160.48	0	0	0	0	0	0	0	0	241.20
29	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	3.8	0	0	3.8	5.7	0	20.56
29	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	29.61	0	0	0	56.21
29	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0	5.01	0.835	6.73
29	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	0	0	0	0	0	77.43	167.58
30	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	35.91	8.55	0	11.97	18.81	44.46	5.13	10.26	243.65
30	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	7.76	46.56	0	46.56	0	0	242.59
30	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	19.92	36.52	0	0	6.64	0	39.84	0	33.2	0	420.86
30	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	2.2	3.3	3.3	2.2	0	0	0	0	0	26.45
30	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	3.5	0	0	0	0	0	5.61
30	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	0	0	110.33	40.12	0	226.12
30	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	10.08	0	0	0	17.64	0	0	0	0	0	40.00
30	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	0	11.4	3.8	23.50
30	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	0	59.22	0	0	112.43
30	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	5.01	0	0	5.77
30	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	2.94	0	2.94	0	0	0	0	0	12.99
30	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	7.72	13.51	9.65	0	0	0	0	3.86	103.20
30	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	0	0	0	0	1.065	2.10
30	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	4.7	0	0	0	0	0	0	4.7	0	8.37
31	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	34.92	46.56	34.92	69.84	27.16	23.28	27.16	3.88	0	0	643.81
31	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	0	7.84	21.21
31	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0	0	5.01	3.34	0	0	0	16.73
31	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	1.705	0	0	0	0	0	0	20.46	68.53
31	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	1.9	0	30.4	0	0	0	0	0	0.95	3.8	57.28
31	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	29.61	0	0	23.03	0	0	13.16	0	0	0	124.92
31	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0.835	0	0	0	0	0	0	0	0	1.67	2.88
31	*Plantago sp*	caf	1	0.7	1	0.9	0	0	0	0	0	1	0	0	0	0	2.53
31	*Ruellia nudiflora*	cpf	0.6	0.3	1	0.9	0	0	0	0	0	0	0	0	2	0	3.61
31	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	1.335	10.68	0	0	26.7	8.01	0	101.13
31	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	0	0	8.52	25.56	2.13	71.24
32	*Artemisia filifolia*	ncpf	0.5	0.2	1	0.9	0.5	0	0	0	0	0	0	0	0	0	0.72
32	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	31.04	0	7.76	3.104	3.88	5.82	7.76	1.94	1.94	11.64	180.08
32	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	0	0.573	0	0	0	0	0	0	0.191	0	2.07
32	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0.725	0	0	0	0	0	0	2.35
32	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0.835	0.668	0	0	0	0	0	0	0	3.01
32	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	0	0.33	0	0.79
32	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0.525	0	0	0	0	0	1.75	0	0	3.65
32	*Evolvulus sericeus*	cpf	1	0.4	1	0.9	3	0	0	0	0	0	0	0	0	0	4.33
32	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0.756	0	2.016	0	0	0	12.6	1.26	24.00
32	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	3.8	0	1.9	0	0	8.81
32	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0	0	1.208	0	0	0	0	0.151	0	0	1.96
32	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	0.3	0	0	0	0	0	0	0	0	0.35
32	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0.334	0	0	0	0	0	0	0.501	0	0.96
32	*Salvia texana*	ncpf	1	0.6	1	0.9	0	1.602	0	0	0.534	0	0	0	0	0	4.62
32	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	0.47	0	0	0.42
32	*Tetraneuris scaposa*	ncpf	1	0.4	1	0.9	0.75	0	0	0	0	0	0	0	0	0	1.08
33	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0.68	1.7	0.68	0.34	13.6	0	0.34	0.34	0	0	27.73
33	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	3.88	0	7.76	0	27.99
33	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	15.68	0	0	0.392	0	0.98	46.13
33	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	1.66	0	0	0	0	0	0	0	0	0	5.13
33	*Convolvulus equitans*	cpf	0.96	0.45	1	0.9	0	0	0	0	1.098	1.098	0	0	0	0	3.71
33	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.11	0	0	0	0	0	0	0	0	0	0.26

33	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0.875	0.875	0	0	0	0	0	0	0	0.175	3.09
33	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	1.003	0	0	0	0	1.51
33	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0.167	0	0.167	0	0	0	0	0.38
33	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	1.23	0	0	0	0	0.246	0	0	2.17
33	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0.658	0.658	0	1.645	0	0	0	0	0	2.54
33	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0.47	0.47	0.705	0.47	0	0.47	0	0	0	0	2.30
33	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	12.39	1.652	2.478	2.478	4.13	4.13	0	0	0	0	98.32
33	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	0	0	0	1.48	0	0	0	0	0	2.37
34	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0.34	0	1.7	0	0	0	0	1.7	5.87
34	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	7.76	0.388	0	0	1.164	0	22.39
34	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	0	5.82	14.00
34	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0.588	0.588	0	0	0	0	0	0	0	0	3.18
34	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	2.9	0	0	9.41
34	*Convolvulus equitans*	cpf	0.96	0.45	1	0.9	0	1.098	0	0	0	0	0	0	0	0	1.86
34	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0.334	0	0	0	0	0.167	0	0	0	1.00
34	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0.11	0	0	0	0	0	0.26
34	*Cynodon dactylon*	cpg	0.55	0.5	1	0.9	0	0	0	0	0	0	0	0.2	0	0	0.66
34	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0.085	0.255	0	0	1.10
34	*Digitalis purpurea*	ncaf	0.9	0.4	1	0.9	0	0	2	0	0	0	0	0	0	0	3.21
34	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0.35	0.175	0	0	0	0	0	0.175	0	1.12
34	*Erigeron compositus*	ncpf	1	0.45	1	0.9	0	0	0	0.5	0	0	0	0	0	0	0.81
34	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	3.255	0	0	0	0	0	0	0	0	0	4.70
34	*Glandularia bipinnatifida*	ncpf	0.8	0.5	1	0.9	0	0	0	0	0	0	0	0.1	0	0	0.23
34	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0.252	0	0	0	0	0.504	0	0	1.09
34	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0.38	0.19	0	0	0	0	0	0	0	0	0.88
34	*Juniperus ashei*	ncpf	0.2	0.45	1	0.9	0	0	0	0	0	0	0	0	0	0.5	4.06
34	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	3.29	0	0	0	0	0	6.25
34	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0	0	0	0	0	0	0.151	0.151	0	0	0.44
34	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0	0.167	0	0	0.19
34	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0.98	0	0	0.098	0	0	0	2.38
34	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	3.345	0	0	0	0	0	0	0	0	0	9.65
34	*Oenothera macrocarpa*	ncpf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	0	1.23	1.77
34	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0	0	0	0	0	0	0	0	1.1	2.00
34	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	0	1.335	0	0	0	0	2.89
34	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	1.065	0	0	0.213	1.704	2.13	0	0	10.06
34	*Scutellaria drummondii*	ncaf	0.95	0.4	1	0.9	0	0	0.2	0	0	0.1	0.2	0	0	0	0.76
34	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	0	0.235	0	0.21
34	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	8.26	8.26	0	8.26	0	0	0	0	89.39
34	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	0	0.74	3.7	0	0	0	0	0	3.7	13.05
35	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	11.64	11.64	11.64	7.76	0	11.64	0.388	0	0	0	131.56
35	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	3.92	0	0	0	0.98	0.98	15.91
35	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0	2.505	0	1.2525	0	0	0	7.53
35	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0.085	0	0	0	0	0	0	0.28
35	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0.875	0.175	0	0.875	0	0	0	0	0	3.09
35	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	5.015	0	0	0	0	0	0	0	7.54
35	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	0	0.252	0.36
35	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0	0	0.151	0.302	0	0	0	0	0	0	0.65
35	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0.167	0	0	1.336	0.835	2.69
35	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	0	0	0	0	0	2.007	0	0	0	5.79
35	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	0	0.246	0	0	0	0	0	0	0.36
35	*Scutellaria drummondii*	ncaf	0.95	0.4	1	0.9	0	0	0	0	0	0	0.2	0	0	0	0.30
36	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	0	19.4	46.65
36	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	1.96	1.96	2.94	0	0.196	0	0	0	0	0	19.09
36	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	1.45	0.145	0	5.18
36	*Castilleja campestris*	ncpf	1	0.65	1	0.9	0	0	0	0	0	0	0	0.24	0	0	0.56
36	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0.167	0	0	0	0	0	0	0.33
36	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0.11	0	0	0	0	0	0.26
36	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0.175	0.875	0.35	2.625	2.625	0	0.35	0	0	0	11.22
36	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	5.7	3.8	0.38	3.8	11.4	2.85	0.95	0.95	0.19	0	46.41
36	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	16.45	0	0	0	0	0	0	0	31.23
36	*Lythrum salicaria*	ncpf	0.35	0.2	1	0.9	0	0	0	0	0	0	0	0.098	0	0	0.20
36	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	20.07	0	0	0	3.345	0	0	20.07	0	125.49
36	*Panicum virgatum*	cpg	0.55	0.4	1	0.9	0	0	0	0	0	5.525	0	0	0	0.442	15.65
36	*Salvia texana*	ncpf	1	0.6	1	0.9	5.34	0	0	0	0	0	0	0	0	0	11.56

36	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	3.195	6.39	6.39	0	0	8.52	3.195	0.213	0	54.90
36	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	5.55	0	0	0	7.4	0	0	0	0	0	20.76
37	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	3.88	7.76	0.388	0	0	0	0	0	0	19.4	75.58
37	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0	0	0.175	0	0.28
37	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	2.5075	0	0	0	0	0	0	0	0	0	3.77
37	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	0	1.9	0	2.94
37	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	3.29	0	3.29	0	0.8225	0	0	14.05
37	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	0.5	0	0	0	0	0	0	0	0	0.90
37	*Salvia texana*	ncpf	1	0.6	1	0.9	5.34	24.03	10.68	10.68	0	0	0	0	0	0	109.79
37	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	1.065	6.39	6.39	6.39	10.65	0	1.065	1.065	0.213	0	65.38
37	*Solidago spp.*	ncpf	0.15	0.3	1	0.9	0	0	0	0.5	0	1	0	0	0	0	10.82
38	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	2.52	0	0	0	0	0	3.64
38	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	0	1.05	0.042	0.021	1.05	3.15	7.67
38	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	0	0	0	12.55	38.80
38	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	5.82	0	0	0	0	0	0	0	0	14.00
38	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	1.91	0	0	0.191	0	0.191	0	0	0	0	6.20
38	*Castilleja campestris*	ncpf	1	0.65	1	0.9	1.2	0.24	0	0.24	0	0.24	0	0	0.24	0	5.06
38	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0.11	0	0	0.22	0.011	0	0	0.82
38	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	1.75	0.35	0.35	1.75	0.875	0.175	0.175	0.35	0	0	9.26
38	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0.329	0	0	0	0	0	0	0	0	0	0.62
38	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	0	0	0	0	0	0	1	0	0	1.16
38	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0.167	0	0	0	0	0	0	0	0.19
38	*Rudbeckia fulgida*	ncpf	0.2	0.15	1	0.9	0.159	0	0	0.159	0.159	0	0	0	0	0	1.29
38	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	0	0	0	0	0	0	0	0	0.5	0.90
38	*Salvia texana*	ncpf	1	0.6	1	0.9	5.34	0.267	0.267	2.67	0.267	14.685	0.267	0	0	2.67	57.21
38	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0.426	0	0.213	0	2.13	0	0.213	0.213	2.13	0	10.48
38	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	0	0	0.235	0.21
38	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0.413	0	0.826	0	0	0.826	0	0	8.26	0	37.24
39	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	43.588	12.818	55.726	0	0	3.06	0	39.134	0	0.204	242.35
39	*Ambrosia trifida*	ncpf	0.8	0.4	1	0.9	11.696	0	0	0	0	0	0	0	0	0	21.09
39	*Annual forb*	ncaf	1	0.4	1	0.9	18.984	15.519	47.187	5.565	1.89	1.176	0	0	1.722	0	132.81
39	*Aristida oligantha*	cag	0.7	0.6	1	0.9	0	0.7028	0	0	0	0	0	0	0	0	2.17
39	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	150.6216	238.4648	52.574	0	93.896	0	155.8596	1662.70
39	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	27.5184	0	0	0	0	0	0	0	74.45
39	*Bromus japonica*	cag	0.95	0.7	1	0.9	0	0.6561	0	0	0	0	0	0	0	0	1.74
39	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	13.746	2.871	0	0	0	53.95
39	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0.506	0.737	0.088	0	0.242	0	0	0.121	0	4.07
39	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0.34	0	0	6.9785	0.4335	0	0	25.17
39	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	13.055	24.255	0.14	0.5075	0	2.17	0	0.945	0	1.7675	68.68
39	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0.708	0	0	0	0	0	0	0	0	1.65
39	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	78.9361	10.9327	14.6438	2.2066	0	0	19.3579	0	0	189.49
39	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	3.515	4.978	0.76	0	0	13.395	0.209	0	0	35.34
39	*Lythrum salicaria*	ncpf	0.35	0.2	1	0.9	0	0	0	0	0	0	0	1.5386	0	0	3.17
39	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0.0167	0.7849	0.2672	0	0	0	6.6132	0	0	0	8.84
39	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	1.372	0	0	0	0.3234	0	0	0	3.74
39	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	50.481	48.7131	0	452.3268	0	1085.14
39	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	0	3.811	0	0	4.181	4.292	3.145	4.921	0	32.62
40	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	0	0.502	0	0	1.55
40	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	38.8	0	0	0	0	0	0	0	0	0	93.31
40	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	2.94	0	1.96	0	0	0	0	0	13.26
40	*Carex planostachys*	cpg	0.5	0.45	1	0.9	0	0	0	2.9	0	0	0	0	0	0	9.41
40	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0.835	0	0	0	0	0	0	0	1.67
40	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0.55	0	0	0	0	1.32
40	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	1.4	0	0	0	2.24
40	*Glandularia bipinnatifida*	ncpf	0.8	0.5	1	0.9	0	0	0	0	0	0.3	0	0	0	0	0.68
40	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	2.52	0	0	0	0	0	0	0	0	3.64
40	*Hymenopappus artemisiifolius*	ncpf	1	0.4	1	0.9	0	0.5	0	0	0	0.2	0.5	0.5	0	0	2.45
40	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	0.95	0	0	1.47
40	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	0	0	0	0	0	0	6.69	0	0	19.31
40	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	6.39	0	0	0	0	0	12.57
40	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	1.88	0	0	0	0	0	0	0	0	1.67
41	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	11.64	7.76	17.46	23.28	77.6	0	0	5.82	0	11.64	373.22
41	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	7.25	0	8.7	0	0	0	2.9	0	61.20
41	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	1.75	0	0	0	0	0	0	0	0	0	2.81

41	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	13.02	0	0	0	0	0	0	0	0	0	18.79
41	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0.756	0	0	0	0	0	0	0	0	0	1.09
41	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	5.7	0	0	0	0	0	0	0	0	0	8.81
41	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	4.935	6.58	49.35	39.48	190.51
41	*Rudbeckia fulgida*	ncpf	0.2	0.15	1	0.9	0	0	0	0	0	0	0	6.36	0	0	17.21
41	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	10.65	8.52	8.52	6.39	2.13	71.24
42	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	19.4	0	5.82	19.4	11.64	0	0	0	0	135.29
42	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	39.2	9.8	7.84	0	0	0	0.98	0	0	0	156.42
42	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	0	0	0	33.2	102.65
42	*Cynodon dactylon*	cpg	0.55	0.5	1	0.9	0	0	0	0	0	0	0	0	2.5	0	8.20
42	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0.756	2.52	0	0	0	0	0	4.73
42	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	0	6.58	0	0	12.49
42	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	5.01	0	0	0	0.835	3.34	0	0	0	10.57
42	*Panicum coloratum*	cpg	0.6	0.4	1	0.9	0	0	0	1.105	0	0	0	0	0	0	2.66
42	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	26.32	0	9.87	0	0	0	0	0	0	0	31.08
42	*Ratibida columnifera*	ncpf	0.99	0.5	1	0.9	0	0	0	0	0	0	0	0	11	0	20.04
42	*Silphium albiflorum*	ncpf	1	0.5	1	0.9	0	0	0	0	0	0	0.3	0	0	0	0.54
42	*Solanum xanti*	ncpf	0.97	0.6	1	0.9	0	0	0	5	0	0	0	0	0	0	11.16
42	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	12.39	0	4.13	0	0	59.59
43	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	0	3.42	0	0	0	6.17
43	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	2.1	0	0	0	0	0	3.03
43	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	15.52	7.76	0	0	0	0	23.28	111.97
43	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	17.64	0	0	3.92	0	58.33
43	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	13.05	0.725	8.7	0	5.8	5.8	0	110.62
43	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	4.4	0	0	0	0	0.77	0	0	12.43
43	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0	0	0	3.5	5.61
43	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	7.6	1.9	17.1	0	9.5	0	3.8	7.6	11.4	9.5	105.74
43	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	0	29.61	0	0	56.21
43	*Panicum virgatum*	cpg	0.55	0.4	1	0.9	37.57	0	13.26	2.21	0	0	0	6.63	0	0	156.54
43	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0	0	0	0	49.35	0	0	0	0	42.38
43	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	12.78	0	2.13	10.65	6.39	0	62.86
43	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	24.78	0	0	0	0	0	0	103.25	461.83
43	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	14.8	0	0	0	0	0	0	0	0	23.73
44	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	23.8	0	0	17	0	0	0	0	0	63.99
44	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	0	0	0	12.6	8.4	10.5	45.45
44	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	23.28	69.84	0	0	0	11.64	46.56	7.76	382.55
44	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	1.1	0	0	0	0	0	0	0	2.65
44	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	1.7	0	0	0	0	0	0	0	0	0	5.52
44	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	15.75	0	5.25	0	0	1.75	1.75	0	39.28
44	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	13.64	0	0	0	0	0	0	42.17
44	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	23.03	0	0	0	0	0	0	43.72
44	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	5.01	0	0	0	5.77
44	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	7.72	0	0	23.16	7.72	0	0	0	0	114.67
44	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	0	0	32.04	0	0	26.7	127.13
44	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	78.81	14.91	0	0	34.08	70.29	40.47	14.91	6.39	12.78	536.43
45	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	13.6	27.2	0	0	0	0	0	0	0	0	63.99
45	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	65.96	93.12	11.64	69.84	27.16	11.64	11.64	7.76	27.16	0	783.76
45	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	37.24	0	0	100.75
45	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	2.2	0	0	0	5.29
45	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	8.75	0	0	0	0	0	8.75	12.25	47.69
45	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	0	13.64	23.87	0	0	0	115.98
45	*Helianthus maximiliani*	cpf	0.35	0.2	1	0.9	0	25	0	0	0	0	0	0	0	0	51.53
45	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	3.8	15.2	0	0	29.37
45	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	5.88	3.92	0	0	0	0	0	0	0	21.64
45	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	12.78	6.39	0	8.52	4.26	4.26	0	10.65	92.20
45	*Yucca sp.*	ncpf	0.8	0.65	1	0.9	0	0	0	0	0	0	0	0	51	110	471.86
46	*Annual forb*	ncaf	1	0.4	1	0.9	16.8	0	0	0	0	0	0	0	0	0	24.24
46	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	20.08	12.55	12.55	0	0	0	0	15.06	7.53	0	209.54
46	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	5.73	0	15.50
46	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	6.68	0	0	0	0	0	0	0	0	0	13.39
46	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	0.55	0	0	1.32
46	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	1.3125	0	8.75	0	0	0.875	0	0	14	0.875	41.38
46	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	3.54	0	0	0	0	0	0	0	0	0	8.24
46	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	3.8	9.5	0	20.56

46	*Linum berlandieri*	ncpf	1	0.4	1	0.9	1.51	0	0	0	0	0	0	0	0	0	2.18
46	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	30	0	0	0	1	0	0	0	0	36.07
46	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0.835	0	0	0	0	0	0	0	0	0	0.96
46	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0	0	0	0	0	3.92	7.84	25.97
46	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	0	0	0	0	0	100.35	0	0	167.25	772.22
46	*Salvia farinacea*	ncpf	1	0.6	1	0.9	0	0	16.02	5.34	0	0	0	0	0	0	46.23
46	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	4.26	159.75	42.6	0	0	0	0	406.51
46	*Sida spp.*	ncpf	0.81	0.2	1	0.9	7.05	0	2.35	0	0	0	0	0	0	0	8.37
47	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	71.82	8.55	5.13	0	0	154.21
47	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	85.36	0	0	15.52	7.76	11.64	0	0	38.8	27.16	447.87
47	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	2.2	3.3	0	0	0	3.3	1.1	23.81
47	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	3.5	0	0	0	24.5	12.25	0	0	0	7	75.75
47	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	44.33	0	27.28	37.51	23.87	30.69	0	0	0	0	506.07
47	*Eustoma exaltatum*	caf	0.5	0.35	1	0.9	1.8	0	0	0	0	0	0	0	0	0	4.55
47	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	50.15	320.96	0	0	0	557.77
47	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	20.16	0	0	0	0	0	29.09
47	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	76	49.4	51.3	7.6	60.8	15.2	72.2	68.4	45.6	55.1	775.44
47	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	11.69	0	8.35	0	0	0	0	0	0	0	23.07
47	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	7.72	0	0	0	0	0	15.44	13.51	3.86	3.86	131.87
47	*Ruellia nudiflora*	cpf	0.6	0.3	1	0.9	0	0	0	14	0	0	0	3	0	17	61.32
47	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	10.65	10.65	4.26	6.39	4.26	10.65	10.65	0	113.15
48	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	0	0	0	5.13	3.42	15.42
48	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	7.76	15.52	124.16	11.64	93.12	54.32	7.76	11.64	69.84	951.71
48	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	13.72	0	37.12
48	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.55	0	0	0	0	0	0	5.5	0	0	14.55
48	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0.175	0	10.5	0	0.875	1.75	0	0	0	0	21.32
48	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	6.82	0	0	0	0	0	21.09
48	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	20.06	170.51	0	180.54	0	270.81	0	0	0	70.21	1070.32
48	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	5.7	0	13.3	15.2	15.2	0	3.8	0	0	0	82.24
48	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	5.01	0	0	3.34	0	0	0	0	0	0	9.61
48	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	9.65	0	0	0	0	0	0	0	0	0	28.67
49	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	0	0	0	0	1.7	2.67
49	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	0.855	2.565	0	0	0	6.17
49	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	5.02	5.02	0	0	31.04
49	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	38.8	0	3.88	7.76	0	1.94	19.4	0	0	0	172.61
49	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	11.64	0	0	27.99
49	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	0	0	0	0.955	3.82	0	0	0	3.82	9.55	49.09
49	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	6.64	0	0	0	0	20.53
49	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.11	0	0	0	0	0	0	0	0.11	0	0.53
49	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0.425	0	0	0	0	0	0	0	1.38
49	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	1.75	0	0	1.75	22.75	0	0.875	8.75	5.25	3.5	71.54
49	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	0	0	0	6.51	0	0	0	0	0	0	9.39
49	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	2.52	0	0	0	0	0	3.64
49	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	3.8	0	3.8	0	1.9	1.9	0	0.95	19	0	48.46
49	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	0	0	0	0	25.56	50.29
49	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	8.26	0	0	0	0	0	0	0	0	0	29.80
49	*Tridens albescens*	cpg	0.6	0.4	1	0.9	0	3	0	0	0	0	0	0	0	0	7.21
50	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	1.7	0	0	0	0	2.67
50	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	0	0	0	0	1.71	3.08
50	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	1.94	1.94	7.76	0	3.88	31.04	65.96	65.96	1.94	433.87
50	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	0	3.88	9.33
50	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	7	0	0	0	0	11.22
51	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	27.2	10.2	10.2	27.2	6.8	0	3.4	0	0	0.68	134.37
51	*Annual forb*	ncaf	1	0.4	1	0.9	0	42	10.5	0	0	0	0	0	0	0	75.75
51	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	38.8	11.64	7.76	11.64	11.64	7.76	214.60
51	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	2.9	7.25	0	0	4.35	0	0	0	47.07
51	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	2.2	0	0	0	0	0	0	0	0	5.29
51	*Desmanthus illinoensis*	cpf	0.7	0.3	1	0.9	3	0	0	0	0	0	0	0	0	0.3	5.10
51	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	1.7	0	0	0	0	0	0	0	0	0	5.52
51	*Elymus virginicus*	cpg	0.95	0.6	1	0.9	0	0	2	0	0	0	0	0	0	0	4.56
51	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	0	0	3.54	0	0	8.24
51	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	5.7	3.8	0	0	22.8	0	0	0	0	0	49.93
51	*Lythrum salicaria*	ncpf	0.35	0.2	1	0.9	7.35	0	2.45	0	0	0	0	0	0	0	20.20
51	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	3.86	0	0	0	0	0	0	0	0	11.47

51	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	3	0	0	0	0	0	0	0	0	0	5.41
51	*Salvia farinacea*	ncpf	1	0.6	1	0.9	0	0	8.01	0	0	0	0	0	0	0	17.34
51	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	7.05	0	0	6.28
51	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	18.5	11.1	0	0	0	0	0	0	0	47.45
52	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	1.05	0	0	0	0	0	1.52
52	*Annual forb*	ncaf	1	0.4	1	0.9	0	1.05	10.5	0	0	2.1	0	8.4	0	0	31.82
52	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	3.88	7.76	0.776	0.388	0.776	7.76	2.716	0	0	0.776	59.72
52	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0.11	0.22	0.11	0.11	0	0.11	0.22	0.11	2.38
52	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	5.25	0	0.35	0	3.5	0.875	0.175	0	0	0.875	17.68
52	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	0	0	0	0	0	0	0	0	13.02	0	18.79
52	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	5.015	10.03	0	0	0	0	0	0	0	0	22.61
52	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	3.8	0	3.8	0	0	0	19	15.2	64.62
52	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	16.45	0	0	0	0	0	0	0	0	0	31.23
52	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0.167	0	0	0	0	0	0	0	0.167	0.167	0.58
52	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0.235	0	0	0	0	0	0	0.21
53	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0.68	0	0	0	0.68	3.4	0.68	0	8.53
53	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	3.88	3.88	1.94	0.388	0	0	0	0	5.82	38.26
53	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0.196	0	0	0	0	0	0	0	0	0.53
53	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0	0.664	0	0	0	0	0	2.05
53	*Cocculus carolinus*	ncpf	1	0.3	1	0.9	2.139	0	0	0	0	0	0	0	0	0	2.31
53	*Cocculus diversifolius*	ncpf	1	0.3	1	0.9	0	0	0	0	0	0	0	0	0	1.426	1.54
53	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0.167	0	0	0	0	0	0	0.33
53	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0.22	0	0.11	0.11	0	0	1.06
53	*Desmanthus illinoensis*	cpf	0.7	0.3	1	0.9	0	0	0	0	0	0.12	0	0	0	0	0.19
53	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0.35	0	0	0.175	0	0.35	0	0	0	0	1.40
53	*Eleocharis erythropoda*	cpg	0.95	0.4	1	0.9	0	0	0	0	0	0	0	0	0.087	0	0.13
53	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	2.604	0	0	1.302	3.255	1.953	0	0	0	0	13.15
53	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	0	0	0	0.341	0	0	0	1.05
53	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0.504	0	0	0.504	0.504	0.504	1.26	0	0	0	4.73
53	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0.95	0	0	0	0	0	0.57	0	2.35
53	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0.167	0.334	0.167	0	0.77
53	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0.386	0	0	0	0.579	0.386	0.772	0	0	0	6.31
53	*Salvia farinacea*	ncpf	1	0.6	1	0.9	0.534	0.534	0	0	0	0	0	0	0	0	2.31
53	*Tridens albescens*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	0.45	0	1.08
54	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	6.8	0	0	0	0	0	0	10.66
54	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	2.1	0	0	0	0	0	3.03
54	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	3.88	194	7.76	0	38.8	7.76	0	0	606.48
54	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0.392	0	0	0	0	0	0	0	0	1.06
54	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	1.45	0	1.45	0	0.29	0	0	0	0	0	10.36
54	*Castilleja campestris*	ncpf	1	0.65	1	0.9	0	0	0	0	0	0	0	0	0.24	0	0.56
54	*Desmanthus illinoensis*	cpf	0.7	0.3	1	0.9	0	2.4	0	0	0	0	0	0	0	0	3.71
54	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0.85	0	0	0	0	0	0	0	0	0	2.76
54	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0.875	0.35	1.75	0	1.3125	0	0	6.87
54	*Helianthus maximiliani*	cpf	0.35	0.2	1	0.9	0	0.2	0	0	0	0	0	0	0	0	0.41
54	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0.329	6.58	0	0	0	0	13.12
54	*Lythrum salicaria*	ncpf	0.35	0.2	1	0.9	9.8	0	0	0	0	0	0	0	0	0	20.20
54	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	1.67	0	0	0	0	0	0	0	0.167	0	2.11
54	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	2.46	1.23	0	0	0	0	0	0	0	0	5.43
54	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	0.267	0	0	0	0	0	0.58
54	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	10.65	0	0	10.65	0	41.91
54	*Sida spp.*	ncpf	0.81	0.2	1	0.9	2.35	0.47	0	0	0	0	0	0	0	0	2.51
54	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	8.26	0	0	0	0	0	29.80
54	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	0	22.2	0.925	1.11	0	0	0	0	0	38.85
55	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	6.8	0	0	0	0	0	0	0	0	10.66
55	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	1.71	0	6.84	13.68	13.68	0	0	64.77
55	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	7.76	15.52	0	7.76	15.52	0	111.97
55	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0	0	0.3	0	0	0	0	0	0	0.54
55	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	0	0	4.4	10.58
55	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	14	7	5.25	0	8.75	10.5	17.5	7	14	8.75	148.70
55	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	7.56	0	0	0	17.64	0	0	0	0	0	36.36
55	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	0	0	19.74	0	37.48
55	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	1.67	0	0	0.167	0	0	0	0	0	3.34	5.96
55	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	7.72	13.51	0	0	7.72	0	9.65	0	0	0	114.67
55	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	0	0	16.45	0	0	0	0	0	0	0	14.13

55	*Plantago sp*	caf	1	0.7	1	0.9	0	0	3	0	0	0	0	2	0	0	12.63
55	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	3	0	0	0	0	0	0	0	0	5.41
55	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	4.26	8.52	2.13	8.52	6.39	4.26	6.39	4.26	6.39	4.26	108.96
55	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	4.7	0	0	4.19
55	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	0	25.9	0	0	0	0	0	0	0	41.52
56	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0.251	5.02	0	12.55	5.02	0	0	0	7.53	2.51	101.66
56	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	19.4	0	0	46.65
56	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	15.52	0	0	37.32
56	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0.196	1.96	0	0	0	0	0	0	0	0	5.83
56	*Bromus texensis*	cag	0.95	0.7	1	0.9	0	0	0	0	7.29	0	7.29	0	0	0	38.75
56	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	8.35	3.34	0	0	0	0	0	0	0	0	23.43
56	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	1.75	0	5.25	0	0	0	0.875	3.5	18.24
56	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0	7.56	0	0	0	0	10.91
56	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	0	0	0	3.29	0	0	6.25
56	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	0.755	0	1.09
56	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0.835	3.34	1.67	3.34	0.835	1.67	0	0	0.835	0.835	15.38
56	*Opuntia engelmannii*	ncpf	0.8	0.15	1	0.9	0	0	0	50	0	0	0	0	0	4	36.52
56	*Salvia texana*	ncpf	1	0.6	1	0.9	0	1.602	0	0	0	0	0	0	0	1.335	6.36
56	*Sida spp.*	ncpf	0.81	0.2	1	0.9	7.05	1.175	2.35	0	4.7	2.35	2.35	0	1.175	1.175	19.88
56	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	20.65	0	0	0	0	0	0	0	74.49
56	*Symphyotrichum ericoides*	cpf	0.9	0.4	1	0.9	0	0	0	0	0	11.1	18.5	0	0	0	47.45
57	*Annual forb*	ncaf	1	0.4	1	0.9	0	4.2	0	0	0	0	0	0	0	0	6.06
57	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	10.04	12.55	10.04	10.04	7.53	15.06	7.53	10.04	7.53	5.02	294.90
57	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	5.88	0	0	15.91
57	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	3.82	0	10.33
57	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0.29	0	0	0	0	0	0.94
57	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0	0.15	0	0	0	0	0	0	0	0.27
57	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0	0	0	0	0	0	6.68	13.39
57	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	1.65	0.55	0	2.2	0	0	0.22	0	11.11
57	*Digitalis purpurea*	ncaf	0.9	0.4	1	0.9	0	0	1	0	0	0	0	0	0	0	1.60
57	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	7	0	0	0	1.75	0	0.875	0	1.75	1.75	21.04
57	*Eleocharis erythropoda*	cpg	0.95	0.4	1	0.9	0	0	0	0	0	0.87	0	0	0	0	1.32
57	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0	0	5.04	0	0	0	7.27
57	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	9.5	0.95	9.5	13.3	1.9	2.85	1.9	61.68
57	*Linum berlandieri*	ncpf	1	0.4	1	0.9	0	0	0	0.755	0	0	0	0.755	0	0	2.18
57	*Melampodium leucanthum*	ncpf	0.93	0.3	1	0.9	0	8	0	0	0	0	0	0	0	2	11.64
57	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	0	0	0	133.8	0	0	0	0	0	386.11
57	*Sida spp.*	ncpf	0.81	0.2	1	0.9	2.35	0	1.175	0	0	4.7	0	0	0	2.35	9.42
58	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	17	10.2	0	0	0	0	0	0	0	0	42.66
58	*Annual forb*	ncaf	1	0.4	1	0.9	0	0	0	0	10.5	12.6	0	0	0	0	33.33
58	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	58.2	31.04	31.04	0	11.64	1.94	7.76	11.64	0	3.88	377.89
58	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	0	2.9	2.9	18.83
58	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0.875	8.75	0	0.875	0	0	16.83
58	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	9.5	0	3.8	0	0	0	0	20.56
58	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0	0	32.9	0	0	0	0	0	62.46
58	*Oenothera speciosa*	ncpf	0.98	0.4	1	0.9	0	0	0	4.92	0	0	0	0	0	0	7.24
58	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	8.01	0	0	0	0	0	17.34
58	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	14.91	4.26	0	10.65	1.065	0	0	60.77
59	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0.34	0	0	0	0	6.8	11.20
59	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	1.96	3.92	0.98	0.392	0	0.196	0	0	0	0	20.15
59	*Callirhoe digitata*	cpf	0.3	0.2	1	0.9	0	0	0	0.1	0	0	0	0	0	0	0.24
59	*Coreopsis grandiflora*	ncaf	0.9	0.5	1	0.9	0	0	0	0	0.501	0	0	0	0	0	1.00
59	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	1.1	0	0	0	0	0	0.11	0.11	3.17
59	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	0	0	0.085	0.28
59	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0.175	0	0	0	0	0	0.28
59	*Eleocharis erythropoda*	cpg	0.95	0.4	1	0.9	0	0	0	0	0	0	0	0	0	3.48	5.29
59	*Erioneuron pilosum*	cpg	0.6	0.6	1	0.9	0	0	0	0	0.48	0	0	0	0	0	1.73
59	*Forestiera pubescens*	ncpf	0.2	0.35	1	0.9	0	0	0	0	0	0	3	0	0	0	18.94
59	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	0.756	0	0	0	0	0	1.09
59	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0.38	0.95	0	0	0	0	0	0	1.9	3.8	10.87
59	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	3.29	1.645	0	0	0	0	0	0	0	0	9.37
59	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0	0	0	0	0	0.098	0	0.22
59	*Muhlenbergia reverchonii*	cpg	0.5	0.4	1	0.9	0	0	6.69	0	0	0	0	0	0	0	19.31
59	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0.235	0	0	0	0	0	0	0	0.21

59	*Trifolium repens*	ncpf	1	0.65	1	0.9	0	0.3	0	0	0	0	0	0	0	0	0.70
60	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	6.8	0	0	0	0	0	0	10.66
60	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	11.97	0	0	13.68	3.42	0	0	5.13	0	0	61.68
60	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	77.6	124.16	0	11.64	42.68	42.68	69.84	85.36	54.32	62.08	1371.59
60	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	7.7	0.55	0	0	0.55	0	0	0.55	22.48
60	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	3.5	5.25	5.25	0	0.875	0	0	23.85
60	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	27.28	51.15	23.87	64.79	47.74	13.64	1.705	0	6.82	732.75
60	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	5.7	0	0	0	0.95	0	5.7	0	19.09
60	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	6.68	5.01	3.34	0.835	0.167	0	0	0	1.67	0	20.38
60	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	0	0	0	0	0	0	4.9	0	1.96	0	15.15
61	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	3.4	0	10.2	57.8	6.8	0	0	0	122.64
61	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	17.1	0	0	0	8.55	46.26
61	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	31.04	0	0	0	0	31.04	0	0	0	0	149.29
61	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	16.6	0	0	0	0	0	0	0	51.32
61	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	2.9	0	0	2.9	4.35	5.8	1.45	5.8	75.32
61	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	13.6	0	0	0	0	0	1.7	49.67
61	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	3.5	0	1.75	0	10.5	0	25.25
61	*Eleocharis erythropoda*	cpg	0.95	0.4	1	0.9	14.79	0	0	0	0	0	0	0	0	0	22.46
61	*Eleocharis sp.*	cpg	0.95	0.4	1	0.9	0	12.18	8.7	3.48	0	6.96	11.31	0	0.87	0	66.07
61	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	20.46	0	0	0	0	0	0	0	63.26
61	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	0	0	0	0	25.2	0	0	0	0	0	36.36
61	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	17.1	58.9	20.9	68.4	22.8	0	13.3	32.3	0	7.6	373.03
61	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	0	0	23.16	0	0	9.65	0	7.72	120.40
61	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	16.52	0	0	0	0	0	28.91	41.3	312.85
61	*Tridens albescens*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	3	4.5	0	0	18.04
62	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	6.8	0	0	0	0	0	0	0	0	10.66
62	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	5.13	6.84	8.55	0	0	0	18.81	18.81	11.97	6.84	138.79
62	*Annual forb*	ncaf	1	0.4	1	0.9	2.1	0	0	0	0	0	0	0	0	0	3.03
62	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	54.32	89.24	0	3.88	3.88	0	0	363.89
62	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	23.28	0	0	0	0	0	27.16	7.76	139.96
62	*Buchloe dactyloides*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	0	3.32	0	0	10.26
62	*Chamaecrista fasciculata*	caf	1	0.4	1	0.9	0	0	11	0	0	0	0	0	4	0	21.64
62	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	1.1	0	0	2.65
62	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	14	14	0	0	0	1.75	15.75	3.5	3.5	12.25	103.81
62	*Eryngium leavenworthii*	ncaf	0.5	0.2	1	0.9	0	0	0	0	0	0	0	26.04	0	0	37.57
62	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	210.63	0	5.015	0	0	0	0	0	324.11
62	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	15.2	0	0	0	23.50
62	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0.835	0	5.01	0	0	0	0	0	0	6.73
62	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0.965	0	0	0	0.965	0	0	0	0	0	5.73
62	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	1.335	0	0	2.67	0	0	8.67
62	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	0	0	0	0	0	2.35	0	0	2.09
63	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0.388	58.2	19.4	38.8	31.04	11.64	0	0	383.48
63	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	0	5.88	15.91
63	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0	0	3.5	1.75	8.42
63	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	0	0	0	1.9	2.94
63	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	1.065	10.65	0.639	10.65	10.65	0	0	14.91	0	0	95.55
63	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	0	0	0	33.04	0	119.18
64	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	0	0	0.068	0	0	0.11
64	*Annual forb*	ncaf	1	0.4	1	0.9	4.2	0	0	0	0	0	0	0	0	0	6.06
64	*Annual forb*	ncaf	1	0.4	1	0.9	0	0.21	0	0	0	0	0	0	0	0	0.30
64	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	19.4	34.92	31.04	58.2	0	27.16	19.4	0	54.32	38.8	681.13
64	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	0	7.84	0	21.21
64	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	0	0	0	0	13.37	9.55	0	0	0	0	62.01
64	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0.055	0	0	0	0	0	0	0	0.13
64	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	3.5	0.4375	0.35	0	3.5	0.875	0.875	1.75	1.75	5.25	29.32
64	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	0	0	0	5.015	0	0	0	7.54
64	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	3.8	0	0	0	0	0	0	0	3.8	0	11.75
64	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	0	0.1645	6.58	0	1.645	0	9.87	0	3.29	40.91
64	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0.334	0	0	0	0.38
64	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	85.54	0	0	0	0	0	0	0	0	0	73.47
64	*Plantago sp*	caf	1	0.7	1	0.9	0	0	0	0	0	0	1	0	0	0	2.53
64	*Rudbeckia fulgida*	ncpf	0.2	0.15	1	0.9	1.59	0	0	0	0	0	0	0	0	0	4.30
64	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	16.02	0	0	0	0	0	0	0	34.67
64	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	0	0	38.34	0	0	75.44

65	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	0	0.34	0	0	0	0.53
65	*Annual forb*	ncaf	1	0.4	1	0.9	0.21	0	0	0	0	0	0	0	0	0	0.30
65	*Annual forb*	ncaf	1	0.4	1	0.9	0	4.2	6.3	10.5	0	0	0	12.6	12.6	6.3	75.75
65	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	3.88	7.76	0.776	0	0	0	0	27.16	95.17
65	*Bouteloua hirsuta*	cpg	0.6	0.45	1	0.9	0	0.382	0	0	0	0	0	0	0	0	1.03
65	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.11	0	0	0.11	0	0.11	0	0	0.55	0.11	2.38
65	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0.175	0.175	3.5	5.25	0.875	1.75	0.35	3.5	1.75	0	27.78
65	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	10.03	0	0	0	0	0	0	5.015	0	0	22.61
65	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	5.7	0	0	0.95	0	0.38	0	1.9	3.8	0.95	21.15
65	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	0	6.58	0	0	0	0.329	0	0	0	0	13.12
65	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	0	0	0	0.167	0	0	0	0.19
65	*Ruellia nudifloa*	cpf	0.6	0.3	1	0.9	0	0	0	0	0	0.1	0	0	0	0	0.18
65	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	8.52	0	0	0	0	1.065	18.86
65	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	20.65	8.26	0	0	0	8.26	0.413	0	0	0	135.57
66	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	0	0	1.7	3.4	0	8.00
66	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	59.85	3.42	0	5.13	46.17	0	11.97	35.91	167.58	0	595.24
66	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	19.4	0	0	0	46.56	0	0	0	0	0	158.62
66	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	0	0	0	0	0	1.1	0	0	2.65
66	*Elymus virginicus*	cpg	0.95	0.6	1	0.9	0	0	0	0	0	0	0	0	2	0	4.56
66	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	68.2	88.66	0	0	10.23	0	30.69	0	0	0	611.51
66	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	661.98	0	0	0	0	0	0	0	0	994.95
66	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	3.8	5.7	13.3	53.2	34.2	0	13.3	0	190.92
66	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0	3.34	0	0	1.67	0	3.34	0	9.61
66	*Monarda citriodora*	ncaf	0.98	0.6	1	0.9	2.94	0	0	0	0	0	0	0	0	0	6.49
66	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	0	15.44	0	7.72	0	0	7.72	0	91.73
66	*Phyla nodiflora*	cpf	0.84	0.2	1	0.9	9.87	6.58	115.15	36.19	0	0	0	0	0	0	144.11
66	*Salvia texana*	ncpf	1	0.6	1	0.9	0	0	0	0	0	0	0	0	0	18.69	40.45
66	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	0	0	0	0	19.17	37.72
66	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	4.13	12.39	0	0	0	20.65	20.65	45.43	0	0	372.44
67	*Aristida purpurea*	cpg	0.7	0.6	1	0.9	0	0	0	0	0	0	0.502	0	7.53	0	24.83
67	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	3.88	0	19.4	1.164	0	0	0	0	58.78
67	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	3.92	0.392	0	0	0	0	0	0	0	0	11.67
67	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	0	0	0	0.725	0	0	0	0	0	0	2.35
67	*Centaurium beyrichii*	ncaf	1	0.5	1	0.9	0	0.03	0.075	0	0	0	0	0	0	0	0.19
67	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0.38	0	0	0.19	0	0.88
67	*Panicum obtusum*	cpg	0.55	0.4	1	0.9	0	0	0	0	0	0	0.663	11.05	0	0	30.73
68	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	0	0	0	0	6.84	0	0	3.42	29.07	70.93
68	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0	0	0	0	62.08	31.04	31.04	0	0	0	298.58
68	*Carex charokeensis*	cpg	0.5	0.45	1	0.9	13.05	11.6	0	0	0	0	0	0	0	0	80.02
68	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0.55	0	0	9.9	0	0	0	2.2	0	0	30.42
68	*Dichanthelium oligosanthes*	cpg	0.5	0.45	1	0.9	0	0	0	0	0	0	0	3.4	0.85	0	13.80
68	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	3.8	0	83.6	11.4	7.6	164.49
68	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	0	0	30.88	0	0	0	0	0	0	91.73
68	*Paspalum dilitatum*	cpg	0.6	0.45	1	0.9	0	0	0	0	0	0	0	5	0	0	13.53
68	*Sporobolus heterolepis*	cpg	0.6	0.6	1	0.9	0	0	0	0	0	0	0	0	0	8.26	29.80
69	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	0	20.52	0	0	0	0	0	0	0	6.84	49.35
69	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	7.76	15.52	7.76	42.68	0	0	0	0	0	46.56	289.25
69	*Bouteloua curtipendula*	cpg	0.6	0.45	1	0.9	0	0	0	0	11.76	0	0	0	0	0	31.82
69	*Chamaecrista fasciculata*	caf	1	0.4	1	0.9	0	0	0	0	0	0	0	0	0	8	11.54
69	*Croton texensis*	ncaf	0.3	0.2	1	0.9	0	0	1.1	0	0	2.2	0	0	0	0	7.94
69	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	7	24.5	14	0	0	10.5	0	5.25	0	21	131.86
69	*Euphorbia bicolor*	ncaf	0.7	0.6	1	0.9	0	0	0	30.69	0	0	0	0	0	0	94.89
69	*Gaillardia pulchella*	ncaf	0.93	0.6	1	0.9	0	0	0	0	0	2.95	0	0	0	0	6.87
69	*Grindelia squarrosa*	ncaf	0.48	0.2	1	0.9	0	0	0	30.09	0	110.33	0	0	0	0	211.05
69	*Gutierrezia sarothrae*	ncaf	1	0.4	1	0.9	5.04	0	0	0	0	0	0	0	0	0	7.27
69	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	0	0	0	0	0	0	30.4	28.5	36.1	0	146.86
69	*Liatris punctata*	ncpf	0.38	0.2	1	0.9	9.87	0	0	16.45	0	0	0	0	0	0	49.97
69	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	6.68	0	0	0	0	0	0	0	0	0	7.69
69	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	9.65	0	0	0	0	1.93	55.97	61.76	50.18	0	533.19
69	*Panicum virgatum*	cpg	0.55	0.4	1	0.9	0	0	0	0	0	0	0	0	6.63	0	17.39
69	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	6.39	0	0	0	0	0	44.73	0	8.52	0	117.34
69	*Sida spp.*	ncpf	0.81	0.2	1	0.9	0	0	4.7	0	0	0	0	0	0	0	4.19
70	*Ambrosia psilostachya*	ncpf	0.46	0.2	1	0.9	0	0	0	0	0	0	0	0	6.8	0	10.66
70	*Amphiachyris dracunculoides*	ncaf	0.8	0.4	1	0.9	13.68	0	3.42	22.23	0	22.23	0	0	0	3.42	117.20

70	*Bothriochloa ischaemum*	cpg	0.6	0.4	1	0.9	0.388	19.4	11.64	23.28	104.76	31.04	19.4	0	0	0	504.78
70	*Bothriochloa laguroides*	cpg	0.6	0.4	1	0.9	0	0	0	0	0	0	0	0	11.64	0	27.99
70	*Diodia virginiana*	ncaf	0.9	0.4	1	0.9	0	0	0	0	0	0	0	10.5	0	0	16.83
70	*Iva angustifolia*	ncaf	0.35	0.15	1	0.9	7.6	17.1	15.2	0	0	0	0	0	9.5	24.7	114.55
70	*Mimosa microphylla*	cpf	0.94	0.3	1	0.9	0	0	0.167	0	0	0	0	0	0	0	0.19
70	*Nassella leucotricha*	cpg	0.85	0.7	1	0.9	0	5.79	0	0	0	0	0	11.58	3.86	0	63.07
70	*Schizachyrium scoparium*	cpg	0.55	0.3	1	0.9	0	0	0	0	0	0	0	0	0	6.39	12.57

APPENDIX G

Table 2.12 Biomass summary table for each sample location showing total production, total consumable biomass, and non-consumable biomass in lbs. per acre per year

Sample Location	Total Annual Production	Consumable Biomass	Non-Consumable Biomass
1	76.68	31.49	45.19
2	1686.08	1320.31	365.78
3	2032.49	1601.34	431.15
4	367.20	174.27	192.93
5	206.60	97.17	109.42
6	1942.55	1124.56	818.00
7	397.43	160.96	236.47
8	437.37	256.96	180.41
9	649.55	358.87	290.68
10	128.11	124.35	3.76
11	840.46	831.44	9.02
12	287.75	243.56	43.88
13	195.08	92.38	102.71
14	1293.18	1083.30	209.88
15	321.62	130.00	191.62
16	3177.07	1542.90	1634.17
17	2034.38	1670.17	364.20
18	1777.33	896.30	881.02
19	464.64	277.63	187.01
20	30.23	30.23	0.00
21	85.06	65.96	19.10
22	2240.20	1297.43	942.77
23	1211.82	1101.64	110.18
24	2334.52	1744.73	589.78
25	225.13	137.26	87.87
26	157.94	77.01	80.92
27	947.95	885.82	62.13
28	1051.98	578.37	473.61
29	1925.07	1393.61	531.46
30	1473.63	774.52	699.12
31	1113.87	745.28	368.59
32	239.21	189.79	49.42
33	223.66	186.59	37.06
34	214.87	174.94	39.93
35	176.06	156.23	19.84
36	389.50	287.72	101.78
37	283.51	141.86	141.66

Sample Location	Total Annual Production	Consumable Biomass	Non-Consumable Biomass
38	194.76	107.81	86.94
39	3649.19	2946.79	702.40
40	164.56	149.41	15.15
41	744.87	505.66	239.21
42	555.42	506.47	48.96
43	1217.45	1028.25	189.20
44	1409.32	1044.93	364.39
45	1784.07	1028.24	755.83
46	1632.69	1404.73	227.95
47	2903.96	781.82	2122.14
48	2252.05	1027.11	1224.94
49	532.35	389.95	142.40
50	460.17	443.20	16.97
51	658.59	341.18	317.40
52	251.14	60.29	190.84
53	88.09	49.31	38.78
54	800.43	737.45	62.97
55	728.51	415.24	313.27
56	490.21	367.55	122.67
57	855.18	709.52	145.66
58	657.91	457.48	200.42
59	104.04	46.99	57.05
60	2277.64	1391.97	885.68
61	1532.22	865.42	666.81
62	1203.09	548.22	654.87
63	625.48	614.12	11.35
64	1051.25	916.16	135.09
65	414.62	251.00	163.62
66	3268.98	818.78	2450.20
67	129.43	128.36	1.07
68	793.30	527.45	265.84
69	1718.46	1008.23	710.24
70	867.85	608.60	259.25

APPENDIX H

Table 2.13. Table of stocking rates in Animal Units per year for each of the grazing thresholds by grazing management unit.

GMU	Option 1 (AU)	Option 2 (AU)	Option 3 (AU)	Option 4 (AU)
Western Maneuver Area - South	236.8	106.8	94.7	106.8
North Fort Hood	9	0	0	9
Western Maneuver Area - North	748.6	277.6	84.9	84.9
Eastern Training Area – North	293	105.1	43.2	293
Eastern Training Area – South	119.8	41.4	27	119.8
West Fort Hood – South	100.6	29.6	8.5	100.6
West Fort Hood – North West	67.1	37.4	2.5	67.1
West Fort Hood – North East	11.8	2.7	0	11.8
Total	1586.7	600.7	260.8	793
Live Fire Area Stocking Rate				750
Grand Total				1543

*Cells highlighted in green were selected for the Option 4 Combination Strategy for each GMU

Option 1: Harvest Efficiency: 25% harvest efficiency using only grazeable acres

Option 2: Maintenance Threshold: Establishing a 750 lb./ac or greater threshold for residual biomass using only grazeable acres

Option 3: Conservation Threshold: Establishing a 1000 lb./ac or greater threshold for residual biomass using only grazeable acres

Option 4: Combination Strategy: Rate based on physical characteristics and use of the GMU using an approach where the most appropriate of Option 1, 2, & 3 and the option to defer, if ecological trend is predicted to be declining or erosion is predicted to be excessive. The specific strategy selected is based on best management strategies considering the condition of the range, other land uses, and potential for conflicts with training activities. A limit of 750 AUs is established in the Live Fire Area

Assumptions for biomass loss due to training and grazing management plan by management units are as follows:

- Western Maneuver Area - South: 15% reduction - Maintenance Threshold
- North Fort Hood: 10% reduction - Harvest Efficiency
- Western Maneuver Area - North: 40% reduction - Conservation Threshold
- Eastern Training Area – North: 10% reduction - Harvest Efficiency
- Eastern Training Area – South: 10% reduction - Harvest Efficiency
- West Fort Hood – South: 10% reduction - Harvest Efficiency
- West Fort Hood – North West: 10% reduction - Harvest Efficiency
- West Fort Hood – North East: 10% reduction - Harvest Efficiency

APPENDIX I

Table 3.14. Table of parameters used to calculate soil loss in each of the sample locations

Sample location	Kw	LS Factor	R	P	C 25% HE	C 1000 res	C 750 res
1	0.32	0.179	240	1	0.220553113	0.218058102	0.218058102
2	0.32	0.2182	240	1	0.09832433	0.047997156	0.04458111
3	0.32	0.6319	240	1	0.06669264	0.10954529	0.114727165
4	0.15	0.5497	240	1	0.130724943	0.121048411	0.121048411
5	0.32	0.135	240	1	0.197561429	0.190412183	0.190412183
6	0.17	0.179	240	1	0.095675379	0.295284106	0.261115228
7	0.32	0.179	240	1	0.260600301	0.246705244	0.246705244
8	0.32	0.135	240	1	0.041472111	0.03841103	0.03841103
9	0.17	0.2096	240	1	0.03621736	0.035737603	0.035737603
10	0.17	0.3322	240	1	0.240231525	0.22996399	0.22996399
11	0.17	0.3322	240	1	0.16931481	0.115883224	0.373388865
12	0.17	0.2096	240	1	0.26680928	0.245663083	0.245663083
13	0.24	0.01	240	1	0.285650879	0.277183277	0.277183277
14	0.32	0.179	240	1	0.076590589	0.223670444	0.191744399
15	0.15	0.9482	240	1	0.038628161	0.037460793	0.037460793
16	0.32	0.135	240	1	0.066183777	0.114102202	0.116339622
17	0.32	0.135	240	1	0.081958225	0.064520864	0.070114954
18	0.32	0.179	240	1	0.043802496	0.100612102	0.052878462
19	0.32	0.135	240	1	0.066549225	0.058184048	0.058184048
20	0.32	0.179	240	1	0.340094427	0.337018257	0.337018257
21	0.15	0.5497	240	1	0.22533593	0.220060783	0.220060783
22	0.32	0.2182	240	1	0.065615607	0.081298938	0.081298938
23	0.17	0.3322	240	1	0.068245005	0.099746034	0.082453746
24	0.32	0.179	240	1	0.096937696	0.048972892	0.054708237
25	0.17	0.3322	240	1	0.120580724	0.113345182	0.113345182
26	0.17	0.3322	240	1	0.20706713	0.201222095	0.201222095
27	0.15	0.9482	240	1	0.084890224	0.158219803	0.035651749
28	0.17	0.157	240	1	0.095067602	0.071858144	0.071858144
29	0.28	0.536	240	1	0.06814519	0.10026662	0.095362743
30	0.28	0.536	240	1	0.046207625	0.065266112	0.133643518
31	0.17	0.3322	240	1	0.15437407	0.111638187	0.15437407
32	0.17	0.157	240	1	0.086349111	0.07875514	0.07875514
33	0.32	0.179	240	1	0.143157279	0.132142032	0.132142032
34	0.32	0.179	240	1	0.091359568	0.083986134	0.083986134
35	0.32	0.179	240	1	0.18393487	0.173019472	0.173019472
36	0.17	0.157	240	1	0.122907681	0.107899714	0.107899714

37	0.15	0.5497	240	I	0.165968772	0.156671656	0.156671656
38	0.28	0.536	240	I	0.256991358	0.247711533	0.247711533
39	0.17	0.157	240	I	0.167683912	0.232964108	0.149282037
40	0.32	0.179	240	I	0.156714112	0.147292467	0.147292467
41	0.32	0.179	240	I	0.036891228	0.035782698	0.035782698
42	0.28	0.2983	240	I	0.07118541	0.055724143	0.055724143
44	0.32	0.135	240	I	0.079466506	0.236220402	0.200305938
45	0.32	0.1643	240	I	0.080159998	0.239107088	0.201662429
46	0.15	0.01	240	I	0.135281648	0.035995532	0.035745663
47	0.17	0.179	240	I	0.173507363	0.120104792	0.374671447
48	0.17	0.157	240	I	0.112238326	0.082624897	0.082624897
49	0.17	0.157	240	I	0.200463848	0.172491144	0.172491144
50	0.32	0.179	240	I	0.228317321	0.194024654	0.194024654
51	0.32	0.179	240	I	0.036084634	0.035764405	0.035764405
52	0.17	0.157	240	I	0.35610859	0.349828585	0.349828585
53	0.17	0.157	240	I	0.230797373	0.226789999	0.226789999
54	0.17	0.3322	240	I	0.035727809	0.039173593	0.039173593
55	0.17	0.3322	240	I	0.215694702	0.184588885	0.184588885
56	0.17	0.3322	240	I	0.204457028	0.177688668	0.177688668
57	0.15	0.01	240	I	0.110586647	0.078975491	0.078975491
58	0.32	0.135	240	I	0.037655818	0.035656201	0.037655818
59	0.17	0.157	240	I	0.205703567	0.202139489	0.202139489
60	0.32	0.179	240	I	0.067865838	0.092917818	0.092917818
61	0.28	0.536	240	I	0.078132671	0.071571273	0.216110109
62	0.17	0.3322	240	I	0.212085002	0.172074248	0.172074248
63	0.32	0.179	240	I	0.063800781	0.047971779	0.047971779
64	0.17	0.157	240	I	0.113088527	0.084819308	0.084819308
65	0.17	0.157	240	I	0.247703675	0.226869434	0.226869434
66	0.32	0.179	240	I	0.054914417	0.065777184	0.16038447
67	0.15	0.9482	240	I	0.041864588	0.040134304	0.040134304
68	0.15	0.9842	240	I	0.042613111	0.053129635	0.053129635
69	0.17	0.179	240	I	0.114070711	0.350990142	0.301993713
70	0.17	0.157	240	I	0.21316565	0.168917377	0.168917377

APPENDIX J

Table 3.15a. Erosion analysis sediment yield data (tons/acre) after removing biomass loss due to training

Sampling Location	Soil	Sediment Yield with 25% Harvest Efficiency	Sediment Yield with 750 lbs./acre Residue	Sediment Yield with 1000 lbs./acre Residue
1	Doss	3.03	3.00	3.00
2	Topsey	1.65	0.75	0.80
3	Evant	3.24	5.57	5.32
4	Real	2.59	2.40	2.40
5	Krum	2.05	1.97	1.97
6	Brackett	0.70	1.91	2.16
7	Doss	3.58	3.39	3.39
8	Krum	0.43	0.40	0.40
9	Brackett	0.31	0.31	0.31
10	Brackett	3.26	3.12	3.12
11	Brackett	2.29	5.06	1.57
12	Brackett	2.28	2.10	2.10
13	Bastsil	0.16	0.16	0.16
14	Doss	1.05	2.64	3.07
15	Eckrant	1.32	1.28	1.28
16	Krum	0.69	1.21	1.18
17	Krum	0.85	0.73	0.67
18	Slidell	0.60	0.73	1.38
19	Krum	0.69	0.60	0.60
20	Doss	4.68	4.63	4.63
21	Real	4.46	4.35	4.35
22	Topsey	1.10	1.36	1.36
23	Brackett	0.92	1.12	1.35
24	Slidell	1.33	0.75	0.67
25	Brackett	1.63	1.54	1.54
26	Brackett	2.81	2.73	2.73
27	Eckrant	2.90	1.22	5.40
28	Nuff	0.61	0.46	0.46
29	Cho	2.45	3.43	3.61
30	Cho	1.66	4.81	2.35
31	Brackett	2.09	2.09	1.51
32	Nuff	0.55	0.50	0.50
33	Slidell	1.97	1.82	1.82
34	Doss	1.26	1.15	1.15

Sampling Location	Soil	Sediment Yield with 25% Harvest Efficiency	Sediment Yield with 750 lbs./acre Residue	Sediment Yield with 1000 lbs./acre Residue
35	Doss	2.53	2.38	2.38
36	Nuff	0.79	0.69	0.69
37	Real	3.28	3.10	3.10
38	Cho	9.26	8.92	8.92
39	Nuff	1.07	0.96	1.49
40	Doss	2.15	2.02	2.02
41	Doss	0.51	0.49	0.49
42	Bosque	1.43	1.12	1.12
44	Krum	0.82	2.08	2.45
45	Doss	1.01	2.54	3.02
46	Real	0.05	0.01	0.01
47	Brackett	1.27	2.74	0.88
48	Nuff	0.72	0.53	0.53
49	Nuff	1.28	1.10	1.10
50	Doss	3.14	2.67	2.67
51	Slidell	0.50	0.49	0.49
52	Nuff	2.28	2.24	2.24
53	Nuff	1.48	1.45	1.45
54	Brackett	0.48	0.53	0.53
55	Brackett	2.92	2.50	2.50
56	Brackett	2.77	2.41	2.41
57	Real	0.04	0.03	0.03
58	Krum	0.39	0.39	0.37
59	Nuff	1.32	1.29	1.29
60	Slidell	0.93	1.28	1.28
61	Cho	2.81	7.78	2.58
62	Brackett	2.87	2.33	2.33
63	Slidell	0.88	0.66	0.66
64	Nuff	0.72	0.54	0.54
65	Nuff	1.59	1.45	1.45
66	Doss	0.75	2.20	0.90
67	Eckrant	1.43	1.37	1.37
68	Eckrant	1.51	1.88	1.88
69	Brackett	0.83	2.21	2.56
70	Nuff	1.37	1.08	1.08

APPENDIX K

Table 3.15b. Sediment yield (tons/acre) by grazing management unit under three grazing options

	Sediment Yield (tons/acre)			Acceptable Soil Loss (tons/acre)
GMU	25% Harvest Efficiency	750 lbs. Residual	1000 lbs. Residual	T Value
Western Maneuver Area - North	1.99	1.93	2.33	3.09
North Fort Hood	0.16	0.16	0.16	5.00
Western Maneuver Area - South	2.11	1.98	2.00	2.79
Eastern Training Area – North	1.60	1.91	1.94	2.00
Eastern Training Area – South	3.53	3.56	3.51	3.71
West Fort Hood – North West	0.96	2.41	2.85	3.50
West Fort Hood – North East	1.40	1.40	1.45	2.00
West Fort Hood – South	1.54	1.63	1.40	2.00

APPENDIX L

FORT HOOD VEGETATION SURVEYS 2005

FINAL REPORT

Prepared for:

U.S. Army Engineer Research and Development Center
Construction Engineering Research Laboratory (CERL)
2902 Farber Drive
Champaign, IL 61822

by:

The Center for Grazinglands and Ranch Management
Texas A&M University
College Station, Texas
October 1, 2005

THE VEGETATION SURVEYS

INTRODUCTION

The Center for Grazinglands and Ranch Management (CGRM) at Texas A&M University implemented a contract via CERL on behalf of Ft. Hood Directorate of Public Works (DPW) and the Central Texas Cattleman's Association (CTCA) to produce an inventory of forage resources. The process involved on-the-ground studies of 131 predetermined points on Ft. Hood used in 2004 by a survey conducted by CGRM. The 131 points in the 2004 survey included 114 points established in 2002 by USDA NRCS in a similar inventory in addition to points added in the Live Fire Area and adjustments to reduce points in areas determined to be adequately represented with fewer points. During the current 2005 survey, adjustments were made also on several points that were agreed to be unrepresentative. The GPS coordinates for the points are shown in Appendix A and the locations plotted on the map in Appendix B.

The current inventory was accomplished with teams formed under the leadership of Dr. Bob Blaisdell and utilizing Texas A&M University graduate students from the Department of Rangeland Ecology and Management, as well as four Gatesville High School student members of the 4-H Grass Judging Team. One of the graduate students and three of the high school students participated in the 2004 survey. Initial field work was completed on July 14, 2005, however, this time was extended by the decision to resurvey five points, three of which were agreed by representatives of DPW and CTCA to be unrepresentative. Two additional points were moved during the initial survey due to ongoing or recent heavy tank disturbance. The new coordinates and explanations for any changes from the 2004 coordinates are documented in the footnotes of Appendix A.

In order to provide efficient access to survey point locations, members of the CTCA familiar with the area served as guides to the teams. Ms. Laura Sanchez, Ft. Hood Directorate of Public Works, worked with teams during the surveys for a second year. Ms. Sanchez' assistance in plant identification and the assistance of the cattleman guides are acknowledged and appreciated. Assistance of Messrs. Steve Burrow and Tim Buchanan in furnishing information needed to accomplish the surveys is recognized and appreciated, as is the cooperation of NRCS personnel. We also appreciate the repeat opportunity for our students to have an educational experience on Ft. Hood.

PROCEDURES

An effort was made to follow as closely as practical the same procedures used by NRCS to conduct the 2002 vegetation survey and by CGRM in conducting the 2004 vegetation survey. This included use of procedures for double sampling contained in Chapter 4 of the National Range and Pasture Handbook. At each sampling point, GPS coordinates were recorded and a 200 ft. tape was stretched in a north direction using a hand-held compass to identify a transect (line) for sampling. Beginning at 20 ft. on the tape and at each 20 ft. interval to the end, a .25 sq. meter sampling plot was placed on alternating sides of the tape. A double sampling procedure was used in which plants present on the sites were identified, harvested and weighed in grams to determine appropriate weight units for each species. The weight units were then used to estimate the weight of each plant species (in grams) contained within the plots. Weights for plants in all 10 plots were estimated and then two plots were completely harvested, weighed and recorded to serve as a basis for evaluating estimated weights. A photo was taken to show an average view of the vegetation at close range (approximately 5 feet above ground). A second photo was taken to show a landscape view. The number of transects within each management unit is presented in Table 1.

Estimates for percent air dry material are based on NRCS guidelines presented in the National Range and Pasture Handbook (Exhibit 4-2). A conversion factor (0.8652) based on a comparison of over 400 air dry to oven dry plants was used to convert air dry estimated weights to oven dry weight. Samples from the clippings were taken from each of the transects and allowed to air dry. These samples were then placed in a drying oven at 65º C for 72 hours to obtain a dry weight. The factor is the percent of air dry weight that is oven dry weight. There was 13.48% moisture in the air dry samples. Present current growth estimates are based on knowledge of individual species growth habits in relation to the time of sampling. Consideration was given to the observation that the development of many warm season grasses had been inhibited by an unusually dry spring. Weight in grams from the 0.25 sq. meter plots was corrected to pounds per acre. The average weight of the harvested plots from transects was used to derive a correlation coefficient for evaluating the accuracy of estimated weights (Figure 1). Our decision was to accept an r^2 value of 0.8 or higher as being adequate to not require correction of the estimated data. Categories of plants, for example, consumable annual forbs (caf), non-consumable annual forbs (ncaf), consumable annual grasses (cag) are identified in the data presented herein (Appendix D). All data was entered into an Access database. SQL statements for calculating pounds per acre for individual species and summary biomass calculations for total perennial biomass and total consumable biomass are present at the end of their respective tables (Appendix D and Appendix E).

DATA PRESENTATION

The data presented in Table 2 is derived from four options for expressing animal units (AU) for the individual management units and for the entire area of the Fort considered in the survey. All AU values are based solely on consumable perennial vegetation identified in the survey. An AU is considered an average forage requirement of 26 pounds of dry matter (oven-dry) per day or 9490 pounds of dry matter per year The final report for the 2002 survey that was available to us had 4 options for expressing AU. Two of these options involved establishment of minimum residue thresholds. One threshold was 750 pounds per acre and was referred to as the "maintenance threshold" and the other was1000 pounds per acre, referred to as the "conservation threshold". We reconstructed the AU for the four options based on the following procedures.

Option 1 is the consumable perennial forage for the total land area in each management unit using 25% harvest efficiency for each sampling point and expressed as AU. Option 2 is the consumable perennial forage for the predetermined grazeable acres (data furnished by NRCS and DPW) in each management unit using a 25% harvest efficiency expressed in AU. Option 3 is based on 1000 pounds per acre threshold residue amount and was calculated based on the consumable perennial forage for the grazeable acres in each management unit as follows. If the forage was >2000 pounds per acre, 25% harvest efficiency was used to determine the AU. If the forage was between 1500 and 2000 pounds per acre, the threshold amount of 1000 pounds per acre was subtracted and 50% harvest efficiency was used on the remainder to determine the AU. If the forage was <1000 pounds per acre, 0 AU were determined. Option 4 is based on 750 pounds per acre threshold residue amount and was calculated based on the consumable perennial forage for the grazeable acres in each management unit as follows. If forage was >1500 pounds per acre, a 25% harvest efficiency was applied to determine the AU. If the forage was between 750 pounds and 1500 pounds per acre, the threshold amount of 750 pounds per acre was subtracted and a harvest efficiency of 50% was used on the remainder to determine the AU. If there was <750 pounds per acre, 0 AU were determined. Table 2 presents the total animal units allowed per year for each management unit under the management plan selected for that unit. The acres used in calculating animal unit values for each survey point are given in Appendix C. When more than one survey point fell within the same ecosite, the sites were averaged together. Averaged sites are listed at the end of Appendix C.

ADDITIONAL DATA PROVIDED

A subjective assessment was made at each sampling point of the 17 factors associated with rangeland health put forth in Chapter 4 of the National Range and Pasture Handbook, section C. The values (indicator scores) for each sampling point can be found in Appendix F, Rangeland Health, and a summary of scores is presented in Table 3.

THE RUSLE COMPONENT

DESCRIPTION OF THE RUSLE PROCEDURES:

The Center for Grazinglands and Ranch Management agreed to enter data into the RUSLE model from the vegetation surveys recently completed on Ft. Hood as part of the contract via CERL on behalf of the Ft. Hood Directorate of Public Works and the Central Texas Cattleman's Association. Soil parameters (K values, T value, Hydrologic group, and texture) were extracted from the SSURGO databases for the soils at the transect points as identified in the Vegetation Monitoring Points shapefile provided by Fort Hood. For new transects, soils were identified by intersecting the new monitoring points layer with the SSURGO map unit layer in the GIS. The parameters for the soil identified by this technique were used in the RUSLE analysis for each of the new points.

For the slope factors in the RUSLE model, slope for each of the monitoring points was determined using the slope coverage for Fort Hood by intersecting the slope grid with the vegetation monitoring points in the GIS. The slope length for all monitoring points was set to a fixed value of 100 feet.

Vegetation parameters (biomass, fall height, litter, and canopy cover) were values derived from field collected data for Total Perennial Biomass and Perennial Consumable Biomass during the June-July 2005 vegetation survey. Biomass calculations for input into RUSLE were calculated the same way as described in the 2003 Supplemental Environmental Assessment for Grazing at Fort Hood. Deductions were made in consumable perennial biomass due to training losses as follows: Western Maneuver Area (North) 40%; Western Maneuver Area (South) 30%; Eastern Training Area (North) 15%; Eastern Training Area (South) 10%;West Ft. Hood (North and South) 10%; North Ft. Hood, 10% (see Table 2). Canopy cover values were estimated using a regression developed from a subset of the monitoring points where canopy cover was recorded.

These parameters were entered into the RUSLE model and the erosion sediment yield was recorded for each transect point (Table 6). Input parameters and output sediment yield by management unit can be seen in Appendix G and Table 4, respectively.

To determine weighted averages of erosion for each management unit, the erosion sediment yield as produced by RUSLE was assigned to the ecological sites in the same way as biomass was assigned for the AU analysis (i.e., each monitoring point is assigned to one or more areas within a management unit that are the same ecological site) for each of the AU options. The sediment yield across ecological sites is then averaged within a management unit using the acres of the ecological site as a weighting factor. Therefore, the erosion estimates are weighted according to the area they represent within the management unit.

The T values (acceptable soil loss in tons/acre) were weighted in the same way within management units. The erosion estimates can then be compared to the weighted T values to determine significance of erosion. If the weighted average of the erosion estimate for a management unit is greater than the weighted average for the T value within a management unit, then erosion is occurring at a rate that is greater than acceptable. If the weighted average of the erosion estimate for a management unit is less than the weighted average for the T value within a management unit, then erosion loss could be considered acceptable.

Weighted averaging was conducted within an Access database. Weighted averages were determined for the 25% Harvest Efficiency, the 1000 pounds per acre residue and the 750 pounds per acre residue scenarios using the grazeable acres as the weighting factor. For the 25% Harvest Efficiency Method for Total Acres scenario, the total acres were used as the weighting factor. The number of acres in each management unit are listed in Table 5. The SQL statement for computing the weighted averages is included with the summary table (Table 4).

DISCUSSION:

There is a substantial decrease in biomass production between the 2004 and 2005 surveys. The differences between the two early growing season periods (April – July) in the two years are reflective of a very unusual, if not unique, situation that produced the low 2005 values. The following observations are considered pertinent:

- The 2004 survey was done in an unusually wet year and with enough moisture during the mid to late growing season to extend tillering and growth of Texas wintergrass and other cool season perennials and annuals. Conversely, 2005 was a unusually dry year during this same time period, thus delaying onset of tillers and production that was measured.

- The predominant warm season perennial grasses on the area were also limited in tiller production and growth by the early season drought and competition for the limited moisture by annual vegetation. While the greatest impact of the dry period was only about 60 days, it came at a time that would have suppressed these plants more than other times during their growing season.

- A factor of 0.9 (the “year” factor) was used for the percent of normal production for calculations in the 2005 data; however, in our opinion this factor underestimates the comparative influence of precipitation and temperature on production during the period of sampling in the two years. An argument could be made for further reducing the factor in an effort to better indicate the influence of the early extreme dry period on total annual production. The year factor is principally a judgment attempt to estimate the total impact of growing conditions through the entire production cycle of a year. To make this judgment at mid-year is tenuous at best. We feel we have been very conservative in the use of the factor.

- The great difference between the two years highlights the need for basing annual production on a series of clippings throughout the year, at least seasonally (spring, summer, fall and winter), as well as protecting sample areas from grazing. This methodology is commonly referred to as the “paired plot” method and is recognized as one of the most accurate ways of determining both annual production and utilization of production by grazing animals. It is a relatively tedious, time consuming method, but it overcomes the problem of production estimates at a single point in time used to represent an entire year.

- We want to reiterate the question concerning the use of training impact discounts on areas that are included in the surveys on which training losses may have already occurred. For example, if our survey was accomplished on an area where training had already significantly impacted production, then our estimates would reflect the training losses. Subsequent reduction from the survey production estimates would over penalize the stocking rate calculations.

- Annual vegetation is an obvious part of the total biomass component available for grazing animals. While the year to year unpredictability of annual vegetation is a reason not to include it in management decisions directed toward improvement of range condition, the reality that a strong annual component of consumable biomass exists makes it unrealistic not to count a portion of these plants in stocking rate calculations.

CONCLUSIONS

We believe that the accompanying documents provide a true assessment of the vegetation and forage on the areas sampled on Ft. Hood at the time of the sampling. We believe also, that they do not represent the best information from which to derive stocking rates for the reason expressed in the above discussion. While we understand that Ft. Hood has mission responsibilities that mandate their decisions, we suggest that the following might be considered:

- Setting a base stocking rate using an average of the available inventory information over a period of years that reflect different growing conditions and training impacts by areas. Adjust this rate at a predetermined time based on precipitation within each year, for example, a rule that would key off deviation from average annual precipitation by a specific date.

- When calibration and validation of the PHYGROW forage production model now being conducted on Ft. Hood is complete, use the model to determine point in time deviation of forage production from long term average production (57 years) and the predictive ability of the model to look 75 days into the future to provide probabilities of production deviations. Utilize the model runs to make adjustments to stocking rates.

- Developing a paired plot sampling system for the areas with carefully selected, minimal numbers of representative sampling locations and sample and move exclosures seasonally. Base stocking rates on accumulated annual measured production and utilization.

APPENDIX M

PREDICTING RAINFALL EROSION LOSSES

A GUIDE TO CONSERVATION PLANNING

UNITED STATES
DEPARTMENT OF
AGRICULTURE

AGRICULTURE
HANDBOOK
NUMBER 537

PREPARED BY
SCIENCE AND
EDUCATION
ADMINISTRATION

PREDICTING RAINFALL EROSION LOSSES

A GUIDE TO CONSERVATION PLANNING

Supersedes Agriculture Handbook No. 282,
"Predicting Rainfall-Erosion Losses From Cropland East of the Rocky Mountains"

Note: See Supplement Dated January 1981 and the errata at the end of this document.

Science and Education Administration
United States Department of Agriculture
in cooperation with
Purdue Agricultural Experiment Station

December 1978

ABSTRACT

Wischmeier, W. H., and Smith, D.D. 1978. Predicting rainfall erosion losses—a guide to conservation planning. U.S. Department of Agriculture, Agriculture Handbook No. 537.

The Universal Soil Loss Equation (USLE) enables planners to predict the average rate of soil erosion for each feasible alternative combination of crop system and management practices in association with a specified soil type, rainfall pattern, and topography. When these predicted losses are compared with given soil loss tolerances, they provide specific guidelines for effecting erosion control within specified limits. The equation groups the numerous interrelated physical and management parameters that influence erosion rate under six major factors whose site-specific values can be expressed numerically. A half century of erosion research in many States has supplied information from which at least approximate values of the USLE factors can be obtained for specified farm fields or other small erosion prone areas throughout the United States. Tables and charts presented in this handbook make this information readily available for field use. Significant limitations in the available data are identified.

The USLE is an erosion model designed to compute longtime average soil losses from sheet and rill erosion under specified conditions. It is also useful for construction sites and other nonagricultural conditions, but it does not predict deposition and does not compute sediment yields from gully, streambank, and streambed erosion.

Keywords: Conservation practices, conservation tillage, construction sites, crop canopy, crop sequence, delivery ratios, erosion factors, erosion index, erosion prediction, erosion tolerances, erosivity, gross erosion, minimum tillage, no-till, rainfall characteristics, rainfall data, residue mulch, runoff, sediment, sediment delivery, slope effect, water quality, soil erodibility.

For sale by the Superintendent of Documents, U.S. Government Printing Office
Washington, D.C. 20402

Stock Number 001-000-03903-2

CONTENTS

TABLES

FIGURES

PREDICTING RAINFALL EROSION LOSSES—A GUIDE TO CONSERVATION PLANNING

Walter H. Wischmeier and Dwight D. Smith[1]

PURPOSE OF HANDBOOK

Scientific planning for soil and water conservation requires knowledge of the relations between those factors that cause loss of soil and water and those that help to reduce such losses. Controlled studies on field plots and small watersheds have supplied much valuable information regarding these complex factor interrelations. But the greatest possible benefits from such research can be realized only when the findings are converted to sound practice on the numerous farms and other erosion prone areas throughout the country. Specific guidelines are needed for selecting the control practices best suited to the particular needs of each site.

The soil loss prediction procedure presented in this handbook provides such guidelines. The procedure methodically combines research information from many sources to develop design data for each conservation plan. Widespread field experience for more than two decades has proved it highly valuable as a conservation planning guide.

The procedure is founded on an empirical soil loss equation that is believed to be applicable wherever numerical values of its factors are available. Research has supplied information from which at least approximate values of the equation's factors can be obtained for specific farm fields or other small land areas throughout most of the United States. Tables and charts presented in this handbook make this information readily available for field use.

This revision of the 1965 handbook (*64*) updates the content and incorporates new material that has been available informally or from scattered research reports in professional journals. Some of the original charts and tables are revised to conform with additional research findings, and new ones are developed to extend the usefulness of the soil loss equation. In some instances, expanding a table or chart sufficiently to meet the needs for widespread field application required projection of empirical factor relationships appreciably beyond the physical limits of the data from which the relationships were derived. Estimates obtained in this manner are the best information available for the conditions they represent. However, the instances are identified in the discussions of the specific erosion factors, tables, and charts. Major research needs are suggested by these discussions and were recently summarized in an available publication by Stewart and others (*42*).

HISTORY OF SOIL LOSS EQUATIONS

Developing equations to calculate field soil loss began about 1940 in the Corn Belt. The soil loss estimating procedure developed in that region between 1940 and 1956 has been generally referred to as the slope-practice method. Zingg (*64*)[2] published an equation in 1940 relating soil loss rate to length and percentage of slope. The following year, Smith (*38, 39*) added crop and conservation practice factors and the concept of a specific soil loss limit, to develop a graphical method for

[1] Retired. Former research statistician (water management), Science and Education Administration (SEA), and professor emeritus, agricultural engineering, Purdue University, West Lafayette, Ind.; and agricultural engineer, SEA, Beltsville, Md.

[2] Numbers in parentheses refer to References p. 48.

determining conservation practices on Shelby and associated soils of the Midwest. Browning and associates (*6*) added soil and management factors and prepared a set of tables to simplify field use of the equation in Iowa. Research scientists and operations personnel of the Soil Conservation Service (SCS) in the North Central States worked together in developing the slope-practice equation for use throughout the Corn Belt.

A national committee met in Ohio in 1946 to adapt the Corn Belt equation to cropland in other regions. This committee reappraised the Corn Belt factor values and added a rainfall factor. The resulting formula, generally known as the Musgrave Equation (*31*), has been widely used for estimating gross erosion from watersheds in flood abatement programs. A graphical solution of the equation was published in 1952 (*19*) and used by the SCS in the Northeastern States.

The soil loss equation presented in this handbook has become known as the Universal Soil Loss Equation (USLE). Regardless of whether the designation is fully accurate, the name does distinguish this equation from the *regionally* based soil loss equations. The USLE was developed at the National Runoff and Soil Loss Data Center established in 1954 by the Science and Education Administration (formerly Agricultural Research Service) in cooperation with Purdue University. Federal-State cooperative research projects at 49 locations[3] contributed more than 10,000 plot-years of basic runoff and soil loss data to this center for summarizing and overall statistical analyses. After 1960, rainfall simulators (*23*) operating from Indiana, Georgia, Minnesota, and Nebraska were used on field plots in 16 states to fill some of the gaps in the data needed for factor evaluation.

Analyses of this large assembly of basic data provided several major improvements for the soil loss equation (*53*): (a) a rainfall erosion index evaluated from local rainfall characteristics; (b) a quantitative soil erodibility factor that is evaluated directly from soil property data and is independent of topography and rainfall differences; (c) a method of evaluating cropping and management effects in relation to local climatic conditions; and (d) a method of accounting for effects of interactions between crop system, productivity level, tillage practices, and residue management.

Developments since 1965 have expanded the use of the soil loss equation by providing techniques for estimating site values of its factors for additional land uses, climatic conditions, and management practices. These have included a soil erodibility nomograph for farmland and construction areas (*58*); topographic factors for irregular slopes (*12, 55*); cover factors for range and woodland (*57*); cover and management effects of conservation tillage practices (*54*); erosion prediction on construction areas (*61, 24, 25*); estimated erosion index values for the Western States and Hawaii (*5, 21, 55*); soil erodibility factors for benchmark Hawaii soils (*9*); and improved design and evaluation of erosion control support practices (*17, 36*).

Research is continuing with emphasis on obtaining a better understanding of the basic principles and processes of water erosion and sedimentation and development of fundamental models capable of predicting specific-storm soil losses and deposition by overland flow (*10, 11, 22, 26, 32*). The fundamental models have been helpful for understanding the factors in the field soil loss equation and for interpreting the plot data.

SOIL LOSS TOLERANCES

The term "soil loss tolerance" denotes the maximum level of soil erosion that will permit a high level of crop productivity to be sustained economically and indefinitely.

[3] The data were contributed by Federal-State cooperative research projects at the following locations: Batesville, Ark.; Tifton and Watkinsville, Ga.; Dixon Springs, Joliet, and Urbana, Ill.; Lafayette, Ind.; Clarinda, Castana, Beaconsfield, Independence, and Seymour, Iowa; Hays, Kans.; Baton Rouge, La.; Presque Isle, Maine; Benton Harbor and East Lansing, Mich.; Morris, Minn.; Holly Springs and State College, Miss.; Bethany and McCredie, Mo.; Hastings, Nebr.; Beemerville, Marlboro, and New Brunswick, N.J.; Ithaca, Geneva, and Marcellus, N.Y.; Statesville and Raleigh, N.C.; Coshocton and Zanesville, Ohio; Cherokee and Guthrie, Okla.; State College, Pa.; Clemson and Spartanburg, S.C.; Madison, S.Dok.; Knoxville and Greeneville, Tenn.; Temple and Tyler, Tex.; Blacksburg, Va.; Pullman, Wash.; LaCrosse, Madison, and Owen, Wis.; and Mayaguez, P.R.

The major purpose of the soil loss equation is to guide methodical decisionmaking in conservation planning on a site basis. The equation enables the planner to predict the average rate of soil erosion for each of various alternative combinations of crop system, management techniques, and control practices on any particular site. When these predicted losses can be compared with a soil loss tolerance for that site, they provide specific guidelines for effecting erosion control within the specified limits. Any cropping and management combination for which the predicted erosion rate is less than the tolerance may be expected to provide satisfactory erosion control. From the satisfactory alternatives indicated by this procedure, the one best suited to a particular farm or other enterprise may then be selected.

Soil loss tolerances ranging from 5 to 2 t/A/year for the soils of the United States were derived by soil scientists, agronomists, geologists, soil conservationists, and Federal and State research leaders at six regional workshops in 1961 and 1962. Factors considered in defining these limits included soil depth, physical properties and other characteristics affecting root development, gully prevention, on-field sediment problems, seeding losses, soil organic matter reduction, and plant nutrient losses. A deep, medium-textured, moderately permeable soil that has subsoil characteristics favorable for plant growth has a greater tolerance than soils with shallow root zones or high percentages of shale at the surface. Widespread experience has shown these soil loss tolerances to be feasible and generally adequate for sustaining high productivity levels indefinitely. Some soils with deep favorable root zones may exceed the 5-t tolerance without loss of sustained productivity.

Soil loss limits are sometimes established primarily for water quality control. The criteria for defining field soil loss limits for this purpose are not the same as those for tolerances designed to preserve cropland productivity. Soil depth is not relevant for offsite sediment control, and uniform limits on erosion rates will allow a range in the quantities of sediment per unit area that are delivered to a river. Soil material eroded from a field slope may be deposited in the field boundaries, in terrace channels, in depressional areas, or on flat or vegetated areas traversed by the overland flow before it reaches a river. The erosion damages the cropland on which it occurs, but sediment deposited near its place of origin is not directly relevant for water quality control.

If the soil loss tolerance designed for sustained cropland productivity fails to attain the desired water quality standard, flexible limits that consider other factors should be developed rather than uniformly lowering the soil loss tolerance. These factors include distance of the field from a major waterway, the sediment transport characteristics of the intervening area, sediment composition, needs of the particular body of water being protected, and the probable magnitude of fluctuations in sediment loads (*42*). Limits of sediment yield would provide more uniform water quality control than lowering the limits on soil movement from field slopes. They would also require fewer restrictions on crop system selection for fields from which only small percentages of the eroded soil become off-farm sediment.

SOIL LOSS EQUATION

The erosion rate at a given site is determined by the particular way in which the levels on numerous physical and management variables are combined at that site. Physical measurements of soil loss for each of the large number of possible combinations in which the levels of these variable factors can occur under field conditions would not be feasible. Soil loss equations were developed to enable conservation planners to project limited erosion data to the many localities and conditions that have not been directly represented in the research.

The USLE is an erosion model designed to predict the longtime average soil losses in runoff from specific field areas in specified cropping and management systems. Widespread field use has substantiated its usefulness and validity for this purpose. It is also applicable for such nonagricultural conditions as construction sites.

With appropriate selection of its factor values, the equation will compute the average soil loss for a multicrop system, for a particular crop year in a rotation, or for a particular cropstage period within a crop year. It computes the soil loss for a given site as the product of six major factors whose most likely values at a particular location can be expressed numerically. Erosion variables reflected by these factors vary considerably about their means from storm to storm, but effects of the random fluctuations tend to average out over extended periods. Because of the unpredictable short-time fluctuations in the levels of influential variables, however, present soil loss equations are substantially less accurate for prediction of specific events than for prediction of longtime averages.

The soil loss equation is

$$A = R\,K\,L\,S\,C\,P \qquad (1)$$

where

A is the computed soil loss per unit area, expressed in the units selected for **K** and for the period selected for **R.** In practice, these are usually so selected that they compute **A** in tons per acre per year, but other units can be selected.

R, the rainfall and runoff factor, is the number of rainfall erosion index units, plus a factor for runoff from snowmelt or applied water where such runoff is significant.

K, the soil erodibility factor, is the soil loss rate per erosion index unit for a specified soil as measured on a unit plot, which is defined as a 72.6-ft length of uniform 9-percent slope continuously in clean-tilled fallow.

L, the slope-length factor, is the ratio of soil loss from the field slope length to that from a 72.6-ft length under identical conditions.

S, the slope-steepness factor, is the ratio of soil loss from the field slope gradient to that from a 9-percent slope under otherwise identical conditions.

C, the cover and management factor, is the ratio of soil loss from an area with specified cover and management to that from an identical area in tilled continuous fallow.

P, the support practice factor, is the ratio of soil loss with a support practice like contouring, stripcropping, or terracing to that with straight-row farming up and down the slope.

The soil loss equation and factor evaluation charts were initially developed in terms of the English units commonly used in the United States. The factor definitions are interdependent, and direct conversion of acres, tons, inches, and feet to metric units would not produce the kind of integers that would be desirable for an expression of the equation in that system. Therefore, only the English units are used in the initial presentation of the equation and factor evaluation materials, and their counterparts in metric units are given in the Appendix under **Conversion to Metric System.**

Numerical values for each of the six factors were derived from analyses of the assembled research data and from National Weather Service precipitation records. For most conditions in the United States, the approximate values of the factors for any particular site may be obtained from charts and tables in this handbook. Localities or countries where the rainfall characteristics, soil types, topographic features, or farm practices are substantially beyond the range of present U.S. data will find these charts and tables incomplete and perhaps inaccurate for their conditions. However, they will provide guidelines that can reduce the amount of local research needed to develop comparable charts and tables for their conditions.

The subsection on **Predicting Cropland Soil Losses,** page 40 illustrates how to select factor values from the tables and charts. Readers who have had no experience with the soil loss equation may wish to read that section first. After they have referred to the tables and figures and located the values used in the sample, they may move readily to the intervening detailed discussions of the equation's factors.

The soil loss prediction procedure is more valuable as a guide for selection of practices if the user has a general knowledge of the principles and factor interrelations on which the equation is based. Therefore, the significance of each factor is discussed before presenting the reference table or chart from which local values may be obtained. Limitations of the data available for evaluation of some of the factors are also pointed out.

RAINFALL AND RUNOFF FACTOR (R)

Rills and sediment deposits observed after an unusually intense storm have sometimes led to the conclusion that the significant erosion is associated with only a few storms, or that it is solely a function of peak intensities. However, more than 30 years of measurements in many States have shown that this is not the case (*51*). The data show that a rainfall factor used to estimate average annual soil loss must include the cumulative effects of the many moderate-sized storms, as well as the effects of the occasional severe ones.

The numerical value used for **R** in the soil loss equation must quantify the raindrop impact effect and must also provide relative information on the amount and rate of runoff likely to be associated with the rain. The rainfall erosion index derived by Wischmeier (*49*) appears to meet these requirements better than any other of the many rainfall parameters and groups of parameters tested against the assembled plot data. The local value of this index generally equals **R** for the soil loss equation and may be obtained directly from the map in figure 1. However, the index does not include the erosive forces of runoff from thaw, snowmelt, or irrigation. A procedure for evaluating **R** for locations where this type of runoff is significant will be given under the topic **R Values for Thaw and Snowmelt.**

Rainfall Erosion Index

The research data indicate that when factors other than rainfall are held constant, storm soil losses from cultivated fields are directly proportional to a rainstorm parameter identified as the **EI** (defined below) (*49*). The relation of soil loss to this parameter is linear, and its individual storm values are directly additive. The sum of the storm **EI** values for a given period is a numerical measure of the erosive potential of the rainfall within that period. The average annual total of the storm **EI** values in a particular locality is the rainfall erosion index for that locality. Because of apparent cyclical patterns in rainfall data (*33*), the published rainfall erosion index values were based on 22-year station rainfall records.

Rain showers of less than one-half inch and separated from other rain periods by more than 6 hours were omitted from the erosion index computations, unless as much as 0.25 in of rain fell in 15 min. Exploratory analyses showed that the **EI** values for such rains are usually too small for practical significance and that, collectively, they have little effect on monthly percentages of the annual **EI.** The cost of abstracting and analyzing 4,000 location-years of rainfall-intensity data was greatly reduced by adopting the 0.5-in threshold value.

EI Parameter

By definition, the value of **EI** for a given rainstorm equals the product, total storm energy (**E**) times the maximum 30-min intensity (I_{30}), where **E** is in hundreds of foot-tons per acre and I_{30} is in inches per hour (in/h). **EI** is an abbreviation for energy-times-intensity, and the term should not be considered simply an energy parameter. The data show that rainfall energy, itself, is not a good indicator of erosive potential. The storm energy indicates the volume of rainfall and runoff, but a long, slow rain may have the same **E** value as a shorter rain at much higher intensity. Raindrop erosion increases with intensity. The I_{30} component indicates the prolonged-peak rates of detachment and runoff. The product term, **EI,** is a statistical interaction term that reflects how total energy and peak inensity are combined in each particular storm. Technically, it indicates how particle detachment is combined with transport capacity.

The energy of a rainstorm is a function of the amount of rain and of all the storm's component intensities. Median raindrop size increases with rain intensity (*62*), and terminal velocities of free-falling waterdrops increase with increased dropsize (*13*). Since the energy of a given mass in motion is proportional to velocity-squared, rainfall energy is directly related to rain intensity. The relationship is expressed by the equation,

$$E = 916 + 331 \log_{10} I, \qquad (2)$$

where **E** is kinetic energy in foot-tons per acre-inch and **I** is intensity in inches per hour (*62*). A limit of 3 in/h is imposed on **I** by the finding that median dropsize does not continue to increase when intensities exceed 3 in/h (*7, 15*). The energy

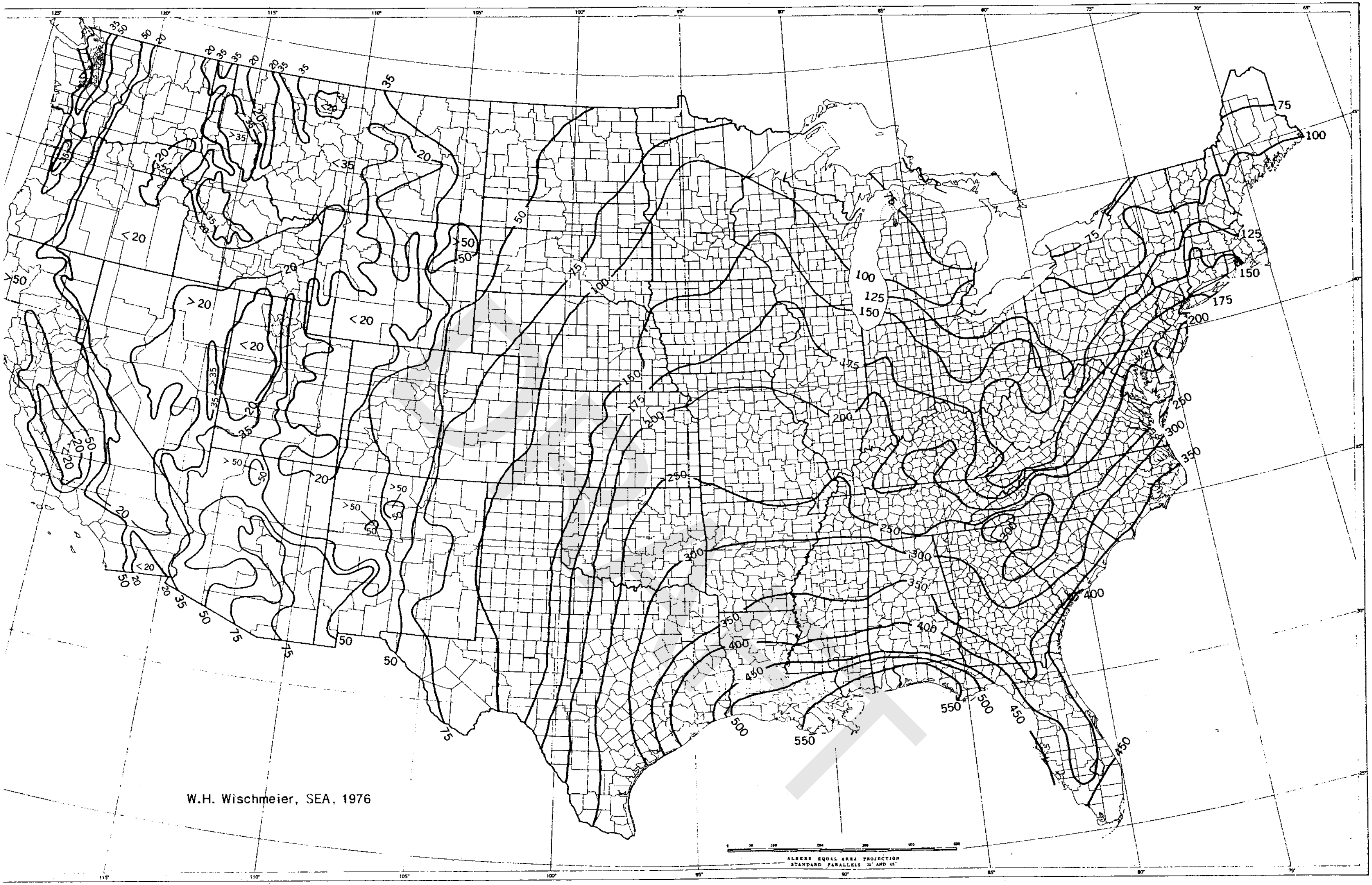


FIGURE 1.—Average annual values of the rainfall erosion index.

of a rainstorm is computed from recording-rain gage data. The storm is divided into successive increments of essentially uniform intensity, and a rainfall energy-intensity table derived from the above formula (app., table 19) is used to compute the energy for each increment. (Because the energy equation and energy-intensity table have been frequently published with energy expressed in foot-tons per acre-inch, this unit was retained in table 19. However, for computation of **EI** values, storm energy is expressed in hundreds of foot-tons per acre. Therefore, energies computed by the published formula or table 19 must be divided by 100 before multiplying by I_{30} to compute **EI**.)

Isoerodent Maps

Local values of the rainfall erosion index may be taken directly from the isoerodent maps, figures 1 and 2. The plotted lines on the maps are called isoerodents because they connect points of equal rainfall erosivity. Erosion index values for locations between the lines are obtained by linear interpolation.

The isoerodent map in the original version of this handbook (*64*) was developed from 22-year station rainfall records by computing the **EI** value for each storm that met the previously defined threshold criteria. Isoerodents were then located between these point values with the help of published rainfall intensity-frequency data (*47*) and topographic maps. The 11 Western States were omitted from the initial map because the rainfall patterns in this mountainous region are sporadic and not enough long-term, recording-rain gage records were available to establish paths of equal erosion index values.

The isoerodent map was extended to the Pacific Coast in 1976 by use of an estimating procedure. Results of investigations at the Runoff and Soil Loss Data Center at Purdue University showed that the known erosion index values in the Western Plains and North Central States could be approximated with reasonable accuracy by the quantity 27.38 $\mathbf{P}^{2.17}$, where **P** is the 2-year, 6-h rainfall amount (*55*). This relationship was used with National Weather Service isopluvial maps to approximate erosion index values for the Western States. The resulting isoerodents are compatible with the few point values that had been established within the 11 Western States and can provide helpful guides for conservation planning on a site basis. However, they are less precise than those computed for the 37-State area, where more data were available and rainfall patterns are less eratic. Also, linear interpolations between the lines will not always be accurate in mountain regions because values of the erosion index may change rather abruptly with elevation changes. The point values that were computed directly from long-term station rainfall records in the Western States are included in table 7, as reference points.

Figure 2 was developed by computing the erosion index for first-order weather stations in Hawaii and deriving the relation of these values to National Weather Service intensity-frequency data for the five major islands. When the present short-term, rainfall-intensity records have been sufficiently lengthened, more point values of the index should be computed by the standard procedure.

Figure 1 shows that local, average-annual values of the erosion index in the 48 conterminous States range from less than 50 to more than 500. The erosion index measures the combined effect of rainfall and its associated runoff. If the soil and topography were exactly the same everywhere, average annual soil losses from plots maintained in continuous fallow would differ in direct proportion to the erosion index values. However, this potential difference is partially offset by differences in soil, topography, vegetative cover, and residues. On fertile soils in the high rainfall areas of the Southern States, good vegetal cover protects the soil surface throughout most of the year and heavy plant residues may provide excellent cover also during the dormant season. In the regions where the erosion index is extremely low, rainfall is seldom adequate for establishing annual meadows and the cover provided by other crops is often for relatively short periods. Hence, serious soil erosion hazards exist in semiarid regions as well as in humid.

Frequency Distribution

The isoerodent maps present 22-year-average annual values of **EI** for the delineated areas. However, both the annual and the maximum-storm values at a particular location vary from year to year. Analysis of 181 station rainfall records showed that they tend to follow log-normal frequency distributions that are usually well defined by continuous records of from 20 to 25 years (*49*). Tables of specific probabilities of annual and maximum-storm **EI** values at the 181 locations are presented in the appendix (tables 17 and 18).

R Values for Thaw and Snowmelt

The standard rainfall erosion index estimates the erosive forces of the rainfall and its directly associated runoff. In the Pacific Northwest, as much as 90 percent of the erosion on the steeply rolling wheatland has been estimated to derive from runoff associated with surface thaws and snowmelt. This type of erosion is not accounted for by the rainfall erosion index but is considered either predominant or appreciable in much of the Northwest and in portions of the central Western States. A linear precipitation relationship would not account for peak losses in early spring because as the winter progresses, the soil becomes increasingly more erodible as the soil moisture profile is being filled, the surface structure is being broken down by repeated freezing and thawing, and puddling and surface sealing are taking place. Additional research of the erosion processes and means of control under these conditions is urgently needed.

In the meantime, the early spring erosion by runoff from snowmelt, thaw, or light rain on frozen soil may be included in the soil loss computations by adding a subfactor, $\mathbf{R_s}$, to the location's erosion index to obtain **R**. Investigations of limited data indicated that an estimate of $\mathbf{R_s}$ may be obtained by taking 1.5 times the local December-through-March precipitation, measured as inches of water. For example, a location in the North-

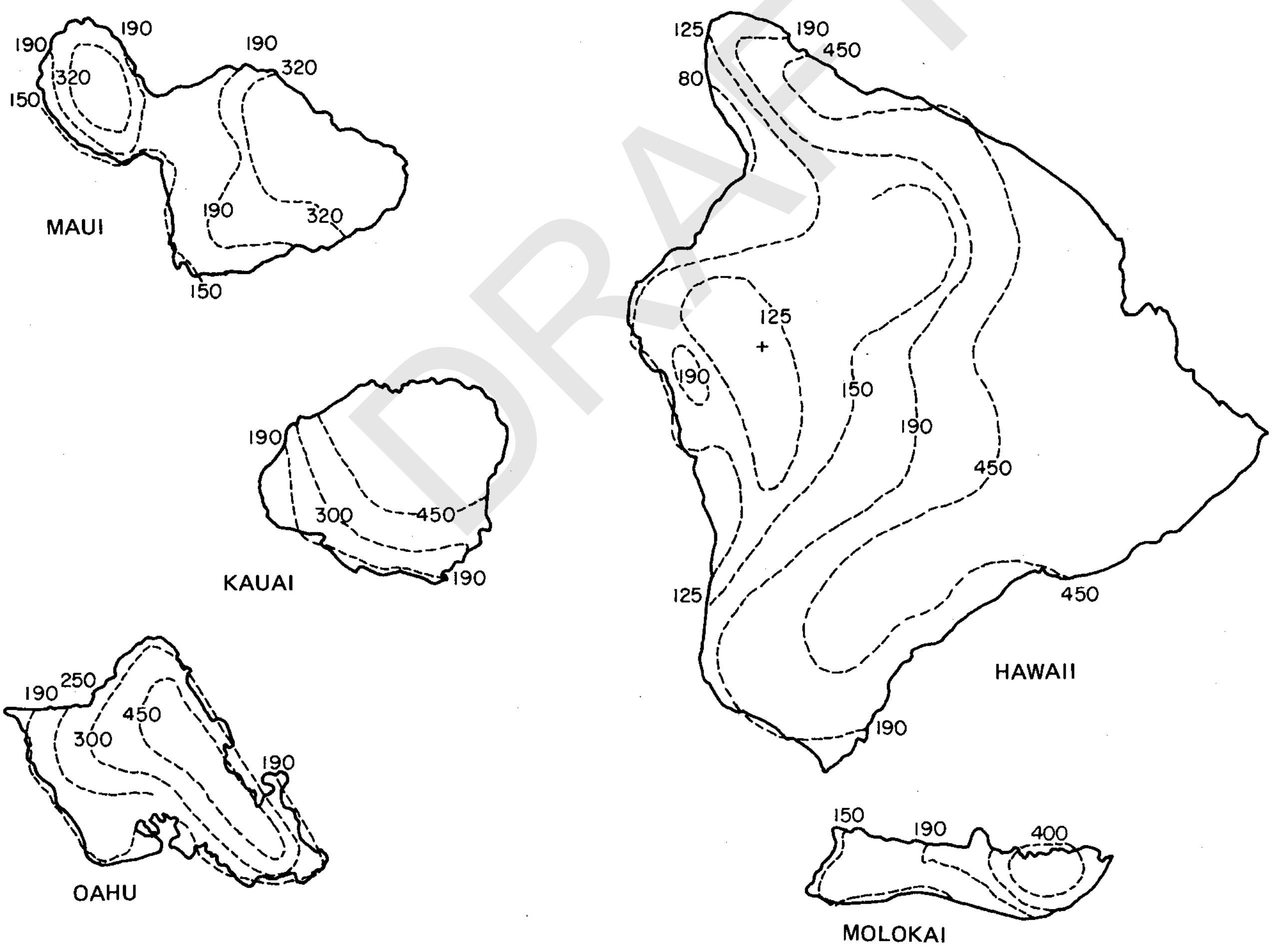


FIGURE 2.—Estimated average annual values of the rainfall erosion index in Hawaii.

west that has an erosion index of 20 (fig. 1) and averages 12 in of precipitation between December 1 and March 31 would have an estimated average annual **R** of 1.5(12) + 20, or 38.

This type of runoff may also be a significant factor in the northern tier of Central and Eastern States. Where experience indicates this to be the case, it should be included in **R** and also in the erosion index distribution curves as illustrated on page 27.

SOIL ERODIBILITY FACTOR (K)

The meaning of the term "soil erodibility" is distinctly different from that of the term "soil erosion." The rate of soil erosion, **A,** in the soil loss equation, may be influenced more by land slope, rainstorm characteristics, cover, and management than by inherent properties of the soil. However, some soils erode more readily than others even when all other factors are the same. This difference, caused by properties of the soil itself, is referred to as the soil erodibility. Several early attempts were made to determine criteria for scientific classifications of soils according to erodibility (*6, 18, 28, 35*), but classifications used for erosion prediction were only relative rankings.

Differences in the natural susceptibilities of soils to erosion are difficult to quantify from field observations. Even a soil with a relatively low erodibility factor may show signs of serious erosion when it occurs on long or steep slopes or in localities with numerous high-intensity rainstorms. A soil with a high natural erodibility factor, on the other hand, may show little evidence of actual erosion under gentle rainfall when it occurs on short and gentle slopes, or when the best possible management is practiced. The effects of rainfall differences, slope, cover, and management are accounted for in the prediction equation by the symbols **R, L, S, C,** and **P.** Therefore, the soil erodibility factor, **K,** must be evaluated independently of the effects of the other factors.

Definition of Factor K

The soil erodibility factor, **K,** in the USLE is a quantitative value experimentally determined. For a particular soil, it is the rate of soil loss per erosion index unit as measured on a "unit" plot, which has been arbitrarily defined as follows:

A unit plot is 72.6 ft long, with a uniform lengthwise slope of 9 percent, in continuous fallow, tilled up and down the slope. Continuous fallow, for this purpose, is land that has been tilled and kept free of vegetation for more than 2 years. During the period of soil loss measurements, the plot is plowed and placed in conventional corn seedbed condition each spring and is tilled as needed to prevent vegetative growth and severe surface crusting. When all of these conditions are met, **L, S, C,** and **P** each equal 1.0, and **K** equals **A/EI.**

The 72.6 ft length and 9 percent steepness were selected as base values for **L, S,** and **K** because they are the predominant slope length and about the average gradient on which past erosion measurements in the United States had been made. The designated management provides a condition that nearly eliminates effects of cover, management, and land use residual and that can be duplicated on any cropland.

Direct measurements of **K** on well-replicated, unit plots as described reflect the combined effects of all the soil properties that significantly influence the ease with which a particular soil is eroded by rainfall and runoff if not protected. However, **K** is an average value for a given soil, and direct measurement of the factor requires soil loss measurements for a representative range of storm sizes and antecedent soil conditions. (See **Individual Storm Soil Losses** under **APPLYING THE SOIL LOSS EQUATION.**) To evaluate **K** for soils that do not usually occur on a 9-percent slope, soil loss data from plots that meet all the other specified conditions are adjusted to this base by **S.**

Values of K for Specific Soils

Representative values of **K** for most of the soil types and texture classes can be obtained from tables prepared by soil scientists using the latest available research information. These tables are available from the Regional Technical Service Centers or State offices of SCS. Values for the exact

TABLE 1.—*Computed* **K** *values for soils on erosion research stations*

Soil	Source of data	Computed K
Dunkirk silt loam	Geneva, N.Y.	[1]0.69
Keene silt loam	Zanesville, Ohio	.48
Shelby loam	Bethany, Mo.	.41
Lodi loam	Blacksburg, Va.	.39
Fayette silt loam	LaCrosse, Wis.	[1].38
Cecil sandy clay loam	Watkinsville, Ga.	.36
Marshall silt loam	Clarinda, Iowa	.33
Ida silt loam	Castana, Iowa	.33
Mansic clay loam	Hays, Kans.	.32
Hagerstown silty clay loam	State College, Pa.	[1].31
Austin clay	Temple, Tex.	.29
Mexico silt loam	McCredie, Mo.	.28
Honeoye silt loam	Marcellus, N.Y.	[1].28
Cecil sandy loam	Clemson, S.C.	[1].28
Ontario loam	Geneva, N.Y.	[1].27
Cecil clay loam	Watkinsville, Ga.	.26
Boswell find sandy loam	Tyler, Tex.	.25
Cecil sandy loam	Watkinsville, Ga.	.23
Zoneis fine sandy loam	Guthrie, Okla.	.22
Tifton loamy sand	Tifton, Ga.	.10
Freehold loamy sand	Marlboro, N.J.	.08
Bath flaggy silt loam with surface stones > 2 inches removed	Arnot, N.Y.	[1].05
Albia gravelly loam	Beemerville, N.J.	.03

[1] Evaluated from continuous fallow. All others were computed from rowcrop data.

soil conditions at a specific site can be computed by use of the soil erodibility nomograph presented in the next subsection.

Usually a soil type becomes less erodible with decrease in silt fraction, regardless of whether the corresponding increase is in the sand fraction or the clay fraction. Overall, organic matter content ranked next to particle-size distribution as an indicator of erodibility. However, a soil's erodibility is a function of complex interactions of a substantial number of its physical and chemical properties and often varies within a standard texture class.

Values of **K** determined for 23 major soils on which erosion plot studies under natural rain were conducted since 1930 are listed in table 1. Seven of these values are from continuous fallow. The others are from row crops averaging 20 plot-years of record and grown in systems for which the cropping effect had been measured in other studies. Other soils on which valuable erosion studies have been conducted[4] were not included in the table because of uncertainties involved in adjustments of the data for effects of cropping and management.

Direct measurement of the erodibility factor is both costly and time consuming and has been feasible only for a few major soil types. To achieve a better understanding of how and to what extent each of various properties of a soil affects its erodibility, an interregional study was initiated in 1961. The study included the use of field-plot rainfall simulators in at least a dozen States to obtain comparative data on numerous soils, laboratory determinations of physical and chemical properties, and operation of additional fallow plots under natural rain. Several empirical erodibility equations were reported (3, 60). A soil erodibility nomograph for farmland and construction sites (58) provided a more generally applicable working tool. Approximate **K** values for 10 benchmark soils in Hawaii are listed in table 2.

[4] See footnote 3, p. 2.

TABLE 2.—*Approximate values of the soil erodibility factor,* **K**, *for 10 benchmark soils in Hawaii*

Order	Suborder	Great group	Subgroup	Family	Series	K
Ultisols	Humults	Tropohumults	Humoxic Tropohumults	Clayey, kaolinitic, isohyperthermic	Waikane	0.10
Oxisols	Torrox	Torrox	Typic Torrox	Clayey, kaolinitic, isohyperthermic	Molokai	.24
Oxisols	Ustox	Eutrustox	Tropeptic Eutrustox	Clayey, kaolinitic, isohyperthermic	Wahiawa	.17
Vertisols	Usterts	Chromusterts	Typic Chromusterts	Very fine, montmorillonitic, isohyperthermic	Lualualei	.28
					Kawaihae	.32
Aridisols	Orthids	Camborthids	Ustollic Camborthids	Medial, isohyperthermic	(Extremely stony phase)	
Inceptisols	Andepts	Dystrandepts	Hydric Dystrandepts	Thixotropic, isothermic	Kukaiau	.17
Inceptisols	Andepts	Eutrandepts	Typic Eutrandepts	Medial, isohyperthermic	Naalehu (Variant)	.20
Inceptisols	Andepts	Eutrandepts	Entic Eutrandepts	Medial, isohyperthermic	Pakini	.49
Inceptisols	Andepts	Hydrandepts	Typic Hydrandepts	Thixotropic, isohyperthermic	Hilo	.10
Inceptisols	Tropepts	Ustropepts	Vertic Ustropepts	Very fine, kaolinitic, isohyperthermic	Waipahu	.20

SOURCE: El-Swaify and Dangler (9).

Soil Erodibility Nomograph

The soil loss data show that very fine sand (0.05-0.10 mm) is comparable in erodibility to silt-sized particles and that mechanical-analysis data are much more valuable when expressed by an interaction term that describes the proportions in which the sand, silt, and clay fractions are combined in the soil. When mechanical analysis data based on the standard USDA classification are used for the nomograph in figure 3, the percentage of very fine sand (0.1-0.05 mm) must first be transferred from the sand fraction to the silt fraction. The mechanical analysis data are then effectively described by a particle-size parameter **M**, which equals percent silt (0.1-0.002 mm) times the quantity 100-minus-percent-clay. Where the silt fraction does not exceed 70 percent, erodibility varies approximately as the 1.14 power of this parameter, but prediction accuracy is improved by adding information on organic matter content, soil structure, and profile permeability class.

For soils containing less than 70 percent silt and very fine sand, the nomograph (fig. 3) solves the equation:

$$100\,K = 2.1\,M^{1.14}\,(10^{-4})\,(12 - a) + 3.25\,(b - 2) + 2.5\,(c - 3) \quad (3)$$

where

M = the particle-size parameter defined above,
a = percent organic matter,
b = the soil-structure code used in soil classification, and
c = the profile-permeability class.

The intersection of the selected percent-silt and percent-sand lines computes the value of **M** on the unidentified horizontal scale of the nomograph. (Percent clay enters into the computation as 100 minus the percentages of sand and silt.)

The data indicate a change in the relation of **M** to erodibility when the silt and very fine sand fraction exceeds about 70 percent. This change was empirically reflected by inflections in the percent-sand curves at that point but has not been described by a numerical equation.

Readers who would like more detail regarding the data and relationships underlying the nomograph equation may obtain this from journal articles (*58, 60*).

Nomograph Solution

With appropriate data, enter the scale at the left and proceed to points representing the soil's percent sand (0.10-2.0 mm), percent organic matter, structure code, and permeability class as illustrated by the dotted line on the nomograph. The horizontal and vertical moves must be made in the listed sequence. Use linear interpolations between plotted lines. The structure code and permeability classes are defined on the nomograph for reference.

Many agricultural soils have both fine granular topsoil and moderate permeability. For these soils, **K** may be read from the scale labeled "first approximation of **K**," and the second block of the graph is not needed. For all other soils, however, the procedure must be completed to the soil erodibility scale in the second half of the graph.

The mechanical analysis, organic matter, and structure data are those for the topsoil. For evaluation of **K** for desurfaced subsoil horizons, they pertain to the upper 6 in of the new soil profile. The permeability class is the profile permeability. Coarse fragments are excluded when determining percentages of sand, silt, and clay. If substantial, they may have a permanent mulch effect which can be evaluated from the upper curve of the chart on mulch and canopy effects (p. 19, fig. 6) and applied to the number obtained from the nomograph solution.

Confidence Limits

In tests against measured **K** values ranging from 0.03 to 0.69, 65 percent of the nomograph solutions differed from the measured **K** values by less than 0.02, and 95 percent of them by less than 0.04. Limited data available in 1971 for mechanically exposed **B** and **C** subsoil horizons indicated about comparable accuracy for these conditions. However, more recent data taken on desurfaced high-clay subsoils showed the nomograph solution to lack the desired sensitivity to differences in erodibilities of these soil horizons. For such soils the content of free iron and aluminum oxides ranks next to particle-size distribution as an indicator of erodibility (37). Some high-clay soils form what has been called irreversible aggregates on the surface when tilled. These behave like larger primary particles.

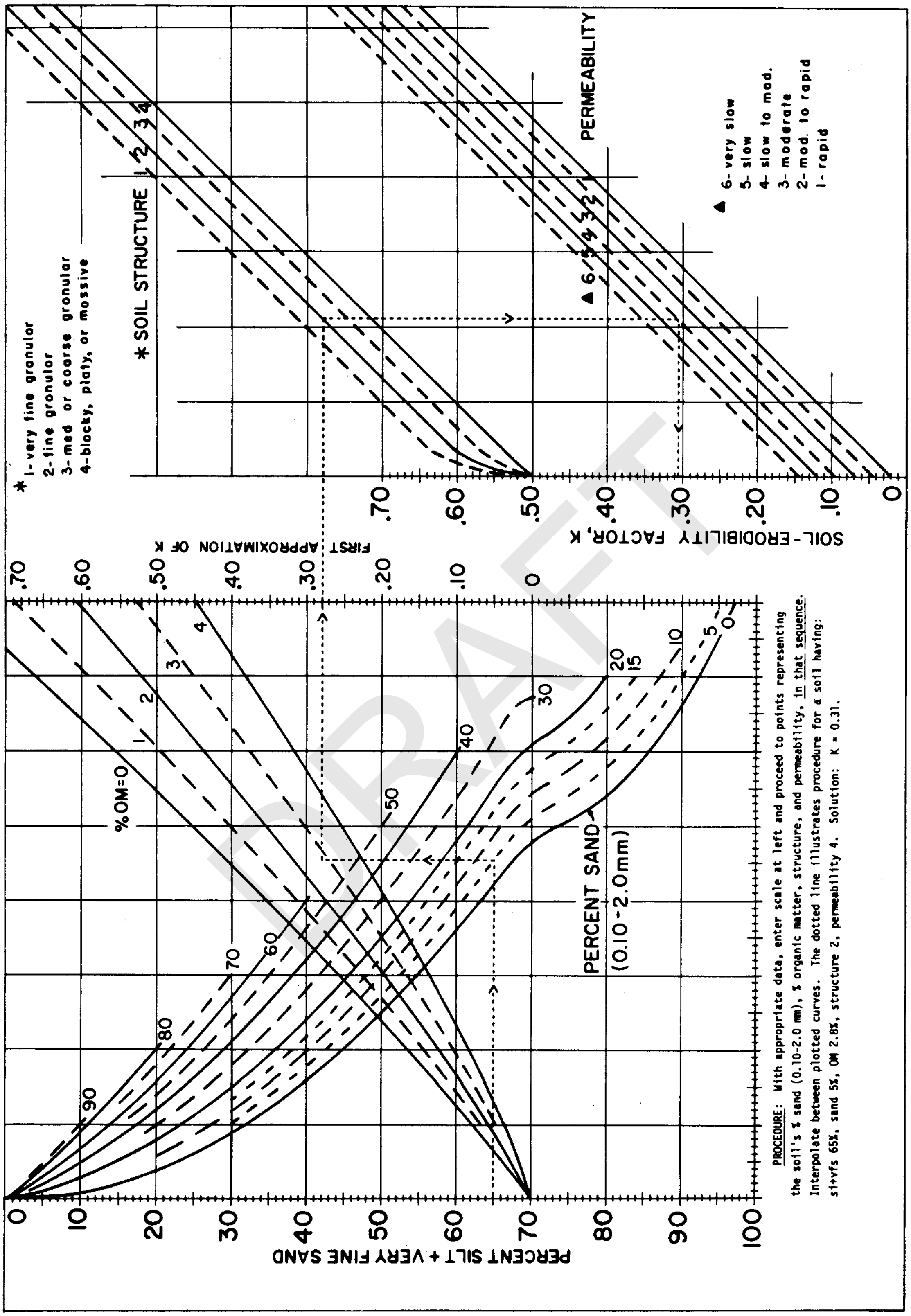


FIGURE 3.—The soil-erodibility nomograph. Where the silt fraction does not exceed 70 percent, the equation is $100\ K = 2.1\ M^{1.14}\ (10^{-4})\ (12 - a) + 3.25\ (b - 2) + 2.5\ (c - 3)$ where M = (percent si + vfs) (100 − percent c), a = percent organic matter, b = structure code, and c = profile permeability class.

TOPOGRAPHIC FACTOR (LS)

Both the length and the steepness of the land slope substantially affect the rate of soil erosion by water. The two effects have been evaluated separately in research and are represented in the soil loss equation by **L** and **S**, respectively. In field applications, however, considering the two as a single topographic factor, **LS**, is more convenient.

Slope-Effect Chart

LS is the expected ratio of soil loss per unit area from a field slope to that from a 72.6-ft length of uniform 9-percent slope under otherwise identical conditions. This ratio for specified combinations of field slope length and uniform gradient may be obtained directly from the slope-effect chart (fig. 4). Enter on the horizontal axis with the field slope length, move vertically to the appropriate percent-slope curve, and read **LS** on the scale at the left. For example, the **LS** factor for a 300-ft length of 10-percent slope is 2.4. Those who prefer a table may use table 3 and interpolate between listed values.

To compute soil loss from slopes that are appreciably convex, concave, or complex, the chart **LS** values need to be adjusted as indicated in the section **LS Values for Irregular Slopes.** Figure 4 and table 3 assume slopes that have essentially uniform gradient. The chart and table were derived by the equation

$$LS = (\lambda/72.6)^m \ (65.41 \ \sin^2 \theta + 4.56 \ \sin \theta + 0.065) \quad (4)$$

where λ = slope length in feet;
θ = angle of slope; and
$m = 0.5$ if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent.

The basis for this equation is given in the subsection discussing the individual effects of slope length and steepness. However, the relationships expressed by the equation were derived from data obtained on cropland, under natural rainfall, on slopes ranging from 3 to 18 percent in steepness and about 30 to 300 ft in length. How far beyond these ranges in slope characteristics the relationships derived from the data continue to be accurate has not been determined by direct soil loss measurements.

The Palouse Region of the Northwest represents

TABLE 3.—*Values of the topographic factor,* **LS**, *for specific combinations of slope length and steepness*[1]

Percent slope	Slope length (feet)											
	25	50	75	100	150	200	300	400	500	600	800	1,000
0.2	0.060	0.069	0.075	0.080	0.086	0.092	0.099	0.105	0.110	0.114	0.121	0.126
0.5	.073	.083	.090	.096	.104	.110	.119	.126	.132	.137	.145	.152
0.8	.086	.098	.107	.113	.123	.130	.141	.149	.156	.162	.171	.179
2	.133	.163	.185	.201	.227	.248	.280	.305	.326	.344	.376	.402
3	.190	.233	.264	.287	.325	.354	.400	.437	.466	.492	.536	.573
4	.230	.303	.357	.400	.471	.528	.621	.697	.762	.820	.920	1.01
5	.268	.379	.464	.536	.656	.758	.928	1.07	1.20	1.31	1.52	1.69
6	.336	.476	.583	.673	.824	.952	1.17	1.35	1.50	1.65	1.90	2.13
8	.496	.701	.859	.992	1.21	1.41	1.72	1.98	2.22	2.43	2.81	3.14
10	.685	.968	1.19	1.37	1.68	1.94	2.37	2.74	3.06	3.36	3.87	4.33
12	.903	1.28	1.56	1.80	2.21	2.55	3.13	3.61	4.04	4.42	5.11	5.71
14	1.15	1.62	1.99	2.30	2.81	3.25	3.98	4.59	5.13	5.62	6.49	7.26
16	1.42	2.01	2.46	2.84	3.48	4.01	4.92	5.68	6.35	6.95	8.03	8.98
18	1.72	2.43	2.97	3.43	4.21	3.86	5.95	6.87	7.68	8.41	9.71	10.9
20	2.04	2.88	3.53	4.08	5.00	5.77	7.07	8.16	9.12	10.0	11.5	12.9

[1] $LS = (\lambda/72.6)^m \ (65.41 \ \sin^2 \theta + 4.56 \ \sin \theta + 0.065)$ where λ = slope length in feet; $m = 0.2$ for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 for 3.5 to 4.5 percent slopes, 0.5 for 5 percent slopes and steeper; and θ = angle of slope. (For other combinations of length and gradient, interpolate between adjacent values or see fig. 4.)

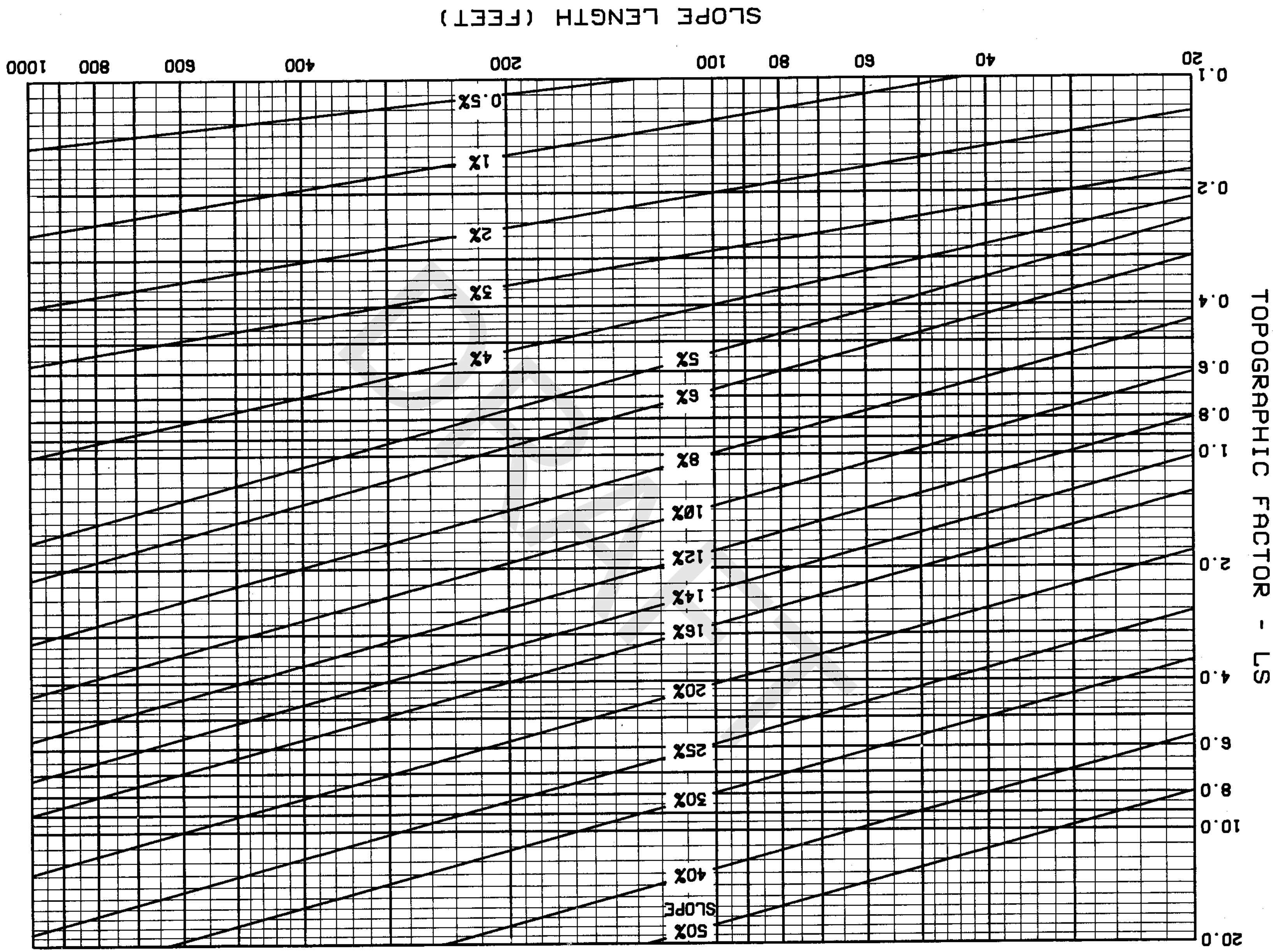


FIGURE 4.—Slope-effect chart (topographic factor, LS). LS = $(\lambda/72.6)^m$ (65.41 $\sin^2\theta$ + 4.56 $\sin\theta$ + 0.065) where λ = slope length in feet; θ = angle of slope; and m = 0.2 for gradients < 1 percent, 0.3 for 1 to 3 percent slopes, 0.4 far 3.5 to 4.5 percent slopes, and 0.5 for slapes of 5 percent or steeper.

a different situation. The rainfall erosion index is quite low because most of the rain comes as small drops and at low intensities. But many of the cropland slopes are long or steep, and substantial erosion occurs because of runoff from snowmelt or light rains over saturated soil surfaces. Limited erosion data from this region, mostly observational, strongly indicate that for this type of runoff (not accompanied by raindrop impact) the effects of percent and length of slope are of lower magnitude than indicated by the humid region data. Investigations designed to develop a more accurate **LS** equation for this region are underway at Pullman, Wash. (*21*). In the meantime, the researchers are temporarily recommending using a modified equation which computes **LS** values that are close to those that would be calculated by the equation given above if $\sin^{1.5}\theta$ were substituted for $\sin^2\theta$ and the length-exponent, **m**, were assumed to equal 0.3. Intuitively, these changes seem reasonable for the conditions under which about 90 percent of the erosion in this region occurs.

Slope-Length Effect

Slope length is defined as the distance from the point of origin of overland flow to the point where either the slope gradient decreases enough that deposition begins, or the runoff water enters a well-defined channel that may be part of a drainage network or a constructed channel (*40*). A change in land cover or a substantial change in gradient along a slope does not begin a new slope length for purposes of soil loss estimation.

The effect of slope length on annual *runoff* per unit area of cropland may generally be assumed negligible. In some of the studies runoff per unit area was slightly lower on the longer slopes during the growing season and slightly higher during the dormant season, but the differences were relatively small and neither of the relationships was consistent (*52*).

However, the *soil loss* per unit area generally increases substantially as slope length increases. The greater accumulation of runoff on the longer slopes increases its detachment and transport capacities.

The plot data showed average soil loss per unit area to be proportional to a power of slope length. Because **L** is the ratio of field soil loss to the corresponding loss from 72.6-ft slope length, its value may be expressed as $L = (\lambda/72.6)^m$, where λ is the field slope length in feet, and **m** assumes approximately the values given in the **LS** equation in the preceding section. These are average values of **m** and are subject to some variability caused by interaction effects which are not now quantitatively predictable.

The existing field plot data do not establish a general value greater than 0.5 for **m** on slopes steeper than 10 percent, as was suggested in 1965 (*64*). Although apparent values up to 0.9 were observed in some of the data (*63*), the higher values appear to have been related to soil, crop, and management variables rather than to greater slope steepness. However, basic modeling work has suggested that **m** may appreciably exceed 0.5 on steep slopes that are highly susceptible to rilling, like some construction slopes (*10*). Additional research data are greatly needed to quantify the significant interaction effects so that specific site values of **m** can be more precisely computed. Subdividing erosion between interrill (or sheet) erosion and rill erosion, being done in recent modeling work (*10, 11, 22*), promises to be quite helpful for solving this problem.

Some observations have indicated that the values of the length exponent that were derived from the plot data may overestimate soil loss when applied to lengths in the range of a quarter of a mile or more. This is logical because slopes of such lengths would rarely have a constant gradient along their entire length, and the slope irregularities would affect the amount of soil movement to the foot of the slope. By the definition of slope length quoted earlier, such slopes would usually consist of several lengths, between points where deposition occurs.

Slope length is difficult to determine for long slopes with an average gradient of less than 1 percent, unless they are precisely formed with a land leveler. On flat slopes, reflecting both the erosion and the deposition accurately by a length factor may not be possible. However, on a nearly zero-percent slope, increased length would have minor effect on runoff velocity, and the greater depths of accumulated runoff water would cushion the raindrop impact. An exponent of 0.2 for gradients of less than 1 percent is compatible with the scarce data available for such slopes and was used to derive figure 4 and table 3.

Distribution of Length Effect

LS values from figure 4 or table 3 predict the average erosion over the entire slope. But this erosion is not evenly distributed over the entire length. The rate of soil loss per unit of area increases as the $\mathbf{m}^{th}$ power of the distance from the top of the slope, where **m** is the length exponent in the preceding equation.

An equation by Foster and Wischmeier (*12*) estimates the relative amounts of soil loss from successive segments of a slope under conditions where there is no deposition by overland flow. When the gradient is essentially uniform and the segments are of equal length, the procedure can be shortened (*55*). Table 4, derived by this procedure, shows the proportionate amounts of soil detachment from successive equal-length segments of a uniform slope.

Table 4 is entered with the total number of equal-length segments, and the fraction of the soil loss for each segment is read beneath the applicable value of **m**. For example, three equal-length segments of a uniform 6-percent slope would be expected to produce 19, 35, and 46 percent, respectively, of the loss from the entire slope.

TABLE 4.—*Estimated relative soil losses from successive equal-length segments of a uniform slope*[1]

Number of segments	Sequence number of segment	Fraction of soil loss		
		m = 0.5	m = 0.4	m = 0.3
2	1	0.35	0.38	0.41
	2	.65	.62	.59
3	1	.19	.22	.24
	2	.35	.35	.35
	3	.46	.43	.41
4	1	.12	.14	.17
	2	.23	.24	.24
	3	.30	.29	.28
	4	.35	.33	.31
5	1	.09	.11	.12
	2	.16	.17	.18
	3	.21	.21	.21
	4	.25	.24	.23
	5	.28	.27	.25

[1] Derived by the formula:

$$\text{Soil loss fraction} = \frac{j^{m+1} - (j-1)^{m+1}}{N^{m+1}}$$

where j = segment sequence number; **m** = slope-length exponent (0.5 for slopes $\geq$ 5 percent, 0.4 for 4 percent slopes, and 0.3 for 3 percent or less); and **N** = number of equol-length segments into which the slope was divided.

Four segments would produce 12, 23, 30, and 35 percent, respectively. Segment No. 1 is always at the top of the slope.

Percent Slope

Runoff from cropland generally increases with increased slope gradient, but the relationship is influenced by such factors as type of crop, surface roughness, and profile saturation. In the natural rain slope-effect studies, the logarithm of runoff from row crops was linearly and directly proportional to percent slope. With good meadow sod and with smooth bare surfaces, the relationship was insignificant. The effect of slope on runoff decreased in extremely wet periods.

Soil loss increases much more rapidly than runoff as slopes steepen. The slope-steepness factor, **S**, in the soil loss equation is evaluated by the equation

$$S = 65.41 \sin^2 \theta + 4.56 \sin \theta + 0.065 \qquad (5)$$

where θ is the angle of slope.

This equation was used to develop the slope-effect chart. The values reflect the average effect of slope steepness on soil loss in the plot studies. The relation of percent slope to soil loss is believed to be influenced by interactions with soil properties and surface conditions, but the interaction effects have not been quantified by research data. Neither are data available to define the limits on the equation's applicability.

This equation can be derived from the formerly published equation for **S**. Expressing the factor as a function of the sine of the angle of slope rather than the tangent is more accurate because raindrop-impact forces along the surface and runoff shear stress are functions of the sine. Substituting 100 sin θ for percent slope, which is 100 tan θ, does not significantly affect the initial statistical derivation or the equation's solutions for slopes of less than 20 percent. But as slopes become steeper, the difference between the sine and the tangent becomes appreciable and projections far beyond the range of the plot data become more realistic. The numerator was divided by the constant denominator for simplification.

Irregular Slopes

Soil loss is also affected by the shape of a slope. Many field slopes either steepen toward the lower end (convex slope) or flatten toward the lower end (concave slope). Use of the average gradient to enter figure 4 or table 3 would underestimate soil movement to the foot of a convex slope and would overestimate it for concave slopes. Irregular slopes can usually be divided into segments that have nearly uniform gradient, but the segments cannot be evaluated as independent slopes when runoff flows from one segment to the next.

However, where two simplifying assumptions can be accepted, **LS** for irregular slopes can be routinely derived by combining selected values from the slope-effect chart and table 4 (55). The assumptions are that (1) the changes in gradient are not sufficient to cause upslope deposition, and (2) the irregular slope can be divided into a small number of equal-length segments in such a manner that the gradient within each segment for practical purposes can be considered uniform.

After dividing the convex, concave, or complex slope into equal-length segments as defined earlier, the procedure is as follows: List the segment gradients in the order in which they occur on the slope, beginning at the upper end. Enter the slope-effect chart with the total slope length and read **LS** for each of the listed gradients. Multiply these by the corrresponding factors from table 4 and add the products to obtain **LS** for the entire slope. The following tabulation illustrates the procedure for a 400-ft convex slope on which the upper third has a gradient of 5 percent; the middle third, 10 percent; and the lower third, 15 percent:

Segment	*Percent slope*	*Table 3*	*Table 4*	*Product*
1	5	1.07	0.19	0.203
2	10	2.74	.35	.959
3	15	5.12	.46	2.355
				LS = 3.517

For the concave slope of the same length, with the segment gradients in reverse order, the values in the third column would be listed in reverse order. The products would then be 0.973, 0.959, and 0.492, giving a sum of 2.42 for **LS**.

Research has not defined just how much gradient change is needed under various conditions for deposition of soil particles of various sizes to begin, but depositional areas can be determined by observation. When the slope breaks are sharp enough to cause deposition, the procedure can be used to estimate **LS** for slope segments above and below the depositional area. However, it will not predict the total sediment moved from such an interrupted slope because it does not predict the amount of deposition.

Changes in Soil Type or Cover Along the Slope

The procedure for irregular slopes can include evaluation of changes in soil type within a slope length (55). The products of values selected from table 3 or figure 4 and table 4 to evaluate **LS** for irregular slopes are multiplied by the respective values of **K** before summing. To illustrate, assume the **K** values for the soils in the three segments of the convex slope in the preceding example were 0.27, 0.32, and 0.37, respectively. The average **KLS** for the slope would be obtained as follows:

Segment No.	*Table 3*	*Table 4*	**K**	*Product*
1	1.07	0.19	0.27	0.055
2	2.74	.35	.32	.307
3	5.12	.46	.37	.871
				KLS = 1.233

Within limits, the procedure can be further extended to account for changes in cover along the slope length by adding a column of segment **C** values. However, it is not applicable for situations where a practice change along the slope causes deposition. For example, a grass buffer strip across the foot of a slope on which substantial erosion is occurring induces deposition. The amount of this deposition is a function of transport relationships (10) and cannot be predicted by the USLE.

Equation for Soil Detachment on Successive Segments of a Slope

This procedure is founded on an equation (*12*) that can be applied also when the slope segments are not of equal length. Concepts underlying this equation include the following:

Sediment load at a location on a slope is controlled either by the transport capacity of the runoff and rainfall or by the amount of detached soil material available for transport. When the amount of detached material exceeds the transport capacity, deposition occurs and the sediment load is determined primarily by the transport capacity of the runoff at that location. Where upslope detachment has not equaled the transport capacity, sediment load at a given location is a function of erosion characteristics of the upslope area and can be computed by the USLE. Soil loss from a given segment of the slope can then be computed as the difference between the sediment loads at the lower and upper ends of the segment.

Foster and Wischmeier (12) present a procedure for using this equation to evaluate **LS** for irregular slopes and to account for the effects of the soil or coverage changes along a slope, so long as the changes do not cause deposition to occur.

COVER AND MANAGEMENT FACTOR (C)

Cover and management effects cannot be independently evaluated because their combined effect is influenced by many significant interrelations. Almost any crop can be grown continuously, or it can be grown in rotations. Crop sequence influences the length of time between successive crop canopies, and it also influences the benefits obtained from residual effects of crops and management. The erosion control effectiveness of meadow sod turned under before a row crop depends on the type and quality of the meadow and on the length of time elapsed since the sod was turned under. Seedbeds can be clean tilled, or they can be protected by prior crop residues. They can be left rough, with much available capacity for surface storage and reduction of runoff velocity, or they can be smoothed by secondary tillage.

Crop residues can be removed, left on the surface, incorporated near the surface, or plowed under. When left on the surface, they can be chopped or dragged down, or they can be allowed to remain as left by the harvesting operation. The effectiveness of crop residue management will depend on the amount of residue available. This, in turn, depends on the amount and distribution of rainfall, on the fertility level, and on the management decisions made by the farmer.

The canopy protection of crops not only depends on the type of vegetation, the stand, and the quality of growth, but it also varies greatly in different months or seasons. Therefore, the overall erosion-reducing effectiveness of a crop depends largely on how much of the erosive rain occurs during those periods when the crop and management practices provide the least protection.

Definition of Factor C

Factor **C** in the soil loss equation is the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled, continuous fallow. This factor measures the combined effect of all the interrelated cover and management variables.

The loss that would occur on a particular field if it were continuously in fallow condition is computed by the product of **RKLS** in the soil loss equation. Actual loss from the cropped field is usually much less than this amount. Just how much less depends on the particular combination of cover, crop sequence, and management practices. It also depends on the particular stage of growth and development of the vegetal cover at the time of the rain. **C** adjusts the soil loss estimate to suit these conditions.

The correspondence of periods of expected highly erosive rainfall with periods of poor or good plant cover differs between regions or locations. Therefore, the value of **C** for a particular cropping system will not be the same in all parts of the country. Deriving the appropriate **C** values for a given locality requires knowledge of how the erosive rainfall in that locality is likely to be distributed through the 12 months of the year and how much erosion control protection the growing plants, crop residues, and selected management practices will provide at the time when erosive rains are most likely to occur. A procedure is presented for deriving local values of **C** on the basis of available weather records and research data that reflect effects of crops and management in successive segments of a rotation cycle. The cropping and weather data needed for this purpose appear in reference form in the subsections entitled, **Soil Loss Ratios** and **Erosion Index Distribution Data.**

Cropstage Periods

The change in effectiveness of plant cover within the crop year is gradual. For practical purposes, the year is divided into a series of cropstage periods defined so that cover and management effects may be considered approximately uniform within each period.

Initially, five periods were used, with the seedling and establishment periods defined as the first and second months after crop seeding (50). Because of the existing ranges in soil fertility, row spacing, plant population, and general growing conditions, however, soil loss prediction accuracy is improved when the cropstage periods are defined according to percentage of canopy cover rather than for uniform time periods. The lengths of the respective periods will then vary with crop, climate, and management and will be determined by conditions in a particular geographic area.

The soil loss ratios presented in the next subsection for computation of **C** were evaluated for six cropstage periods defined as follows:

Period F (rough fallow)—Inversion plowing to secondary tillage.

Period SB (seedbed)—Secondary tillage for seedbed preparation until the crop has developed 10 percent canopy cover.

Period 1 (establishment)—End of *SB* until crop has developed a 50 percent canopy cover. (Exception: period 1 for cotton ends at 35 percent canopy cover.)

Period 2 (development)—End of period 1 until canopy cover reaches 75 percent. (60 percent for cotton.)

Period 3 (maturing crop)—End of period 2 until crop harvest. This period was evaluated for three levels of final crop canopy.

Period 4 (residue or stubble)—Harvest to plowing or new seeding.

Quantitative Evaluations of Crop and Management Effects

More than 10,000 plot-years of runoff and soil loss data from natural rain,[5] and additional data from a large number of erosion studies under simulated rainfall, were analyzed to obtain empirical measurements of the effects of cropping system and management on soil loss at successive stages of crop establishment and development. Soil losses measured on the cropped plots were compared with corresponding losses from clean-tilled, continuous fallow to determine the soil loss reductions ascribable to effects of the crop system and management. The reductions were then analyzed to identify and evaluate influential subfactors, interactions, and correlations. Mathematical relationships observed for one crop or geographic region were tested against data from other research sites for consistency. Those found compatible with all the relevant data were used to compute soil loss reductions to be expected from conditions not directly represented in the overall plot studies.

The value of **C** on a particular field is determined by many variables, one of which is weather. Major variables that can be influenced by management decisions include crop canopy, residue mulch, incorporated residues, tillage, land use residual, and their interactions. Each of these effects may be treated as a subfactor whose numerical value is the ratio of soil loss with the effect to corresponding loss without it (57). **C** is the product of all the pertinent subfactors.

Crop Canopy

Leaves and branches that do not directly contact the soil have little effect on amount and velocity of *runoff* from prolonged rains, but they reduce the effective rainfall energy by intercepting falling raindrops. Waterdrops falling from the canopy may regain appreciable velocity but usually less than the terminal velocities of free-falling

[5] See footnote 3, p. 2.

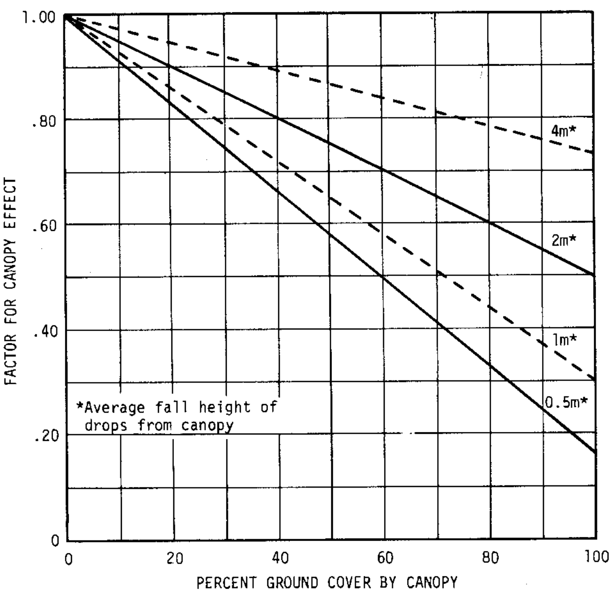


FIGURE 5.—Influence of vegetative canopy on effective EI values. Canopy factor is a subfactor of C.

raindrops. The amount by which energy expended at the soil surface is reduced depends on the height and density of the canopy. The subfactor for canopy effect can be estimated for specified conditions by reference to figure 5.

Residue Mulch

Residue mulches and stems from close-growing vegetation are more effective than equivalent percentages of canopy cover. Mulches intercept falling raindrops so near the surface that the drops regain no fall velocity, and they also obstruct runoff flow and thereby reduce its velocity and transport capacity. Measurements of the effectiveness of several types and rates of mulch have been published (*1, 2, 20, 27, 43*). Average subfactors for specific percentages of surface cover by plant materials at the soil surface are given by the upper curve of figure 6. Guides for estimating percent cover are given in the appendix.

If the cover includes both canopy and mulch, the two are not fully additive; the impact energy of drops striking the mulch is dissipated at that point regardless of whether canopy interception has reduced its velocity. The expected effects of mulch and canopy combinations have been computed and are given in figures 6 and 7. Figure 6 applies to corn, sorghum, and cotton in the maturing stage. Figure 7 applies to small grain, soybeans, potatoes, and the establishment period for taller row crops. Enter either figure 6 or 7 along the horizontal scale, move vertically to the appro-

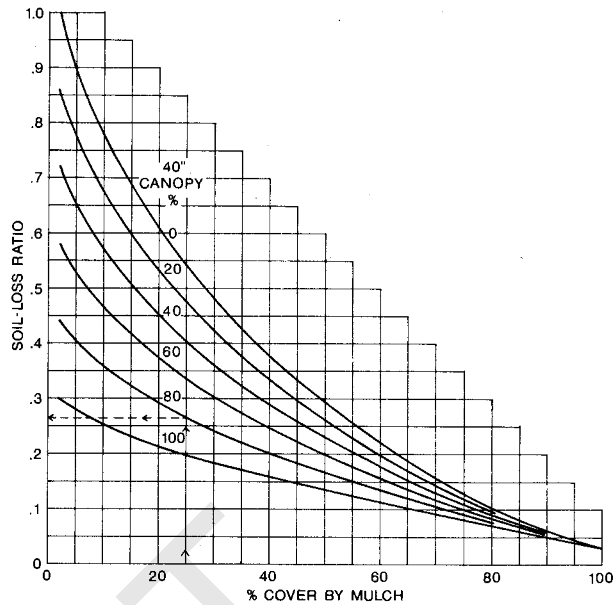


FIGURE 6.—Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 40 inches (1 m).

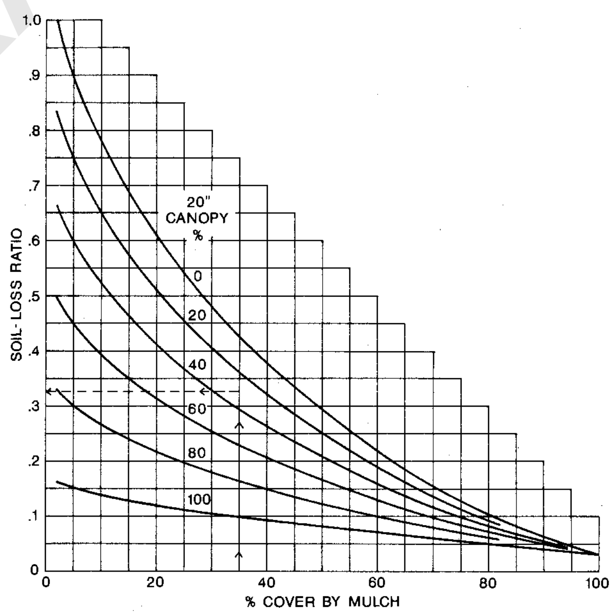


FIGURE 7.—Combined mulch and canopy effects when average fall distance of drops from canopy to the ground is about 20 inches (0.5 m).

priate percent-canopy curve, and read at the left the soil loss ratio from cover effect. This ratio is a subfactor that may be combined with other pertinent subfactors to account for the cropstage soil loss of table 5 or to estimate others.

Incorporated Residues

The plot data indicate that, at least during the seedbed and establishment periods, the erosion-reducing effectivensss of residues mixed into the upper few inches of soil by shallow tillage is appreciably greater than the residual effect of long-term annual incorporation with a moldboard plow. However, the incorporated residues are less effective than if left on the surface.

Tillage

The type, frequency, and timing of tillage operations influence porosity, roughness, cloddiness, compaction, and microtopography. These, in turn, affect water intake, surface storage, runoff velocity, and soil detachability, all of which are factors in potential erosion. These effects are highly correlated with cropland residual effects.

Land Use Residuals

These include effects of plant roots; long-term residue incorporation by plowing; changes in soil structure, detachability, density, organic matter content, and biological activity; and probably other factors. The residual effects are most apparent during seedbed and establishment periods.

Some residual effect will be apparent on nearly any cropland, but the magnitude of its erosion-reducing effectiveness will differ substantially with crops and practices. Tillage and land use residuals are influenced by so many factor interrelations that development of charts like those for canopy and mulch has not been feasible. However, apparent values of these subfactors for some situations were derived from the data and used for expansion of the soil loss ratio table to include conditions somewhat different from those directly represented in the plot studies.

Plowing residues down is far less effective than leaving them on the surface but better than burning them or removing them from the land. After several years of turning the crop residues under with a moldboard plow before row crop seeding in plot studies under natural rainfall, both runoff and soil loss from the row crops were much less than from similar plots from which cornstalks and grain straw were removed at harvesttimes (*52, 54, 59*).

Short periods of rough fallow in a rotation will usually lose much less soil than the basic, clean-tilled, continuous fallow conditions for which **C** = 1. This is largely because of residual effects and is also partly because of the roughness and cloddiness.

The most pronounced residual effect is that from long-term sod or forest. The effect of a grass-and-legume rotation meadow turned under diminishes gradually over about 2 years. In general, the erosion-reducing effectiveness of sod residual (from grass or grass-and-legume meadows) in the plot studies was directly proportional to hay yields. Site values of the subfactor for sod residuals in rotations can be obtained from soil loss ratio table 5-D. The effectiveness of virgin sod and of long periods of alfalfa in which grass became well established was longer lasting. Mixtures of grasses and legumes were more effective than legumes alone.

Residual effectiveness of winter cover crops plowed under in spring depends largely on the type and quality of the crop and its development stage at the time it is plowed under. The effectiveness of grass-and-legume catch crops turned under in spring was less and of shorter duration than that of full-year rotation meadows. Covers such as vetch and ryegrass seeded between corn or cotton rows before harvest and turned under in April were effective in reducing erosion during the winter and showed some residual effect in the following seedbed and establishment periods. Small grain seeded alone in corn or cotton residues showed no residual effect under the next crop. Small grain or vetch on fall-plowed seedbed and turned at spring planting time lost more soil than adjacent plots with undisturbed cotton residues on the surface.

Soil Loss Ratios

Factor **C** is usually given in terms of its average annual value for a particular combination of crop system, management, and rainfall pattern. To derive site values of **C**, soil loss ratios for the individual cropstage periods must be combined with erosion-index distribution data, as demonstrated later. Ratios of soil losses in each cropstage period of specified cropping and management systems to corresponding losses from the basic long-term fallow condition were derived from analysis of about a quarter million plot soil loss observations. The ratios are given in table 5 as percentages.

The observed soil loss ratios for given conditions often varied substantially from year to year because of influences of unpredictable random variables and experimental error. The percentages listed in table 5 are the best available averages for the specified conditions. To make the table inclusive enough for general field use, expected ratios had to be computed for cover, residue, and management combinations that were not directly represented in the plot data. This was done by using empirical relationships of soil losses to the subfactors and interactions discussed in the preceding subsection. The user should recognize that the tabulated percentages are subject to appreciable experimental error and could be improved through additional research. However, because of the large volume of data considered in developing the table, the listed values should be near enough to the true averages to provide highly valuable planning and monitoring guidelines. A ratio derived locally from 1-year rainfall simulator tests on a few plots would not necessarily represent the true average for that locality more accurately. Small samples are more subject to bias by random variables and experimental error than larger samples.

Table for Cropland

Table 5, with its supplements 5A, B, C, and D, replaces tables 2, 3, and 4 in the 1965 edition. The supplements had to be separated from the main table to accommodate changes in format requirements. The ratios are expressed as percentages in the tables to eliminate decimal points.

More than half the lines in table 5 are for conditions associated with conservation tillage practices (65), which were not included in the 1965 edition. Also, it provides a direct means of crediting effects of faster and more complete canopy development by improved fertility, closer row spacing, and greater plant population. Because the table includes several times as many specific conditions as the table in the 1965 edition and defines applicable field conditions more accurately, some simplicity has been sacrificed. However, it is not intended for direct use by each field technician or farmer.

Table 5 as presented here is designed to provide the details needed by a trained agronomist to develop simple handbook tables of **C** values for conditions in specific climatic areas. It is designed for use of the revised definitions of cropstage periods given in the preceding section. The agronomist will first determine, for the particular climatic area, the number of weeks normally required for the crop canopies to attain 10, 50, and 75 percent surface cover, respectively. The table will then be used as illustrated in the next major section. Linear interpolation between ratios listed in the table is recommended where appropriate.

Semiarid Regions

Water erosion is a serious problem also in subhumid and semiarid regions. Inadequate moisture and periodic droughts reduce the periods when growing plants provide good soil cover and limit the quantities of plant residue produced. Erosive rainstorms are not uncommon, and they are usually concentrated within the season when cropland is least protected. Because of the difficulty of establishing rotation meadows and the competition for available soil moisture, sod-based rotations are often impractical. One of the most important opportunities for a higher level of soil and moisture conservation is through proper management of available residues. The effects of mulch-tillage practices in these areas can be evaluated from lines 129 to 158 of table 5 and item 12 of 5-B.

Erosion Index Distribution Data

The rainfall factor, **R**, in the soil loss equation does not completely describe the effects of local differences in rainfall pattern on soil erosion. The erosion control effectiveness of a cropping system on a particular field depends, in part, on how the year's erosive rainfall is distributed among the six cropstage periods of each crop included in the system. Therefore, expected monthly distribution

TABLE 5.—*Ratio of soil loss from cropland to corresponding loss from continuous fallow*

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]							
				F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER C, GS, G OR COT IN MEADOWLESS SYSTEMS										
	Moldboard plow, conv till:										
1	RdL, sprg TP	4,500	—	31	55	48	38	—	—	20	23
2		3,400	—	36	60	52	41	—	24	20	30
3		2,600	—	43	64	56	43	32	25	21	37
4		2,000	—	51	68	60	45	33	26	22	47
5	RdL, fall TP	HP[2]	—	44	65	53	38	—	—	20	—
6		GP	—	49	70	57	41	—	24	20	—
7		FP	—	57	74	61	43	32	25	21	—
8		LP	—	65	78	65	45	32	26	22	—
9	RdR, sprg TP	HP	—	66	74	65	47	—	—	22	56
10		GP	—	67	75	66	47	—	27	23	62
11		FP	—	68	76	67	48	35	27	—	69
12		LP	—	69	77	68	49	35	—	—	74
13	RdR, fall TP	HP	—	76	82	70	49	—	—	22	—
14		GP	—	77	83	71	50	—	27	23	—
15		FP	—	78	85	72	51	35	27	—	—
16		LP	—	79	86	73	52	35	—	—	—
17	*Wheeltrack pl, RdL, TP*[8]	4,500	—	—	31	27	25	—	—	18	23
18		3,400	—	—	36	32	30	—	22	18	30
19		2,600	—	—	43	36	32	29	23	19	37
20		2,000	—	—	51	43	36	31	24	20	47
21	*Deep off-set disk or*	4,500	10	—	45	38	34	—	—	20	23
22	*disk plow*	3,400	10	—	52	43	37	—	24	20	30
23		2,600	5	—	57	48	40	32	25	21	37
24		2,000	—	—	61	51	42	33	26	22	47
25	*No-till plant in crop residue*[9]	6,000	95	—	2	2	2	—	—	2	14
26		6,000	90	—	3	3	3	—	—	3	14
27		4,500	80	—	5	5	5	—	—	5	15
28		3,400	70	—	8	8	8	—	8	6	19
29		3,400	60	—	12	12	12	12	9	8	23
30		3,400	50	—	15	15	14	14	11	9	27
31		2,600	40	—	21	20	18	17	13	11	30
32		2,600	30	—	26	24	22	21	17	14	36
	Chisel, shallow disk, or fld cult, as only tillage:										
33	On moderate slopes	6,000	70	—	8	8	7	—	—	7	17
34			60	—	10	9	8	—	—	8	17
35			50	—	13	11	10	—	—	9	18
36			40	—	15	13	11	—	—	10	19
37			30	—	18	15	13	—	—	12	20
38			20	—	23	20	18	—	—	16	21
39	Do.	4,500	70	—	9	8	7	—	—	7	18
40			60	—	12	10	9	—	—	8	18
41			50	—	14	13	11	—	—	9	19
42			40	—	17	15	13	—	—	10	20
43			30	—	21	18	15	—	—	13	21
44			20	—	25	22	19	—	—	16	22

Line No.	Cover, crop sequence, and management[1]	Spring residue[2]	Cover after plant[3]	Soil loss ratio[4] for cropstage period and canopy cover[5]							
				F	SB	1	2	3:80	90	96	4L[6]
		Lb	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*	*Pct*
	CORN AFTER WC OF RYEGRASS OR WHEAT SEEDED IN C STUBBLE										
	WC reaches stemming stage:										
79	No-till pl in killed WC	4,000	—	—	7	7	7	—	7	6	(13)
80		3,000	—	—	11	11	11	11	9	7	
81		2,000	—	—	15	15	14	14	11	9	
82		1,500	—	—	20	19	18	18	14	11	
	Strip till one-fourth row space										
83	Rows U/D slope	4,000	—	—	13	12	11	—	11	9	(13)
84		3,000	—	—	18	17	16	16	13	10	
85		2,000	—	—	23	22	20	19	15	12	
86		1,500	—	—	28	26	24	22	17	14	
87	Rows on contour[11]	4,000	—	—	10	10	10	—	10	8	(13)
88		3,000	—	—	15	15	15	15	12	9	
89		2,000	—	—	20	20	19	19	15	12	
90		1,500	—	—	25	24	23	22	17	14	
91	TP, conv seedbed	4,000	—	36	60	52	41	—	24	20	(13)
92		3,000	—	43	64	56	43	31	25	21	
93		2,000	—	51	68	60	45	33	26	22	
94		1,500	—	61	73	64	47	35	27	23	
	WC succulent blades only:										
95	No-till pl in killed WC	3,000	—	—	11	11	17	23	18	16	(13)
96		2,000	—	—	15	15	20	25	20	17	
97		1,500	—	—	20	20	23	26	21	18	
98		1,000	—	—	26	26	27	27	22	19	
99	Strip till one-fourth row space	3,000	—	—	18	18	21	25	20	17	(13)
100		2,000	—	—	23	23	25	27	21	18	
101		1,500	—	—	28	28	28	28	22	19	
102		1,000	—	—	33	33	31	29	23	20	
	CORN IN SOD-BASED SYSTEMS										
	No-till pl in killed sod:										
103	3 to 5 tons hay yld	—	—	—	1	1	1	—	1	1	1
104	1 to 2 tons hay yld	—	—	—	2	2	2	2	2	2	2
	Strip till, 3-5 ton M:										
105	50 percent cover, tilled strips	—	—	—	2	2	2	—	2	2	4
106	20 percent cover, tilled strips	—	—	—	3	3	3	—	3	3	5
	Strip till, 1-2 ton M:										
107	40 percent cover, tilled strips	—	—	—	4	4	4	4	4	4	6
108	20 percent cover, tilled strips	—	—	—	5	5	5	5	5	5	7
	Other tillage after sod:			(14)	(14)	(14)	(14)	(14)	(14)	(14)	(14)
	CORN AFTER SOYBEANS										
109	*Sprg TP, conv till*	HP	—	40	72	60	48	—	—	25	29
110		GP	—	47	78	65	51	—	30	25	37
111		FP	—	56	83	70	54	40	31	26	44
112	*Fall TP, conv till*	HP	—	47	75	60	48	—	—	25	—
113		GP	—	53	81	65	51	—	30	25	—
114		FP	—	62	86	70	54	40	31	26	—

45	Do.	3,400	60	—	13	11	10	—	10	8	20
46			50	—	16	13	12	—	12	9	24
47			40	—	19	17	16	—	14	11	25
48			30	—	23	21	19	—	17	14	26
49			20	—	29	25	23	—	21	16	27
50			10	—	36	32	29	—	24	20	30
51	Do.	2,600	50	—	17	16	15	15	13	10	29
52			40	—	21	20	19	19	15	12	30
53			30	—	25	23	22	22	18	14	32
54			20	—	32	29	28	27	22	17	34
55			10	—	41	36	34	32	25	21	37
56	Do.	2,000	40	—	23	21	20	20	15	12	37
57			30	—	27	25	24	23	19	15	39
58			20	—	35	32	30	28	22	18	42
59			10	—	46	42	38	33	26	22	47
	On slopes > 12 percent.										
60	Lines 33-59 times factor of:	—	—	—	1.3	1.3	1.1	1.0	1.0	1.0	1.0
	Disk or harrow after spring chisel or fld cult:										
	Lines 33-59 times factor of:										
61	On moderate slopes	—	—	—	1.1	1.1	1.1	1.0	1.0	1.0	1.0
62	On slopes > 12 percent	—	—	—	1.4	1.4	1.2	1.0	1.0	1.0	1.0
	Ridge plant:[10]										
	Lines 33-59 times factor of:										
63	Rows on contour[11]	—	—	—	.7	.7	.7	.7	.7	.7	.7
64	Rows U/D slope < 12 percent	—	—	—	.7	.7	1.0	1.0	1.0	1.0	1.0
65	Rows U/D slope > 12 percent	—	—	—	.9	.9	1.0	1.0	1.0	1.0	1.0
	Till plant:										
	Lines 33-59 times factor of:										
66	Rows on contour[11]	—	—	—	.7	.85	1.0	1.0	1.0	1.0	1.0
67	Rows U/D slope < 7 percent	—	—	—	1.0	1.0	1.0	1.0	1.0	1.0	1.0
	Strip till one-fourth of row spacing:										
68	Rows on contour[11]	4,500	[12]60	—	12	10	9	—	—	8	23
69		3,400	50	—	16	14	12	—	11	10	27
70		2,600	40	—	22	19	17	17	14	12	30
71		2,000	30	—	27	23	21	20	16	13	36
72	Rows U/D slope	4,500	[12]60	—	16	13	11	—	—	9	23
73		3,400	50	—	20	17	14	—	12	11	27
74		2,600	40	—	26	22	19	17	14	12	30
75		2,000	30	—	31	26	23	20	16	13	36
	Vari-till:										
76	Rows on contour[11]	3,400	40	—	13	12	11	—	—	11	22
77		3,400	30	—	16	15	14	14	13	12	26
78		2,600	20	—	21	19	19	19	16	14	34

115	Fall & sprg chisel or cult	HP	[15]30	—	40	35	29	—	—	23	29
116		GP	25	—	45	39	33	—	27	23	37
117		GP	20	—	51	44	39	34	27	23	37
118		FP	15	—	58	51	44	36	28	23	44
119		LP	10	—	67	59	48	36	28	23	54
120	*No-till pl in crop res'd*	HP	[15]40	—	25	20	19	—	14	11	26
121		GP	30	—	33	29	25	22	18	14	33
122		FP	20	—	44	38	32	27	23	18	40
	BEANS AFTER CORN										
123	*Sprg TP, RdL, conv till*	HP	—	33	60	52	38	—	20	17	([16])
124		GP	—	39	64	56	41	—	21	18	
125		FP	—	45	68	60	43	29	22	—	
126	*Fall TP, RdL, conv till*	HP	—	45	69	57	38	—	20	17	([16])
127		GP	—	52	73	61	41	—	21	18	
128		FP	—	59	77	65	43	29	22	—	
	Chisel or fld cult:			([17])	([17])	([17])	([17])	([17])	([17])	([17])	([18])
	BEANS AFTER BEANS			([18])	([18])	([18])	([18])	([18])	([18])	([18])	([16])
	GRAIN AFTER C, G, GS, COT[19]										
129	*In disked residues:*	4,500	70	—	12	12	11	7	4	2	([20])
130		3,400	60	—	16	14	12	7	4	2	
131			50	—	22	18	14	8	5	3	
132			40	—	27	21	16	9	5	3	
133			30	—	32	25	18	9	6	3	
134			20	—	38	30	21	10	6	3	
135	Do.	2,600	40	—	29	24	19	9	6	3	([20])
136			20	—	43	34	24	11	7	4	
137			10	—	52	39	27	12	7	4	
138	Do.	2,000	30	—	38	30	23	11	7	4	([20])
139			20	—	46	36	26	12	7	4	
140			10	—	56	43	30	13	8	5	
141	*In disked stubble, RdR*	—	—	—	79	62	42	17	11	6	([20])
142	*Winter G after fall TP, RdL*	HP	—	31	55	48	31	12	7	5	([20])
143		GP	—	36	60	52	33	13	8	5	
144		FP	—	43	64	56	36	14	9	5	
145		LP	—	53	68	60	38	15	10	6	
	GRAIN AFTER SUMMER FALLOW										
146	*With grain residues*	200	10	—	70	55	43	18	13	11	([21])
147		500	30	—	43	34	23	13	10	8	
148		750	40	—	34	27	18	10	7	7	
149		1,000	50	—	26	21	15	8	7	6	
150		1,500	60	—	20	16	12	7	5	5	
151		2,000	70	—	14	11	9	7	5	5	
152	*With row crop residues*	300	5	—	82	65	44	19	14	12	([21])
153		500	15	—	62	49	35	17	13	11	
154		750	23	—	50	40	29	14	11	9	
155		1,000	30	—	40	31	24	13	10	8	
156		1,500	45	—	31	24	18	10	8	7	
157		2,000	55	—	23	19	14	8	7	5	
158		2,500	65	—	17	14	12	7	5	4	
	POTATOES										
159	*Rows with slope*	—	—	43	64	56	36	26	19	16	
160	*Contoured rows, ridged when canopy cover is about 50 percent*[11]	—	—	43	64	56	18	13	10	8	

See footnotes, p. 24.

Footnotes for table 5.

[1] Symbols: B, soybeans; C, corn; conv till, plow, disk and harrow for seedbed; cot, cotton; F, rough fallow; fld cult, field cultivator; G, small grain; GS, grain sorghum; M, grass and legume meadow, at least 1 full year; pl, plant; RdL, crop residues left on field; RdR, crop residues removed; SB, seedbed period; sprg, spring; TP, plowed with moldboard; WC, winter cover crop; —, insignificant or an unlikely combination of variables.

[2] Dry weight per acre after winter loss and reductions by grazing or partial removal: 4,500 lbs represents 100 to 125 bu corn; 3,400 lbs, 75 to 99 bu; 2,600 lbs, 60 to 74 bu; and 2,000 lbs, 40 to 59 bu; with normal 30-percent winter loss. For RdR or fall-plow practices, these four productivity levels are indicated by HP, GP, FP and LP, respectively (high, good, fair, and low productivity). In lines 79 to 102, this column indicates dry weight of the winter-cover crop.

[3] Percentage of soil surface covered by plant residue mulch *after* crop seeding. The difference between spring residue and that on the surface after crop seeding is reflected in the soil loss ratios as residues mixed with the topsoil.

[4] The soil loss ratios, given as percentages, assume that the indicated crop sequence and practices are followed consistently. One-year deviations from normal practices do not have the effect of a permanent change. Linear interpolation between lines is recommended when justified by field conditions.

[5] Cropstage periods are as defined on p. 18. The three columns for cropstage 3 are for 80, 90, and 96 to 100 percent canopy cover at maturity.

[6] Column 4L is for all residues left on field. Corn stalks partially standing as left by some mechanical pickers. If stalks are shredded and spread by picker, select ratio from table 5-C. When residues are reduced by grazing, take ratio from lower spring-residue line.

[7] Period 4 values in lines 9 to 12 are for corn stubble (stover removed).

[8] Inversion plowed, no secondary tillage. For this practice, residues must be left and incorporated.

[9] Soil surface and chopped residues of *matured* preceding crop undisturbed except in narrow slots in which seeds are planted.

[10] Top of old row ridge sliced off, throwing residues and some soil into furrow areas. Reridging assumed to occur near end of cropstage 1.

[11] Where lower soil loss ratios are listed for rows on the contour, this reduction is in addition to the standard field contouring credit. The *P* value for contouring is used with these reduced loss ratios.

[12] Field-average percent cover; probably about three-fourths of percent cover on undisturbed strips.

[13] If again seeded to WC crop in corn stubble, evaluate winter period as a winter grain seeding (lines 132 to 148). Otherwise, see table 5-C.

[14] Select the appropriate line for the crop, tillage, and productivity level and multiply the listed soil loss ratios by sod residual factors from table 5-D.

[15] Spring residue may include carryover from prior corn crop.

[16] See table 5-C.

[17] Use values from lines 33 to 62 with appropriate dates and lengths of cropstage periods for beans in the locality.

[18] Values in lines 109 to 122 are best available estimates, but planting dates and lengths of cropstages may differ.

[19] When meadow is seeded with the grain, its effect will be reflected through higher percentages of cover in cropstages 3 and 4.

[20] Ratio depends on percent cover. See table 5-C.

[21] See item 12, table 5-B.

TABLE 5-A.—*Approximate soil loss ratios for cotton*

Practice Number / Tillage operation(s)			
Expected final canopy percent cover:	65	80	95
Estimated initial percent cover from defoliation + stalks down:	30	45	60
Practice Number — Tillage operation(s)	Soil loss ratio[1]		
COTTON ANNUALLY:	*Percent*		
1....*None:*			
Defoliation to Dec. 31	36	24	15
Jan. 1 to Feb. or Mar. tillage:			
Cot Rd only	52	41	32
Rd & 20 percent cover vol veg[2]	32	26	20
Rd & 30 percent cover vol veg	26	20	14
2....*Chisel plow soon after cot harvest:*			
Chiseling to Dec. 31	40	31	24
Jan. 1 to sprg tillage	56	47	40
3....*Fall disk after chisel:*			
Disking to Dec. 31	53	45	37
Jan. 1 to sprg tillage	62	54	47
4....*Chisel plow Feb-Mar, no prior tillage:*			
Cot Rd only	50	42	35
Rd & 20 percent vol veg	39	33	28
Rd & 30 percent vol veg	34	29	25
5....*Bed ("hip") Feb-Mar, no prior tillage:*			
Cot Rd only	100	84	70
Rd & 20 percent vol veg	78	66	56
Rd & 30 percent vol veg	68	58	50
Split ridges & plant after hip, or Disk & plant after chisel (SB):			
Cot Rd only	61	54	47
Rd & 20 percent vol veg	53	47	41
Rd & 30 percent vol veg	50	44	38
Cropstage 1:			
Cot Rd only	57	50	43
Rd & 20 percent vol veg	49	43	38
Rd & 30 percent vol veg	46	41	36
Cropstage 2	45	39	34
Cropstage 3	40	27	17
6....*Bed (hip) after 1 prior tillage:*			
Cot Rd only	110	96	84
Rd & 20 percent veg	94	82	72
Rd & 30 percent veg	90	78	68
Split ridges after hip (SB):			
Cot Rd only	66	61	52
Rd & 20 to 30 percent veg	61	55	49
Cropstage 1:			
Cot Rd only	60	56	49
Rd & 20 to 30 percent veg	56	51	46
Cropstage 2	47	44	38
Cropstage 3	42	30	19
7....*Hip after 2 prior tillages:*			
Cot Rd only	116	108	98
Rd & 20-30 percent veg	108	98	88
Split ridges after hip (SB)	67	62	57
8....*Hip after 3 or more tillages:*	120	110	102
Split ridges after hip (SB)	68	64	59
9....*Conventional moldboard plow and disk:*			
Fallow period	42	39	36
Seedbed period	68	64	59
Cropstage 1	63	59	55
Cropstage 2	49	46	43
Cropstage 3	44	32	22
Cropstage 4 (See practtices 1, 2, and 3)			

COTTON AFTER SOD CROP:

For the first or second crop after a grass or grass-and-legume meadow has been turnplowed, multiply values given in the last five lines above by sod residual factors from table 5-D.

COTTON AFTER SOYBEANS:

Select values from above and multiply by 1.25.

See footnotes at right.

of erosive rainfall at a particular location is an element in deriving the applicable value of cover and management, **C.**

Central and Eastern States

A location's erosion index is computed by summing **EI** values of individual rainstorms over periods from 20 to 25 years. Thus, the expected monthly distribution of the erosion index can be computed from the same data. For each rainfall record abstracted for development of the isoerodent map, the monthly **EI** values were computed and expressed as percentages of the location's average annual erosion index. When the monthly percentages are plotted cumulatively against time, they define **EI** distribution curves such as illustrated in figure 8 for three locations. The three contrasting curves are presented to demonstrate how drastically the normal **EI** distribution can differ among climatic regions.

On the basis of observed seasonal distributions of **EI**, the 37 States east of the Rocky Mountains were divided into the 33 geographic areas delineated in figure 9. The changes in distribution are usually gradual transitions from one area to the next, but the average distribution within any one of the areas may, for practical purposes, be considered applicable for the entire area. The **EI** distributions in the 33 areas, expressed as cumulative percentages of annual totals, are given in table 6. The area numbers in the table correspond to those in figure 9. The data in the table were

[1] *Alternate procedure for estimating the soil loss ratios:*

The ratios given above for cotton are based on estimates for reductions in percent cover through normal winter loss and by the successive tillage operations. Research is underway in Mississippi to obtain more accurate residue data in relation to tillage practices. This research should provide more accurate soil loss ratios for cotton within a few years.

Where the reductions in percent cover by winter loss and tillage operations are small, the following procedure may be used to compute soil loss ratios for the preplant and seedbed periods: Enter figure 6 with the percentage of the field surface covered by residue mulch, move vertically to the upper curve, ond read the mulch factor on the scale at the left. Multiply this factor by a factor selected from the following tobulation to credit for effects of land-use residual, surface roughness and porosity.

Productivitty level	No tillage	Rough surface	Smoothed surface
High	0.66	0.50	0.56
Medium	.71	.54	.61
Poor	.75	.58	.65

Values for the bedded period on slopes of less than 1 percent should be estimated at twice the value computed above for rough surfaces.

[2] Rd, crop residue; vol veg, volunteer vegetation.

TABLE 5-B.—*Soil loss ratios for conditions not evaluated in table 5*

COTTON:
 See table 5-A.
CROPSTAGE 4 FOR ROWCROPS:
 Stalks broken and partially standing: Use col. 4L.
 Stalks standing after hand picking: Col. 4L times 1.15.
 Stalks shredded without soil tillage: See table 5-C.
 Fall chisel: Select values from lines 33-62, seedbed column.
CROPSTAGE 4 FOR SMALL GRAIN:
 See table 5-C.
DOUBLE CROPPING:
 Derive annual C value by selecting from table 5 the soil loss percentages for the successive cropstage periods of each crop.
ESTABLISHED MEADOW, FULL-YEAR PERCENTAGES:

Grass and legume mix, 3 to 5 t hay	0.4
Do. 2 to 3 t hay	.6
Do. 1 t hay	1.0
Sericea, after second year	1.0
Red clover	1.5
Alfalfa, lespedeza, and second-year sericea	2.0
Sweetclover	2.5

MEADOW SEEDING WITHOUT NURSE CROP:
 Determine appropriate lengths of cropstage periods SB, 1, and 2 and apply values given for small grain seeding.
PEANUTS:
 Comparison with soybeans is suggested.
PINEAPPLES:
 Direct data not available. Tentative values derived analytically are available from the SCS in Hawaii or the Western Technical Service Center at Portland, Oreg. (Reference 5).
SORGHUM:
 Select values given for corn, on the basis of expected crop residues and canopy cover.
SUGARBEETS:
 Direct data not available. Probably most nearly comparable to potatoes, without the ridging credit.
SUGARCANE:
 Tentative values available from sources given for pineapples.
SUMMER FALLOW IN LOW-RAINFALL AREAS, USE GRAIN OR ROW CROP RESIDUES:
 The approximate soil loss percentage after each successive tillage operation may be obtained from the following tabulation by estimating the percent surface cover after that tillage and selecting the column for the appropriate amount of initial residue. The given values credit benefits of the residue mulch, residues mixed with soil by tillage, and the crop system residual.

Percent cover by mulch	Initial residue (lbs/A)			
	>4,000	3,000	2,000	1,500
90	4	—	—	—
80	8	[1]8	—	—
70	12	13	[1]14	—
60	16	17	[1]18	[1]19
50	20	22	24	[1]25
40	25	27	30	32
30	29	33	37	39
20	35	39	44	48
10	47	55	63	68

[1] For grain residue only.

WINTER COVER SEEDING IN ROW CROP STUBBLE OR RESIDUES:
 Define cropstage periods based on the cover seeding date and apply values from lines 129 to 145.

TABLE 5-C.—*Soil loss ratios (percent) for cropstage 4 when stalks are chopped and distributed without soil tillage*

Mulch cover[1]	Corn or Sorghum: Tilled seedbed[2]	Corn or Sorghum: No-till	Soybeans: Tilled seedbed[2]	Soybeans: No-till in corn rd[3]	Grain Stubble[4]
20	48	34	60	42	48
30	37	26	46	32	37
40	30	21	38	26	30
50	22	15	28	19	22
60	17	12	21	16	17
70	12	8	15	10	12
80	7	5	9	6	7
90	4	3	—	—	4
95	3	2	—	—	3

[1] Part of a field surface directly covered by pieces of residue mulch.
[2] This column applies for all systems other than no-till.
[3] Cover after bean harvest may include an appreciable number of stalks carried over from the prior corn crop.
[4] For grain with meadow seeding, include meadow growth in percent cover and limit grain period 4 to 2 mo. Thereafter, classify as established meadow.

abstracted from the published **EI** distribution curves.

The percentage of the annual erosion index that is to be expected within each cropstage period may be obtained by reading from the appropriate line of table 6, the values for the last and first date of the period, and subtracting. Interpolate

TABLE 5-D.—*Factors to credit residual effects of turned sod*[1]

Crop	Hay yield	Factor for cropstage period: F	SB and 1	2	3	4
	Tons					
First year after mead:						
Row crop or grain ...	3-5	0.25	0.40	0.45	0.50	0.60
	2-3	.30	.45	.50	.55	.65
	1-2	.35	.50	.55	.60	.70
Second year after mead:						
Row crop	3.5	.70	.80	.85	.90	.95
	2-3	.75	.85	.90	.95	1.0
	1-2	.80	.90	.95	1.0	1.0
Spring grain	3-5	—	.75	.80	.85	.95
	2-3	—	.80	.85	.90	1.0
	1-2	—	.85	.90	.95	1.0
Winter grain	3-5	—	.60	.70	.85	.95
	2-3	—	.65	.75	.90	1.0
	1-2	—	.70	.85	.95	1.0

[1] These factors are to be multiplied by the appropriate soil loss percentages selected from table 5. They are directly applicable for sod-forming meadows of at least 1 full year duration, plowed not more than 1 month before final seedbed preparation.

When sod is fall plowed for spring planting, the listed values for all cropstage periods are increased by adding 0.02 for each additional month by which the plowing precedes spring seedbed preparation. For example, September plowing would precede May disking by 8 months and 0.02(8—1), or 0.14, would be added to each value in the table. For nonsod-forming meadows, like sweetclover or lespedeza, multiply the factors by 1.2. When the computed value is greater than 1.0, use as 1.0.

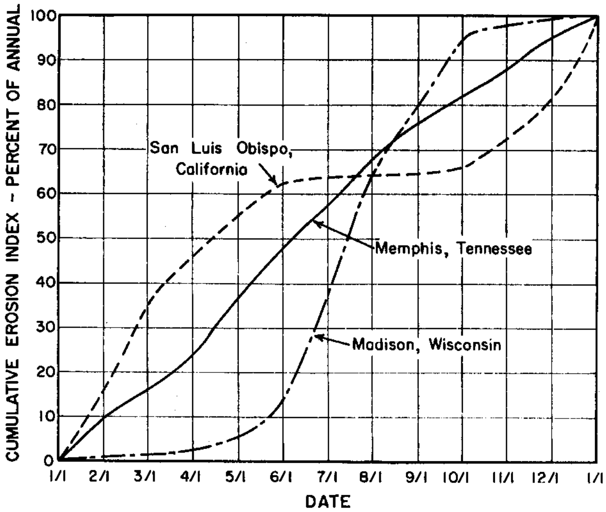


FIGURE 8.—Typical EI-distribution curves for three rainfall patterns.

between values in the selected line when the desired dates are not listed.

Western States, Hawaii, and Puerto Rico

Normal rainfall patterns in these mountainous States often change abruptly within a short distance. Figure 9 was not extended to include these States because long-term intensity data were not available for enough locations to delineate boundaries of homogeneous areas. However, **EI** distributions indicated by station records that were abstracted are given in table 7 for reference.

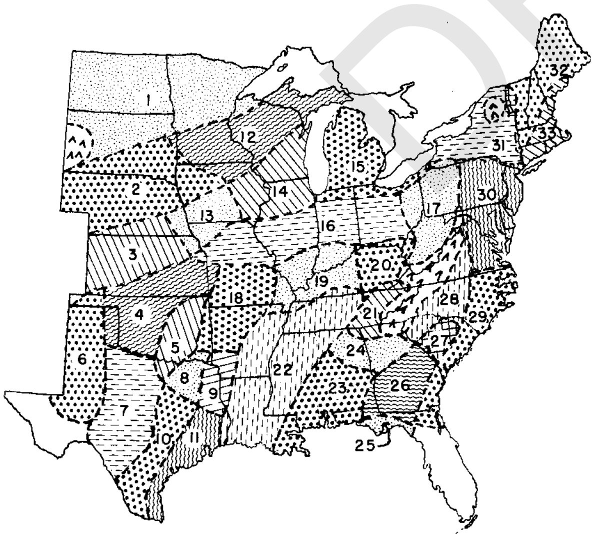


FIGURE 9.—Key map for selection of applicable EI-distribution data from table 6.

Winter Periods

Site **EI** values reflect only rain falling at erosive intensities. Where the winter precipitation comes as snow or light rain, **EI** distribution curves may show insignificant percentages for several winter months. Yet, snowmelt and low intensity rains on frozen soil may cause appreciable runoff that is erosive even though the associated maximum 30-minute rainfall intensity is extremely low or zero. The section on **Isoerodent Maps** pointed out that where this type of runoff is significant its erosive force must be reflected in an $\mathbf{R_s}$ value that is added to the **EI** value to obtain **R**. This additional erosive force must also be reflected in the *monthly distribution* of **R**. Otherwise, poor management during the winter period will not be reflected in the USLE estimate of annual soil loss because a zero cropstage **R** value would predict zero soil loss regardless of the relevant soil loss ratio.

Soil erosion by thaw runoff is most pronounced in the Northwest, where $\mathbf{R_s}$ values often exceed the average annual **EI**. However, it may also be significant in other Northern States. Probable amounts of thaw runoff were not available for inclusion in the calculations of the **EI** distributions given in tables 6 and 7, but the significance and probable time of occurrence of such runoff can be estimated by local people. The procedure for adjusting table 6 cumulative percentages to include this erosive potential will be illustrated.

Based on the previously described estimating procedure, $\mathbf{R_s}$ values in area No. 1, figure 9, appear to equal about 8 percent of the annual **EI**. Assuming that the thaw runoff in that area normally occurs between March 15 and April 15, the percentage in table 6 for April 1 is increased by 4, the April 15 and all subsequent readings are increased by 8, and all the adjusted readings are then divided by 1.08. This procedure corrects the data given in line 1, table 6, for dates April 1 to September 1 to the following cumulative percentages listed in chronological sequence: 5, 9, 10, 13, 18, 29, 41, 53, 66, 79, 91. The other values are unchanged. Such adjustments in monthly distribution of **R** where thaw runoff is significant will be particularly helpful when the USLE is used to estimate seasonal distribution of sediment from agricultural watersheds.

TABLE 6.—*Percentage of the average annual* **EI** *which normally occurs between January 1 and the indicated dates.*[1] *Computed for the geographic areas shown in figure 9*

Area No.	Jan.		Feb.		Mar.		Apr.		May		June		July		Aug.		Sept.		Oct.		Nov.		Dec.	
	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15	1	15
1	0	0	0	0	0	0	1	2	3	6	11	23	36	49	63	77	90	95	98	99	100	100	100	100
2	0	0	0	0	1	1	2	3	6	10	17	29	43	55	67	77	85	91	96	98	99	100	100	100
3	0	0	0	0	1	1	2	3	6	13	23	37	51	61	69	78	85	91	94	96	98	99	99	100
4	0	0	1	1	2	3	4	7	12	18	27	38	48	55	62	69	76	83	90	94	97	98	99	100
5	0	1	2	3	4	6	8	13	21	29	37	46	54	60	65	69	74	81	87	92	95	97	98	99
6	0	0	0	0	1	1	1	2	6	16	29	39	46	53	60	67	74	81	88	95	99	99	100	100
7	0	1	1	2	3	4	6	8	13	25	40	49	56	62	67	72	76	80	85	91	97	98	99	99
8	0	1	3	5	7	10	14	20	28	37	48	56	61	64	68	72	77	81	86	89	92	95	98	99
9	0	2	4	6	9	12	17	23	30	37	43	49	54	58	62	66	70	74	78	82	86	90	94	97
10	0	1	2	4	6	8	10	15	21	29	38	47	53	57	61	65	70	76	83	88	91	94	96	98
11	0	1	3	5	7	9	11	14	18	27	35	41	46	51	57	62	68	73	79	84	89	93	96	98
12	0	0	0	0	1	1	2	3	5	9	15	27	38	50	62	74	84	91	95	97	98	99	99	100
13	0	0	0	1	1	2	3	5	7	12	19	33	48	57	65	74	82	88	93	96	98	99	100	100
14	0	0	0	1	2	3	4	6	9	14	20	28	39	52	63	72	80	87	91	94	97	98	99	100
15	0	0	1	2	3	4	6	8	11	15	22	31	40	49	59	69	78	85	91	94	96	98	99	100
16	0	1	2	3	4	6	8	10	14	18	25	34	45	56	64	72	79	84	89	92	95	97	98	99
17	0	1	2	3	4	5	6	8	11	15	20	28	41	54	65	74	82	87	92	94	96	97	98	99
18	0	1	2	4	6	8	10	13	19	26	34	42	50	58	63	68	74	79	84	89	93	95	97	99
19	0	1	3	6	9	12	16	21	26	31	37	43	50	57	64	71	77	81	85	88	91	93	95	97
20	0	2	3	5	7	10	13	16	19	23	27	34	44	54	63	72	80	85	89	91	93	95	96	98
21	0	3	6	10	13	16	19	23	26	29	33	39	47	58	68	75	80	83	86	88	90	92	95	97
22	0	3	6	9	13	17	21	27	33	38	44	49	55	61	67	71	75	78	81	84	86	90	94	97
23	0	3	5	7	10	14	18	23	27	31	35	39	45	53	60	67	74	80	84	86	88	90	93	95
24	0	3	6	9	12	16	20	24	28	33	38	43	50	59	69	75	80	84	87	90	92	94	96	98
25	0	1	3	5	7	10	13	17	21	24	27	33	40	46	53	61	69	78	89	92	94	95	97	98
26	0	2	4	6	8	12	16	20	25	30	35	41	47	56	67	75	81	85	87	89	91	93	95	97
27	0	1	2	3	5	7	10	14	18	22	27	32	37	46	58	69	80	89	93	94	95	96	97	99
28	0	1	3	5	7	9	12	15	18	21	25	29	36	45	56	68	77	83	88	91	93	95	97	99
29	0	1	2	3	4	5	7	9	11	14	17	22	31	42	54	65	74	83	89	92	95	97	98	99
30	0	1	2	3	4	5	6	8	10	14	19	26	34	45	56	66	76	82	86	90	93	95	97	99
31	0	0	0	1	2	3	4	5	7	12	17	24	33	42	55	67	76	83	89	92	94	96	98	99
32	0	1	2	3	4	5	6	8	10	13	17	22	31	42	52	60	68	75	80	85	89	92	96	98
33	0	1	2	4	6	8	11	13	15	18	21	26	32	38	46	55	64	71	77	81	85	89	93	97

[1] For dates not listed in the table, interpolate between adjacent values.

Procedure for Deriving Local C Values

Factor **C** in the USLE measures the combined effect of all the interrelated cover and management variables and is defined as the ratio of soil loss from land cropped under specified conditions to the corresponding loss from clean-tilled continuous fallow. It is usually expressed as an annual value for a particular cropping and management system. Soil loss ratios, as used in table 5, express a similar ratio for a short time interval within which cover and management effects are relatively uniform. The cropstage soil loss ratios must be combined in proportion to the applicable percentages of **EI** to derive annual **C** values.

To compute the value of **C** for any particular crop and management system on a given field, one needs first to determine the most likely seeding and harvest dates, rate of canopy development, and final canopy cover. Also, the system to be evaluated must be carefully defined with regard to crop and residue management details. Within the broad limits of tables 5 and 6, these tables then supply the research data needed to complete

TABLE 7.—*Monthly distribution of* **EI** *at selected raingage locations*

Location[1]	Average percentage of annual EI occurring from 1/1 to: 2/1	3/1	4/1	5/1	6/1	7/1	8/1	9/1	10/1	11/1	12/1	12/31
California												
Red Bluff (69)	18	36	47	55	62	64	65	65	67	72	82	100
San Luis Obispo (51)	19	39	54	63	65	65	65	65	65	67	83	100
Colorado												
Akron (91)	0	0	0	1	18	33	72	87	98	99	100	100
Pueblo (68)	0	0	0	5	14	23	40	82	84	100	100	100
Springfield (98)	0	0	1	4	26	36	60	94	96	99	100	100
Hawaii												
Hilo (770)	9	23	34	44	49	51	55	60	65	72	87	100
Honolulu (189)	19	33	43	51	54	55	56	57	58	62	81	100
Kahului (107)	14	32	49	62	67	68	69	70	71	76	86	100
Lihue (385)	19	29	36	41	44	45	48	51	56	64	80	100
Montana												
Billings (18)	0	0	1	6	22	49	86	88	96	100	100	100
Great Falls (17)	1	1	2	6	20	56	74	93	98	99	100	100
Miles City (28)	0	0	0	1	10	32	65	93	98	100	100	100
New Mexico												
Albuquerque (15)	1	1	2	4	10	21	52	67	89	98	99	100
Roswell (52)	0	0	2	7	20	34	55	71	92	99	99	100
Oregon												
Pendleton (6)	8	12	15	22	56	64	67	67	74	87	96	100
Portland (43)	15	27	35	37	40	45	46	47	54	65	81	100
Puerto Rico												
Mayaguez (600)	1	2	3	6	15	31	47	63	80	91	99	100
San Juon (345)	5	8	11	17	33	43	53	66	75	84	93	100
Washington												
Spokane (8)	5	9	11	15	25	56	61	76	84	90	94	100
Wyoming												
Casper (11)	0	0	1	6	32	44	70	90	96	100	100	100
Cheyenne (32)	0	1	2	5	17	42	73	90	97	99	100	100

[1] Numbers in parentheses ore the observed average annual EI.

the computation of **C**. The procedure will be explained by an example that, for illustration purposes, was selected to include many changes in field conditions.

Problem. Evaluate **C** for a 4-year rotation of wheat-meadow-corn-corn on moderately sloping land in Central Illinois or Indiana, assuming the following management details and dates: Wheat is seeded October 15 in a 40-percent cover of disked corn residue, and a grass and legume meadow mix is seeded with the wheat. The wheat would normally develop a 10-percent cover by November 1, 50 percent by December 1, 75 percent by April 15, and nearly 100 percent in the maturing stage. It is harvested July 15, leaving an 80-percent surface cover of straw and small grass. The sod developed under 1 full year of meadow, yielding more than 3 t of hay, is turned under in April. The field is disked May 5 and is harrowed and planted to corn May 10. The first-year corn, harvested October 15, is followed by fall chiseling about November 15 and spring disking for second-year corn. Residue cover is 50 percent after fall chiseling and 30 percent after corn planting on May 10. Fertility, row spacing, and plant population for both corn years are such that 10, 50, and 75 percent canopy covers will be developed in 20, 40, and 60 days, respectively, from planting, and final canopy cover is more than 95 percent.

Procedure. Set up a working table similar to the one illustrated in table 8, obtaining the needed information as follows:

Column 1. List in chronological sequence all the land-cover changes that begin new cropstage periods, as previously defined.

Column 2. List the date on which each cropstage period begins.

Column 3. Select the applicable area number

TABLE 8.—*Sample working table for derivation of a rotation* **C** *value*

(1) Event	(2) Date	(3) Table 6, area 16	(4) Crop-stage period	(5) EI in period	(6) Soil loss ratio[1]	(7) Sod Factor	(8) Cropstage C value	(9) Crop year
Pl W[2]	10/15	92	SB	0.03	0.27(132)	0.95	0.0077	
10 percent c	11/1	95	1	.03	.21	.95	.0060	
50 percent c	12/1	98	2	.12	.16	1.0	.0192	
75 percent c	4/15	10	3	.46	.03		.0138	
Hv W	7/15	56	4	.28	.07(5C)		.0196	0.066
Meadow	9/15	84		1.26	.004(5B)	1.0	.0050	.005
TP	4/15	10	F	.05	.36(2)	.25	.0045	
Disk	5/5	15	SB	.10	.60	.40	.0240	
Pl C	5/10	—						
10 percent c	6/1	25	1	.13	.52	.40	.0270	
50 percent c	6/20	38	2	.14	.41	.45	.0258	
75 percent c	7/10	52	3	.40	.20	.50	.0400	
Hv C	10/15	92	4L	.05	.30	.60	.0090	.130
Chisel	11/15	97	4c	.17	.16(46)	.60	.0163	
Disk	5/1	14	SB	.11	.25(48 & 61)	.80	.0220	
Pl C	5/10	—						
10 percent c	6/1	25	1	.13	.23	.80	.0239	
50 percent c	6/20	38	2	.14	.21	.85	.0250	
75 percent c	7/10	52	3	.40	.14(48)	.90	.0504	.138
Hv C & pl W	10/15	92						
Rotation totals				4.0			0.3392	
Average annual C value for rotation							.085	

[1] Numbers in parentheses are line numbers in table 5.

[2] Abbreviations: c, canopy cover; C, corn; hv, harvest; pl, plant; TP, moldboard plow; W, wheat.

from figure 9, and from the line in table 6 having the corresponding area number (in this case, 16), read the cumulative percentage of **EI** for each date in column 2. Values for the corn planting dates were omitted in table 8 because the seedbed periods had begun with the spring diskings. The **EI** percentage for May 5 was obtained by interpoiating between readings from May 1 and 15.

Column 4. Identify the cropstage periods.

Column 5. Subtract the number in column 3 from the number in the next lower line. If the cropstage period includes a year end, subtract from 100 and add the number in the next lower line. The differences are percentages and may be pointed off as hundredths.

Column 6. Obtain from table 5. Enter the table with crop and management, pounds of spring residue or production level, and percent mulch cover after planting, in that sequence. The data in the selected line are percentages and are used as hundredths in the computation of **C**. For cropstage 3, use the column whose heading corresponds with expected final canopy. For conditions not listed in the primary table, consult supplements 5-A to D. Lines used for the examples are given in parentheses in column 6.

Column 7. From table 5-D.

Column 8. The product of values in columns 5, 6 and 7. The sum of these products is the value of **C** for the entire rotation. Because **C** is usually desired as an average annual value, this sum is divided by the number of years in the rotation.

Column 9. The subtotals in this column are **C** values for the individual crop-years. They also show the relative contributions of the four crops to the rotation **C** value.

Changes in geographic area or in planting dates would affect the **C** value by changing columns 3 and 5. Changes in amount or disposition of residues, tillage practices, or canopy development would change column 6. Thus **C** can vary substantially for a given crop system.

Values of **C** for one-crop systems are derived by the same procedure but would require only a few lines. Also, column 7 is omitted for meadowless systems.

C-Value Tables for Cropland

It will rarely, if ever, be necessary for a field technician or farmer to compute values of **C**. Persons experienced in the procedures outlined above have prepared **C** value tables for specific geographic areas. Such a table will list all the one-crop and multicrop systems likely to be found within the designated area and will list the **C** values for each system for each of the combinations of management practices that may be associated with it. They are usually listed in ascending or descending order of magnitude of the **C** values. The user can then quickly determine all the potential combinations of cropping and management that have **C** values smaller than any given threshold value. Persons in need of **C** values for a particular locality can usually obtain a copy of the applicable table from the nearest SCS state office.

C Values for Construction Areas

Site preparations that remove all vegetation and also the root zone of the soil not only leave the surface completely without protection but also remove the residual effects of prior vegetation. This condition is comparable to the previously defined continuous fallow condition, and **C** = 1. Roots and residual effects of prior vegetation, and partial covers of mulch or vegetation, substantially reduce soil erosion. These reductions are reflected in the soil loss prediction by **C** values of less than 1.0.

Applied mulches immediately restore protective cover on denuded areas and drastically reduce **C** (*1*, *2*, *20*, *27*, *43*). Soil loss ratios for various percentages of mulch cover on field slopes are given by the upper curve of figure 6. Where residual effects are insignificant, these ratios equal **C**. The percentage of surface cover provided by a given rate of uniformly spread straw mulch may be estimated from figure 10 (appendix).

Straw or hay mulches applied on steep construction slopes and not tied to the soil by anchoring and tacking equipment may be less effective than equivalent mulch rates on cropland. In Indiana tests on a 20 percent slope of scalped subsoil, a 2.3-t rate of unanchored straw mulch allowed soil loss of 12 t/A when 5 in of simulated rain was applied at 2.5 in/h on a 35-ft plot (*61*). There was evidence of erosion from flow beneath the straw. Mulches of crushed stone at 135 or more t/A, or wood chips at 7 or more t/A, were more effective. (Broadcast seedings of grass after the tests gave good stands on the plots mulched with 135 or 240 t crushed stone, 70 t road gravel, 12 t wood chips, or 2.3 t straw. Stands were poor on the no-mulch and the 15-t rate of crushed stone mulch.)

Table 9 presents approximate **C** values for straw, crushed stone, and woodchip mulches on construction slopes where no canopy cover exists, and also shows the maximum slope lengths on which these values may be assumed applicable.

Soil loss ratios for many conditions on construc-

TABLE 9.—*Mulch factors and length limits for construction slopes*[1]

Type of mulch	Mulch Rate	Land Slope	Factor C	Length limit[2]
	Tons per acre	*Percent*		*Feet*
None	0	all	1.0	—
Straw or hay,	1.0	1-5	0.20	200
tied down by	1.0	6-10	.20	100
anchoring and				
tacking	1.5	1-5	.12	300
equipment[3]	1.5	6-10	.12	150
Do.	2.0	1-5	.06	400
	2.0	6-10	.06	200
	2.0	11-15	.07	150
	2.0	16-20	.11	100
	2.0	21-25	.14	75
	2.0	26-33	.17	50
	2.0	34-50	.20	35
Crushed stone,	135	<16	.05	200
¼ to 1½ in	135	16-20	.05	150
	135	21-33	.05	100
	135	34-50	.05	75
Do.	240	<21	.02	300
	240	21-33	.02	200
	240	34-50	.02	150
Wood chips	7	<16	.08	75
	7	16-20	.08	50
Do.	12	<16	.05	150
	12	16-20	.05	100
	12	21-33	.05	75
Do.	25	<16	.02	200
	25	16-20	.02	150
	25	21-33	.02	100
	25	34-50	.02	75

[1] From Meyer and Ports (*24*). Developed by an interagency workshop group on the basis of field experience and limited research data.

[2] Maximum slope length for which the specified mulch rote is considered effective. When this limit is exceeded, either a higher application rate or mechanical shortening of the effective slope length is required.

[3] When the straw or hay mulch is not anchored to the soil, **C** values on moderate or steep slopes of soils having K values greater than 0.30 should be taken at double the values given in this table.

tion and developmental areas can be obtained from table 5 if good judgment is exercised in comparing the surface conditions with those of agricultural conditions specified in lines of the table. Time intervals analogous to cropstage periods will be defined to begin and end with successive construction or management activities that appreciably change the surface conditions. The procedure is then similar to that described for cropland.

Establishing vegetation on the denuded areas as quickly as possible is highly important. A good sod has a **C** value of 0.01 or less (table 5-B), but such a low **C** value can be obtained quickly only by laying sod on the area, at a substantial cost. When grass or small grain is started from seed, the probable soil loss for the period while cover is developing can be computed by the procedure outlined for estimating cropstage-period soil losses. If the seeding is on topsoil, without a mulch, the soil loss ratios given in line 141 of table 5 are appropriate for cropstage **C** values. If the seeding is on a desurfaced area, where residual effects of prior vegetation are no longer significant, the ratios for periods SB, 1 and 2 are 1.0, 0.75 and 0.50, respectively, and line 141 applies for cropstage 3. When the seedbed is protected by a mulch, the pertinent mulch factor from the upper curve of figure 6 or table 9 is applicable until good canopy cover is attained. The combined effects of vegetative mulch and low-growing canopy are given in figure 7. When grass is established in small grain, it can usually be evaluated as established meadow about 2 mo after the grain is cut.

C Values for Pasture, Range, and Idle Land

Factor **C** for a specific combination of cover conditions on these types of land may be obtained from table 10 (57). The cover characteristics that must be appraised before consulting this table are defined in the table and its footnotes. Cropstage periods and **EI** monthly distribution data are generally not necessary where perennial vegetation has become established and there is no mechanical disturbance of the soil.

Available soil loss data from undisturbed land were not sufficient to derive table 10 by direct comparison of measured soil loss rates, as was done for development of table 5. However, analyses of the assembled erosion data showed that the research information on values of **C** can be extended to completely different situations by combining subfactors that evaluate three separate and distinct, but interrelated, zones of influence: (a) vegetative cover in direct contact with the soil surface, (b) canopy cover, and (c) residual and tillage effects.

Subfactors for various percentages of surface cover by mulch are given by the upper curve of

TABLE 10.—*Factor **C** for permanent pasture, range, and idle land*[1]

Vegetative canopy: Type and height[2]	Vegetative canopy: Percent cover[3]	Cover that contacts the soil surface: Type[4]	Percent ground cover: 0	20	40	60	80	95+
No appreciable canopy		G	0.45	0.20	0.10	0.042	0.013	0.003
		W	.45	.24	.15	.091	.043	.011
Tall weeds or short brush with average drop fall height of 20 in	25	G	.36	.17	.09	.038	.013	.003
		W	.36	.20	.13	.083	.041	.011
	50	G	.26	.13	.07	.035	.012	.003
		W	.26	.16	.11	.076	.039	.011
	75	G	.17	.10	.06	.032	.011	.003
		W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes, with average drop fall height of 6½ ft	25	G	.40	.18	.09	.040	.013	.003
		W	.40	.22	.14	.087	.042	.011
	50	G	.34	.16	.08	.038	.012	.003
		W	.34	.19	.13	.082	.041	.011
	75	G	.28	.14	.08	.036	.012	.003
		W	.28	.17	.12	.078	.040	.011
Trees, but no appreciable low brush. Average drop fall height of 13 ft	25	G	.42	.19	.10	.041	.013	.003
		W	.42	.23	.14	.089	.042	.011
	50	G	.39	.18	.09	.040	.013	.003
		W	.39	.21	.14	.087	.042	.011
	75	G	.36	.17	.09	.039	.012	.003
		W	.36	.20	.13	.084	.041	.011

[1] The listed **C** values assume that the vegetation and mulch are randomly distributed over the entire area.

[2] Canopy height is measured as the average fall height of water drops falling from the canopy to the ground. Canopy effect is inversely proportional to drop fall height and is negligible if fall height exceeds 33 ft.

[3] Portion of total-area surface that would be hidden from view by canopy in a vertical projection (a bird's-eye view).

[4] G: cover at surface is grass, grasslike plants, decaying compacted duff, or litter at least 2 in deep.

W: cover at surface is mostly broadleaf herbaceous plants (as weeds with little lateral-root network near the surface) or undecayed residues or both.

TABLE 11.—*Factor* **C** *for undisturbed forest land*[1]

Percent of area covered by canopy of trees and undergrowth	Percent of area covered by duff at least 2 in deep	Factor C[2]
100-75	100-90	.0001-.001
70-45	85-75	.002-.004
40-20	70-40	.003-.009

[1] Where effective litter cover is less than 40 percent or canopy cover is less than 20 percent, use table 6. Also use table 6 where woodlands are being grazed, harvested, or burned.

[2] The ranges in listed **C** values are caused by the ranges in the specified forest litter and canopy covers and by variations in effective canopy heights.

figure 6. Subfactors for various heights and densities of canopy cover are given in figure 5. The subfactor for residual effects of permanent pasture, range, idle land, or grazed or harvested woodland has been estimated to vary from 0.45 to 0.10 (57). Major influences on this subfactor are plant roots, organic matter buildup in the topsoil, reduced soil compaction, and surface stabilization after long periods without soil disturbance. The **C** values given in table 10 were derived by combining subfactors for specified combinations of type, height, and density of canopy cover; type and density of cover at the soil surface; and probable residual effects of longtime existence of the specified cover on the land. They are compatible with the rather scarce existing soil loss data from undisturbed land areas.

C Values for Woodland

Three categories of woodland are considered separately: (1) undisturbed forest land; (2) woodland that is grazed, burned, or selectively harvested; and (3) forest lands which have had site preparation treatments for re-establishment after harvest.

In undisturbed forests, infiltration rates and organic matter content of the soil are high, and much or all of the surface is usually covered by a layer of compacted decaying forest duff or litter several inches thick. Such layers of duff shield the soil from the erosive forces of runoff and of drop impact and are extremely effective against soil erosion. Where cover by trees and litter is incomplete, the spots with little or no litter cover are partially protected by undergrowth canopy. Factor **C** for undisturbed forest land may be obtained from table 11. These estimated **C** values are supported by the quite limited existing data and also by the subfactor-evaluation procedure discussed in the preceding subsection.

Woodland that is grazed or burned, or has been recently harvested, does not merit the extremely low **C** values of table 11. For these conditions, **C** is obtained from table 10. However, the buildup of organic matter in the topsoil under permanent woodland conditions is an added factor that should be accounted for by a reduction in the **C** value read from table 10. An earlier publication (57) recommended a factor of 0.7 for this purpose.

Site preparation treatments for re-establishing trees on harvested forest land usually alter the erosion factors substantially. Canopy effect is initially greatly reduced or lost entirely, and its restoration is gradual. Some of the forest litter is incorporated in the soil, and it may be entirely removed from portions of the area. A surface roughness factor is introduced. Windrowed debris, if across slope, may function as terraces by reducing effective slope length and inducing deposition above and in the windrows. The amount of residual effect retained depends on the amount and depth of surface scalping. Some of the changes are analogous to cropland situations. Some of the relationships available from tables 5 and 10 can be used to evaluate **C** for these conditions, but neither table is directly applicable.

Table 12 presents **C** values computed for Southern Pine Forests that have had site preparation treatments after harvesting. This table was jointly developed (in 1977) by representatives of SEA, SCS, and Forest Service, using factor relationships from tables 5, 10, and 11 as basic guides. Its application on forest lands in other climatic regions may require some modifications of factor values. Research designed to refine and improve tables 10, 11, and 12 is underway.

Tree plantings on converted cropland should, in the initial years, be evaluated similarly to cropland because the forest residual effect which underlies tables 10 to 12 will not be applicable. The subfactor for residual effects may be estimated by selecting from lines 1 to 16 of table 5 the line that most nearly describes the condition of the converted cropland and assuming a residual subfactor equal to the seedbed-period value given in that line. If the cropland has most recently been in

TABLE 12.—*Factor* **C** *for mechanically prepared woodland sites*

Site preparation	Mulch cover[1]	Soil condition[2] and weed cover[3]							
		Excellent		Good		Fair		Poor	
		NC	WC	NC	WC	NC	WC	NC	WC
	Percent								
Disked, raked, or bedded[4]	None	0.52	0.20	0.72	0.27	0.85	0.32	0.94	0.36
	10	.33	.15	.46	.20	.54	.24	.60	.26
	20	.24	.12	.34	.17	.40	.20	.44	.22
	40	.17	.11	.23	.14	.27	.17	.30	.19
	60	.11	.08	.15	.11	.18	.14	.20	.15
	80	.05	.04	.07	.06	.09	.08	.10	.09
Burned[5]	None	.25	.10	.26	.10	.31	.12	.45	.17
	10	.23	.10	.24	.10	.26	.11	.36	.16
	20	.19	.10	.19	.10	.21	.11	.27	.14
	40	.14	.09	.14	.09	.15	.09	.17	.11
	60	.08	.06	.09	.07	.10	.08	.11	.08
	80	.04	.04	.05	.04	.05	.04	.06	.05
Drum chopped[5]	None	.16	.07	.17	.07	.20	.08	.29	.11
	10	.15	.07	.16	.07	.17	.08	.23	.10
	20	.12	.06	.12	.06	.14	.07	.18	.09
	40	.09	.06	.09	.06	.10	.06	.11	.07
	60	.06	.05	.06	.05	.07	.05	.07	.05
	80	.03	.03	.03	.03	.03	.03	.04	.04

[1] Percentage of surface covered by residue in contact with the soil.

[2] *Excellent* soil condition—Highly stable soil aggregates in topsoil with fine tree roots and litter mixed in.

Good—Moderately stable soil aggregates in topsoil or highly stable aggregates in subsoil (topsoil removed during raking), only traces of litter mixed in.

Fair—Highly unstable soil aggregates in topsoil or moderately stable aggregates in subsoil, no litter mixed in.

Poor—No topsoil, highly erodible soil aggregates in subsoil, no litter mixed in.

[3] NC—No live vegetation.

WC—75 percent cover of grass and weeds having an average drop fall height of 20 in. For intermediate percentages of cover, interpolate between columns.

[4] Modify the listed **C** values as follows to account for effects of surface roughness and aging:

First year after treatment: multiply listed **C** values by 0.40 for rough surface (depressions >6 in); by 0.65 for moderately rough; and by 0.90 for smooth (depressions <2 in).

For 1 to 4 years after treatment: multiply listed factors by 0.7.

For 4+ to 8 years: use table 6.

More than 8 years: use table 7.

[5] For first 3 years: use **C** values as listed.

For 3+ to 8 years after treatment: use table 6.

More than 8 years after treatment: use table 7.

meadow, the selected seedbed soil loss ratio is multiplied by a factor from table 5-D. If mulch is applied, a subfactor read from the upper curve of figure 6 is multiplied by the residual subfactor to obtain **C**. When canopy develops, a canopy subfactor from figure 5 is also included.

SUPPORT PRACTICE FACTOR (P)

In general, whenever sloping soil is to be cultivated and exposed to erosive rains, the protection offered by sod or close-growing crops in the system needs to be supported by practices that will slow the runoff water and thus reduce the amount of soil it can carry. The most important of these supporting cropland practices are contour tillage, stripcropping on the contour, and terrace systems. Stabilized waterways for the disposal of excess rainfall are a necessary part of each of these practices.

By definition, factor **P** in the USLE is the ratio of soil loss with a specific support practice to the corresponding loss with up-and-down-slope culture. Improved tillage practices, sod-based rotations, fertility treatments, and greater quantities of crop residues left on the field contribute materially to erosion control and frequently provide the major control in a farmer's field. However, these are considered conservation cropping and management practices, and the benefits derived from them are included in **C**.

Contouring

The practice of tillage and planting on the contour, in general, has been effective in reducing erosion. In limited field studies, the practice provided almost complete protection against erosion from storms of moderate to low intensity, but it provided little or no protection against the occasional severe storms that caused extensive breakovers of the contoured rows. Contouring appears to be the most effective on slopes in the 3- to 8-percent range. As land slope decreases, it approaches equality with contour row slope, and the soil loss ratio approaches 1.0. As slope increases, contour row capacity decreases and the soil loss ratio again approaches 1.0.

Effectiveness of contouring is also influenced by the slope length. When rainfall exceeds infiltration and surface detention in large storms, breakovers of contour rows often result in concentrations of runoff that tend to become progressively greater with increases in slope length. Therefore, on slopes exceeding some critical length the amount of soil moved from a contoured field may approach or exceed that from a field on which each row carries its own runoff water down the slope. At what slope length this could be expected to occur would depend to some extent on gradient, soil properties, management, and storm characteristics.

P Values for Contouring

A joint SEA and SCS workshop group, meeting at Purdue University in 1956, adopted a series of contour **P** values that varied with percent slope. The **P** values were based on available data and field observations supplemented by group judgment. Subsequent experience indicated only a few minor changes. Current recommendations are given in table 13. They are average values for the factor on the specified slopes. Specific-site values may vary with soil texture, type of vegetation, residue management, and rainfall pattern, but data have not become available to make the deviations from averages numerically predictable.

Full contouring benefits are obtained only on fields relatively free from gullies and depressions other than grassed waterways. Effectiveness of this practice is reduced if a field contains numerous small gullies and rills that are not obliterated by normal tillage operations. In such instances, land smoothing should be considered before contouring. Otherwise, a judgment value greater than shown in table 13 should be used when computing the benefits for contouring.

TABLE 13.—**P** *values and slope-length limits for contouring*

Land slope percent	P value	Maximum length[1]
		Feet
1 to 2	0.60	400
3 to 5	.50	300
6 to 8	.50	200
9 to 12	.60	120
13 to 16	.70	80
17 to 20	.80	60
21 to 25	.90	50

[1] Limit may be increased by 25 percent if residue cover after crop seedlings will regularly exceed 50 percent.

Slope-Length Limits

After the 1956 workshop, the SCS prepared reference tables for use with the Corn Belt slope-practice procedure. They included guides for slope-length limits for effective contouring, based largely on judgment. These limits, as modified with later data and observations (*16*, *42*), are also given in table 13. Data to establish the precise limits for specific conditions are still not available. However, the **P** values given in table 13 assume slopes short enough for full effectiveness of the practice. Their use for estimating soil loss on unterraced slopes that are longer than the table limits specified is speculative.

Contour Listing

Contour listing, with corn planted in the furrows, has been more effective than surface planting on the contour (*29*). However, the additional effectiveness of the lister ridges applies only from the date of listing until the ridges have been largely obliterated by two corn cultivations. Therefore, it can be more easily credited through **C** than through **P**. This is done by a 50-percent reduction in the soil loss ratios (table 5) that apply to the time interval during which the ridges are intact. The standard **P** value for contouring is applicable in addition to the **C** value reduction.

Potato rows on the contour present a comparable condition from lay-by time until harvest. However, this ridging effect has been already credited in table 5, line 160, and should not be duplicated.

Controlled-Row Grade Ridge Planting

A method of precise contouring has been developed that provides effective conservation on farm fields where the land slope is nearly uniform, either naturally or by land smoothing, and runoff from outside the field can be diverted. The practice uses ridge planting with undiminished channel capacity to carry water maintained throughout the year. It is being studied in Texas (*36*), Arkansas, Mississippi (*8*), and Iowa (*30*). In Texas, the channel cross section, with 40-in row spacing, was nearly 0.5 ft^2, and row grades varied from nearly zero at the upper end to 1 percent at the lower end of a 1,000-ft length. Measured soil loss compared favorably with that from an adjacent terraced watershed. Soil loss measurements in Mississippi and Iowa showed similar effectiveness during the test periods.

Because each furrow functions as an individual terrace, **P** values similar to those for terracing seem appropriate. Slope-length limits for contouring would then not apply, but the length limits would be applicable if the channel capacity were only sufficient for a 2-year design storm.

Contoured-Residue Strips

Contoured strips of heavy crop-residue mulch, resembling contour stripcropping without the sod, may be expected to provide more soil loss reduction than contouring alone. **P** values equal to about 80 percent of those for contouring are recommended if fairly heavy mulch strips remain throughout the year. If the strips are maintained only from harvest until the next seedbed preparation, the credit should be applied to the soil loss ratio for cropstage 4 rather than the **P** value.

Contour Stripcropping

Stripcropping, a practice in which contoured strips of sod are alternated with equal-width strips of row crops or small grain, is more effective than contouring alone. Alternate strips of grain and meadow year after year are possible with a 4-year rotation of corn-wheat with meadow seeding-meadow-meadow. This system has the added advantage of a low rotation **C** value. A stripcropped rotation of corn-corn-wheat-meadow is less effective. Alternate strips of winter grain and row crop were effective on flat slopes in Texas (*14*), but alternate strips of spring-seed grain and corn on moderate to steep slopes have not provided better erosion control than contouring alone.

Observations from stripcrop studies showed that much of the soil eroded from a cultivated strip was filtered out of the runoff as it was slowed and spread within the first several feet of the adjacent sod strip. Thus the stripcrop factor, derived from soil loss measurements at the foot of the slope, accounts for off-the-field soil movement but not for all movement within the field.

P Values, Strip Widths, and Length Limits

Recommended **P** values for contour stripcropping are given in table 14. The system to which each column of factors applies is identified in the table footnotes. The strip widths given in column 5 are essentially those recommended by the 1956 slope-practice workshop and are to be considered approximate maximums. Reasonable adjustments to accommodate the row spacing and row multiple of the planting and harvesting equipment are permissible. Slope-length limit is generally not a critical factor with contour stripcropping except on extremely long or steep slopes. The lengths given in column 6 are judgment values based on field experience and are suggested as guides.

Buffer Stripcropping

This practice consists of narrow protective strips alternated with wide cultivated strips. The location of the protective strips is determined by the width and arrangement of adjoining strips to be cropped in the rotation and by the location of steep, severely eroded areas on slopes. Buffer strips usually occupy the correction areas on sloping land and are seeded to perennial grasses and legumes. This type of stripcropping is not as effective as contour stripcropping (*4*).

TABLE 14.—**P** *values, maximum strip widths, and slope-length limits for contour stripcropping*

Land slope percent	P values[1]			Strip width[2]	Maximum length
	A	B	C		
				Feet	Feet
1 to 2	0.30	0.45	0.60	130	800
3 to 5	.25	.38	.50	100	600
6 to 8	.25	.38	.50	100	400
9 to 12	.30	.45	.60	80	240
13 to 16	.35	.52	.70	80	160
17 to 20	.40	.60	.80	60	120
21 to 25	.45	.68	.90	50	100

[1] **P** values:

A For 4-year rotation of row crop, small grain with meadow seeding, and 2 years of meadow. A second row crop can replace the small grain if meadow is established in it.

B For 4-year rotation of 2 years row crop, winter grain with meadow seeding, and 1-year meadow.

C For alternate strips of row crop and small grain.

[2] Adjust strip-width limit, generally downward, to accommodate widths of farm equipment.

Terracing

The most common type of terrace on gently sloping land is the broadbase, with the channel and ridge cropped the same as the interterrace area. The steep backslope terrace is most common on steeper land. Difficulty in farming point rows associated with contoured terraces led to developing parallel terracing techniques (*16*). Underground outlets, landforming, and variable channel grades help establish parallel terraces. The underground outlets are in the low areas along the terrace line. The ridge is constructed across these areas. Another type of terrace, using a level and broad channel with either open or closed ends, was developed to conserve moisture in dryland farming areas.

Terraces with underground outlets, frequently called impoundment terraces, are highly effective for erosion control. Four-year losses from four such terrace systems in Iowa (*17*) averaged less than 0.4 t/A/year, which was less than 5 percent of the calculated soil movement to the channel. Comparable losses were measured from installations in Nebraska.

Terracing combined with contour farming and other conservation practices is more effective than those practices without the terraces because it positively divides the slope into segments equal to the horizontal terrace interval. The horizontal terrace interval for broadbase terraces is the distance from the center of the ridge to the center of the channel for the terrace below. For steep backslope terraces with the backslope in sod, it is the distance from the point where cultivation begins at the base of the ridge to the base of the frontslope of the terrace below (*44*). With terracing, the slope length is this terrace interval; with stripcropping or contouring alone, it is the entire field slope length.

P Values

Values of **P** for contour farming terraced fields are given in table 15. These values apply to contour farmed broadbase, steep backslope, and level terraces. However, recognize that the erosion control benefits of terraces are much greater than indicated by the **P** values. As pointed out earlier, soil loss per unit area on slopes of 5 percent or steeper is approximately proportional to the square root of slope length. Therefore, dividing a field slope into **n** approximately equal horizontal terrace intervals divides the average soil loss per unit area by the square root of **n**. This important erosion control benefit of terracing is not included in **P** because it is brought into the USLE computation through a reduced **LS** factor obtained by using the horizontal terrace interval as the slope length when entering figure 4 or table 3.

Erosion control between terraces depends on the crop system and other management practices evaluated by **C**. The total soil movement within a contour-farmed terrace interval may be assumed equal to that from the same length of an identical slope that is contoured only. Therefore, if a control level is desired that will maintain soil movement between the terraces within the soil loss tolerance limit, the **P** value for a contour-farmed terraced field should equal the contour factor (col. 2, table 15), and use of these values for farm planning purposes is generally recommended.

With contour stripcropping, the soil deposited in the grass strips is not considered lost because it remains on the field slope. With terraces, most of the deposition occurs in the terrace channels, but research measurements have shown that this deposition may equal 80 percent of the soil moved from the contour-farmed slopes between the terraces (*67*). Use of the contour factor as the **P** value for terracing assumes that all of the eroded soil deposited in the terrace channels is lost from the productive areas of the field. With broadbase terraces, the channels and ridges are cropped the same as

TABLE 15.—**P** *values for contour-farmed terraced fields*[1]

Land slope (percent)	Farm planning		Computing sediment yield[3]	
	Contour factor[2]	Stripcrop factor	Graded channels sod outlets	Steep backslope underground outlets
1 to 2	0.60	0.30	0.12	0.05
3 to 8	.50	.25	.10	.05
9 to 12	.60	.30	.12	.05
13 to 16	.70	.35	.14	.05
17 to 20	.80	.40	.16	.06
21 to 25	.90	.45	.18	.06

[1] Slope length is the horizontal terrace interval. The listed values are for contour farming. No additional contouring factor is used in the computation.

[2] Use these values for control of interterrace erosion within specified soil loss tolerances.

[3] These values include entrapment efficiency and are used for control of offsite sediment within limits and for estimating the field's contribution to watershed sediment yield.

the interterrace slopes, and some of the material deposited in the channels is moved to the ridges in terrace maintenance. The 1956 slope-practice group felt that some of the deposition should be credited as soil saved and recommended use of a terracing practice factor equal to the stripcrop factor (64). However, the more conservative values given in column 2 are now commonly used in conservation planning.

When the USLE is used to compute a terraced field's contribution to offsite sediment or watershed gross erosion, the substantial channel deposition must be credited as remaining on the field area. For this purpose, the **P** values given in the last two columns of table 15 are recommended unless an overland flow deposition equation based on transport relationships is used with the USLE.

With widespread use of large multirow equipment, farming with field boundaries across nonparallel terraces is not uncommon in some regions. When terraces are not maintained and overtopping is frequent, $\mathbf{P} = 1$ and the slope length is the field slope length. However, if the terraces are periodically maintained so that overtopping occurs only during the most severe storms, **LS** is based on the horizontal terrace interval. If farming across terraces is at an angle that approximates contour farming, **P** values less than 1.0 but greater than the contour factors would be appropriate.

Soil Loss Terrace Spacing

Traditionally, terrace spacing has been based on slope gradient; however, some recent spacing guides have included modifying factors for severity of rainfall and for favorable soil and tillage combinations. A major objective of cropland conservation planning is to hold the productive topsoil in place. Extending this objective to terrace system design suggests limiting slope lengths between terraces sufficiently so that specified erosion tolerances will not be exceeded. Using the USLE in developing spacing guides will make this possible.

The USLE may be written as $\mathbf{LS} = \mathbf{T/RKCP}$, where **T** is the tolerance limit. If $\mathbf{T/RKP} = \mathbf{Z}$, then $\mathbf{LS} = \mathbf{Z/C}$, and $\mathbf{C} = \mathbf{Z/LS}$. The values **T**, **R**, **K** and **P** are constant for a given location and can be obtained from handbook tables and charts as illustrated in the section **Predicting Cropland Soil Losses.** Factor **C** can be selected as the **C** value of the most erosion-vulnerable crop system that a farmer is likely to use on the terraced field. **LS** can be computed by solving the equation as written above and, with the percent slope known, the maximum allowable length can be read from the slope-effect chart, figure 4.

To illustrate the procedure, assume a 6-percent slope at a location where $\mathbf{R} = 175$, $\mathbf{K} = 0.32$, $\mathbf{T} = 5$, $\mathbf{P} = 0.5$, and the most erodible crop expected to occur on the field has a **C** value of 0.24. (An assumption that the field will always be in a sod based rotation or that the operator will always make the best possible use of the crop residues would be too speculative to serve as a guide for terrace spacing.) With these assumptions, $\mathbf{Z} = 5/175(0.32)(0.5) = 0.179$ and $\mathbf{LS} = 0.179/0.24$, or 0.744. Enter the slope-effect chart, figure 4, on the **LS** scale with a value of 0.744, move horizontally to intersect the 6 percent-slope line and read the corresponding slope length, 120 ft, on the horizontal scale. Add to this value the width of the terrace frontslope and compute the vertical interval: $\left(\frac{120 + 12}{100}\right)6 = 7.9$ ft. However, the horizontal interval should not exceed the slope-length limit for effectiveness of contouring. From table 13 the length limit for contouring on a 6-percent slope is 200 ft, so the computed terrace interval is satisfactory. A small modification in spacing may be made to adjust to an even multiple of machinery width.

The maximum **C** value that will allow a horizontal terrace spacing equal to the length limit for effective contouring on the given slope can also be determined by using figure 4 and table 13. For the conditions in the illustration above, $\mathbf{C} = 0.179/\mathbf{LS}$. The maximum acceptable length for contouring is 200 ft. From figure 4, the **LS** value for a 200-ft length of 6-percent slope is 0.95. Therefore, the maximum allowable $\mathbf{C} = 0.179/0.95$, which is 0.188. With terraces spaced at 200-ft intervals, any cropping and management system with a **C** value of less than 0.188 should provide the level of conservation prescribed by the assumed soil loss tolerance limit of 5 t/A/year.

One additional consideration is important. For a terrace to function satisfactorily, the channel capacity must be sufficient to carry the runoff safely to a stabilized outlet without excessive channel scour or overtopping of the ridge. SCS engineering practice standards specify a capacity sufficient to control the runoff from a 10-year-frequency, 24-hour storm without overtopping. Some SCS practice standards may require a shorter terrace interval than would be indicated by the foregoing procedure.

The discussion of the topographic factor pointed out that the erosion rate increases as slope length increases. Table 4 lists the relative soil losses for successive equal-length increments of a uniform slope divided into 2, 3, 4, or 5 segments. The third column of table 4 shows that if a uniform 6-percent slope were controlled at a tolerance of 5 t average soil loss, the average loss per unit area from the lower third of the slope would exceed the tolerance by about 38 percent. Soil loss from the upper third would be 43 percent less than the tolerance limit. To have an average rate of 5 t from the lower third, the **T** values used in the spacing calculation would need to be 1/1.38 times the 5-t tolerance, or 3.6 t. This is an approach that can be used to calculate terrace spacings for a higher level of conservation.

Effect of Terraces on Amount and Composition of Offsite Sediment

By reducing runoff velocity and inducing deposition of sediment in the channels, terraces have a profound effect on the amount and composition of offsite sediments from cultivated fields. The type of terrace, the channel grade, and the type of outlet influence the magnitude of the effect.

The greatest reduction in sediment is attained with the impoundment type terrace systems that use underground outlets. With the outlets in the lower areas of the field and terrace ridges built across these areas, temporary ponds are created around the risers of the outlet tile. The outlets are designed to drain the impounded runoff in 1 to 2 days. Thus, the ponds provide a maximum stilling effect, and only the smallest and lightest soil particles are carried off the field in the runoff water. The increased time for infiltration also reduces runoff.

Sediments collected from four impoundment terrace systems over 4 years in Iowa (*17*) showed the following percentages of fine materials:

Soil type	< 0.002 mm	< 0.008 mm
	Percent	*Percent*
Fayette silt loam	78	91
Sharpsburg silty clay loam	68	96
Floyd loam	31	82
Clarion loam	35	78

Sediment concentrations in the runoff ranged from about 1,300 p/m on the Fayette soil to 6,300 p/m on the Clarion. Average annual sediment from the outlets was less than 800 lb/A for all four systems.

Farm chemical losses in runoff vary with type and formulation, amount, placement, and time of rainfall in relation to time of application, as well as with the usual runoff and erosion factors. Principal chemicals are the fertilizers, insecticides, fungicides, and herbicides. Losses are by solution and by suspension of chemical granules or adsorption on soil particles suspended in the runoff water.

Terracing exerts its greatest influence in reducing offsite pollution from those chemicals that are adsorbed on soil particles. Examples of these are the phosphates, organic nitrogen, and persistent organochlorine insecticides. Reductions in offsite *sediment* by terrace systems with contouring are estimated to range from 82 to 95 percent. However, the reductions in chemical transport are generally not proportional to reductions in soil loss because of an enrichment process that applies to the suspensions. The nutrient content of sediments is often 50 percent greater than that of the soil. Offsite delivery of sediment is also affected by watershed characteristics, particularly size of the drainage area. This reduction is measured by a "delivery ratio" that ranges from 0.33 for an area of one-half square mile to 0.08 for a 200-mi^2 area (*45*).

Terracing has the least effect on offsite pollution from those chemicals transported primarily in solution. Annual runoff reductions by terracing and contour farming, at 21 locations throughout the United States, have been estimated to vary only from 9 to 37 percent (*42*). Examples of farm chemicals transported primarily in solution are the nitrates and some herbicides such as 2,4-D ((2,4-dichlorophenoxy) acetic acid). The predominate transport modes for an extensive list of pesticides are listed in volumes 1 and 2 of "Control of Water Pollution From Cropland" (*42*).

APPLYING THE SOIL LOSS EQUATION

The major purpose of the soil loss prediction procedure is to supply specific and reliable guides for selecting adequate erosion control practices for farm fields and construction areas. The procedure is also useful for computing the upland erosion phase of sediment yield as a step in predicting rates of reservoir sedimentation or stream loading, but the USLE factors are more difficult to evaluate for large mixed watersheds. Specific applications of the soil loss equation are discussed and illustrated below.

Predicting Cropland Soil Losses

The USLE is designed to predict longtime-average soil losses for specified conditions. This may be the average for a rotation or for a particular crop year or cropstage period in the rotation. Where the term "average loss" is used below, it denotes the average for a sufficient number of similar events or time intervals to cancel out the plus and minus effects of short-time fluctuations in uncontrolled variables.

Rotation Averages

To compute the average annual soil loss from a particular field area, the first step is to refer to the charts and tables discussed in the preceding sections and select the values of **R**, **K**, **LS**, **C**, and **P** that apply to the specific conditions on that field. For example, assume a field on Russell silt loam soil in Fountain County, Ind. The dominant slope is about 8 percent with a length of 200 ft. Fertility and crop management on this field are such that crop yields are rarely less than 85 bu corn, 40 bu wheat, or 4 t alfalfa-brome hay. The probability of meadow failure is slight.

Factor **R** is taken from the isoerodent map (fig. 1). Fountain County, in west-central Indiana, lies between isoerodents of 175 and 200. By linear interpolation, **R** = 185. **K** is taken from a table of **K** values that were derived either by direct research measurement or by use of the soil erodibility nomograph (fig. 3). For the Russell silt loam soil, **K** = 0.37. The slope-effect chart, figure 4, shows that an 8 percent slope 200 ft long has an **LS** of 1.41. If the field were continuously in clean-tilled fallow, the average annual soil loss from the dominant slope would equal the product **RKLS**; that is, 185(0.37)(1.41) = 96.5 t/A.

Next, we need to know the effect of the cropping and management system and support practices existing on the field. This effect is represented by factors **C** and **P**. The **C** value for the field may either be derived by the procedure previously presented, using data from tables 5 and 6, or it may be obtained from a centrally prepared **C** value table available from the SCS. For convenience, assume the same crop system and management as were assumed for the problem illustrating the derivation of locality **C** values. From table 8, **C** then equals 0.085. If rows and tillage are in the direction of the land slope, factor **P** = 1.0. The computed average soil loss is then 96.5(0.085)(1.0) = 8.2 t/A/year.

From table 13, contour farming on 8 percent slopes not exceeding 200 ft in length has a **P** value of 0.5. Therefore, if farming were on the contour, the computed average soil loss for the field would be 96.5(0.085)(0.5) = 4.1 t. If the length of 8-percent slope was appreciably greater than 200 ft, the effectiveness of contouring could not be assumed, and the **P** value of 0.5 would not be applied unless the slope length was broken by terraces or diversions. Any change in either the crop sequence or the management practices would likely increase or decrease soil loss. This would be reflected in the USLE solution through a change in the **C** value.

When **C** is used at its average annual value for a rotation that includes a sod crop, as was done in the example given in table 8, the heavier losses experienced during row crop years are diluted by trivial losses in the meadow year(s). For holding longtime-average soil losses below some prescribed tolerance limit, this dilution poses no problem. But from the viewpoint of offsite water quality, it may not be desirable. The USLE may also be used to compute the average soil loss for each crop in the rotation or for a particular cropstage period.

Crop-Year Averages

The subtotals in column 9 of table 8 show that with the assumed management system, **C** for the first-year corn would be 0.130 and for the second-year, 0.138. For the second-year corn, without contouring, the expected average soil loss would equal 185(0.37)(1.41)(0.138), or 13.3 t. If, in the same crop system, the corn residues were plowed down in fall, the **C** value for second-year corn would be 0.29, and the soil loss would average 28 t. On the other hand, no-till planting the second-year corn in a 70-percent cover of shredded cornstalks would reduce the **C** value for this crop to 0.08 and the soil loss to about 8 t. This would also reduce the rotation average for straight row farming to 7 t. Killing the meadow instead of turning it under, and no-till planting, would reduce the **C** value for the first-year corn to 0.01 and the soil loss to less than 1 t. Thus, crop-year **C** values can be helpful for sediment control planning.

Cropstage Averages

Additional information can be obtained by computing the average annual soil loss for each cropstage period. First, the computed cropstage soil losses will show in which portions of the crop year (or rotation cycle) improved management practices would be most beneficial. Second, they provide information on the probable seasonal distribution of sediment yields from the field. When a tabulation like table 8 has been prepared, the values in column 8 will be directly proportional to the cropstage soil losses. They can be converted to tons per acre for a specific field by multiplying them by the product of factors **R**, **K**, **LS**, and **P**.

To estimate the average soil loss for a particular cropstage when such a table has not been prepared, the cropstage soil loss ratio from table 5 is used as **C**. The annual **EI** fraction that is applicable to the selected period is obtained from table 6 and is multiplied by the location's annual erosion index value (fig. 1) to obtain the relevant **R** value. **K**, **LS**, and **P** will usually be assumed to have the same values as for computation of average annual soil losses.

Suppose, for example, that one wishes to predict the average soil loss for the seedbed and establishment periods of corn that is conventionally planted about May 15 on spring plowed soybean land in southwestern Iowa (area No. 13, fig. 9). Suppose also that the corn is on a field for which the combined value of factors **K**, **LS**, and **P** is 0.67 and the fertility and crop management are such that corn planted by May 15 usually develops a 10 percent canopy cover by June 5, 50 percent by June 25, and a final canopy cover of more than 95 percent. Interpolating between values in line 13 of table 6 shows cumulative **EI** percentages of 12, 23, and 43 for these three dates. Therefore, on the average, 11 percent of the annual **EI** would occur in the seedbed period, and 20 percent would occur in the establishment period. From line 109 of table 5, the soil loss ratios for these two cropstage periods under the assumed management are 0.72 and 0.60. From figure 1, the average annual **EI** is 175. The soil loss would be expected to average $0.11(175)(0.72)(0.67) = 9.3$ t/A in the seedbed period and $0.20(175)(0.60)(0.67) = 14$ t in the establishment period. The cropping assumed for this example represents an extremely erodible condition. For second-year corn with good residue management, the applicable soil loss ratios and the predicted soil losses would be much lower.

Individual Storm Soil Losses

The USLE factors derived from tables and charts presented herein compute longtime-average soil losses for specified cover and management on a given field. The USLE is not recommended for prediction of specific soil loss events.

If it is applied to a specific rainstorm, using the storm **EI** for **R** and the relevant cropstage soil loss ratio for **C**, it will estimate the *average* soil loss for a large number of storms of this size occurring on that field and in that cropstage period. However, the soil loss from any one of these events may differ widely from this average because of interactions with variables whose values fluctuate randomly over time (56).

When rain falls on relatively dry, freshly tilled soil, most of the water may infiltrate before runoff begins, resulting in a low-average soil loss per unit of **EI** for that storm. When rain falls on presaturated soil, runoff begins quickly, and most of the rain becomes runoff. Such rains usually produce above-average soil loss per **EI** unit. Some rains are accompanied by high winds that increase the impact energy of raindrops; others occur in a fairly calm atmosphere. Some storms begin with a high intensity and seal the surface quickly so that trailing lower intensities encounter a low infiltration rate. In other storms the moderate intensities precede the high ones. In some seasons the soil is cultivated when wet and remains cloddy; in other seasons it is cultivated when soil moisture is ideal for fine pulverization. A claypan or fragipan subsoil may substantially influence permeability in early spring or in a wet growing season and yet have no significant effect on infiltration rates during intense thunderstorms on dry soil.

The soil loss ratios of table 5 are averages for cropstage periods that cover several weeks to several months. Early in a cropstage period, the ratio will usually be higher than the average because the development of cover is gradual. Later in the period it will be lower than average. In a poor growing season the ratio will be above average because cover and water use by transpiration are below normal. In a favorable growing season, the ratio will be below average. Cover effect in a specific year may be substantially influenced by abnormal rainfall. A crop canopy or conservation tillage practice may delay the start of runoff long enough to be 100 percent effective for moderate storms on a given field and yet allow substantial erosion by prolonged runoff periods.

The irregular fluctuations in these and other variables can greatly influence specific-storm soil losses. However, they do not invalidate the USLE for predicting long-term-average soil losses for specific land areas and management conditions. Their positive and negative effects tend to balance over a longtime period, and their average effects are reflected in the factor-evaluation tables and charts.

Two recent research reports are recommended references for those who find it necessary to estimate specific-storm soil losses (*34, 10*). The authors present modifications of **R** and **LS** that are designed to account for some random effects discussed.

Specific-Year Soil Losses

In any given year, both the annual **EI** and its monthly distribution may differ substantially from the location averages. Therefore, **R** values from figure 1 and **EI** distribution data from table 6 will not correctly reflect specific-year values of these variables. The most accurate procedure is to compute the **EI** value for each storm from a recording-rain gage record for the location and year by the method given in the appendix. The storm values are summed for each cropstage period, and the subtotals are combined with soil loss ratios from table 5 to estimate the soil loss for each cropstage period. The sum of the cropstage soil losses then reflects the effects of possible abnormal **EI** distribution, as well as the corrected **R** value for the specific year. However, the irregular fluctuations in variables discussed in the preceding subsection are often related to abnormalities in rainfall. The plus and minus effects on soil loss may not average out within 1 year but may appreciably bias specific-year soil losses. These biases will not be evaluated by the USLE. Therefore, specific-year estimates of soil loss will be less accurate than USLE estimates of long-term, crop-year averages.

Soil Loss Probabilities

Soil loss probabilities are a function of the combination of the probabilities for annual **EI**, seasonal distribution of the erosive rains, abnormal antecedent soil moisture conditions, favorable or unfavorable conditions for soil tillage and crop development, and other factors. The section on the **Rainfall Erosion Index** pointed out that a location's annual and maximum storm **EI** values tend to follow log-normal frequency distributions and that specific probability values are listed in tables 17 and 18 for 181 key locations. When these probabilities of **EI** are used for **R** in the USLE, the equation will estimate the soil loss that would occur if all the other factors were at their normal levels. However, the seasonal distribution of erosive rains, and the surface conditions in the field, may also be abnormal in years of rainfall extremes. Deriving probable relationships of these variables to extremes in annual **EI** would require longer records than were available.

Stochastic modeling techniques (*66*) are available that could be used to generate synthetic data having the same statistical properties as historical data. Such data could be used to estimate the probable range in specific-year soil losses in a particular rainfall area.

Determining Alternative Land Use and Treatment Combinations

The soil loss prediction procedure supplies the practicing conservationist with concise reference tables from which he can ascertain, for each particular situation encountered, which specific land use and management combinations will provide the desired level of erosion control. A number of possible alternatives are usually indicated. From these, the farmer will be able to make a choice in line with his desires and financial resources.

Management decisions generally influence erosion losses by affecting the factor **C** or **P** in the erosion equation. **L** is modified only by constructing terraces, diversions, or contour furrows with sufficient capacity throughout the year to carry the runoff water from the furrow area above. **R, K,** and **S** are essentially fixed as far as a particular field is concerned.

When erosion is to be limited within a predetermined tolerance, **T,** the term **A** in the equation is replaced by **T,** and the equation is rewritten in the form **CP** = **T/RKLS.** Substituting the site values of the fixed factors in this equation and solving for **CP** give the maximum value that the product **CP** may assume under the specified field conditions. With no supporting practices, **P** = 1, and the most intensive cropping plan that can be safely used on the field is one for which **C** just equals this value. When a supporting practice like contouring or stripcropping is added, the computed value of **T/RKLS** is divided by the practice factor, **P,** to obtain the maximum permissible cover and management factor value. Terracing increases the value of **T/RKLS** by decreasing the value **L.**

A special USLE calculator, originally designed in Tennessee (*41*) and recently updated, enables rapid and systematic calculation of either average annual soil loss or **T/RKLS** for any specific situation.

Many practicing conservationists prefer to use handbook tables. **C**-value tables for specific geographic areas (fig. 9) are centrally prepared by persons who are experienced in the procedures outlined in a preceding section and who obtain the needed data from tables 5 and 6. Values of **T/RKLS** are also centrally computed and arranged in two-way classification as illustrated in table 16 for **R** = 180, **K** = 0.32, and **T** = 5. Similar tables are prepared for other combinations of **R, K,** and **T.**

A conservationist working in the field usually carries a pocket-sized handbook which includes the **R** value(s), **T** and **K** soil values, applicable tables of **T/RKLS** values, and a table of **C** values for the area. These items will provide all the information needed to use this procedure as a guide

TABLE 16.—*Maximum permissible* **C** *values* (**T/RKLS**) *for* **R** = *180,* **K** = *0.32 and* **T** = *5*

Gradient percent	Values for slope lengths (feet)							
	50	75	100	150	200	250	300	400
	STRAIGHT ROW							
2	0.53	0.47	0.43	0.38	0.35	0.33	0.31	0.28
4	.29	.24	.22	.18	.16	.15	.14	.12
6	.18	.15	.13	.11	.091	.082	.074	.064
8	.12	.10	.087	.072	.062	.055	.050	.044
10	.090	.073	.063	.052	.045	.040	.037	.032
12	.068	.056	.048	.039	.034	.030	.028	.024
14	.054	.044	.038	.031	.027	.024	.022	.019
16	.043	.035	.030	.025	.022	.019	.018	.015
	CONTOURED[1]							
2	0.89	0.78	0.72	0.64	0.58	0.55	0.52	0.47
4	.57	.49	.43	.37	.33	.30	.28	.25
6	.36	.30	.26	.21	.18	.16	([2])	—
8	.25	.20	.17	.14	.12	.11	—	—
10	.15	.12	.11	.086	([2])	—	—	—
12	.11	.093	.080	.065	—	—	—	—
14	.077	.062	.054	([2])	—	—	—	—
16	.062	.050	.044	—	—	—	—	—

[1] The values for contour farming are T/**RKLSP**, where **P** is dependent on percent slope (see table 13).

[2] Omission of values indicates that the slope-lengths exceed the limits for effectiveness of contouring. Use corresponding values from upper half of table.

for selecting conservation practices in each field. Solving the equation or performing field computations rarely will be necessary.

Example. The first step is to ascertain the soil type, percent slope, and slope length for the field being planned. From his handbook data, the conservationist can then obtain the values of **R, K,** and **T.** To complete the illustration, assume that **R** = 180, **K** = 0.32, **T** = 5, and the field slope is 400 ft long with a nearly uniform gradient of 6 percent. For this combination, the **T/RKLS** table shows a value of 0.064 for straight-row farming with the land slope (table 16). This is the maximum **C** value that will hold the average annual soil loss from that field within the 5-t tolerance limit, if no supporting practices are used. Consulting the **C** value table will show that a **C** as low as 0.064 can be attained only with well-managed, sod-based crop systems, or with no-till planting in residue covers of at least 70 percent.

A logical improvement is to add contouring. Table 13 shows a slope-length limit of 200 ft (250 ft if residue cover after seeding exceeds 50 percent) for contouring on 6-percent slope. Therefore, the **P** value of 0.5 for contouring will not be applicable on the 400-ft slope without terracing. Construction of three, equally spaced terraces across the slope would divide it into four 100-ft slope lengths. Shortening the slope lengths to 100 ft will assure contour effectiveness and will also reduce the site value of **L**. For a 100-ft length of 6-percent slope farmed on the contour, table 16 shows a **T/RKLSP** value of 0.26. Any combination of cropping and management practices having a **C** value less than 0.26 will now be acceptable. Consulting the table of **C** values will show that with the terraces and contouring, the conservationist can recommend a range of possibilities for land use and management. If a system with a **C** value appreciably less than 0.26 is selected, a higher level of conservation will be attained than required by the 5-t tolerance limit.

Had the slope length in the example been only 200 ft, the contour **P** value of 0.5 (table 13) would have been applicable without the terraces. Table 16 shows that this combination would have permitted use of any system having a **C** value less than 0.18.

Thus, by this procedure a conservationist can list all the alternative crop system and management combinations that would control erosion on a field at an acceptable level. Study of this list will show how an erosion control program can be improved and still increase crop yields or decrease labor and fuel costs. In making a selection from this list, practices needed for control of nutrient and pesticide losses in the runoff (*42*) should also be considered.

Construction Sites

Procedures and data have been presented for predicting erosion losses from specific cropland areas and logically determining alternative ways in which the losses from each field may be held below given tolerance limits. These procedures and data can also be adapted to conditions on highway, residential, and commercial developing areas. The USLE will show under which development plan the area will produce the least sediment, and it will also show about how much sediment the developer will need to trap in sediment basins (*46*) during construction to prevent excessive soil movement to streams or reservoirs.

Evaluating the erosion factors for construction site conditions is discussed below. However, those primarily concerned with this particular phase of sediment control should also read the preceding discussions of the USLE factors and the procedures for predicting cropland soil losses.

Factor R. For a construction project extending over several years, the average annual **R** value for the site is obtained directly from figure 1. Probabilities of **EI** values greater than average are given in table 17. Using **EI** probabilities for **R** was discussed in the subsection **Soil Loss Probabilities.**

For construction periods of less than 1 year, the procedure outlined for predicting cropland soil losses for specific cropstage periods is appropriate. The portion of the annual **R** value that is applicable to the construction period is obtained from table 6 as illustrated on p. 41 for cropstage averages.

Factor K. Because the soil surface is often unprotected during construction, this factor assumes even greater importance than for cropland. The soil erodibility nomograph (fig. 3) can be especially helpful for sediment prediction and erosion control planning on construction sites because it can predict the changes in erodibility when various subsoil horizons are exposed in the reshaping process. Some subsoils are substantially more erodible than the original topsoil, and others are less erodible. The planner can usually obtain a detailed description of the successive horizons of his soil from published soil survey data. By using the data for each soil horizon separately to follow the steps of the nomograph solution, the **K** value can be determined after various depths of desurfacing. Soil losses from the successive soil horizons, if exposed on similar slopes, would be directly proportional to the horizon **K** values. Information on the subsoil **K** values not only shows the depths of cut that would result in the most or the least soil erosion but also indicates whether return of stockpiled topsoil on the exposed subsoil would be profitable on the particular site.

When a chemical soil additive is used that stabilizes the soil and makes it less erodible, the **K** value is the nomograph solution times a factor for the effectiveness of the chemical additive.

Factor LS. Within limits, the **LS** value for a given length and steepness of uniform slope can be obtained directly from figure 4 or table 3. When the slope is concave or convex, the figure 4 value needs to be adjusted by the procedure outlined for irregular slopes in the section on **The Topographic Factor.**

Development planning may include measures designed to reduce sediment yield by lowering **LS.** The effect of shortening slope lengths by diversions or stabilized drainageways is credited by entering figure 4 with the reduced slope length. A slope graded to flatten toward the bottom (concave) will lose less soil than an equivalent uniform slope whereas one that steepens toward the bottom (convex) will lose more. Reduction or increase in soil loss can be predicted by the procedure illustrated in the subsection **Irregular Slopes.**

Data are not available to evaluate **LS** on very steep slopes, like 2:1 and 3:1 roadbank slopes, in relation to soil and rainstorm characteristics. The best presently available estimates of **LS** for these slopes can be obtained by the **LS** equation presented earlier. However, values projected by this equation for steep slopes are speculative because the equation was derived from data obtained on slopes of less than 20 percent.

Factor C. Procedures for selecting **C** values for construction sites were given in the **Cover and Management Factor** section.

Factor P. This factor as used for soil conservation planning on cropland would rarely have a counterpart during construction on development areas, and **P** will usually equal 1.0. Erosion-reducing effects of shortening slopes or reducing slope gradients are accounted for through the **LS** factor.

If the lower part of a grass or woodland slope on a development area can be left undisturbed while the upper part is being developed, the procedure outlined for computing the value of **LSC** on irregular slopes is applicable, and sediment deposition on the undisturbed strip must be accounted for separately. For prolonged construction periods, buffer strips of grass, small grain, or high rates of anchored mulch may also be feasible to induce deposition within the area. Such deposition is important for water quality or offsite sediment control, but it should be evaluated from soil-transport factors rather than by a **P** factor.

Alternative plans. When appropriate numerical values of the six erosion factors are combined, their product is the soil loss estimate for the particular area in tons per acre and for the time interval for which **R** was evaluated. With the information supplied by the tables and charts in this handbook, the six factor values can be derived for each feasible alternative plan. Successive solutions of the equation will then provide comparative soil loss estimates to help guide decisions by the developer.

Estimating Upslope Contributions to Watershed Sediment Yield

The importance of predicting watershed sediment yields and identifying the major sediment sources was increased by the Federal Water Pollution Control Act Amendments of 1972, Public Law 92-500. Sources, causes, and potentials of sediment, nutrient, and pesticide losses from cropland, and measures that may be necessary to control these pollutants, are dealt with in depth in a two-volume manual developed by SEA and the Environmental Protection Agency (EPA) (*42*). Volume II, "An Overview," also includes an extensive list of other relevant publications. Only sediment yield prediction will be considered here.

Estimates show that about one-fourth of the amount of sediment moved by flowing water in the United States annually reaches major streams (*42*). The USLE can be used to compute average sheet and rill erosion in the various parts of a watershed, but deposition and channel-type erosion must be estimated by other means. A fully tested equation for sediment transport to use on agricultural land is not now available. One presented by Neibling and Foster (*32*) is perhaps the best now available for use with the USLE. It estimates transport capacity for sand and large silt-sized particles and does not consider the transport of clay particles.

Of the several methods now used for estimating sediment yield, the Gross Erosion-Sediment Delivery Method uses the USLE. A brief description of this method follows. More details are available from the SCS National Engineering Handbook (*45*). The equation is

$$\mathbf{Y} = \mathbf{E(DR)/W_s} \qquad (6)$$

where **Y** is sediment yield per unit area,
E is the gross erosion,
DR is the sediment delivery ratio, and
$\mathbf{W_s}$ is the area of the watershed above the point for which the sediment yield is being computed.

Gross Erosion

Gross erosion is the summation of erosion from all sources within the watershed. It includes sheet and rill erosion from tilled cropland, meadows, pastures, woodlands, construction sites, abandoned acreages, and surface-mined areas; gully erosion from all sources; and erosion from streambeds and streambanks. The relative importance of each of these sources of gross erosion will vary between watersheds.

The USLE can be used to estimate the sediment generated by sheet and rill erosion that is usually, but not always, the major portion of a watershed's gross erosion. Sediment from gully, streambank and streambed erosion, and from uncontrolled roadsides must be added to the USLE estimates. Methods for estimating sediment yields from these sources are discussed in Section 3 of the SCS National Engineering Handbook (*45*).

For small areas like farm fields or construction sites, the six USLE factors can usually be evaluated directly from the information presented in this handbook. For a large heterogeneous watershed, the factors are more difficult to define. Several methods of computing the average slope length and gradient for a large drainage area are available. Using **LS** values based on such averages, together with estimated watershed-average soil and cover factors, simplifies the computing procedure, but the saving in time is at the expense of substantial loss in accuracy. Erosion hazards are highly site specific. The parameters that determine the USLE factor values vary within a large watershed, and the variations are often not interrelated. Combining overall averages in the equation does not reflect the particular way in which the factors are actually combined in different parts of the watershed. Neither does it show which portions of the drainage area are contributing most of the sediment.

A more accurate procedure is to divide the heterogeneous drainage area into subareas for which representative soil type, slope length, gradient, cover, and erosion-control practice factors can be defined. The USLE is then used to compute the sheet and rill erosion on each subarea. For this purpose, eroded soil that is entrapped within the field area by terrace systems is not soil loss. An estimate of the entrapped sediment can be excluded from the USLE soil loss estimates by using values from the last two columns of table 15 as the **P** values. An alternate procedure is to estimate the channel deposition by sediment-transport relationships and subtract this amount from the soil loss computed by using the standard terracing factor (col. 2, table 15) in the USLE. By this procedure, the subarea soil loss computations identify the portions of the drainage area that contribute most of the sediment and also show how much of the sediment derives from tracts that receive heavy applications of agricultural chemicals.

Procedures for computing soil losses from cropped, idle, pasture, range, or wooded areas and from construction or development areas were outlined in the preceding sections. Factor values derived by the prescribed procedures are assumed applicable also for surface-mined areas. However, the effect of mining processes on soil erodibility, **K**, has not been determined. Length and percent slope and deposition within the area also are hard to determine for rugged strip mine spoils. Sometimes nearly all the sediment may be trapped within the bounds of the area. The USLE can be quite useful for predicting the effectiveness of each feasible reclamation plan for such areas.

Sediment Delivery Ratio

Eroded soil materials often move only short distances before a decrease in runoff velocity causes their deposition. They may remain in the fields where they originated or may be deposited on more level slopes that are remote from the stream system. The ratio of sediment delivered at a given location in the stream system to the gross erosion from the drainage area above that location is the sediment delivery ratio for that drainage area. A general equation for computing watershed delivery ratios is not yet available, but the ratios for some specific drainage areas have been computed directly from local data. Helpful guides for estimating this factor for other drainage areas were published by SCS in Section 3 of their National Engineering Handbook (*45*), and most of these guides were also included in a publication by SEA and EPA (*42*). Therefore, the relationships involved will be only briefly summarized here.

Available watershed data indicate that the delivery ratio varies approximately as the 0.2 power of drainage-area size, with representative values of about 0.33 for 0.5 mi^2; 0.18 for 10 mi^2; and 0.10 for 100 mi^2. There were indications that the exponent in this relationship may be as small as 0.1 for very large areas. But the ratio may vary substantially for any given size of drainage area. Other important factors include soil texture, relief, type of erosion, sediment transport system, and areas of deposition within the watershed. Fine soil texture, high channel density, and high stream gradients generally indicate delivery ratios that are above average for the drainage-area size.

A substantial reduction in sediment delivered to a stream may sometimes result in a compensatory increase in channel erosion. Channel erosion produces sediment that is immediately available to the transport system and that may remain in motion as bedload and suspended sediment. The composition of sediment derived from channel erosion will usually differ substantially from that derived from cropland erosion. This is particularly important from the viewpoint of transported chemical pollutants.

With reference to a field-sized area, the delivery ratio can closely approach 1.0 if the runoff drains directly into a lake or stream system with no intervening obstructions or flattening of the land slope. On the other hand, a substantial width of forest litter or dense vegetation below the eroding area may cause deposition of essentially all the sediment except colloidal material. Anything that reduces runoff velocity (such as reduction in gradient, physical obstructions, vegetation, and ponded water) reduces its capacity to transport sediment. When the sediment load exceeds the transport capacity of the runoff, deposition occurs.

From analysis of runoff and soil loss data from small single-cropped watersheds, Williams (*48*) concluded that the need for a sediment delivery ratio could be eliminated by using the watershed runoff times peak rate as the storm **R** value in the USLE.

Accuracy of USLE Predictions

Soil losses computed with the USLE are best available estimates, not absolutes. They will generally be most accurate for medium-textured soils, slope lengths of less than 400 ft, gradients of 3 to 18 percent, and consistent cropping and management systems that have been represented in the erosion plot studies. The farther these limits are exceeded, the greater will be the probability of significant extrapolation error.

An indication of the accuracy of the equation, tables, and charts presented herein was obtained by using them to compute longtime average soil losses for plots in past erosion studies and comparing these with the actually measured losses on each plot. About 53 percent of the differences were less than 1 t/A, 84 percent were less than 2 t, and 5 percent were as much as 4.6 t (*53*). The mean annual soil loss for this 2,300 plot-year sample was 11.3 t. Of those differences that exceeded 1 t/A, 67 percent were from comparisons with plot records whose duration was less than half of a normal 22-year rainfall cycle (*33*). Such short records are subject to bias by cyclical effects and random fluctuations in uncontrolled variables whose effects are averaged in the USLE factor values (*56*). Testing the complete equation against the assembled plot data was statistically valid because the equation for each factor, as a function of several parameters, was independently derived from only selected portions of the data.

The accuracy of a predicted soil loss will depend on how accurately the physical and management conditions on the particular piece of land are described by the parameter values used to enter the factor-evaluation tables and charts. An error in the selection of a factor value will produce an equivalent percentage error in the soil loss estimate. Large-scale averaging of parameter values on mixed drainage areas will usually also reduce accuracy. For reasons previously pointed out and discussed in depth in another publication (*56*), specific-storm or specific-year soil losses and short-term averages may differ substantially from the longtime average predicted by the USLE for the specified physical and management conditions.

REFERENCES

(1) Adams, J. E. 1966. Influence of mulches on runoff, erosion, and soil moisture depletion. Soil Science Society of America Proceedings 30:110-114.

(2) Barnett, A. P., Diseker, E. G., and Richardson, E. C. 1967. Evaluation of mulching methods for erosion control on newly prepared and seeded highway backslopes. Agronomy Journal 59:83-85.

(3) ——— and Rogers, J. S. 1966. Soil physical properties related to runoff and erosion from artificial rainfall. American Society of Agricultural Engineers Transactions 9:123-125.

(4) Blakely, B. D., Coyle, J. J., and Steele, J. G. 1957. Erosion on cultivated land. *In* Soil, Yearbook of Agriculture, pp. 290-306.

(5) Brooks, F. L. 1976. Use of the universal soil loss equation in Hawaii. *In* Soil Erosion: Prediction and Control. Soil Conservation Society of America, pp. 29-30.

(6) Browning, G. M., Parish, C. L., and Glass, J. A. 1947. A method for determining the use and limitation of rotation and conservation practices in control of soil erosion in Iowa. Soil Science Society of America Proceedings 23:246-249.

(7) Carter, C. E., Greer, J. D., Braud, H. J., and Floyd, J. M. 1974. Raindrop characteristics in South Central United States. American Society of Agricultural Engineers Transactions 17:1033-1037.

(8) ——— and Carreker, J. R. 1969. Controlling water erosion with graded furrows. American Society of Agricultural Engineers Transactions 12:677-680.

(9) El-Swaify, S. A., and Dangler, E. W. 1976. Erodibility of selected tropical soils in relation to structural and hydrological parameters. *In* Soil Erosion: Prediction and Control, Soil Conservation Society of America, pp. 105-114.

(10) Foster, G. R., Meyer, L. D., and Onstad, C. A. 1977. A runoff erosivity factor and variable slope length exponents for soil loss estimates. American Society of Agricultural Engineers Transactions 20:683-687.

(11) ——— Meyer, L. D., and Onstad, C. A. 1977. An erosion equation derived from basic erosion principles. American Society of Agricultural Engineers Transactions 20:678-682.

(12) ——— and Wischmeier, W. H. 1974. Evaluating irregular slopes for soil loss prediction. American Society of Agricultural Engineers Transactions 17:305-309.

(13) Gunn, R., and Kinzer, G. D. 1949. The terminal velocity of fall for water droplets. Journal Met. 6:243-248.

(14) Hill, H. O., Peevy, W. J., McCall, A. G., and Bell, F. G. 1944. Investigations in erosion control and reclamation of eroded land at the Blackland Conservation Experiment Station, 1931-41. U.S. Department of Agriculture, Technical Bulletin 859, 109 pp.

(15) Hudson, N. W. 1971. Raindrop size. *In* Soil Conservation: Cornell University Press, Ithaca, New York, pp. 50-56.

(16) Jamison, V. C., Smith, D. D., and Thornton, J. F. 1968. Soil and Water research on a claypan soil. U.S. Department of Agriculture, Technical Bulletin 1379.

(17) Laflen, J. M., and Johnson, H. P. 1976. Soil and water loss from impoundment terrace systems. 3d Federal Inter-Agency Sedimentation Conference Proceedings 2:20-41.

(18) Lillard, J. H., Rogers, H. T., and Elson, Jesse. 1941. Effects of slope, character of soil, rainfall, and cropping treatments on erosion losses from Dunmore silt loam. Virginia Agricultural Experiment Station Technical Bulletin 72, 32 pp.

(19) Lloyd, C. H., and Eley, G. W. 1952. Graphical solution of probable soil loss formula for Northeastern Region. Journal of Soil and Water Conservation 7:189-191.

(20) Mannering, J. V., and Meyer, L. D. 1963. Effects of various rates of surface mulch on infiltration and erosion. Soil Science Society of America Proceedings 27:84-86.

(21) McCool, D. K., Papendick, R. I., and Brooks, F. L. 1976. The universal soil loss equation as adapted to the Pacific Northwest. 3d Federal Inter-Agency Sedimentation Conference Proceedings 2:135-147.

(22) Meyer, L. D., Foster, G. R., and Romkens, M. J. M. 1975. Source of soil eroded by water from upland slopes. Sediment Prediction Workshop Proceedings, Oxford, Miss. ARS-S-40:177-189.

(23) ——— and McCune, D. L. 1958. Rainfall simulator for runoff plots. Agricultural Engineering 39:644-648.

(24) ——— and Ports, M. A. 1976. Prediction and control of urban erosion and sedimentation. National Symposium on Urban Hydrology, Hydraulics, and Sedimentation Proceedings, University of Kentucky, Lexington, Bulletin 111, pp. 323-331.

(25) ——— and Romkens, M. J. M. 1976. Erosion and sediment control on reshaped land. 3d Federal Inter-Agency Sedimentation Conference Proceedings 2:65-72.

(26) ——— and Wischmeier, W. H. 1969. Mathematical simulation of the process of soil erosion by water. American Society of Agricultural Engineers Transactions 12:754-758, 762.

(27) ——— Wischmeier, W. H., and Foster, G. R. 1970. Mulch rates required for erosion control on steep slopes. Soil Science Society of America Proceedings 34:928-931.

(28) Middleton, H. E., Slater, C. S., and Byers, H. G. 1932-1934. Physical and chemical characteristics of the soils from the erosion experiment stations. U.S. Department of Agriculture, Technical Bulletin No. 316 and 430.

(29) Moldenhauer, W. C., and Wischmeier, W. H. 1960. Soil and water losses and infiltration rates on Ida silt loam as influenced by cropping systems, tillage practices and rainfall characteristics. Soil Science Society of America Proceedings 24:409-413.

(30) ——— Lovely, W. G., Swanson, N. P., and Currence, H. D. 1971. Effect of row grades and tillage systems on soil and water losses. Journal of Soil and Water Conservation 26(5): 193-195.

(31) Musgrave, G. W. 1947. The quantitative evaluation of factors in water erosion, a first approximation. Journal of Soil and Water Conservation 2(3):133-138.

(32) Neibling, W. H., and Foster, G. R. 1977. Estimating deposition and sediment yield from overland flow processes. 1977 International Symposium on Urban Hydrology, Hydraulics, and Sediment Control Proceedings, University of Kentucky, Lexington.

(33) Newman, J. E. 1970. Climate in the 1970's. American Society of Agronomy, Crops and Soils 22(4):9-12.

(34) Onstad, C. A., and Foster, G. R. 1975. Erosion modeling on a watershed. American Society of Agricultural Engineers Transactions 18:288-292.

(35) Peele, T. C., Latham, E. E., and Beale, O. W. 1945. Relation of the physical properties of different soil types to erodibility. South Carolina Agricultural Experiment Station Bulletin No. 357.

(36) Richardson, C. W. 1973. Runoff, erosion and tillage efficiency on graded furrows and terraced watersheds. Journal of Soil and Water Conservation 28(4):162-164.

(37) Roth, C. B., Nelson, D. W., and Romkens, M. J. M. 1974. Prediction of subsoil erodibility using chemical, mineralogical and physical parameters. U. S. Environmental Protection Agency Report No. 660/2-74-043. 111 pp.

(38) Smith, D. D. 1941. Interpretation of soil conservation data for field use. Agricultural Engineering 22:173-175.

(39) ——— and Whitt, D. M. 1947. Estimating soil losses from field areas of claypan soils. Soil Science Society of America Proceedings 12:485-490.

(40) ——— and Wischmeier, W. H. 1957. Factors affecting sheet and rill erosion. American Geophysical Union Transactions 38:889-896.

(41) Springer, D. L., Breinig, C. B., and Springer, M. E. 1963. Predicting soil losses in Tennessee. Journal of Soil and Water Conservation 18(4):157-158.

(42) Stewart, B. A., Wischmeier, W. H., Woolhiser, and others. 1975. Control of water pollution from cropland: Vol. I, a manual for guideline development; Vol. II, an overview. U.S. Department of Agriculture, ARS-H-5-1 and ARS-H-5-2.

(43) Swanson, N. P., Dedrick, A. R., Weakley, H. E., and Hoise, H. R. 1965. Evaluation of mulches for water-erosion control. American Society of Agricultural Engineers Transactions 8: 438-440.

(44) U.S. Department of Agriculture. 1977. Terracing Code 600. *In* National Engineering Handbook. U.S. Department of Agriculture, Soil Conservation Service.

(45) ——— 1971. Sediment sources, yields and delivery ratios. *In* National Engineering Handbook, Section 3, Sedimentation. U.S. Department of Agriculture,Soil Conservation Service.

(46) ——— 1975. Standards and specifications for soil erosion and sediment control in developing areas, approved by Maryland Water Resources Administration. U.S. Department of Agriculture, Soil Conservation Service. 200 pp.

(47) U. S. Weather Bureau. 1958. Rainfall intensity-frequency regime. Technical Paper No. 29, 5 parts.

(48) Williams, J. R. 1975. Sediment-yield prediction with the universal equation using a runoff energy factor. U.S. Department of Agriculture, ARS-S-40:244-252.

(49) Wischmeier, W. H. 1959. A rainfall erosion index for a universal soil-loss equation. Soil Science Society of America Proceedings 23:246-249.

(50) ——— 1960. Cropping-management factor evaluations for a universal soil-loss equation. Soil Science Society of America Proceedings 23:322-326.

(51) ——— 1962. Storms and soil conservation. Journal of Soil Water and Conservation 17(2):55-59.

(52) Wischmeier, W. H. 1966. Relation of field-plot runoff to management and physical factors. Soil Science Society of America Proceedings 30:272-277.

(53) ——— 1972. Upslope erosion analysis. *In* Environmental Impact on Rivers. Water Resources Publications, Fort Collins, Colo.

(54) ——— 1973. Conservation tillage to control water erosion. National Conservation Tillage Conference Proceedings, Soil Conservation Society of America, pp. 133-141.

(55) ——— 1974. New developments in estimating water erosion. 29th Annual Meeting of the Soil Conservation Society of America Proceedings, pp. 179-186.

(56) ——— 1976. Use and misuse of the universal soil loss equation. Journal of Soil and Water Conservation 31(1): 5-9.

(57) ——— 1975. Estimating the soil loss equation's cover and management factor for undisturbed areas. Sediment Yield Workshop Proceedings, Oxford, Miss. U.S. Department of Agriculture, ARS-S-40.

(58) ——— Johnson, C. B., and Cross, B. V. 1971. A soil erodibility nomograph for farmland and construction sites. Journal of Soil and Water Conservation 26:189-193.

(59) ——— and Mannering, J. V. 1965. Effect of organic matter content of the soil on infiltration. Journal of Soil and Water Conservation 20:150-152.

(60) ——— and Mannering, J. V. 1969. Relation of soil properties to its erodibility. Soil Science Society of America Proceedings 33:131-137.

(61) ——— and Meyer, L. D. 1973. Soil erodibility on construction areas. Highway Research Board, National Academy of Science Special Report 135:20-29.

(62) ——— and Smith, D. D. 1958. Rainfall energy and its relationship to soil loss. American Geophysical Union Transactions 39:285-291.

(63) ——— Smith, D. D., and Uhland, R. E. 1958. Evaluation of factors in the soil loss equation. Agricultural Engineering 39:458-462, 474.

(64) ——— and Smith, D. D. 1965. Predicting rainfall-erosion losses from cropland east of the Rocky Mountains—Guide for selection of practices for soil and water conservation. Agricultural Handbook No. 282.

(65) Witmuss, H. D., Triplett, G. B., Jr., and Creb, B. W. 1973. Concepts of conservation tillage systems using surface mulches. National Conservation Tillage Conference Proceedings, Soil Conservation Society of America 5-12.

(66) Woolhiser, D. G. 1975. Simulation of unsteady overland flow. *In* Unsteady Flow in Open Channels. Water Resources Publications, Fort Collins, Colo. Vol. II, Ch. 12, pp. 485-508.

(67) Zingg, R. W. 1940. Degree and length of land slope as it affects soil loss in runoff. Agricultural Engineering 21:59-64.

APPENDIX

Estimating Percentages of Canopy and Mulch Covers

"Percent canopy cover" is the percentage of the field area that could not be hit by vertically falling raindrops because of canopy interception. It is the portion of the soil surface that would be covered by shadows if the sun were directly overhead. Because the blades from adjacent rows intertwine does not necessarily indicate 100 percent canopy cover.

"Percent mulch cover" is the percentage of the field area that is covered by pieces of mulch lying on the surface. Researchers in Indiana attempted to relate percent cover to mulch rate by photographing numerous small, equal-sized areas in harvested corn fields. The residues on the photographed areas were carefully picked up, dried, and weighed to measure mulch rates, and the photographs were projected on grids to determine percent cover. The indicated average relation of percent cover to dry weight of well-distributed corn stover mulch is shown by the solid-line curve in figure 10. However, observed differences between samples were appreciable. The average relation of percent cover to dry weight of straw mulch uniformly distributed over research plots is shown by the broken-line curve.

A simple method of estimating percent mulch cover on a field is with a cord, preferably not shorter than 50 ft, that has 100 equally spaced knots or other readily visible markings. The cord is stretched diagonally across several rows, and the knots that contact a piece of mulch are counted. This procedure is repeated at randomly selected spots on the field, and the data are averaged to obtain a representative value for the field.

Probability Values of **EI** in the United States

The annual and maximum-storm values of **EI** at any given location differ substantially from year to year. The observed ranges and 50 percent, 20 percent and 5 percent probabilities of annual **EI** values from 22-year precipitation records at 181 locations in 44 States are listed in table 17. Other probabilities can be derived by plotting the 50 percent and 5 percent values on log-probability paper and joining the two points by a straight line. Annual maxima storm probabilities for the same locations are given in table 18.

Computing the Erosion Index from Recording-Rain Gage Records

Soil loss prediction by the method presented in this handbook does not require computation of **EI** values by application personnel, but the procedure is included here for the benefit of those who may wish to do so.

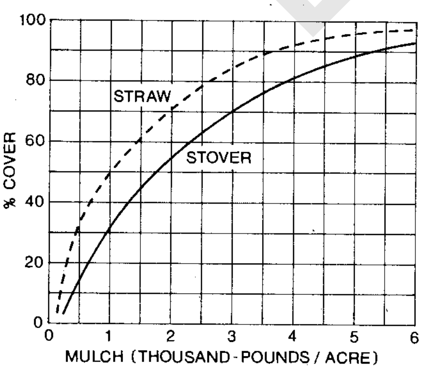


FIGURE 10.—Relation of percent cover to dry weight of uniformly distributed residue mulch.

The kinetic energy of a given amount of rain depends on the sizes and terminal velocities of the raindrops, and these are related to rainfall intensity. The computed energy per inch of rain at each intensity is shown in table 19. The energy of a given storm depends on all the intensities at which the rain occurred and the amount that occurred at each intensity. A recording-rain gage record of the storm will provide this information. Clock time and rain depth are read from the chart at each point where the slope of the pen line changes and are tabulated as shown in the first two columns of the sample computation below. Clock times (col. 1) are subtracted to obtain the time intervals given in column 3, and the depths (col. 2) are subtracted to obtain the incremental amounts tabulated in column 4. The intensity for each increment (col. 5) is the incremental amount times 60, divided by column 3.

Chart readings		For each increment			Energy	
Time	Depth (inch)	Duration (minute)	Amount (inch)	Intensity (in/hr)	Per inch	Total
4:00	0					
:20	0.05	20	0.05	0.15	643	32
:27	.12	7	.07	.60	843	59
:36	.35	9	.23	1.53	977	225
:50	1.05	14	.70	3.00	1074	752
:57	1.20	7	.15	1.29	953	143
5:05	1.25	8	.05	.38	777	39
:15	1.25	20	0	0	0	0
:30	1.30	15	.05	.20	685	34
Totals		90	1.30			1,284

Kinetic energy of the storm $= 1{,}284(10^{-2}) = 12.84$

The energy per inch of rain in each interval (col. 6) is obtained by entering table 19 with the intensity given in column 5. The incremented energy amounts (col. 7) are products of columns 4 and 6. The total energy for this 90-minute rain is 1,284 foot-tons per acre. This is multiplied by a constant factor of 10^{-2} to convert the storm energy to the dimensions in which **EI** values are expressed.

The maximum amount of rain falling within 30 consecutive minutes was 1.08 in, from 4:27 to 4:57. I_{30} is twice 1.08, or 2.16 in/h. The storm **EI** value is $12.84(2.16) = 27.7$. When the duration of a storm is less than 30 minutes, I_{30} is twice the amount of the rain.

The **EI** for a specified time is the sum of the computed values for all significant rain periods within that time. The average annual erosion index for a specific locality, as given in figures 1 and 2, is the sum of all the significant storm **EI** values over 20 to 25 years, divided by the number of years. For erosion index calculations, 6 h or more with less than 0.5 in of precipitation was defined as a break between storms. Rains of less than 0.5 in, separated from other showers by 6 h or more, were omitted as insignificant unless the maximum 15-min intensity exceeded 0.95 in/h.

Recent studies showed that the median dropsize of rain does not continue to increase for intensities greater than about 2.5 to 3 in/h (7, 15). Therefore, energy per unit of rainfall also does not continue to increase, as was assumed in the derivation of the energy-intensity table published in 1958 (62). The value given in table 19 for rain at 3 in/h (7.6 cm/h in table 20) should be used for all greater intensities. Also, analysis of the limited soil loss data available for occasional storms with 30-min intensities greater than 2.5 in/h showed that placing a limit of 2.5 in (6.35 cm)/h on the I_{30} component of **EI** improved prediction accuracy for these storms. Both of these limits were applied in the development of figure 1. They slightly lowered previously computed erosion index values in the Southeast, but average-annual **EI** values for the U.S. mainland other than the Southeast were not significantly affected by the limits because they are rarely exceeded.

Conversion to Metric System

Metric equivalents were not included in the procedures and tables presented in this handbook because direct conversion of each English unit would produce numbers that would be awkward and undesirable. Converting the USLE as a whole is more appropriate. Metric units can then be selected so that each of the interdependent factors will have a metric counterpart whose values will be expressed in numbers that are easy to visualize and to combine in computations.

A convenient unit for measuring cropland soil losses is metric tons per hectare per year. **EI** values of convenient magnitude can be obtained by expressing rainfall energy in metric ton-meters per hectare, expressing intensities in centimeters per hour, and retaining the constant factor of 10^{-2} that has been used consistently for **EI** calculations in English units. Factor **K** will then be in metric tons per hectare per metric **EI** unit. If 22 meters is taken as the basic slope length and 9 percent is retained as the basic slope gradient, the **LS** factor will not be significantly affected. Using these units is recommended and is assumed in the following paragraphs.

The USLE factors will normally be derived directly in these units by procedures outlined below. However, the following conversion factors will facilitate comparisons of the metric factor values with the English values published in this handbook. Factors expressed in the recommended metric units are identified by the subscript, **m**.

Text continues on page 56.

TABLE 17.—*Observed range and 50-, 20-, and 5- percent probability values of erosion index at each of 181 key locations*

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
Alabama:				
Birmingham	179-601	354	461	592
Mobile	279-925	673	799	940
Montgomery	164-780	359	482	638
Arkansas:				
Fort Smith	116-818	254	400	614
Little Rock	103-625	308	422	569
Mountain Home	98-441	206	301	432
Texarkana	137-664	325	445	600
California:				
Red Bluff	11-240	54	98	171
San Luis Obispo	5-147	43	70	113
Colorado:				
Akron	8-247	72	129	225
Pueblo	5-291	44	93	189
Springfield	4-246	79	138	233
Connecticut:				
Hartford	65-355	133	188	263
New Haven	66-373	157	222	310
District of Columbia	84-334	183	250	336
Florida:				
Apalachicola	271-944	529	663	820
Jacksonville	283-900	540	693	875
Miami	197-1225	529	784	1136
Georgia:				
Atlanta	116-549	286	377	488
Augusta	148-476	229	308	408
Columbus	215-514	336	400	473
Macon	117-493	282	357	447
Savannah	197-886	412	571	780
Watkinsville[1]	182-544	278	352	441
Illinois:				
Cairo	126-575	231	349	518
Chicago	50-379	140	212	315
Dixon Springs[1]	89-581	225	326	465
Moline	80-369	158	221	303
Rantoul	73-286	152	201	263
Springfield	38-315	154	210	283
Indiana:				
Evansville	104-417	188	263	362
Fort Wayne	60-275	127	183	259
Indianapolis	60-349	166	225	302
South Bend	43-374	137	204	298
Terre Haute	81-413	190	273	389
Iowa:				
Burlington	65-286	162	216	284
Charles City	39-308	140	205	295
Clarinda[1]	75-376	162	220	295
Des Moines	30-319	136	198	284
Dubuque	54-389	175	251	356
Sioux City	56-336	135	205	308
Rockwell City	40-391	137	216	335
Kansas:				
Burlingame	57-447	176	267	398
Coffeyville	66-546	234	339	483
Concordia	38-569	131	241	427
Dodge City	16-421	98	175	303
Goodland	10-166	76	115	171
Hays[1]	66-373	116	182	279
Wichita	42-440	188	292	445
Kentucky:				
Lexington	54-396	178	248	340
Louisville	84-296	168	221	286
Middlesboro	107-301	154	197	248
Louisiana:				
Lake Charles	200-1019	572	786	1063
New Orleans	273-1366	721	1007	1384
Shreveport	143-707	321	445	609
Maine:				
Caribou	26-120	58	79	106
Portland	36-241	91	131	186
Skowhegan	39-149	78	108	148
Maryland:				
Baltimore	50-388	178	263	381
Massachusetts:				
Boston	39-366	99	159	252
Washington	65-229	116	153	198
Michigan:				
Alpena	14-124	57	85	124
Detroit	56-179	100	134	177
East Lansing	35-161	86	121	166
Grand Rapids	33-203	84	123	178
Minnesota:				
Alexandria	33-301	88	147	240
Duluth	7-227	84	127	189
Fosston	22-205	62	108	184
Minneapolis	19-173	94	135	190
Rochester	46-338	142	207	297
Springfield	37-290	96	154	243
Mississippi:				
Meridian	216-820	416	557	737
Oxford	131-570	310	413	543
Vicksburg	165-786	365	493	658
Missouri:				
Columbia	98-419	214	297	406
Kansas City	28-361	170	248	356
McCredie[1]	64-410	189	271	383
Rolla	105-415	209	287	387
Springfield	97-333	199	266	352
St. Joseph	50-359	178	257	366
St. Louis	59-737	168	290	488
Montana:				
Billings	2-82	12	26	50
Great Falls	3-62	13	24	44
Miles City	1-101	21	40	72
Nebraska				
Antioch	18-131	60	86	120
Lincoln	44-289	133	201	299
Lynch	34-217	96	142	205
North Platte	14-236	81	136	224
Scribner	69-312	154	205	269
Valentine	4-169	64	100	153

See footnote at end of table.

TABLE 17.—*Observed range and 50-, 20-, and 5- percent probability values of erosion index at each of 181 key locations*—Continued

Location	Values of erosion index (*EI*)			
	Observed 22-year range	50-percent probability	20-percent probability	5-percent probability
New Hampshire:				
Concord	52-212	91	131	187
New Jersey:				
Atlantic City	71-318	166	229	311
Marlboro[1]	58-331	186	254	343
Trenton	37-382	149	216	308
New Mexico:				
Albuquerque	0-46	10	19	35
Roswell	5-159	41	73	128
New York:				
Albany	40-172	81	114	159
Binghamton	20-151	76	106	146
Buffalo	20-148	66	96	139
Geneva[1]	33-180	73	106	152
Marcellus[1]	24-241	74	112	167
Rochester	22-180	66	101	151
Salamanca	31-202	70	106	157
Syracuse	8-219	83	129	197
North Carolina:				
Asheville	76-238	135	175	223
Charlotte	113-526	229	322	443
Greensboro	102-357	184	244	320
Raleigh	152-569	280	379	506
Wilmington	196-701	358	497	677
North Dakota:				
Bismarck	9-189	43	73	120
Devils Lake	21-171	56	90	142
Fargo	5-213	62	113	200
Williston	4-71	30	45	67
Ohio:				
Cincinnati	66-352	146	211	299
Cleveland	21-186	93	132	185
Columbiana	29-188	96	129	173
Columbus	45-228	113	158	216
Coshocton[1]	72-426	158	235	343
Dayton	56-245	125	175	240
Toledo	32-189	83	120	170
Oklahoma:				
Ardmore	100-678	263	395	582
Cherokee[1]	49-320	167	242	345
Guthrie[1]	69-441	210	316	467
McAlester	105-741	272	411	609
Tulsa	19-584	247	347	478
Oregon:				
Pendleton	2-28	4	8	16
Portland	16-80	40	56	77
Pennsylvania:				
Erie	11-534	96	181	331
Franklin	50-228	97	135	184
Harrisburg	48-232	105	146	199
Philadelphia	72-361	156	210	282
See footnote at end of table.				
Pittsburgh	43-201	111	148	194
Reading	84-308	144	204	285
Scranton	52-198	104	140	188
Puerto Rico:				
San Juan	203-577	345	445	565
Rhode Island:				
Providence	53-225	119	167	232
South Carolina:				
Charleston	174-1037	387	559	795
Clemson[1]	138-624	280	384	519
Columbia	81-461	213	298	410
Greenville	130-589	249	350	487
South Dakota:				
Aberdeen	19-295	74	129	219
Huron	18-145	60	91	136
Isabel	16-141	48	78	125
Rapid City	10-140	37	64	108
Tennessee:				
Chattanooga	163-468	269	348	445
Knoxville	64-370	173	239	325
Memphis	139-595	272	384	536
Nashville	116-381	198	262	339
Texas:				
Abilene	27-554	146	253	427
Amarillo	33-340	110	184	299
Austin	59-669	270	414	624
Brownsville	46-552	267	386	549
Corpus Christi	124-559	237	330	451
Dallas	93-630	263	396	586
Del Rio	19-405	121	216	374
El Paso	4-85	18	36	67
Houston	176-1171	444	674	1003
Lubbock	17-415	82	158	295
Midland	35-260	82	139	228
Nacogdoches	153-769	401	571	801
San Antonio	77-635	220	353	556
Temple[1]	81-644	261	379	542
Victoria	108-609	265	385	551
Wichita Falls	79-558	196	298	447
Vermont:				
Burlington	33-270	72	114	178
Virginia:				
Blacksburg[1]	81-245	126	168	221
Lynchburg	64-366	164	232	324
Richmond	102-373	208	275	361
Roanoke	78-283	129	176	237
Washington:				
Pullman[1]	1-30	6	12	21
Spokane	1-19	7	11	17
West Virginia:				
Elkins	43-223	118	158	209
Huntington	56-228	127	173	233
Parkersburg	69-303	120	165	226
Wisconsin:				
Green Bay	17-148	77	107	147
LaCrosse[1]	61-385	153	228	331
Madison	38-251	118	171	245
Milwaukee	31-193	93	139	202
Rice Lake	24-334	122	202	327
Wyoming:				
Casper	1-24	9	15	26
Cheyenne	8-66	28	43	66

[1] Computations based on SEA rainfall records. All others are based on Weather Bureau records.

TABLE 18.—*Expected magnitudes of single-storm erosion index values*

Location	Index values normally exceeded once in—				
	year 1	years 2	years 5	years 10	years 20
Alabama:					
Birmingham	54	77	110	140	170
Mobile	97	122	151	172	194
Montgomery	62	86	118	145	172
Arkansas:					
Fort Smith	43	65	101	132	167
Little Rock	41	69	115	158	211
Mountain Home	33	46	68	87	105
Texarkana	51	73	105	132	163
California:					
Red Bluff	13	21	36	49	65
San Luis Obispo	11	15	22	28	34
Colorado:					
Akron	22	36	63	87	118
Pueblo	17	31	60	88	127
Springfield	31	51	84	112	152
Connecticut:					
Hartford	23	33	50	64	79
New Haven	31	47	73	96	122
District of Columbia	39	57	86	108	136
Florida:					
Apalachicola	87	124	180	224	272
Jacksonville	92	123	166	201	236
Miami	93	134	200	253	308
Georgia:					
Atlanta	49	67	92	112	134
Augusta	34	50	74	94	118
Columbus	61	81	108	131	152
Macon	53	72	99	122	146
Savannah	82	128	203	272	358
Watkinsville	52	71	98	120	142
Illinois:					
Cairo	39	63	101	135	173
Chicago	33	49	77	101	129
Dixon Springs	39	56	82	105	130
Moline	39	50	89	116	145
Rantoul	27	39	56	69	82
Springfield	36	52	75	94	117
Indiana:					
Evansville	26	38	56	71	86
Fort Wayne	24	33	45	56	65
Indianapolis	29	41	60	75	90
South Bend	26	41	65	86	111
Terre Haute	42	57	78	96	113
Iowa:					
Burlington	37	48	62	72	81
Charles City	33	47	68	85	103
Clarinda	35	48	66	79	94
Des Moines	31	45	67	86	105
Dubuque	43	63	91	114	140
Rockwell City	31	49	76	101	129
Sioux City	40	58	84	105	131
Kansas:					
Burlingame	37	51	69	83	100
Coffeyville	47	69	101	128	159
Concordia	33	53	86	116	154
Dodge City	31	47	76	97	124
Goodland	26	37	53	67	80
Hays	35	51	76	97	121
Wichita	41	61	93	121	150
Kentucky:					
Lexington	28	46	80	114	151
Louisville	31	43	59	72	85
Middlesboro	28	38	52	63	73
Louisiana:					
New Orleans	104	149	214	270	330
Shreveport	55	73	99	121	141
Maine:					
Caribou	14	20	28	36	44
Portland	16	27	48	66	88
Skowhegan	18	27	40	51	63
Maryland:					
Baltimore	41	59	86	109	133
Massachusetts:					
Boston	17	27	43	57	73
Washington	29	35	41	45	50
Michigan:					
Alpena	14	21	32	41	50
Detroit	21	31	45	56	68
East Lansing	19	26	36	43	51
Grand Rapids	24	28	34	38	42
Minnesota:					
Duluth	21	34	53	72	93
Fosston	17	26	39	51	63
Minneapolis	25	35	51	65	78
Rochester	41	58	85	105	129
Springfield	24	37	60	80	102
Mississippi:					
Meridian	69	92	125	151	176
Oxford	48	64	86	103	120
Vicksburg	57	78	111	136	161
Missouri:					
Columbia	43	58	77	93	107
Kansas City	30	43	63	78	93
McCredie	35	55	89	117	151
Rolla	43	63	91	115	140
Springfield	37	51	70	87	102
St. Joseph	45	62	86	106	126
Montana:					
Great Falls	4	8	14	20	26
Miles City	7	12	21	29	38
Nebraska:					
Antioch	19	26	36	45	52
Lincoln	36	51	74	92	112
Lynch	26	37	54	67	82
North Platte	25	38	59	78	99
Scribner	38	53	76	96	116
Valentine	18	28	45	61	77

TABLE 18.—*Expected magnitudes of single-storm erosion index values*—Continued

Location	Index values normally exceeded once in—				
	1 year	2 years	5 years	10 years	20 years
New Hampshire:					
Concord	18	27	45	62	79
New Jersey:					
Atlantic City	39	55	77	97	117
Marlboro	39	57	85	111	136
Trenton	29	48	76	102	131
New Mexico:					
Albuquerque	4	6	11	15	21
Roswell	10	21	34	45	53
New York:					
Albany	18	26	38	47	56
Binghamton	16	24	36	47	58
Buffalo	15	23	36	49	61
Marcellus	16	24	38	49	62
Rochester	13	22	38	54	75
Salamanca	15	21	32	40	49
Syracuse	15	24	38	51	65
North Carolina:					
Asheville	28	40	58	72	87
Charlotte	41	63	100	131	164
Greensboro	37	51	74	92	113
Raleigh	53	77	110	137	168
Wilmington	59	87	129	167	206
North Dakota:					
Devils Lake	19	27	39	49	59
Fargo	20	31	54	77	103
Williston	11	16	25	33	41
Ohio:					
Cincinnati	27	36	48	59	69
Cleveland	22	35	53	71	86
Columbiana	20	26	35	41	48
Columbus	27	40	60	77	94
Coshocton	27	45	77	108	143
Dayton	21	30	44	57	70
Toledo	16	26	42	57	74
Oklahoma:					
Ardmore	46	71	107	141	179
Cherokee	44	59	80	97	113
Guthrie	47	70	105	134	163
McAlester	54	82	127	165	209
Tulsa	47	69	100	127	154
Oregon:					
Portland	6	9	13	15	18
Pennsylvania:					
Franklin	17	24	35	45	54
Harrisburg	19	25	35	43	51
Philadelphia	28	39	55	69	81
Pittsburgh	23	32	45	57	67
Reading	28	39	55	68	81
Scranton	23	32	44	53	63
Puerto Rico:					
San Juan	57	87	131	169	216
Rhode Island:					
Providence	23	34	52	68	83
South Carolina:					
Charleston	74	106	154	196	240
Clemson	51	73	106	133	163
Columbia	41	59	85	106	132
Greenville	44	65	96	124	153
South Dakota:					
Aberdeen	23	35	55	73	92
Huron	19	27	40	50	61
Isabel	15	24	38	52	67
Rapid City	12	20	34	48	64
Tennessee:					
Chattanooga	34	49	72	93	114
Knoxville	25	41	68	93	122
Memphis	43	55	70	82	91
Nashville	35	49	68	83	99
Texas:					
Abilene	31	49	79	103	138
Amarillo	27	47	80	112	150
Austin	51	80	125	169	218
Brownsville	73	113	181	245	312
Corpus Christi	57	79	114	146	171
Dallas	53	82	126	166	213
Del Rio	44	67	108	144	182
El Paso	6	9	15	19	24
Houston	82	127	208	275	359
Lubbock	17	29	53	77	103
Midland	23	35	52	69	85
Nacogdoches	77	103	138	164	194
San Antonio	57	82	122	155	193
Temple	53	78	123	162	206
Victoria	59	83	116	146	178
Wichita Falls	47	63	86	106	123
Vermont:					
Burlington	15	22	35	47	58
Virginia:					
Blacksburg	23	31	41	48	56
Lynchburg	31	45	66	83	103
Richmond	46	63	86	102	125
Roanoke	23	33	48	61	73
Washington:					
Spokane	3	4	7	8	11
West Virginia:					
Elkins	23	31	42	51	60
Huntington	18	29	49	69	89
Parkersburg	20	31	46	61	76
Wisconsin:					
Green Bay	18	26	38	49	59
LaCrosse	46	67	99	125	154
Madison	29	42	61	77	95
Milwaukee	25	35	50	62	74
Rice Loke	29	45	70	92	119
Wyoming:					
Casper	4	7	9	11	14
Cheyenne	9	14	21	27	34

Note: These conversions are incorrect. Refer to the supplement for corrections.

$$\begin{aligned} 1\ \text{t/ha} &= 2.242\ \text{tons per acre} \\ 1\ \text{t-m/ha/cm} &= 0.269\ \text{ft-tons per acre per inch} \\ 1\ E_m &= 0.683\ E \\ 1\ I_{30m} &= 2.54\ I_{30} \\ 1\ (EI)_m &= 1.735\ EI \\ 1\ K_m &= 1.292\ K \end{aligned} \qquad (7)$$

Factor R. The procedure for computing $(\mathbf{EI})_m$ for a given rain period is similar to that described in the preceding section for computation of **EI**, but the input data will be in different units. If the rain gage chart used for the preceding example had been calibrated in millimeters, the computation would have been as follows:

Chart readings		Storm increments			Energy	
Time	Depth *(mm)*	Duration *(min)*	Amount *(cm)*	Intensity *(cm/h)*	Per cm	For increment
4:00	0					
:20	1.2	20	0.12	0.36	175	21
:27	3.0	7	.18	1.54	226	41
:36	8.8	9	.58	3.87	263	153
:50	26.6	14	1.78	7.68	289	514
:57	30.4	7	.38	3.26	256	97
5:05	31.7	8	.13	.98	220	29
:15	31.7	10	0	0	0	0
:30	33.0	15	.13	.52	184	24
Totals		90	3.30			879

Kinetic energy of the storm $= 879(10^{-2}) = 8.79$

TABLE 19.—*Kinetic energy of rainfall expressed in foot-tons per acre per inch of rain*[1]

Intensity inch per hour	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0	—	254	354	412	453	485	512	534	553	570
0.1	585	599	611	623	633	643	653	661	669	677
.2	685	692	698	705	711	717	722	728	733	738
.3	743	748	752	757	761	765	769	773	777	781
.4	784	788	791	795	798	801	804	807	810	814
.5	816	819	822	825	827	830	833	835	838	840
.6	843	845	847	850	852	854	856	858	861	863
.7	865	867	869	871	873	875	877	878	880	882
.8	884	886	887	889	891	893	894	896	898	899
.9	901	902	904	906	907	909	910	912	913	915
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
1	916	930	942	954	964	974	984	992	1000	1008
2	1016	1023	1029	1036	1042	1048	1053	1059	1064	1069
3	[2]1074									

[1] Computed by the equation, $E = 916 + 331 \log_{10} I$, where E = kinetic energy in foot-tons per acre per inch of rain, and I = rainfall intensity in inches per hour.

[2] The 1074 value also applies for all intensities greater than 3 in/h (see text).

TABLE 20.—*Kinetic energy of rainfall expressed in metric ton-meters per hectare per centimeter of rain*[1]

Intensity cm/h	.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
0	0	121	148	163	175	184	191	197	202	206
1	210	214	217	220	223	226	228	231	233	235
2	237	239	241	242	244	246	247	249	250	251
3	253	254	255	256	258	259	260	261	262	263
4	264	265	266	267	268	268	269	270	271	272
5	273	273	274	275	275	276	277	278	278	279
6	280	280	281	281	282	283	283	284	284	285
7	286	286	287	287	288	288	[2]289			

[1] Computed by the equation $E = 210 + 89 \log_{10} I$,
where E = kinetic energy in metric-ton meters per hectare per centimeter of rain, and
I = rainfall intensity in centimeters per hour.

[2] The 289 value also applies for all intensities greater than 7.6 cm/h.

Values for column 6 are obtained by entering table 20 with the intensities listed in column 5, and their sum, 879, is the kinetic energy ($\mathbf{E}_m$) of the 3.30 cm of rain expressed in metric ton-meters per hectare. The constant factor of 10^{-2} used for the English system should be applied here also so that storm $(\mathbf{EI})_m$ values will usually not exceed 100. The maximum amount of rain in any 30-minute period was 2.74 cm, from 4:27 to 4:57. Therefore $\mathbf{I}_{30m} = 2(2.74 = 5.48$ cm/h. $(\mathbf{EI})_m = 8.79(5.48) = 48.17$

The procedure for combining storm **EI** values for local erosion index values was fully described in the preceding section. For predicting average annual soil losses from rainfall and its associated runoff, **R** equals the erosion index. Where runoff from thaw, snowmelt, or irrigation is significant, an $\mathbf{R}_s$ factor must be added to the **EI** value as previously discussed.

Where adequate rainfall intensity data are not available, the erosion index cannot be estimated solely from annual precipitation data. It is a function of the sizes and intensities of the individual rainstorms, and these are not closely related to annual precipitation. Therefore a given annual rainfall will indicate only a broad range of possible values of the local erosion index. However, the United States data indicate that the range of likely values can be somewhat narrowed by knowledge of the general climatic conditions in the particular geographic area.

In the U.S. Northern and Northeastern States, the winter precipitation generally comes as snow and low-intensity rains, but erosive intensities occur during the spring and summer. There, the local erosion index values, $(\mathbf{EI})_m$, have ranged from **2P**-52 to 2.6**P**, where **P** is the average annual precipitation expressed in centimeters. In several Northwestern States, where rain intensities rarely exceed 2.5 cm/h, the annual $(\mathbf{EI})_m$ is generally less than **P**, but $\mathbf{R}_s$ values are high. Near the Gulf of Mexico and along the southern half of the Atlantic Coast, the rainfall characteristics are substantially influenced by coastal storms, 24-h rainfall exceeds 10 cm at least once in 2 years, on the average, and erosive rains occur in nearly every month of the year. There, erosion index values range between 4.2**P** and 6.7**P**. Values computed from the few long-term, recording-raingage records available for the islands of Hawaii and Puerto Rico were also within this range. In the large region between the northern and southern extremes mentioned above, the annual $(\mathbf{EI})_m$ values range from 2.5**P** to 4.5**P**. Brief, high-intensity thunderstorms are common in this region during the summer months, but general rains of longer duration also occur.

Where data are adequate to determine 2-year probabilities of 6-hour rainfall, these probabilities may provide more specific estimates of the local erosion index values. In the U.S. data, local erosion index values were approximately equal to the quantity 27.38 $\mathbf{P}^{2.17}$, where $\mathbf{P} =$ the 2-year, 6-hour precipitation in inches. Converted to the recommended metric units, $(\mathbf{EI})_m$ equals approximately 6.28$\mathbf{P}^{2.17}$, where **P** is expressed in centimeters. However, this estimating procedure should not be substituted for the standard erosion index calculation procedure where adequate intensity data are available.

Factor K. This factor is the average soil loss in metric tons per hectare per unit of $(\mathbf{EI})_m$, measured on unit plots of the given soil. A unit plot is a 22-m length of uniform 9 percent slope that has been in clean fallow for more than 2 years and is tilled to prevent vegetative growth and surface crusting during the period of soil loss measurement. If a gradient other than 9 percent must be used, the data are adjusted by an **LS** factor available from figure 11. If the soil-erodibility nomograph (fig. 3) is used to evaluate $\mathbf{K}_m$, the **K** value read from the nomograph is multiplied by a conversion factor of 1.292.

The most accurate direct measurement of **K** for a given soil is obtained by measuring soil losses from unit plots under natural rain for at least 5 years, beginning 2 years after the clean-fallow condition was established. This permits averaging the interactions of soil erodibility with antecedent soil moisture, storm size, and other randomly distributed variables. The fallow plots receive the same annual tillage as conventionally tilled row crops.

Using rainfall simulators to evaluate **K** is quicker and less costly, but it requires caution. A one-time simulator test, even though replicated on several plots, measures soil loss from only one storm size and rain intensity, on one set of antecedent conditions, and these may or may not represent natural rainfall patterns. When simulated rainfall is used to evaluate **K**, measuring the soil losses for four or five successive 30-minute periods is helpful so that the segmented data can be rearranged to represent small, intermediate, and large storms beginning at various antecedent soil moisture levels. These can be weighted according to their probability of occurrence in natural rainfall (*58*).

Factor LS. Selecting 22 m as the basic slope length and retaining 9 percent as the basic slope gradient leaves the **LS** values essentially unchanged from those used in the English system of units. For uniform slopes, **LS** may be obtained by entering figure 11 with the field slope length expressed in meters. For concave or convex slopes, the value read from figure 11 should be modified by the procedure given in the subsection **Irregular Slopes.**

Factors C and P. Soil loss ratios (table 5) and **P** values (tables 13, 14, 15) are not affected by the units selected for the other factors. However, in countries where crops and farming techniques are different from those reflected in table 5, measurements of soil loss reductions attainable with feasible changes in crop system, tillage methods, and residue management may merit priority over establishing **EI** and **K** values.

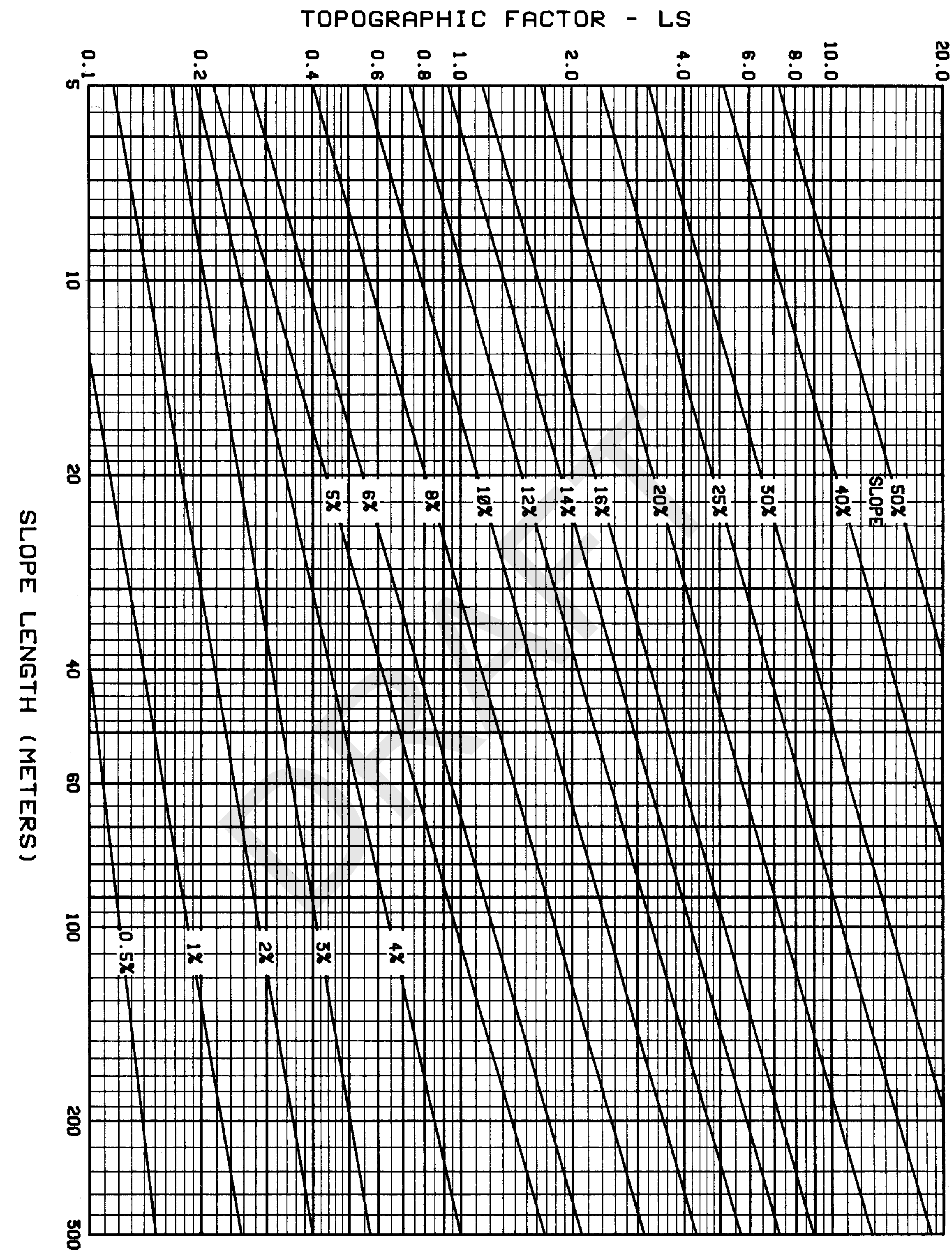


FIGURE 11.—Slope-effect chart for metric system.

☆U.S. GOVERNMENT PRINTING OFFICE: 1978 O—278-995/6583

AH-537, PREDICTING RAINFALL EROSION LOSSES— A GUIDE TO CONSERVATION PLANNING

note: ERRATA Jan. 1981

The following corrections and minor additions should be made with pen and ink in existing desk copies of AH-537. Corrected words or numbers have been identified by underlining. Additional footnotes that were added to clarify original content can be inserted in the lower margins of the indicated pages.

Page

4 Insert footnote symbol [4] after the definitions of **R** and **K** in column 1 and add footnote:

[4] The erosion index values in figures 1 and 2 and the EI values used in the text have the dimension 100 (foot-ton inch)/(acre hour). K values in tables 1 and 2 and figure 3 are in tons per acre per EI unit and have the dimensions 0.01 (ton acre hour)/(acre foot-ton inch).

---

5 Equation (2) $\underline{e} = 916 + 331 \log_{10} \underline{i}$,

where $\underline{e}$ is kinetic energy in foot-tons per acre-inch and $\underline{i}$ is intensity in in/h (62). A limit of 3 in/h is imposed on $\underline{i}$ . . .

---

9 column 2. Change footnote number from [4] to [5].

---

18 column 1. Change footnote number from [5] to [6].

---

19 column 1, last sentence. Insert footnote symbol [7] after "The expected effects of mulch and canopy combinations" and add footnote in lower margin:

[7] Figures 6 and 7 and table 5 assume that slope-length limits for full effectiveness of residue mulches at the stated rates are not exceeded. Beyond these limits, the subfactor for mulch effect approaches 1.0. The length limits vary inversely with mulch rate, runoff depth and velocity, but have not been precisely defined by research.

FIGURE 6 and 7. Change the ordinate labels from "SOIL-LOSS RATIO" to SUBFACTOR FOR EFFECT OF COVER.

---

23 TABLE 5, line 160. Change 50 percent to 10 percent and reduce the ratio for cropstage 1 from 56 to 28.

---

24 Add to footnote [4]: *See also* footnote [7], page 19.

Change footnote 13 to: Divide the winter-cover period into cropstages for the seeded cover and use lines 132-145.

---

32 TABLE 10. Corrected title: *Factor* **C** *for permanent pasture, range, idle land, or grazed woodland*[1]

Change second category of vegetative canopy to: Tall grass, weeds or bushes with average drop fall height of less than 3 ft.[5]

Footnote [1]: The listed C values assume that the vegetation and mulch are randomly distributed over the entire area.

For grazed woodland with high buildup of organic matter in the topsoil under permanent forest conditions, multiply the table values by 0.7.

For areas that have been mechanically disturbed by root plowing, implement traffic or other means, use table 5 or 12.

Footnote [4], G: cover at surface is grass, grasslike plants, or decaying compacted duff. (Delete "or litter at least 2 in deep")

Add footnote [5]: [5] The portion of a grass or weed cover that contacts the soil surface during a rainstorm and interferes with water flow over the soil surface is included in "cover at the surface." The remainder is included in canopy cover. Use table 5-B for nearly complete grass covers.

TABLE 11. 33
Second column heading: Delete "at least 2 in deep."

Footnote [1]: The references to table 6 should be to table 10, and the following may be added: For sites that are mechanically treated following harvest, use table 12.

TABLE 12, footnotes [4] and [5]. The references to tables 6 and 7 should be to tables 10 and 11, respectively. 34

TABLE 13, footnote [1]. Change the word "seedlings" to plantings. 35

TABLE 14, footnote [1]. C For alternate strips of row crop and winter grain. 36

---

column 2, line 6. 0.5 should be 0.05 in of precipitation . . . 51

centered heading. Insert footnote symbol [8] after **Conversion to Metric System** and add footnote in lower margin:

[8] See supplement for a recommended metrication of the USLE in the International System of Units (SI), which may be substituted for this section.

TABLES 19 and 20, footnotes. Change E to $\underline{e}$ and I to $\underline{i}$ in the energy equations. 56

Below the footnotes for table 20, insert the note: The table values multiplied by 9.81 would equal kilojoules of energy in the SI system.

UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURE HANDBOOK NUMBER 537

PREPARED BY SCIENCE AND EDUCATION ADMINISTRATION

Washington, D.C.

PREDICTING RAINFALL EROSION LOSSES— A GUIDE TO CONSERVATION PLANNING

(Co/42.)

U.S.D.A. **Supplement to Agriculture Handbook No. 537**

METRICATION OF THE USLE IN THE INTERNATIONAL SYSTEM OF UNITS (SI)

The metric conversion originally presented in this handbook and in prior publications (*53, 60*) is not completely in the International System of Units (SI), which is expected to gain widespread usage. This supplement presents an alternative conversion in which all the Universal Soil Loss Equation (USLE) factors are expressed in standard SI units or approved multiples thereof, and the order of magnitude of each new unit is similar to the old.

Both conversion systems are authentic, and conservationists who have adopted the originally recommended metric units would not improve their USLE accuracy by changing to the new units. For future conversions, however, the revised procedure, which is fully outlined below, is recommended because its use will facilitate standardization of units.

The USLE terms **A, LS, C,** and **P** need no change from the recommendations in the preceding section. Strictly, the **SI** units for mass and area are kilograms and square meters. Because of common use, however, metric ton (a special name for megagram) and hectare (a special name for square hectometer) will be used. Soil loss (**A**) wil be expressed in metric tons per hectare, and factor **K** in metric tons per hectare per metric **EI** unit. Factors **LS, C,** and **P** are dimensionless. **L** is expressed relative to slope lengths measured in meters, but selecting 22 m as the basic slope length and retaining 9 percent as the basic slope gradient leaves the **LS** values essentially unchanged. **C** and **P** are not affected by the units selected for the other factors.

Factor **R** will be in different units than previously recommended. In the **SI** system, energy is measured in joules and rainfall in millimeters. The use of "centi" as a multiple is minimized. Metric **EI** values can be obtained in standard **SI** units by expressing rainfall energy in megajoules (**MJ**) per hectare and maximum 30-minute intensity (I_{30}) in mm/h, but use of cm/h to express I_{30} is more expedient for the following reasons: With I_{30} expressed in mm/h, the metric **EI** values would be 17 times the magnitude of **EI** in U.S. customary units. Annual erosion index values would be in four- or five-digit numbers, which are harder to visualize and compare mentally than the present smaller numbers. Of greater importance, the large metric **EI** values would result in extremely small metric **K** values, ranging downward from a maximum of about 0.09. Absolute differences between **K** values would be so small that many casual users of the USLE would tend to neglect important soil differences as insignificant.

Reducing the magnitude of I_{30} by a factor of 10 alleviates these disadvantages and does not preclude the use of mm as the unit for rainfall amounts and incremental intensities in energy computations. The energy equation or table will also be expressed in MJ/ha per mm of rain. Only I_{30} will be converted to cm as a matter of expedience. This is directly comparable to the U.S. customary procedure of computing energy in ft-tons/acre and dividing by 100 to obtain more convenient magnitudes. The metric **EI** will then equal storm energy in MJ/ha times I_{30} in cm/h.

Assuming use of the metric units specified above, a comparison of U.S. customary and **SI** dimensions for the terms in the USLE is as follows:

Term	*US customary dimensions*	*SI dimensions*	*Symbol*
A	ton/acre	metric ton/hectare	t/ha
R	$\frac{\text{100 foot-ton inch}}{\text{acre hour}}$	$\frac{\text{megajoule centimeter}}{\text{hectare hour}}$	$\frac{\text{MJ cm}}{\text{ha h}}$
K	$\frac{\text{.01 ton acre hour}}{\text{acre foot-ton inch}}$	$\frac{\text{metric ton hectare hour}}{\text{hectare megajoule centimeter}}$	$\frac{\text{t ha h}}{\text{ha MJ cm}}$
L,S,C,P	dimensionless	dimensionless	

The USLE terms will usually be derived directly in the **SI** units by procedures outlined below. However, the following conversion factors will facilitate comparisons of the metric factor values with the U.S. customary values published in this handbook. Terms expressed in metric units are identified by the subscript $_m$.

To convert from:	*multiply by:*	*to obtain:*
A in tons/acre	2.242	A_m in t/ha
E in 100 ft-tons/acre	0.670	E_m in MJ/ha
I_{30} in in/h	2.540	I_{30m} in cm/h
EI in $\frac{\text{100 ft-ton in}}{\text{acre h}}$	1.702	$(EI)_m$ in $\frac{\text{MJ cm}}{\text{ha h}}$
K in $\frac{\text{.01 ton acre h}}{\text{acre ft-ton in}}$	1.313	K_m in $\frac{\text{t ha h}}{\text{MJ ha cm}}$

Page 56 revised

Factor R. The procedure for computing $(EI)_m$ for a given rain period is similar to that described in the preceding section for computing **EI**, but the input data will be in different units. If the raingage chart used for the example on page 51 had been calibrated in millimeters, the computation would have been as follows:

Chart readings		*Storm increments*			*Energy*	
Time	Depth (mm)	Duration (min)	Amount (mm)	Intensity (mm/h)	Per mm of rain (MJ/ha mm)	Increment total (MJ/ha)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
4:00	0					
:20	1	20	1	3	0.161	0.161
:27	3	7	2	17	.226	.452
:36	9	9	6	40	.259	1.554
:50	27	14	18	77	.283	5.094
:57	30	7	3	26	.242	.726
5:05	32	8	2	15	.222	.444
:15	32	10	0	0	0	0
:30	33	15	1	4	.172	.172
Totals		90	33			8.603

Kinetic energy of the storm: 8.60 MJ/ha

Values for column 6 are obtained by entering the revised table 20 with the intensities listed in column 5. The sum of the products of corresponding values from columns 4 and 6 (8.60) is the kinetic energy, E_m, of the 33 mm of rain expressed in megajoules per hectare. The maximum amount of rain in any 30-minute period was 27 mm, from 4:27 to 4:57. Therefore the maximum 30-minute intensity was 2×27, or 54, mm/h, and $I_{30m} = 54/10 = 5.4$ cm/h. $(EI)_m = 8.60 \times 5.4 = 46.4$ (MJ cm)/(ha h).

For the **EI** computations, the rain occurring between two successive periods of 6 hours or more with less than 1.3 mm (0.05 in) of precipitation is considered one storm. Rain showers of less than 12 mm are omitted as insignificant unless they include a 15-minute intensity of at least 25 mm/h. The erosion index at a given location, as mapped in figures 1 and 2, is the average annual total of storm **EI** values over 20 to 25 years. For predicting average annual soil losses from rainfall and its associated runoff, **R** equals the erosion index. Where runoff from thaw, snowmelt, or irrigation is significant, **R** equals the **EI** plus an R_s value as discussed on page 7.

The erosion index cannot be reliably estimated from annual-rainfall data alone. It is a function of the sizes and intensities of the individual rainstorms, and these have no common relationship to annual rainfall totals. However, later analyses of the U.S. annual erosion index values that had been derived by the above procedure indicated that they were roughly equal to the quantity $27.38\ P^{2.17}$, where P = the 2-year, 6-hour rainfall expressed in inches. By direct conversion, the average annual $(EI)_m$ would be roughly estimated by $0.0416\ P^{2.17}$, where P is expressed in mm. This estimating formula is appreciably less accurate than the standard erosion index calculation procedure and should not be substituted for it where intensity data are available.

Factor K. The soil-erodibility factor **K** is the average soil loss in metric tons per hectare per unit of metric **EI**, measured on unit plots of the given soil. A unit plot (see p. 8) is a 22-m length of uniform 9 percent slope that has been in clean fallow for more than 2 years and is tilled to prevent vegetative growth and surface crusting during the period of soil loss measurement. If a gradient other than 9 percent must be used, the data are adjusted by the appropriate **LS** factor. If the soil-erodibility nomograph (fig. 3) is used to evaluate K_m, the **K** value read from the nomograph must be multiplied by a conversion factor of 1.313.

The basic slope length used for **K** and **L** in this handbook is 72.6 ft, which equals 22.134 m. For experimental evaluation of factor **K** in metric units, rounding this to 22.0 m is more convenient and introduces no error when 22.0 m is also used as the basic length for **L**, as in figure 11. The slight reduction in basic length increases factor **L** by 0.3 of 1 percent and decreases factor **K** by the same percentage, so the product of **K** and **L** is unchanged. For conversion of the U.S. customary **K** values in this handbook to metric **K** values based on a 22.0 m length, the relatively insignificant potential error is avoided by including an **L**-value of 0.997 in the conversion factor. The **K**-conversion factor of 1.313 given above has been so adjusted.

Factor LS. The preceding paragraph applies here, also. For uniform slopes, **LS** may be obtained by entering figure 11 with the field slope length expressed in meters or it may be computed by the equation

$$LS = (\lambda/22)^m\ (65.41\ \sin^2\theta + 4.56\ \sin\theta + 0.065)$$

where λ = slope length in m; θ = angle of slope; and m = 0.5 if the percent slope is 5 or more, 0.4 on slopes of 3.5 to 4.5 percent, 0.3 on slopes of 1 to 3 percent, and 0.2 on uniform gradients of less than 1 percent. For concave, convex, or mixed-gradient slopes, the value so computed or read from figure 11 should be modified by the procedure outlined on page 16.

Factor C and P. Soil loss ratios (table 5) and **P** values (tables 13, 14, 15) are not affected by the units selected for the other factors and therefore need no conversion.

TABLE 20. (revised).—*Kinetic energy of rainfall at specified intensities, expressed in megajoules per hectare per millimeter of rain*[1]

Intensity (mm/h)	0	1	2	3	4	5	6	7	8	9
0 ..	0	0.119	0.145	0.161	0.172	0.180	0.187	0.193	0.198	0.202
10 ..	.206	.210	.213	.216	.219	.222	.224	.226	.229	.231
20 ..	.233	.234	.236	.238	.240	.241	.242	.244	.245	.247
30 ..	.248	.249	.250	.252	.253	.254	.255	.256	.257	.258
40 ..	.259	.260	.261	.262	.262	.263	.264	.265	.266	.267
50 ..	.267	.268	.269	.270	.270	.271	.272	.272	.273	.274
60 ..	.274	.275	.276	.276	.277	.277	.278	.278	.279	.280
70 ..	.280	.281	.281	.282	.282	.283	.283[2]			

[1] Computed by the equation $e = 0.119 - 0.0873 \log_{10} i$, where e = kinetic energy in megajoules/(hectare millimeter) and i = rainfall intensity in mm/h.

[2] The value of 0.283 also applies for all intensities greater than 76 mm/h.

ESTIMATING FACTOR C FOR AN UNUSUAL CONDITION OR CROP THAT IS NOT LISTED IN TABLES 5 through 5-D of Ag. Handbook No. 537.

W. H. Wischmeier, 11-13-79

Soil-loss ratios can sometimes be closely estimated by comparing characteristic conditions in each cropstage period with conditions associated with a crop and management that is listed in the table. The cropstage ratios may need to be selected from several lines rather than following one line across the table.

Another possible procedure is to multiply-together a number of subfactor values obtained from field observations, guided by the following information.

Benchmark values throughout table 5 were obtained from direct soil-loss measurements under conditions involving various combinations of the subfactors. However, study of the ratios obtained by this method suggested a number of underlying subfactor relationships that can help guide estimation of appropriate ratios for untested conditions or crops. Before using this procedure, please read carefully the background material on pages 18-21 of AH-537.

For each cropstage period, estimate the percentage of surface cover by canopy and the percentage of cover by mulch, using the definitions given on pages 18 & 19 and evaluating the two separately. Include expected volunteer vegetation in the estimates of cover if significant. Then, use the following guides to estimate a subfactor value for each of the listed sub-parameters:

1. Canopy without mulch. Enter Fig. 5 with percent canopy cover, move vertically to drop fall height, and read the subfactor value at the left.

2. Mulch without canopy. Enter Fig. 6 with the percent cover by mulch, move vertically to the line for zero percent canopy (upper curve), and read subfactor value at left.

3. Combination of canopy and mulch. Use the other curves of Fig. 6 or 7, interpolating between the lines.

4. Land-use residual. The greatest residual effect is from sod crops or longterm woodland. Obtain residual sod-effect subfactor from table 5-D. Virgin sod or woodland would be even more effective.

Some residual effect will be apparent on nearly any cropland. For continuous corn with residues removed annually before turnplowing, the residual factor seems to be about 0.82 to 0.86, depending on productivity level. (These are the values given for the SB period in lines 13-16 of table 5.) This is a good starting point from which to move with judgment. This subfactor is in addition to subfactors for residues incorporated or sod-effect when those are also applicable.

(continued, p.2)

5. Residues plowed-down annually by inversion plowing. Credit for this may be approximated by multiplying the number of tons of residue per acre plowed down annually by: 0.12 for periods F, SB and 1; by 0.09 for period 2; and by 0.06 for periods 3 and 4. The residue-incorporated subfactor is 1.0 minus this amount.

6. Residues incorporated in the upper few inches of soil by shallow non-inversion tillage. Estimate effect by multiplying tons of residue so incorporated annually by: 0.20 for periods SB and 1; 0.16 for period 2; 0.12 for period 3; and 0.06 for period 4. Subtract product from 1.0 to obtain subfactor.

7. Random surface roughness. The condition left by inversion plowing and several diskings (with residues removed) has a roughness factor of 1.0. Freshly plowed land would rate a roughness subfactor of from 0.8 to 0.5, depending on amount of residue, soil-moisture at time of plowing, and other conditions. Chiseled or disked land would fall between these extremes.

In all cases, the subfactor becomes larger for each successive cropstage period because of rainfall and tillage effects. It reaches a value of 1.0 no later than the end of cropstage 3 and in some cases appreciably sooner.

8. Detachability. Soil that receives no tillage or traffic gradually becomes less detachable by rainfall. No-till systems with crop residues on the surface seem to merit a detachability subfactor of about 0.7. This is in addition to the mulch factor and may vary with soil texture.

9. Orientation of residues. The mulch-effect curves of figures 6 and 7 are based on fairly uniform, random distribution of the mulch over the field. When residues are concentrated in strips by the harvester, the percent-cover is reduced. However, when the strips are across the slope, they are more effective than the reduced percent-cover would indicate. When the strips are across-slope, they can probably be evaluated as equivalent to the percent cover that they would have provided if they had been fairly uniformly distributed. See figure 10, page 50. However, this does not apply if the strips are up and down slope.

10. High population of close-growing stems (like wheat). More effective than canopy from spreading plants like corn or bushes.

When these guides have been used to estimate the listed subfactors for each cropstage period, the subfactors are multiplied together to compute the soil-loss ratios.

This procedure should not be used for conditions covered by table 5 and its supplements. The relationships given above are only approximate and will provide less accuracy than direct measurements such as used to develop the table.

Slope-length limits for effectiveness of moderate mulch rates and random roughness are of course also applicable with this procedure.

Fort Hood Military Installation – TA40	
Sampling Location: 39	
Photo Direction: North	
Date: 07/16/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA40	
Sampling Location: 39	
Photo Direction: East	
Date: 07/16/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA40

Sampling Location:
39

Photo Direction:
South

Date:
07/16/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA40

Sampling Location:
39

Photo Direction:
West

Date:
07/16/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA110	
Sampling Location: 54	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA110	
Sampling Location: 54	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA110	
Sampling Location: 54	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA110	
Sampling Location: 54	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43

Sampling Location: 36	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43

Sampling Location: 36	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA43

Sampling Location: 36	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43

Sampling Location: 36	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43	
Sampling Location: 59	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43	
Sampling Location: 59	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43

Sampling Location: 59	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA43

Sampling Location: 59	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA44</td></tr>
<tr><td>Sampling Location:
35</td><td rowspan="4">
</td></tr>
<tr><td>Photo Direction:
North</td></tr>
<tr><td>Date:
07/17/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – South</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA44</td></tr>
<tr><td>Sampling Location:
35</td><td rowspan="4">
</td></tr>
<tr><td>Photo Direction:
East</td></tr>
<tr><td>Date:
07/17/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – South</td></tr>
</table>

Fort Hood Military Installation – TA44

Sampling Location: 35	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA44

Sampling Location: 35	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA45

Sampling Location:
34

Photo Direction:
North

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA45

Sampling Location:
34

Photo Direction:
East

Date:
07/17/2019

GMU:
Western Maneuver Area – South

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA45	
Sampling Location: 34	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA45	
Sampling Location: 34	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA45	
Sampling Location: 53	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA45	
Sampling Location: 53	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA45

Sampling Location:
53

Photo Direction:
South

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA45

Sampling Location:
53

Photo Direction:
West

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA46

Sampling Location:
33

Photo Direction:
North

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA46

Sampling Location:
33

Photo Direction:
East

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA46	
Sampling Location: 33	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA46	
Sampling Location: 33	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA40	
Sampling Location: 38	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA40	
Sampling Location: 38	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA40

Sampling Location: 38	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA40

Sampling Location: 38	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41	
Sampling Location: 37	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41	
Sampling Location: 37	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41

Sampling Location: 37	
Photo Direction: South	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41

Sampling Location: 37	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA44

Sampling Location: 65	
Photo Direction: North	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA44

Sampling Location: 65	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA44

Sampling Location:
65

Photo Direction:
South

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA44

Sampling Location:
65

Photo Direction:
West

Date:
07/17/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA42

Sampling Location: 52	
Photo Direction: North	
Date: 07/17/2019	
Description:	

Fort Hood Military Installation – TA42

Sampling Location: 52	
Photo Direction: East	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA42

Sampling Location: 52	
Photo Direction: South	
Date: 07/17/2019	
Description:	

Fort Hood Military Installation – TA42

Sampling Location: 52	
Photo Direction: West	
Date: 07/17/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41

Sampling Location: 41	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41

Sampling Location: 41	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41	
Sampling Location: 41	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41	
Sampling Location: 41	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

CYPRESS

Fort Hood Military Installation – TA41	
Sampling Location: 40	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41	
Sampling Location: 40	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA41

Sampling Location:
40

Photo Direction:
South

Date:
07/18/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA41

Sampling Location:
40

Photo Direction:
West

Date:
07/18/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA63

Sampling Location: 18	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA63

Sampling Location: 18	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA63	
Sampling Location: 18	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA63	
Sampling Location: 18	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA60	
Sampling Location: 63	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA60	
Sampling Location: 63	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA60	
Sampling Location: 63	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA60	
Sampling Location: 63	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA61</td></tr>
<tr><td>Sampling Location:
26</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
North</td></tr>
<tr><td>Date:
07/18/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA61</td></tr>
<tr><td>Sampling Location:
26</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
East</td></tr>
<tr><td>Date:
07/18/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

Fort Hood Military Installation – TA61

Sampling Location: 26	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA61

Sampling Location: 26	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA61	
Sampling Location: 25	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA61	
Sampling Location: 25	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA61	
Sampling Location: 25	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA61	
Sampling Location: 25	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA65	
Sampling Location: 51	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 51	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA65	
Sampling Location: 51	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 51	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA42

Sampling Location: 64	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA42

Sampling Location: 64	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA42	
Sampling Location: 64	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA42	
Sampling Location: 64	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA52	
Sampling Location: 49	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 49	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 49	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 49	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 50	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 50	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA52</td></tr>
<tr><td>Sampling Location:
50</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
South</td></tr>
<tr><td>Date:
07/18/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA52</td></tr>
<tr><td>Sampling Location:
50</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
West</td></tr>
<tr><td>Date:
07/18/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

Fort Hood Military Installation – TA52

Sampling Location:
27

Photo Direction:
North

Date:
07/18/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA52

Sampling Location:
27

Photo Direction:
East

Date:
07/18/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA52

Sampling Location:
27

Photo Direction:
South

Date:
07/18/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA52

Sampling Location:
27

Photo Direction:
West

Date:
07/18/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA53	
Sampling Location: 28	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53	
Sampling Location: 28	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53	
Sampling Location: 28	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53	
Sampling Location: 28	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA64	
Sampling Location: 24	
Photo Direction: North	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA64	
Sampling Location: 24	
Photo Direction: East	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA64	
Sampling Location: 24	
Photo Direction: South	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA64	
Sampling Location: 24	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA65

Sampling Location:
23

Photo Direction:
North

Date:
07/18/2019

Description:

Fort Hood Military Installation – TA65

Sampling Location:
23

Photo Direction:
East

Date:
07/18/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA65

Sampling Location: 23	
Photo Direction: South	
Date: 07/18/2019	
Description:	

Fort Hood Military Installation – TA65

Sampling Location: 23	
Photo Direction: West	
Date: 07/18/2019	
GMU: Western Maneuver Area – North	

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA47</td></tr>
<tr><td>Sampling Location:
32</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
North</td></tr>
<tr><td>Date:
07/19/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – South</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA47</td></tr>
<tr><td>Sampling Location:
32</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
East</td></tr>
<tr><td>Date:
07/19/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – South</td></tr>
</table>

Fort Hood Military Installation – TA47	
Sampling Location: 32	
Photo Direction: South	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA47	
Sampling Location: 32	
Photo Direction: West	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA47	
Sampling Location: 1	
Photo Direction: North	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA47	
Sampling Location: 1	
Photo Direction: East	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA47

Sampling Location: 1	
Photo Direction: South	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA47

Sampling Location: 1	
Photo Direction: West	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA42

Sampling Location: 42	
Photo Direction: North	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA42

Sampling Location: 42	
Photo Direction: East	
Date: 07/19/2019	
GMU: Western Maneuver Area – South	

Fort Hood Military Installation – TA42

Sampling Location:
42

Photo Direction:
South

Date:
07/19/2019

GMU:
Western Maneuver Area – South

Fort Hood Military Installation – TA42

Sampling Location:
42

Photo Direction:
West

Date:
07/19/2019

GMU:
Western Maneuver Area – South

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA12	
Sampling Location: 13	
Photo Direction: North	
Date: 07/19/2019	
GMU: North Fort Hood	

Fort Hood Military Installation – TA12	
Sampling Location: 13	
Photo Direction: East	
Date: 07/19/2019	
GMU: North Fort Hood	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA12

Sampling Location: 13	
Photo Direction: South	
Date: 07/19/2019	
GMU: North Fort Hood	

Fort Hood Military Installation – TA12

Sampling Location: 13	
Photo Direction: West	
Date: 07/19/2019	
GMU: North Fort Hood	

Fort Hood Military Installation – TA20	
Sampling Location: 4	
Photo Direction: North	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA20	
Sampling Location: 4	
Photo Direction: East	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA20	
Sampling Location:	
Photo Direction: South	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA20	
Sampling Location: 4	
Photo Direction: West	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA22

Sampling Location:
67

Photo Direction:
North

Date:
07/19/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA22

Sampling Location:
67

Photo Direction:
East

Date:
07/19/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA22

Sampling Location:
67

Photo Direction:
South

Date:
07/19/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA22

Sampling Location:
67

Photo Direction:
West

Date:
07/19/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA23

Sampling Location: 19	
Photo Direction: North	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA23

Sampling Location: 19	
Photo Direction: East	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA23	
Sampling Location: 19	
Photo Direction: South	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA23	
Sampling Location: 19	
Photo Direction: West	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 2	
Photo Direction: North	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 2	
Photo Direction: East	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 2	
Photo Direction: South	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 2	
Photo Direction: West	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 22	
Photo Direction: North	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65	
Sampling Location: 22	
Photo Direction: East	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA65

<table>
<tr><td>Sampling Location:
22</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
South</td></tr>
<tr><td>Date:
07/19/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

Fort Hood Military Installation – TA65

<table>
<tr><td>Sampling Location:
22</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
West</td></tr>
<tr><td>Date:
07/19/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

Fort Hood Military Installation – TA66

Sampling Location: 21	
Photo Direction: North	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA66

Sampling Location: 21	
Photo Direction: East	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA66

Sampling Location: 21	
Photo Direction: South	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA66

Sampling Location: 21	
Photo Direction: West	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

CYPRESS Environmental Science & Engineering

Fort Hood Military Installation – TA62

Sampling Location: 61	
Photo Direction: North	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA62

Sampling Location: 61	
Photo Direction: East	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA62

Sampling Location: 61	
Photo Direction: South	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA62

Sampling Location: 61	
Photo Direction: West	
Date: 07/19/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA16

Sampling Location:
68

Photo Direction:
North

Date:
07/19/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA16

Sampling Location:
68

Photo Direction:
East

Date:
07/19/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA16	
Sampling Location: 68	
Photo Direction: South	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA16	
Sampling Location: 68	
Photo Direction: West	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA16	
Sampling Location: 14 **Photo Direction:** North **Date:** 07/19/2019 **GMU:** Eastern Training Area – North	

Fort Hood Military Installation – TA16	
Sampling Location: 14 **Photo Direction:** East **Date:** 07/19/2019 **GMU:** Eastern Training Area – North	

Fort Hood Military Installation – TA16

Field	Photo
Sampling Location: 14	
Photo Direction: South	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA16

Sampling Location: 14	
Photo Direction: West	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA15	
Sampling Location: 3	
Photo Direction: North	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA15	
Sampling Location: 3	
Photo Direction: East	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA15

Sampling Location: 3 **Photo Direction:** South **Date:** 07/19/2019 **GMU:** Eastern Training Area – North	

Fort Hood Military Installation – TA15

Sampling Location: 3 **Photo Direction:** West **Date:** 07/19/2019 **GMU:** Eastern Training Area – North	

Fort Hood Military Installation – TA24

Sampling Location: 6	
Photo Direction: North	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA24

Sampling Location: 6	
Photo Direction: East	
Date: 07/19/2019	
GMU: Eastern Training Area – North	

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA24</td></tr>
<tr><td>Sampling Location:
6</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
South</td></tr>
<tr><td>Date:
07/19/2019</td></tr>
<tr><td>GMU:
Eastern Training Area – North</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA24</td></tr>
<tr><td>Sampling Location:
6</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
West</td></tr>
<tr><td>Date:
07/19/2019</td></tr>
<tr><td>GMU:
Eastern Training Area – North</td></tr>
</table>

Fort Hood Military Installation – TA25

Sampling Location:
15

Photo Direction:
North

Date:
07/20/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA25

Sampling Location:
15

Photo Direction:
East

Date:
07/20/2019

GMU:
Eastern Training Area – North

Fort Hood Military Installation – TA25

Sampling Location: 15	
Photo Direction: South	
Date: 07/20/2019	
GMU: Eastern Training Area – North	

Fort Hood Military Installation – TA25

Sampling Location: 15	
Photo Direction: West	
Date: 07/20/2019	
GMU: Eastern Training Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA31	
Sampling Location: 5	
Photo Direction: North	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA31	
Sampling Location: 5	
Photo Direction: East	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA31	
Sampling Location: 5	
Photo Direction: South	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA31	
Sampling Location: 5	
Photo Direction: West	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA36

Sampling Location: 8	
Photo Direction: North	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA36

Sampling Location: 8	
Photo Direction: East	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA36

Sampling Location: 8	
Photo Direction: South	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA36

Sampling Location: 8	
Photo Direction: West	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA35	
Sampling Location: 7	
Photo Direction: North	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA35	
Sampling Location: 7	
Photo Direction: East	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA35

Sampling Location: 7	
Photo Direction: South	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA35

Sampling Location: 7	
Photo Direction: West	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA112

Sampling Location: 16 **Photo Direction:** North **Date:** 07/20/2019 **GMU:** Eastern Training Area – South	

Fort Hood Military Installation – TA112

Sampling Location: 16 **Photo Direction:** East **Date:** 07/20/2019 **GMU:** Eastern Training Area – South	

Fort Hood Military Installation – TA112	
Sampling Location: 16 **Photo Direction:** South **Date:** 07/20/2019 **GMU:** Eastern Training Area – South	

Fort Hood Military Installation – TA112	
Sampling Location: 16 **Photo Direction:** West **Date:** 07/20/2019 **GMU:** Eastern Training Area – South	

Fort Hood Military Installation – TA30

Sampling Location:
20

Photo Direction:
North

Date:
07/20/2019

GMU:
Eastern Training Area – South

Fort Hood Military Installation – TA30

Sampling Location:
20

Photo Direction:
East

Date:
07/20/2019

GMU:
Eastern Training Area – South

Fort Hood Military Installation – TA30

Sampling Location: 20	
Photo Direction: South	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA30

Sampling Location: 20	
Photo Direction: West	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA30</td></tr>
<tr><td>Sampling Location:
66</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
North</td></tr>
<tr><td>Date:
07/20/2019</td></tr>
<tr><td>GMU:
Eastern Training Area – South</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA30</td></tr>
<tr><td>Sampling Location:
66</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
East</td></tr>
<tr><td>Date:
07/20/2019</td></tr>
<tr><td>GMU:
Eastern Training Area – South</td></tr>
</table>

Fort Hood Military Installation – TA30	
Sampling Location: 66	
Photo Direction: South	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA30	
Sampling Location: 66	
Photo Direction: West	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA34

Sampling Location: 17	
Photo Direction: North	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA34

Sampling Location: 17	
Photo Direction: East	
Date: 07/20/2019	
GMU: Eastern Training Area – South	

Fort Hood Military Installation – TA34

Sampling Location:
17

Photo Direction:
South

Date:
07/20/2019

GMU:
Eastern Training Area – South

Fort Hood Military Installation – TA34

Sampling Location:
17

Photo Direction:
West

Date:
07/20/2019

GMU:
Eastern Training Area – South

Fort Hood Military Installation – TA71	
Sampling Location: 18	
Photo Direction: North	
Date: 07/20/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA71	
Sampling Location: 18	
Photo Direction: East	
Date: 07/20/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA71

Sampling Location:
18

Photo Direction:
South

Date:
07/20/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA71

Sampling Location:
18

Photo Direction:
West

Date:
07/20/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA71	
Sampling Location: 55	
Photo Direction: North	
Date: 07/20/2019	
GMU: West Fort Hood – Northeast	

Fort Hood Military Installation – TA71	
Sampling Location: 55	
Photo Direction: East	
Date: 07/20/2019	
GMU: West Fort Hood – Northeast	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA71	
Sampling Location: 55	
Photo Direction: South	
Date: 07/20/2019	
GMU: West Fort Hood – Northeast	

Fort Hood Military Installation – TA71	
Sampling Location: 55	
Photo Direction: West	
Date: 07/20/2019	
GMU: West Fort Hood – Northeast	

Fort Hood Military Installation – TA71

Sampling Location:
69

Photo Direction:
North

Date:
07/20/2019

GMU:
West Fort Hood – Northeast

Fort Hood Military Installation – TA71

Sampling Location:
69

Photo Direction:
East

Date:
07/20/2019

GMU:
West Fort Hood – Northeast

Fort Hood Military Installation – TA71

Sampling Location:
69

Photo Direction:
South

Date:
07/20/2019

GMU:
West Fort Hood – Northeast

Fort Hood Military Installation – TA71

Sampling Location:
69

Photo Direction:
West

Date:
07/20/2019

GMU:
West Fort Hood – Northeast

Fort Hood Military Installation – TA74

Sampling Location: 11	
Photo Direction: North	
Date: 07/21/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA74

Sampling Location: 11	
Photo Direction: East	
Date: 07/21/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA74

Sampling Location:
11

Photo Direction:
South

Date:
07/21/2019

GMU:
West Fort Hood – South

Fort Hood Military Installation – TA74

Sampling Location:
11

Photo Direction:
West

Date:
07/21/2019

GMU:
West Fort Hood – South

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA75	
Sampling Location: 47	
Photo Direction: North	
Date: 07/21/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75	
Sampling Location: 47	
Photo Direction: East	
Date: 07/21/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75	
Sampling Location: 47	
Photo Direction: South	
Date: 07/21/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75	
Sampling Location: 47	
Photo Direction: West	
Date: 07/21/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA70	
Sampling Location: 44	
Photo Direction: North	
Date: 07/21/2019	
GMU: West Fort Hood – Northwest	

Fort Hood Military Installation – TA70	
Sampling Location: 44	
Photo Direction: East	
Date: 07/21/2019	
GMU: West Fort Hood – Northwest	

Fort Hood Military Installation – TA70

Sampling Location:
44

Photo Direction:
South

Date:
07/21/2019

GMU:
West Fort Hood – Northwest

Fort Hood Military Installation – TA70

Sampling Location:
44

Photo Direction:
West

Date:
07/21/2019

GMU:
West Fort Hood – Northwest

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA70</td></tr>
<tr><td>Sampling Location:
45</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
North</td></tr>
<tr><td>Date:
07/21/2019</td></tr>
<tr><td>GMU:
West Fort Hood –
Northwest</td></tr>
</table>

<table>
<tr><td colspan="2">Fort Hood Military Installation – TA70</td></tr>
<tr><td>Sampling Location:
45</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
East</td></tr>
<tr><td>Date:
07/21/2019</td></tr>
<tr><td>GMU:
West Fort Hood –
Northwest</td></tr>
</table>

Fort Hood Military Installation – TA70

Sampling Location: 45 **Photo Direction:** South **Date:** 07/21/2019 **GMU:** West Fort Hood – Northwest	

Fort Hood Military Installation – TA70

Sampling Location: 45 **Photo Direction:** West **Date:** 07/21/2019 **GMU:** West Fort Hood – Northwest	

Fort Hood Military Installation – TA44

Sampling Location: 30	
Photo Direction: North	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA44

Sampling Location: 30	
Photo Direction: East	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA44	
Sampling Location: 30	
Photo Direction: South	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA44	
Sampling Location: 30	
Photo Direction: West	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA42

Sampling Location: 48	
Photo Direction: North	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA42

Sampling Location: 48	
Photo Direction: East	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA42

Sampling Location: 48	
Photo Direction: South	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA42

Sampling Location: 48	
Photo Direction: West	
Date: 07/21/2019	
GMU: Western Maneuver Area – North	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA72	
Sampling Location: 9	
Photo Direction: North	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA72	
Sampling Location: 9	
Photo Direction: East	
Date: 07/22/2019	
GMU: West Fort Hood – South	

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA72

Sampling Location: 9	
Photo Direction: South	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA72

Sampling Location: 9	
Photo Direction: West	
Date: 07/22/2019	
GMU: West Fort Hood – South	

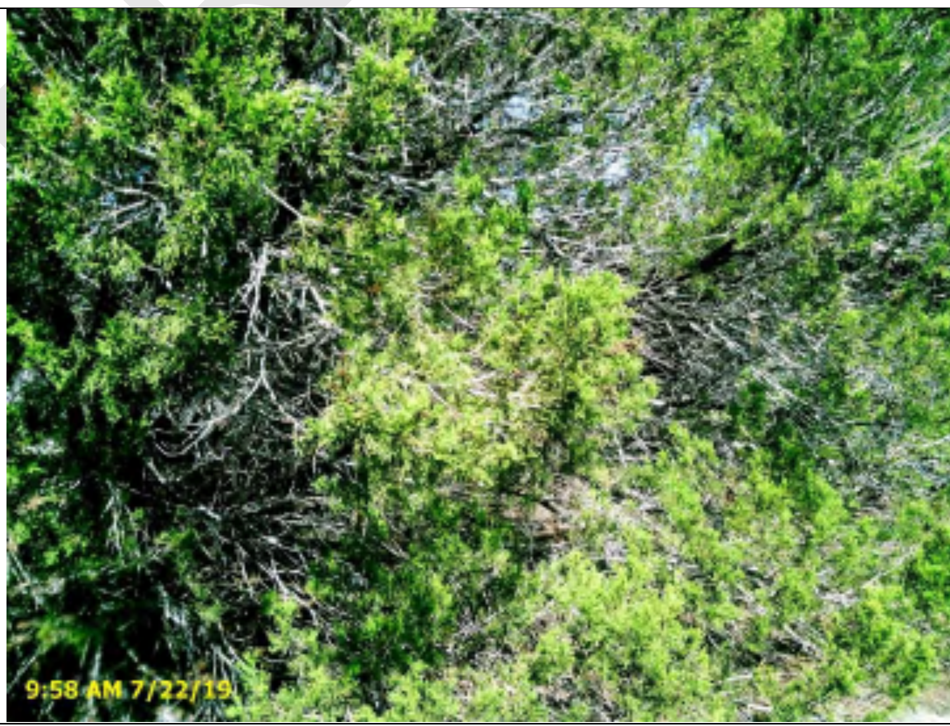
Fort Hood Military Installation – TA72	
Sampling Location: 10	
Photo Direction: North	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA72	
Sampling Location: 10	
Photo Direction: East	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA72

Sampling Location: 10	
Photo Direction: South	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA72

Sampling Location: 10	
Photo Direction: West	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73

Sampling Location: 57	
Photo Direction: North	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73

Sampling Location: 57	
Photo Direction: East	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73	
Sampling Location: 57	
Photo Direction: South	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73	
Sampling Location: 57	
Photo Direction: West	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73	
Sampling Location: 46	
Photo Direction: North	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73	
Sampling Location: 46	
Photo Direction: East	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73

Sampling Location: 46	
Photo Direction: South	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA73

Sampling Location: 46	
Photo Direction: West	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75

Sampling Location:
58

Photo Direction:
North

Date:
07/22/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA75

Sampling Location:
58

Photo Direction:
East

Date:
07/22/2019

GMU:
Western Maneuver Area – North

CYPRESS
Environmental Science & Engineering

Fort Hood Military Installation – TA75	
Sampling Location: 58	
Photo Direction: South	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA75	
Sampling Location: 58	
Photo Direction: West	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA74	
Sampling Location: 56 **Photo Direction:** North **Date:** 07/22/2019 **GMU:** West Fort Hood – South	

Fort Hood Military Installation – TA74	
Sampling Location: 56 **Photo Direction:** East **Date:** 07/22/2019 **GMU:** West Fort Hood – South	

Fort Hood Military Installation – TA74

Sampling Location: 56	
Photo Direction: South	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA74

Sampling Location: 56	
Photo Direction: West	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75	
Sampling Location: 12	
Photo Direction: North	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75	
Sampling Location: 12	
Photo Direction: East	
Date: 07/22/2019	
GMU: West Fort Hood – South	

Fort Hood Military Installation – TA75

Sampling Location:
12

Photo Direction:
South

Date:
07/22/2019

GMU:
West Fort Hood – South

Fort Hood Military Installation – TA75

Sampling Location:
12

Photo Direction:
West

Date:
07/22/2019

GMU:
West Fort Hood – South

Fort Hood Military Installation – TA53

Sampling Location: 62	
Photo Direction: North	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53

Sampling Location: 62	
Photo Direction: East	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53

Sampling Location: 62	
Photo Direction: South	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53

Sampling Location: 62	
Photo Direction: West	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53

Sampling Location: 31	
Photo Direction: North	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA53

Sampling Location: 31	
Photo Direction: East	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

<table>
<tr><th colspan="2">Fort Hood Military Installation – TA53</th></tr>
<tr><td>Sampling Location:
31</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
South</td></tr>
<tr><td>Date:
07/22/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

<table>
<tr><th colspan="2">Fort Hood Military Installation – TA53</th></tr>
<tr><td>Sampling Location:
31</td><td rowspan="4"></td></tr>
<tr><td>Photo Direction:
West</td></tr>
<tr><td>Date:
07/22/2019</td></tr>
<tr><td>GMU:
Western Maneuver Area – North</td></tr>
</table>

Fort Hood Military Installation – TA52

Sampling Location:
60

Photo Direction:
North

Date:
07/22/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA52

Sampling Location:
60

Photo Direction:
East

Date:
07/22/2019

GMU:
Western Maneuver Area – North

Fort Hood Military Installation – TA52

Sampling Location: 60	
Photo Direction: South	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 60	
Photo Direction: West	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 29	
Photo Direction: North	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 29	
Photo Direction: East	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 29	
Photo Direction: South	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 29	
Photo Direction: West	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 70	
Photo Direction: North	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52

Sampling Location: 70	
Photo Direction: East	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 70	
Photo Direction: South	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	

Fort Hood Military Installation – TA52	
Sampling Location: 70	
Photo Direction: West	
Date: 07/22/2019	
GMU: Western Maneuver Area – North	