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Physical/Structural Erosion Control
for Training Land Rehabilitation

Erosion Control Management Plan for Army Training Lands

by
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The Army faces major land management issues in maintaining its training areas to be environmentally sound and support the mission. Erosion of training lands has diminished the allowable capacity and the realism of training activities while other training trends have placed additional demands on these lands.

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FOREWORD

This work was performed for the U.S. Army Engineering and Housing Support Center (USAEHSC) under Project 4A162720A896, "Base Facility Environmental Quality"; Work Unit AO-047, "Physical/Structural Erosion Control for Training Land Rehabilitation." The USAEHSC Technical Monitor was Donald M. Bandel, Chief of Natural and Cultural Resources, CEHSC-FN.

The study was conducted by the U.S. Army Construction Engineering Research Laboratory (USACERL) Environmental Division (EN). Dr. R.K. Jain is Chief, EN. The USACERL technical editor was Gordon L. Cohen, Information Management Office.

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COL Everett R. Thomas is Commander and Director of USACERL, and Dr. L.R. Shaffer is Technical Director.

CONTENTS

CONTENTS (Cont'd)

FIGURES

FIGURES (Cont'd)

TABLES

EROSION CONTROL MANAGEMENT PLAN FOR ARMY TRAINING LANDS

1 INTRODUCTION

Background

Today the Army is confronted with more difficult training land maintenance issues than ever before. The increasingly high rate of soil erosion on training lands has resulted in resource losses that diminish the land's training capacity and ability to provide a realistic training environment. Coupled with the erosion problem is that mobile weapons systems operating over large areas and concentrated demands on multipurpose training areas are subjecting these lands to even more intensive use.

Laws such as the conservation provisions of the 1985 Food Security Act[1] and the Water Quality Act of 1987[2] have drawn attention to the far-reaching, detrimental effects of erosion in terms of soil resource loss and as a nonpoint source of water pollution. The U.S. Environmental Protection Agency (USEPA) has issued guidance for the implementation of state nonpoint source pollution water management programs. The Water Quality Act of 1987 calls for state assessment reports on their nonpoint source pollution programs that identify nonpoint pollution sources and strategies for developing optimal management practices. In an effort to be a responsible steward of the land and a good neighbor, the Army also is examining management practices that will effectively reduce soil erosion, resource loss, stream pollution, and off-site sedimentation.

To step up its fight against soil erosion, the Army is adopting a comprehensive management approach. Called the Integrated Training Area Management (ITAM) Program, it includes an important land maintenance management subprogram for erosion prevention and abatement.* To implement this portion of the program effectively, installations need a standardized methodology for each step involved in the identification of erosion control projects and their placement into the Annual Work Plan. The U.S. Army Construction Engineering Research Laboratory (USACERL) has proposed the Erosion Control Management Plan (ECMP) as such a method. This plan consists of a five-step procedure for problem identification, needs assessment, and technology selection. ECMP assists the user in technology selection for new erosion control structures and systems and prescribes maintenance and repair (M&R) procedures for existing ones. Compilation of an eroded site inventory through the use of the ECMP also forms the basis for an installation land restoration and maintenance paneling document.

Objective

The objective of this work is to develop an erosion control management plan for Army training lands that encompasses both M&R of existing erosion control structures/systems and cost-effective selection of new technologies based on conditions unique to the installation's eroded sites.

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[1] Public Law (PL) 99-198, *Food Security Act of 1985*, 99 Stat. 1354.

[2] PL 100-4, *Water Quality Act of 1987*, 100 Stat. 7.

* ITAM is being developed and field-tested by the U.S. Army Construction Engineering Research Laboratory. The program is receiving widespread acceptance and formal documentation is expected to be published in the near future.

Approach

Installations were visited to examine present methods for routine site inspection and land maintenance practices. These visits and communications with installation natural resource personnel experienced in Army land maintenance and erosion problems provided lessons learned and valuable insights about the dynamics and complexities of Army-unique erosion problems. Army technical manuals, installation conservation plans, long-range planning guidance, and rear area development plans were reviewed for their treatment of erosion and erosion project management. Handbooks published by Federal, State, and regional agencies establishing procedures and standards for erosion and sedimentation control were reviewed. The literature on soil and water conservation engineering principles, cost/benefit analysis, and site work and construction cost estimating was surveyed. Product distributors and manufacturers were contacted during Fall 1987 to obtain price information for materials. All information collected was analyzed and incorporated into the ECMP. During Fall 1988, draft copies of the plan were sent to many District conservationists with the U.S. Department of Agriculture (USDA) Soil Conservation Service (SCS) and to Department of Defense Natural Resource Land Managers for technical review. A revised draft report was completed Fall 1989 and distributed for peer review. This report is the result of revisions to the plan from the pilot testing and peer comments received.

Mode of Technology Transfer

The information in this report eventually will be used by installation planners and land managers for erosion problem identification, needs assessment, and technology cost-comparison and selection. The plan will support the erosion control component of the Army's ITAM program. The information will be distributed to the field through a Technical Manual and workshops.

2 PLACEMENT OF EROSION CONTROL CONSTRUCTION, MAINTENANCE, AND REPAIR PROJECTS INTO THE INSTALLATION ANNUAL WORK PLAN

Installation Annual Work Plan Development

Erosion control construction, maintenance, and repair projects that enter into installation Annual Work Plan (AWP) development are considered Real Property Maintenance Activities (RPMAs). Budgetary guidance for projects funded through RPMA is provided in Department of the Army (DA) Pamphlet 420-8, *Facilities Engineering Management Handbook,* Chapter 7. The development of projects considered part of Military Construction, Army (MCA) is covered in Army Regulation (AR) 415-15 and that of Minor Military Construction, Army (MMCA) is covered in AR 415-35.[3]

The AWP is the basic planning document within the Directorate of Engineering and Housing (DEH). It is normally prepared and approved for the following fiscal year during the fourth quarter of each fiscal year after receipt of the Command Operating Budget (COB). It ensures the careful consideration of work requirements and application of available resources to work in priorities dictated by the installation mission and condition of facilities. It serves as a source for engineer troop projects and identifies work to be done by contract and in-house labor forces. All known minor construction and deficiency maintenance requirements are developed as project work packages with recurring maintenance requirements specified.

Financial resource requirements representing manpower, equipment, and materials must be projected for all erosion control projects that will be included in the installation AWP. Requirements are projected by the third quarter of the fiscal year before the work will be done.

For work projects to be activated, they must pass through the classification, prioritization, approval, planning, and budgetary processes of the facilities engineering resource planning management system. Projects are itemized on planning and budgetary documents that report priorities and resource requirements.

Project Origination

Financial resource requirements for projects to be included in the installation AWP are projected by compiling a comprehensive inventory of all types of erosion control projects expected to have work performed during the next fiscal year. The inventory lists projects according to the work classification standards discussed below. Whereas the M&R procedures outlined in Appendix A are for identifying problems and assessing needs of existing structures, other procedures are used to evaluate sites where no erosion control structures or systems exist or where existing ones must be replaced. Site evaluation under these circumstances is completed in preliminary and detailed assessment phases of the Erosion Control Management plan as outlined in subsequent chapters. Appendix B contains evaluation sheets for preliminary and detailed site assessments and worksheets to be used for needs assessment and technology selection. These sheets provide a summary of workup data and information used for site assessment,

[3] Department of the Army Pamphlet (DA Pam) 420-8, *Facilities Engineering Management Handbook* (Headquarters, Department of the Army [HQDA], September 1978); Army Regulation (AR) 415-15, *Military Construction, Army (MCA) Program Development* (HQDA, December 1983); AR-415-35, *Minor Construction, Emergency Construction, Replacement of Facilities Damaged or Destroyed* (HQDA, 15 October 1983).

erosion control selection, project origination, and the projection of financial resource requirements for each eroded site.

Figure 1 is a process flowchart that identifies the main elements of the ECMP and shows how erosion control construction, maintenance, and repair projects that eventually enter the installation AWP are generated. Erosion control projects originate as a result of site inspections conducted (1) on a regular, short-term basis as recurring maintenance requirements; (2) to evaluate and correct damage that requires repair on a nonscheduled basis, or (3) to assess a site as part of a training land restoration watershed treatment or rehabilitation long-term plan whereby training areas are deactivated due to their degraded physical condition. In all three cases, structures for erosion control may or may not exist.

Work Classification

Figure 1 indicates that erosion control projects can be generated as maintenance, repair, and construction projects. The DEH should be familiar with the principles of Army work classification. Policy is provided in AR 420-10 and AR 415-35.[4] The terms "maintenance" and "repair" are defined in AR 420-10. DA Pamphlet 420-8, Change 1, Chapter 9, explains terms and provides guidance on the application of work classification principles.

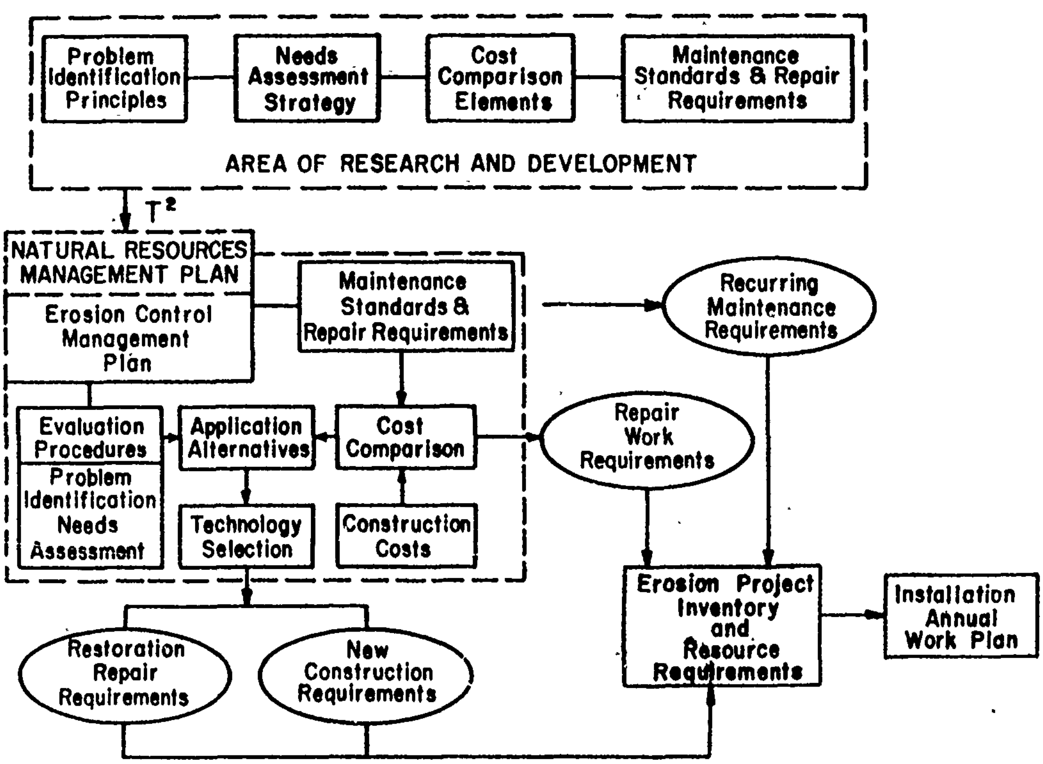

Figure 1. Process flowchart of Erosion Control Management Plan.

[4] AR 420-10, *Management of Installation Directorates of Engineering and Housing* (HQDA, 2 July 1987); AR 415-35.

AR 420-10, Chapter 3, describes a maintenance project or repair project as a "....logical plan of work on one or more real property facilities." These projects "are single undertakings of finite scope which satisfy specific maintenance or repair requirements."

Work needed to keep a conservation structure or an erosion control structure or system preserved and maintained in such a condition that it can be used effectively for its designated functional purpose is considered maintenance. It includes cyclical work performed to prevent damage that would be more costly to restore than to prevent and work to sustain components.

Appendix A summarizes the M&R requirements generally associated with erosion control structures and systems used under agricultural conditions. Technical Manual (TM) 5-820-4,[5] Chapter 4, discusses standard requirements for design of surface and subsurface drainage systems for military construction other than airfields and heliports at Army and Air Force installations. Erosion control and riprap protection are also discussed. TM 5-630[6] also discusses standard maintenance practices and procedures for drainage and watershed improvement. In addition to these requirements, other needs may exist for particular types of Army training activities. Structures require periodic inspection. Annual inspection following the season of greatest risk for incurring damage is recommended. More frequent inspections should be scheduled for critical areas with highly erodible soils or recurring problems to ensure that structures remain functional for designated purposes and to prevent future damage that would result in more extensive, costly repairs. Inspections made before the vegetative growing season begins will provide optimal visibility of structures and surrounding soil surface conditions.

The maintenance procedures for erosion control structures and systems itemized in Appendix A can be used to develop work plans outlining uniform maintenance standards. These standards can then be used as a basis for assessing needs during routine site inspections and for projecting maintenance requirements that represent costs for labor, equipment, and materials needed to perform erosion projects originating in the first case mentioned above (i.e., recurring maintenance requirements). Use of these standards assists the site evaluator by permitting a comparison of conditions as they exist during site inspection with accepted standards for the technology concerned.

This information also is useful for site inspections conducted as a result of nonscheduled repairs or as part of a long-term plan where structures already exist. Where structures do not exist, they should be considered as a factor for cost comparison in selecting potential new construction projects (refer to Figure 1). The standards can also become itemized contract requirements and used as the basis of performance standards when the DEH M&R function is done by commercial activities (CAs).

Some conditions affecting the level of M&R at a real property facility (RPF) are itemized as:

1. Current status (active or inactive use).
2. Work plans--uniform maintenance standards.
3. Planned use.
4. Plans for disposal.
5. Environmental factors.

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[5] Technical Manual (TM) 5-820-4/Air Force Manual (AFM) 88-5, *Drainage Areas for Other Than Airfields* (HQDA, 14 October 1983).

[6] TM 5-630/AFM 126-2/Naval Facilities Engineering Command Maintenance and Operation Manual [NAVFAC MO] 100.1, *Natural Resources - Land Management* (Department of the Army, Air Force, and Navy, 1 July 1982).

6. Energy conservation.
7. Historical significance.
8. Conformance with fire, safety, and health standards.

Items 2 and 3 are especially important for erosion control M&R projects.

Project Description and Justification

Erosion control construction, maintenance, and repair projects are often related to environmental protection standards and natural resource guidelines. In such cases, this fact should be stated in the justification when the project is first submitted so it can be taken into account during project prioritization. Likewise, cyclical, routine M&R projects necessary to preserve the functional operation of existing erosion control structures and systems in accordance with established engineering standards should be identified in the project description so they will be reported as annual recurring requirements (ARR).

It is essential that projects submitted for approval be described adequately, justified properly, scoped, and classified according to work type at the time of their origination. This information is necessary for determining project approval level and adherence to statutory and regulatory requirements, and for establishing priorities.

Military Construction, Army (MCA) Program

Planning for MCA projects requires a schedule of events separate from the AWP. MCA program appropriations provide funds to meet specific Army requirements for major and minor construction. Although MCA peacetime construction typically provides permanent facilities such as barracks, tactical equipment shops, hospitals, and administrative buildings, a situation may arise for which costs associated with an erosion control construction project are of such magnitude that requires it to be funded through the MMCA or MCA appropriations. AR 415-15 provides guidance for planning, programming, and budgeting MCA projects. The MMCA program, which is related to the major MCA program, provides appropriations for projects costing $1 million or less.

The MCA program is linked to installation development and master planning. Prioritized construction projects are forwarded to the Major Command (MACOM). The MACOM program is then developed and forwarded to HQDA. Construction requirements from the Army's annual MCA program request is reflected in the construction annex of the Five-Year Defense Program (FYDP). Supporting documentation for MCA projects is critical. It must include a Project Development Brochure (PDB) that lists planning objectives and provides an overview of the project. Figure 2 summarizes the events associated with MCA project development. Compliance with the schedule of events is essential to MCA project development. Each MCA project must include erosion controls needed for all phases of the project life.

Action Plan for Placement of Erosion Control Projects Into the Installation AWP

Figure 3 shows the elements of the Erosion Control Management Plan. It indicates the five-step sequence for problem identification, needs assessment, and erosion control selection. The five main steps of the management plan are:

Step 1. Conduct preliminary site assessment for compiling an inventory of erosion project sites.

Step 2. Identify erosion-related natural factors.

Step 3. Examine site erosion conditions and contributing factors.

Step 4. Assess erosion control needs.

Step 5. Estimate costs for erosion control selection and resource requirement projections.

The five-step plan was developed for selecting erosion controls at sites where no constructed erosion controls exist or where existing ones must be totally replaced. Appendix A presents maintenance procedures for existing erosion control structures and systems. Appendix B contains evaluation sheets to be used for the five-step plan.

The plan can be used where previous decisions have been made to rest and rehabilitate training areas based on data generated from Land Condition Trend Analysis (LCTA) or on judgments associated with other training area recovery or watershed treatment programs. It can also be used as routine erosion control maintenance where no formal rotational recovery programs are in effect. The land manager bases decisions regarding erosion project origination on information gathered from archival sources and the field. It is important that the time spent for gathering information produce the maximum amount of well organized, essential data needed for accurate problem identification, needs assessment, and technology selection.

Preliminary site assessment is discussed in Chapter 3. Eroded sites requiring more than routine planting and seeding methods will need more detailed site assessment for identifying problems, determining needs, and selecting erosion control methods. Procedures for detailed site assessment are presented in Chapters 4 and 5. Chapter 6 discusses the development of "desk" estimates used for relative cost comparison of erosion controls during technology selection and for projecting financial resource requirements for erosion projects that will be placed into the installation AWP.

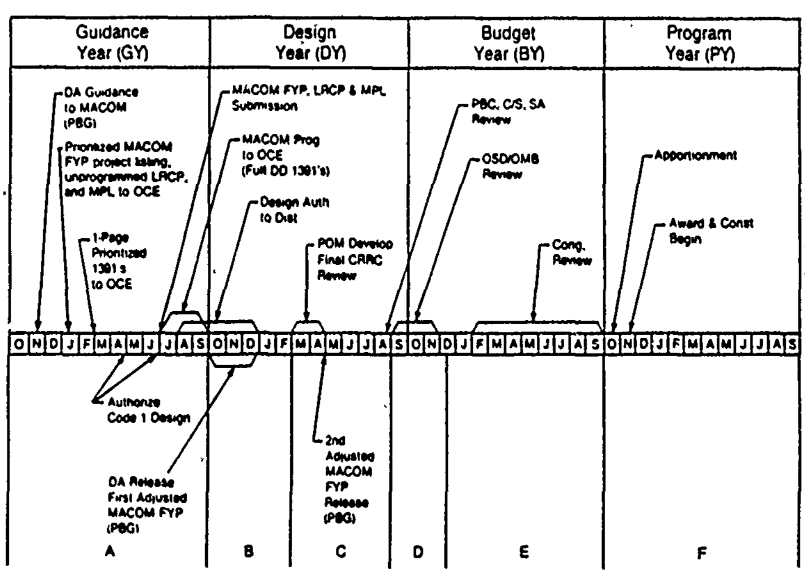

Figure 2. Summary of events associated with MCA projects. (Acronyms are explained in the List of Abbreviations at the end of this report.)

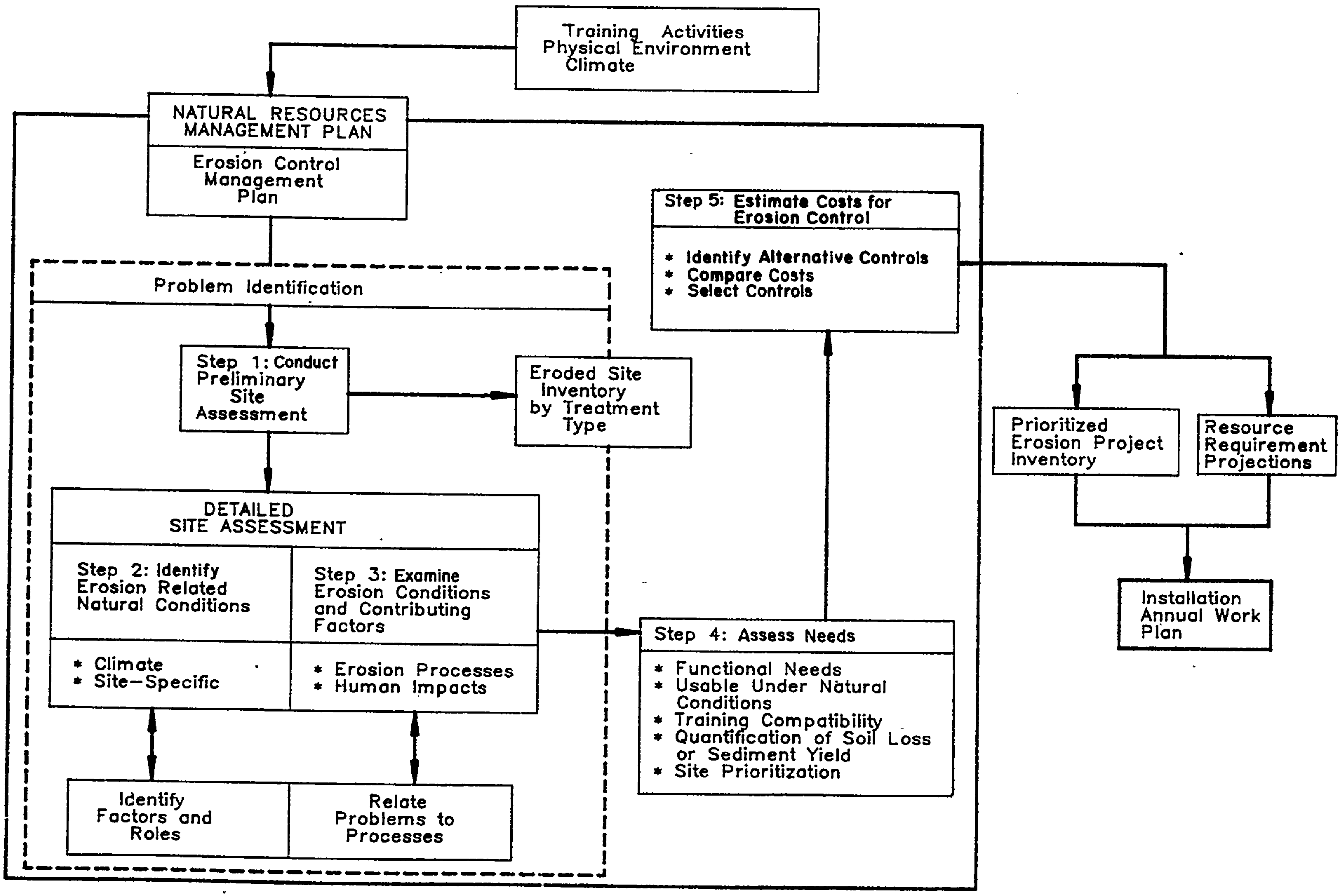

Figure 3. Erosion Control Management Plan (ECMP) elements and their relationships in the technology selection process.

3 PROBLEM IDENTIFICATION: PRELIMINARY SITE ASSESSMENT

Principles for Step 1: Preliminary Site Assessment

Preliminary site assessment is performed to categorize sites into groups according to erosion control treatment approach. This organization of information allows resource requirement estimates to be tabulated quickly for groups of sites requiring minimal treatment; it facilitates the task of calculating costs for more complex projects by grouping them to allow the evaluator to consider similar key factors that impact project costs. Preliminary assessment also allows early identification of eroded sites that should receive high priority for rehabilitation due to their obvious threat to water quality and other environmental factors.

An erosion treatment approach is defined by a set of criteria reflecting the complexity of erosion conditions, slopes, vegetation or protective ground cover, type of design or technical specifications required, and kinds of equipment required to do the type of work planned for the site. These criteria and treatment approaches are summarized in Table 1. Technical specification, design requirements, and equipment type are used as criteria because they indicate participation and, hence, costs associated with labor work groups having the capabilities to perform those tasks.

If other modes of doing the work or special requirements and conditions that impact work costs exist, they should be reflected in criteria that the installation evaluator will use for determining control treatment approaches. The resulting classes or categories of erosion control treatment approaches will be used in the same way to project financial resource requirements.

Figure 4 is a flow diagram illustrating the rationale and thought processes used to determine treatment approaches. Individuals performing site evaluation for Step 1 should use this flow diagram and Table 1 when gathering archival and field data to determine site classification. Classes or categories of sites that result range from those needing no treatment to those requiring complex control methods and formal design.

Troop construction is included as a treatment approach class because it is important for the land manager to know the number and location of project sites that could be done as unfunded projects in the event of funding shortfalls. During preliminary site assessment, prospective troop construction projects receive designation as Class B or C in the inventory. After completion of the detailed site assessment, if the types of tasks involved in site restoration pertain to troop engineering unit mission-essential tasks (METL) or Army Training and Evaluation Programs (ARTEP), the projects are noted as having major parts suitable for troop construction projects and they are cross referenced in Class D. Unless a specific number of hours of troop construction time will be obligated to erosion control projects, cost estimates for those projects should be itemized as funded project cost estimates along with the other Class B and C projects that require financial resources. After the inventory of eroded sites has been compiled, the land manager submits a list of suitable projects to the Troop Projects Office (TPO). The TPO coordinates selection of those projects with troop units.

The dynamics of soil erosion and vegetation conditions at sites due to intensive training or natural conditions present a problem when planning and estimating far in advance for project implementation. These events are especially a problem for distinguishing nontreatment Class O sites from minimal treatment Class A sites. Knowledge of soil erodibility, training intensity, projected training schedules, past cover condition, and Land Condition Trend Analysis (LCTA) information can be used to help the evaluator predict future erosion and vegetation conditions. Where training area rotational rehabilitation programs are used, these factors would have been used to help determine schedules for rotation and duration of rest periods.

Table 1

Criteria for Erosion Site Classification According to Erosion Control Approach

EROSION CONDITION	TOPOGRAPHY	VEGETATION/ GROUND COVER	EQUIPMENT TYPE	TECHNICAL SPECS.	TREATMENT APPROACH	CLASS
NO SIGNIFICANT DEGRADATION; NO APPARENT SOIL LOSS OR OFF-SITE THREAT OF EROSIVE RUNOFF OR SEDIMENT	ANY	CONDITIONS ARE HISTORICALLY SELF-HEALING: CAN RECOVER DURING REST PERIOD OF ROTATIONAL PLAN OR ONE GROWING SEASON	NONE	NONE	NO TREATMENT	O
WATER EROSION (SHEET,SPLASH, RILL)	SLOPES GENERALLY LESS THAN 5x	CONDITIONS HISTORICALLY CANNOT SELF HEAL IN ONE GROWING SEASON OR REST PERIOD OF ROTATIONAL PLAN	SMALL MAINTENANCE, CULTIVATION ie, DISC,HARROW,SEEDER, SMALL TRACTOR	FERTILITY & SEEDING SPECIFICATIONS	ROUTINE PLANTING AND SEEDING METHODS	A
a) WATER EROSION (SHEET,SPLASH, RILL,GULLEY) OR b) WIND EROSION	a) SLOPES GENERALLY BETWEEN 5 AND 12x FOR WATER EROSION OR b) ANY TOPOGRAPHY FOR WIND EROSION	ANY CONDITION REQUIRING TREATMENT	SMALL MAINTENANCE, SOME HEAVY CONSTRUCTION EQUIP.	SOIL CONSERVATION SERVICE (SCS) RECOMMENDATIONS AND CONSERVATION PRACTICES	INFORMAL DESIGN USING LESS COMPLEX AGRICULTURAL CONSERVATION PRACTICES	B
WATER EROSION WITH COMPLEX RUNOFF CONDITIONS OR SEVERE WIND EROSION PROBLEMS	SLOPES GENERALLY GREATER THAN 12x BUT NOT RESTRICTED	ANY CONDITION REQUIRING TREATMENT	HEAVY CONSTRUCTION, SOME SMALL MAINTENANCE EQUIPMENT FOR FINISHING TASKS	SOIL CONSERVATION SERVICE OR OTHER ENGINEERING SERVICES	FORMAL AGRIC,ENGR, OR OTHER ENGINEERING DESIGN;BIOTECHNICAL,GEOTECHNICAL & INNOVATIVE TECHNOLOGIES	C
ALL TYPES	ANY WELL DEFINED SMALL AREAS OR DEFINED SUB-AREAS OF LARGE SITES	ANY CONDITION REQUIRING TREATMENT	TROOP UNIT TYPE	ROUTINE ENGINEERING TASKS: LIMITED AND WELL DEFINED IN SCOPE: RELATED TO ARTEPS AND METL. MAY BE JOB--PHASE SUB--COMPONENTS OF CLASSES B AND C	TROOP CONSTRUCTION	D

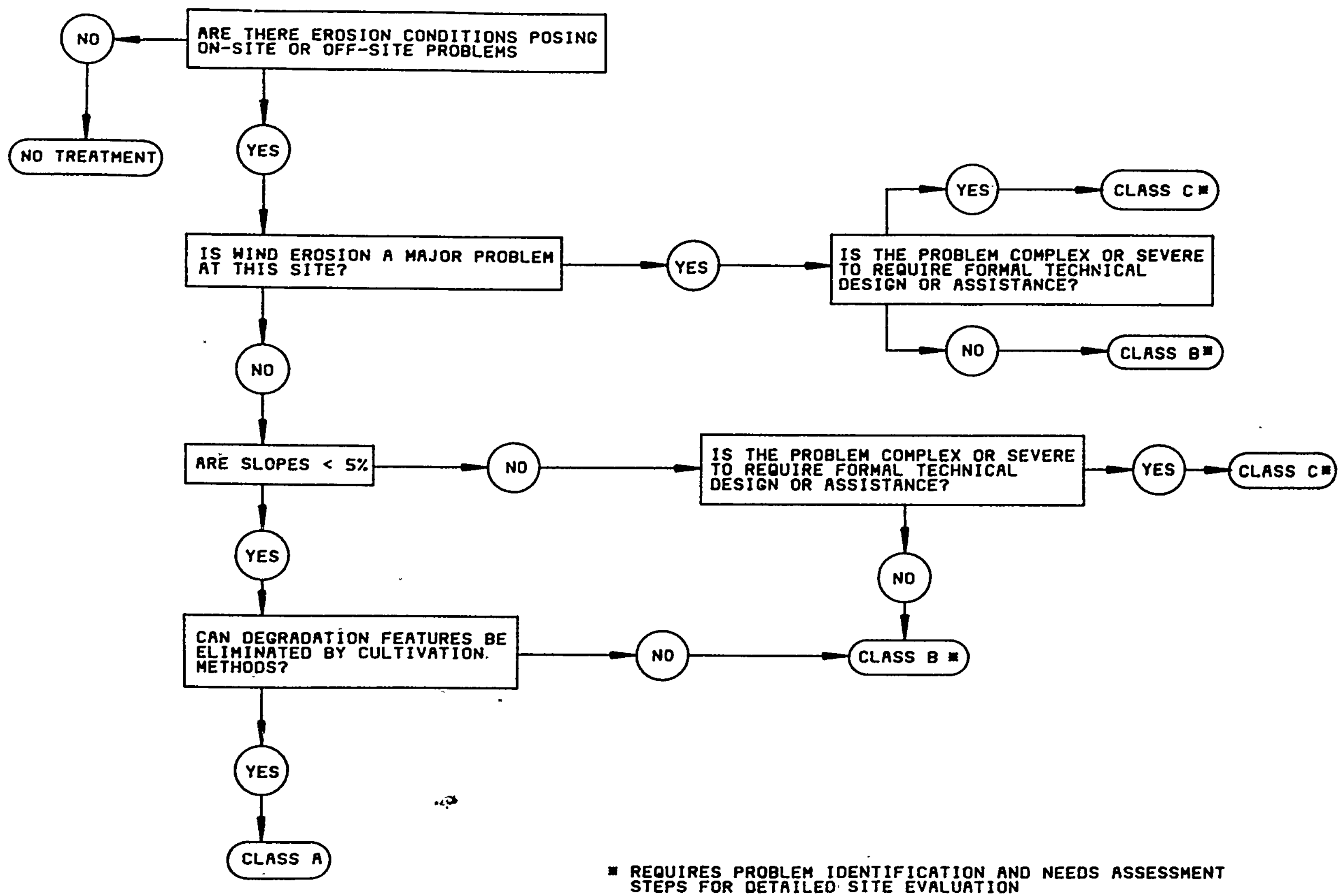

Figure 4. Rationale and thought processes in determining treatment approaches.

Problems associated with time lapse between estimate and project commencement are somewhat minimized by the topographic and complexity criteria used to distinguish Classes A, B, and C. Topography will remain fairly constant over the time period spanning the estimate and project commencement. As a result, many Class B and C as well as Class D projects can be identified accurately in advance. Areas having erosion and slopes greater than 5 percent can be considered for cost purposes as requiring at least Class A treatment, and will probably need some additional conservation treatment of Class B.

Complexity of runoff patterns and other erosion-influencing factors prevailing at the site which are considered during detailed site assessment are also very likely to exist at the site over time. The complexity and severity factor is used to distinguish Class C from Class B sites. The main cost difference between these two site classes results from costs incurred for technical assistance in formal project design and more extensive use of heavy equipment.

The complexity factor is a somewhat flexible determinant with regard to the point at which an evaluator will require technical assistance for solving erosion problems. The more experienced evaluator may not require the same amount or level of assistance as the less experienced individual. Also, the number of similar sites for which an evaluator has file information containing formal design may also affect the number of manhours that will be required for technical design in some cases. As personnel gain more experience in erosion project management, the ability to solve erosion problems increases. However, regardless of an evaluator's experience or ability, it is required by regulation and state laws that some conservation structures be designed by a certified engineer.

Preliminary Site Assessment

Where no erosion controls exist or where existing controls must be totally replaced, eroded sites are categorized during the preliminary assessment phase according to the type of treatment approach that will be used on them. The result is an inventory of erosion project sites from which financial resource requirement estimates can be then be tabulated in an orderly fashion by the land manager. This organization of collected data facilitates the estimation process by allowing the land manager to systematically calculate costs at the same time for a group of projects having similar job phases and key factors that impact project costs. This method is especially helpful where large training areas are being rehabilitated and many erosion sites exist in addition to projects generated through repair and recurring maintenance requirements.

Resource requirements for sites that need only routine planting and seeding methods can be calculated immediately after the preliminary site assessment is completed. Resource requirements for eroded sites where additional work is needed are projected after those detailed assessments are completed. Guidance for projecting resource requirements for those types of sites is presented in Chapter 6 of this report. Although in some cases it may be more expedient for the evaluator to conduct the detailed phase while present at the site for preliminary assessment, it is not necessary that the detailed phase be accomplished then or by the same person doing the preliminary assessment. The land manager might plan to have detailed site assessments performed at a later date by personnel more experienced at erosion site evaluation. Time schedules, distance, familiarity with training areas, and level of personnel expertise in erosion control work are criteria used in making this decision.

An advantage of performing preliminary assessments of all sites first is that quick identification of the number of sites according to treatment class is possible. It also enables quick tabulation of resources needed for sites requiring only minimal treatment. When preliminary and detailed assessments are combined, the total number of sites requiring minimal treatment will not be known until all sites of every class have been assessed. If the combined approach is used, the evaluator will also need to carry to the field information sources that will be used for both kinds of assessment.

Another major advantage of performing preliminary assessments of all sites first is that all sites will receive preliminary site prioritization based on visual inspection. This enables the land manager to direct erosion control efforts to sites that pose obvious problems to water quality and other environmental factors at the earliest possible time.

Site Prioritization

One of the foremost considerations for site prioritization is the effect that the site's soil loss and sediment yield has on surface water quality. In general, eroded sites adjacent to surface water (including streams, lakes, and wetlands) should be evaluated carefully with regard to their potential degradation of water quality. Such sites can also have undesirable impacts on offsite locations as sediment is carried downstream. They should receive high priority for treatment if they are posing problems or are an imminent threat to water quality. Quantification of sediment yield and soil loss along with observations of water turbidity, effects on fish and wildlife, and mass movement of sediment in the field can help in prioritizing those kinds of sites (see Chapter 5). The evaluator should be aware of any sensitivities or uniqueness of that particular environment (as well as those affected downstream) and the presence of any threatened or endangered species.

When considering sites that contribute sediment yield and soil loss directly to surface water, the evaluator should be aware of upslope drainage patterns that carry erosive runoff, overland flow, and sediment to downslope sites located adjacent to the water (refer to the last part of item 8 in Table B2). Those upslope areas contributing to the problems of such sites should also receive high priority. Predictive capabilities of watershed analyses and the automated ARMSED model can be used to identify those watershed portions contributing significant amounts of sediment to surface water.

Considerations for prioritizing upland or floodplain sites include (1) the extent of losses and kind of damage with regard to the value of fish, wildlife, or impacted property for habitat, training space, or other cultural purposes (such as economic or recreational) as a result of present or imminent conditions, and (2) the potential of the erosion problem for promoting progressive, intensive, and extensive damage on- or offsite.

Information Sources for Compiling an Erosion Project Site Inventory

Information needed to compile an erosion project site inventory is gathered from the field and archival sources. Recent air photographs are useful in helping to locate severely eroded sites. Installations using the Geographic Resources Analysis Support System (GRASS) can generate maps containing topographic and vegetation information. GRASS can reduce the amount of field work needed for preliminary site assessment by generating maps that indicate large areas by percentage of slope and cover. Through the use of information system layers containing climate data, slope, vegetation condition, and soil erodibility factors, GRASS users can also generate maps showing areas where erosion sites are likely to occur due to natural conditions.

Materials needed for compiling an erosion site inventory through preliminary site assessment include this report, the county soil survey report, a distance-measuring instrument, a slope angle measuring instrument (such as an Abney level or clinometer), and soil sampling equipment. It is also helpful to use a camera.

Procedures for Preliminary Site Assessment Documentation

Appendix B contains evaluation tables to be used for erosion site assessment. Table B1 is an example Preliminary Site Evaluation Sheet for Step 1. This sheet is used along with Figure 4 or Table 1 by the individual responsible for gathering field, automated, and other archival information needed to develop an inventory of erosion project sites. It is used for all evaluated sites.

Preliminary site assessment includes identification of the kinds of erosion present at an eroded site. Consult Appendix C for descriptions of features associated with each kind of erosion. It also calls for identification of sites that are visibly contributing sediment to surface waters (e.g., streams and lakes). This information is needed as input to prioritize sites for treatment. It is a means to earmark sites early in the erosion project site inventory process that should receive high priority for environmental reasons. Preliminary prioritization identifies sites presenting obvious environmental problems. Final site prioritization is performed after sites requiring detailed problem and needs assessment are evaluated and soil losses are quantified (see Chapter 5). Item 3 of Table B1 is used to record the evaluator's preliminary priority rating of the site based on visual inspection. If a Class A site contributes sediment to surface water or poses obvious water quality problems, it may be desirable to quantify soil loss or sediment yield for prioritizing this site with others posing similar problems. The evaluator can use Table B4 for this purpose, although no other needs assessment performed on that sheet need be completed. For Class A sites, the evaluator must complete only Table B1 and prioritization information for compiling the inventory of eroded sites. Some of the items on Table B2 pertaining to quantification of soil loss or sediment yield can be used to record values for factors used in soil loss quantification.

The evaluator should obtain the average percent slope measurement of the area to be treated. Steepness of slope and slope length are used as major criteria for determining the treatment approach class due to their direct relationship to runoff and conditions and the geotechnical and equipment limitations. Slopes generally between 6 and 12 percent are likely to have runoff conditions that will require conservation practices in addition to routine revegetation methods. Slopes steeper than 12 percent are likely to present more complex drainage problems in many cases, requiring formally designed conservation practices. Slopes are commonly categorized in the terms presented in Table 2.

To measure percentage slope using an Abney level, sight an object about 100 m away and aim at an eye-level target. Read the incline from the level. Using a clinometer, sight an upslope or downslope target that is eye level and read the percentage scale for slope measurements.

Preliminary assessment also includes measurement estimates of sites that require treatment so that materials (including seed and soil amendments) and an approximation of time needed for tasks related to routine planting and seeding can be estimated. This information is needed for all erosion project site classes where general revegetation will be needed after, or in conjunction with, physical/structural erosion control implementation. Soil samples are also taken to determine soil amendment (fertility) requirements and rates for sites that receive treatment using revegetation techniques alone or in combination with structural erosion controls. Application rates of fertilizer and deficient elements are then reported back to the user as treatment recommendations for the area sampled.

Soil samples are generally taken from each site and submitted to the local County Cooperative Extension Office for fertility requirement analysis at the State Agricultural Experiment Station Soil Laboratory. The local Cooperative Extension office provides detailed instructions on how to take, package, and submit soil samples for analysis (see Appendix D). It also provides technical guidance for sampling under prevailing local conditions or for special purposes and problems.

Table 2

Slope Descriptions*

Description	Percent Slope
Nearly level	0 - 2
Gently sloping	2 - 6
Moderately sloping	6 - 12
Strongly sloping	12 - 18
Steep	18 - 25
Very steep	25 or greater

*Source: R. H. Beck et al., *Introductory Soil Science: A Laboratory Manual* (Stipes Publishing, Champaign, IL, 1984). Used with permission.

In general, samples should be taken before soil temperatures drop below 50 °F, and the soil should be dry enough for using a probe or spade. Refer to the county soil survey map to see what soil types are present at the site. If the site has a uniform soil type, take several samples as directed by the extension office. Take at least five random subsamples per acre and mix them thoroughly to fill one soil sample box. If there is a variation of soil types, keep samples taken from each soil type area separate.

A soil probe or auger facilitates vertical sampling of the soil profile, although a spade or trowel can be used to slice down the side of a hole to obtain a depth sample. The depth to which the sample must be taken depends on what type of plants will be planted or seeded. Obtain specifications for special types of seeding from the extension office. Approximately 8 in. (20 cm) deep is generally adequate for grasses. Avoid taking samples from beneath trees because soil is affected by the tree roots' uptake of nutrients and by canopy wash during rain. Remove large pieces of organic matter such as roots, stalks, and leaves from the sample. Additional samples or larger sample amounts may be needed if texture or other analyses will be requested. As soon as soil analysis reports with recommendations for soil amendment (fertility) requirements are received, financial resource requirements for Class A sites can be determined.

SCS specifications for recovery of critical areas in that locality should be considered for use at sites expected to receive intense usage. These specifications usually call for increased seeding application rates. Resource estimates are derived by using site dimensional data to estimate time requirements for labor and equipment, and fuel consumption, and to calculate amounts of seed and soil amendments according to recommended application rates.

As indicated in Figure 4, it will be necessary to conduct detailed site evaluations for Class B and C sites to identify erosion controls that can be considered as alternative solutions to the existing problems. While only Table B1 and part of Table B4 are needed for Class A site evaluation, Tables B1, B2, B3, B4, and B5 are needed for Class B and C sites. Detailed site evaluations can be conducted at those sites in conjunction with the preliminary evaluation or separately. The land manager will determine what sequence of tasks is most expedient for operations at the installation.

4 PROBLEM IDENTIFICATION: DETAILED SITE ASSESSMENT

Principles for Steps 2 and 3: Detailed Site Assessment

The information presented here for detailed site assessment is intended to provide step-by-step guidance for the inexperienced evaluator or to serve as a summarized checklist for the more experienced individual. These procedures lead to problem identification through examination of natural erosion-related conditions, human activities, and the functional relationships between them and erosion processes. Figure 3 shows factors and relationships involved in detailed investigations for problem identification and needs assessment.

Detailed site assessment is implemented by completing Step 2 and Step 3 evaluation sheets (Tables B2 and B3) for each site considered to be classes B and C during preliminary site classification. Time can be saved if data is collected for these two steps at the same time. In Step 2, the evaluator identifies the prevailing erosion-related natural conditions. This involves consideration of general climatic conditions for all or part of the installation and identification of site-specific erosion-related natural conditions. In Step 3 the evaluator examines the actual erosion conditions and how natural and human factors contribute to them. Information is collected for accurate problem identification and for later use during needs assessment. Much of this data will ultimately be used to determine design specifications for the conservation structures and systems selected.

If detailed site assessment is performed separately from the preliminary evaluation, it will be most efficient to first complete all items on detailed evaluation sheets that require information from the appendixes of this report, other literature, and data systems in the office. Evaluation sheets should first be reviewed to identify information sources for evaluation sheet items. Sources are noted on each sheet. Sections of this text, entitled "Information Sources," also identify where information can be obtained.

Where preliminary and detailed assessments are made on separate occasions, the evaluator should reserve the time spent in the field for site analysis and collecting only the information that cannot otherwise be obtained. While at a site, the evaluator should gather all information for all detailed site assessment evaluation sheets during the same visit. This eliminates time wasted as a result of having to return repeatedly to the site.

If the detailed site assessment is conducted at the same time as preliminary assessment, sources of information should be made available for use to the maximum possible extent prior to site visits. When possible, these information sources should then be brought along in the field so they will be available if sites are found to require detailed assessment. This makes information about erosion-related factors available for consideration during field analysis, thus minimizing the need for return visits.

Principles, information sources, and procedures of Steps 2 and 3 for detailed site assessment are presented to help individuals collect information needed for problem identification. Suggested archival information sources include (1) soil surveys and other cited SCS conservation literature, (2) U. S. Army technical manuals and other Department of Defense (DOD) publications pertinent to land management and soil erosion, (3) installation terrain analyses, (4) topographic maps developed by the USGS or the installation, (5) meteorological records from the National Weather Service and military weather observation stations, (6) natural resource inventories, (7) range and site conservation plans, (8) outlease records, (9) training area schedules and range usage records, (10) LCTA data, and (11) automated systems such as geographic information systems (GISs) such as GRASS and the Soil Information Retrieval System (SIRS). Field inspections are conducted to record evidence of erosion, site-specific and changed natural conditions, and evidence of human contributions to accelerated erosion.

Where portions of a site are severely eroded, or where natural conditions such as soils, topography, vegetation, or ground cover vary considerably from the remainder of the site, the values representing these conditions should *not* be averaged with data for the rest of the site. Averaging would misrepresent the severity and scope of erosion problems at the site. The site evaluation should clearly specify any areas that are considerably heterogeneous.

Quantification of soil loss and tolerance (for needs assessment in Step 5) is necessary for project justification. The choice of quantitative method should be made before beginning data collection. This is necessary to ensure that data is collected in accordance with the requirements of the selected method. When the Universal Soil Loss Equation (USLE)[7] is chosen as the quantitative method for Step 5, the resulting estimate reflects the average annual soil loss from splash, sheet, and rill erosion for the specific field segment chosen. In general, the USLE should be used on field segments where erosion is more severe. The USLE is not used to estimate soil erosion from gullies, however.[8] (The formula for calculating gully erosion can be found in Equation 2 on page 35.) To calculate gully erosion, one can use a math formula to determine volume of soil, which is then connected to tons of soil that is lost to erosion on an average annual basis. The formula is presented in Chapter 5. Collection of data for use of this quantitative method does not eliminate the need for additional descriptive data for the other steps of the evaluation plan from the remaining portions of the site.

Information summarized in Tables B2 and B3 for Steps 2 and 3 is considered along with erosion-related climate conditions that generally exist at all sites throughout an installation. Except in instances where mountain ranges or other natural factors create a significant variation in weather and moisture conditions, climate information is an erosion-related factor that remains constant across the whole installation. These general conditions are taken into account along with variable, site-specific information collected in these steps.

Identifying Erosion-Related Natural Factors

Climate (R factor), soil characteristics (K factor), vegetation (C factor), and topography (LS factor) are highly variable factors that all influence soil erosion. These factors must be evaluated during site assessment to determine how each contributes to on-site erosion. Knowledge about their characteristics allows the evaluator to later determine (during needs assessment) whether specific types of erosion controls can be considered as solutions for the kinds of erosion problems prevailing at the site.

Erosion-Related Climatic Factors

Climate influences soil erosion in many direct and indirect ways. Annual rainfall volume, intensity, and distribution over time affect the efficiency of water and wind erosion processes. An interpretive number correlating rainfall intensity and duration is the rainfall factor R. In cold climates snow may provide a protective soil surface cover. Where significant snowfall occurs, consideration must be given to the effect of snowmelt on runoff conditions. Under arid, windy conditions, unprotected soil may be particularly susceptible to wind erosion. Furthermore, seasonal fluctuations in temperature (related to freeze/thaw cycles or permafrost conditions) affect infiltration rates of water into the soil.

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[7] The USLE is demonstrated in Equation 1 on page 35 of this report as part of the discussion of needs assessment. For more information see USDA Agricultural Handbook 537, *Predicting Rainfall Erosion Losses: A Guide to Conservation Planning* (USDA Science and Education Administration, December 1978).

[8] Cooperative Extension Service Circular 1220, *Estimating Soil Losses with the Universal Soil Loss Equation (USLE)* (University of Illinois College of Agriculture, November 1983).

Climate affects soil erosion indirectly by affecting conditions for soil formation and plant growth. Rates of chemical processes that occur during soil formation, uptake of nutrients, and plant growth are temperature- and moisture-dependent. Temperature extremes may retard or prevent seed germination and plant growth. Lack of adequate moisture for maintaining a vegetative cover increases the susceptibility of the soil surface to erosion. This makes reclamation of eroded sites especially difficult where plant root systems help to stabilize the soil as well as erosion control structures in biotechnical applications. Seasonal variation and lengths of growing seasons affect not only the types of plants that will be used for revegetation, but also dictate the planning and timing of M&R operations.

Rainfall amounts for design storms* are needed for physical process model input as well as design specifications for structures and systems that require the calculation of peak flows. The 10-year 24-hour design storm is commonly used for this purpose, but information about other design storms is also readily available.[9]

Soil Characteristics

Texture influences a soil's capability to handle moisture and serve as a medium for plant growth. Texture affects soil infiltration rates, percolation rates, total water storage available for plant growth, and aeration for root growth. The impact that texture has on a soil's electrolytic properties also links it to fertility. Knowledge of hydrologic soil conditions provides information about how the soil handles runoff. The volume of runoff from an area is largely affected by the soil and its hydrologic condition. Soil hydrologic groups are classified according to water infiltration rates. Groups range from infiltration rates of A (highest) to D (lowest) (see Appendix E). Soils containing high percentages of silt and clay have a low rate of water infiltration and a high runoff potential. Soils containing a high percentage of coarse, gravelly sand usually have a high infiltration rate and a low runoff potential, even when thoroughly wet.

Hydrologic soil information is needed as input for the physical process models and, eventually, for design specifications of conservation structures and systems. Hydrologic properties and plasticity index rating are important engineering characteristics that affect the suitability and design of some constructed erosion controls.

Special geotechnical conditions (e.g., shallow depths to bedrock or water tables, slope instability, seismic factors) must also be noted because they will pose problems for engineering activities and water management. Soils with water management limitations may have characteristics that will cause seepage in ponds and reservoirs; piping or ponding in embankments, dikes, and levees; and erosion or wetness for terraces, diversions, and waterways. This category of information is essential when considering alternative erosion solutions.

A soil's water erodibility refers to its inherent susceptibility to particle detachment and transport by rainfall and runoff. It results in sheet and rill erosion. High K erodibility index values mean high susceptibility to sheet and rill erosion by water. The K erodibility index value is also needed to determine soil loss using the USLE and physical process modeling.

Wind erodibility refers to soil characteristics that affect their susceptibility to blowing. If more than one-third of a site has soil with high wind erodibility, the entire site should be considered highly erodible.

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* A statistical or theoretical storm whose magnitude, rate, and intensity are used as a basis for an engineering project's design specifications.

9 For example see G.O. Schwab, R.K. Frevert, K.K. Barnes, and T.W. Edminster, *Soil and Water Conservation Engineering*, 3d ed. (John Wiley and Sons, 1981).

Vegetation and Ground Cover

The type and condition of vegetation and ground cover are also evaluated in detailed site assessment. This information is used to determine the C-factor value for USLE calculations. The role of vegetation as a retardant to soil erosion cannot be overemphasized. Plants protect the surface of soil. They play particularly important roles in preventing wind, splash, sheet, and rill erosion. Ground cover intercepts raindrops, absorbs rainfall energy, reduces soil particle detachment, and lowers runoff velocities. Root systems bind and stabilize soil particles and combine with plant residues to increase soil porosity and infiltration. Foliage and botanical "litter" prevent soil surface sealing from raindrop impact. Transpiration of soil moisture by plants creates voids in the soil that can trap new rainfall. Increased infiltration reduces runoff peak discharge rates, which in turn reduces the translocation of soil.

The use of vegetation in combination with engineered structural erosion controls is called biotechnical erosion control. Where biotechnical methods are used, the mutually reinforcing effects of the vegetation and structure increase the overall stability and effectiveness of the control system.

Topographical Factors

Length (L) and steepness (S) of slope affect the soil detachment and translocation processes that produce sheet, rill, and gully erosion. For USLE calculations, LS indicates a linear numerical relationship between slope length and steepness. Steep slopes promote increased shear stresses and increased runoff velocities which, in turn, promote detachment and translocation (movement) of soil. Long slopes increase detachment and transport capacities due to the greater accumulation of runoff.

In windy locations, level, open areas present conditions favorable for wind erosion. Where the soil is unprotected by plants or other factors, soils with high wind erodibility characteristics are particularly susceptible.

Off-site factors must also be considered in topographic evaluation. The position of the site within the watershed and the impact of conditions adjacent to the site are important factors for problem identification. This information is particularly valuable where runoff conditions or sedimentation pose problems. It should be noted whether the site contributes or receives and conducts runoff to adjacent sites. This is important because in order to effectively treat erosion damage existing in lower parts of a watershed, it is necessary to treat upslope conditions that contribute to the downslope erosion damage.

Information Sources for Step 2

Appendices E and F provide information for completing Table B2, which is used to record erosion-related natural conditions at sites requiring detailed assessment. The county soil survey report contains tables with rainfall and growing season data for the area. General climate information is available in the soil survey's section pertaining to the general nature of the survey area. It can also be obtained from the figures in Appendix F for installations located in the continental United States (CONUS). Figure F2 shows climatic regions for CONUS as they pertain to plant growth. For detailed information see the U.S. Air Force technical manual *Natural Resources Land-Management*,[10] from which Figure F2 was reprinted. Climatic regions are discussed in Chapter 4 of that publication. It also contains maps of CONUS indicating average warm-season precipitation amounts and average length of frost-free periods. Figure F4 includes design storm data for Alaska and Hawaii. To obtain climate-related data for other locations, consult the U.S. Weather Service or the nearest military weather observation detachment.

[10]TM 5-630/AFM 126-2/NAVFAC MO 100.1.

SCS county soil survey data and computer databases should be used where available as sources of information for items 3 through 6 on Table B2. Automated database information and computer-generated erosion classification maps can be used as sources of information for items pertaining to soils and vegetation. Slope dimensions used for USLE calculations and rehabilitation purposes, however, must pertain specifically to the eroded part of the slope. More information about using the USLE is available in SCS publications and various other soil conservation texts. Publications such as the previous cited Agricultural Handbook 537 and University of Illinois Circular 1220 contain tables for determining C, LS, and P factors. Similar guides can be obtained from local Soil Conservation Service field offices.

The soil survey contains descriptions of the detailed soil map units indicating erosion hazards based on permeability and surface runoff rates. Descriptions of the general soil map units, detailed soil maps units, physical properties, and engineering properties provide additional helpful information. Soil survey tables summarize K factor, water management limitations, and hydrologic soil group classification. The automated SIRS also provides soil information. If available for the installation under study, the terrain analysis can be consulted for items 4 through 6 of Step 2.

Data Collection Procedures for Step 2

First organize the data collection plan, separating field tasks from those that can be completed in the office. (Do this for both steps 2 and 3 of the detailed site assessment.) For example, complete items 1 through 6 in the office prior to fieldwork. Time can also be saved by previewing Table B3 to see which items can be collected in the office at the same time. Then proceed to the site to hand texture the soil, determine slope, aspect, dimensions, position of the site within the watershed, and evaluate vegetation and ground cover conditions to verify archival information. Revision of archival information may be necessary to reflect recent degradation due to human activities or natural events. While at the same site, continue to gather information for Step 3 (Table B3) after Step 2 is completed.

Rainfall information is needed for item 1 on Table B2. The evaluator should consider climate conditions as they relate to erosion processes. The R index value for rainfall intensity and duration is used to calculate soil loss and tolerance when applying the USLE. If snowmelt runoff (Rs factor) is significant at the location, add it to the R value. The value for R is computed by multiplying the amount of precipitation from December through March by 1.5. The amount is measured in inches of water. An example of this calculation is presented in Appendix F.

On Table B2, record the method used for determining soil texture according to the USDA Soil Classification System. Hand texturing in the field is generally used in conjunction with maps and soil series descriptions from the USDA soil survey. Unless the site is located at a boundary of one of the soil map units, textures of field samples are likely to be that as described for that soil series.

Engineering properties for soil series are given in the SIRS database, the installation terrain analysis, and the soil survey. The Unified Soil Classification System (USCS) is presented in Appendix E. By using the cited information sources, note the general suitability of the soils at the site for engineering purposes. Record any comments on Table B2, along with plasticity index and liquid limits. This information will be useful later when selecting erosion controls most suitable for use under prevailing site conditions. Generally, where engineered structures will be built, engineering tests are performed on the soil to verify its suitability as a construction material. Laboratory mechanical analysis should be performed to determine particle size distribution where hand texturing may be unreliable or where engineered construction projects will take place. When laboratory test results for soil fertility, particle size, and other engineering properties are received for sites requiring detailed assessment, attach the reports to Table B2 and file for future use.

Using the soil survey or SIRS, find the K factor value for the soil series. If using the soil survey book, check the table itemizing wind erodibility and designate the susceptibility of the series in terms provided by the survey's section about physical and chemical properties. As noted previously, the more severely eroded areas should not be averaged in when characterizing a site: they should be considered as distinct areas. If more than one-third of a site is highly erodible, however, the entire site should be considered highly erodible.

The type of vegetation is recorded as tree canopy, brush or weeds in terms of percentage. The percentage of cover is then used to derive an index value for use in USLE calculations to determine soil loss and tolerance (see Tables F-2 and F-3). Determine the percentage of ground cover consisting of stone, gravel, and other impervious material. Canopy and ground cover factors are also components of surface characteristics. Percentage of cover can be determined in the field using the point-intercept method. Mark off a 100- yard transect (1 yard = 0.9144 meters) that typifies the site. At each 1-yard interval, record the type of ground cover according to categories present at the yard mark. This method can also be used to determine percentage of vegetation according to kind, as outlined on Tables F2 and F3.

The method used for quantification of soil loss determines which types of slope measurements should be taken in the field. Data for Army Sediment (ARMSED)[11] physical process modeling is marked optional on Table B2. Refer to user information for the USDA Water Erosion Prediction Project (WEPP)[12] system when determining slope for WEPP physical process modeling. Regardless of quantitative method, however, topographic characteristics of the site should be recorded in terms of site-specific features as well as its relationship to the overall drainage system of the area.

Hillside slopes can be measured with an Abney level, clinometer, or other angle measuring instrument as discussed in Step 1. The LS value is determined by obtaining slope percent and length (see Table F1). For USLE calculations, slope length is the distance from the point of origin of overland flow to a point of deposition or where runoff erodes a well defined channel.[13] Average slope steepness is measured for the critical area of concern (i.e., the eroded area).

Slope aspect refers to the direction in which a slope faces. This factor often relates to the severity of erosion and problems associated with the establishment and survival of vegetation. In northern latitudes, growth is generally later on north-facing slopes. Slopes with southern exposures are usually warmer and drier, which can result in lower moisture for plants during hot, dry months. Exposure to the prevailing wind, heavy snowfall, intense rainfall, and limited sunlight creates a microclimate that may promote erosion in many ways. Freeze/thaw cycles and growing conditions are also modified where such conditions prevail at sites located in such positions on the landscape. Conditions at such sites might require special kinds of erosion controls and revegetation methods.

Examining Site Erosion Conditions and Contributing Factors

Examination of site erosion conditions involves (1) the identification of erosion processes and (2) recognition of how natural factors and human activities contribute to those processes. Identification of erosion problems is facilitated by a process-oriented, cause-and-effect approach in assessing site

[11] See R.E. Riggins and T.J. Ward, *A Runoff and Sediment Yield Model for Army Training Land Watershed Management*, Draft Automatic Data Processing (ADP) Report (USACERL, 1988).

[12] See User Requirements, USDA Water Erosion Prediction Process (WEPP), Draft 6.2 (USDA Agricultural Research Service, SCS, and U.S. Department of the Interior (USDI) Bureau of Land Management, 15 January 1987).

[13] USDA Agricultural Handbook 537.

conditions; certain features in the field are considered to be evidence that particular erosion processes have taken place.

Recognition of how natural factors contribute to problems at a site is an integral part of erosion problem identification and needs assessment. Examination of prevailing erosion-related factors helps identify the site's deficiencies for resisting erosion and leads to a more accurate and complete assessment of needs. The role of human activities must also be taken into account. The needs assessment portion of the Erosion Control Management Plan involves identification of the types of erosion controls that interrupt erosion by reducing erosive forces, increasing resistance to those forces, or both.

Kinds of erosion prevailing at the site are identified on the preliminary evaluation sheet. Figure 5 indicates the phases of erosion processes associated with specific kinds of erosion.

Soil loss exceeding the rate of natural erosion process is called "accelerated erosion." This occurs when the efficiency of erosion is enhanced by an increase erosive energy, a decrease in resistance to that energy, or both. Erosion processes are said to have "positive feedback mechanisms" because the results of erosion tend to make subsequent erosive processes more efficient. Because of this a site can erode severely in a relatively short time.

Precipitation, running water, ice, wind, animals, and humans all cause erosion. Three phases are associated with wind and water erosion: detachment, translocation, and deposition (see Figure 5). Processes such as freezing, thawing, raindrop impact, and soil disturbance caused by man and animals loosen and detach soil particles. Soil properties that resist erosive forces are inhibited by those processes making the soil more susceptible to erosion. For example, wind erosion is assisted by processes that dry out the soil and loosen particles.

Flowing water, raindrop splashes, and wind all move soil particles. The volume and erosive force of runoff increases as it moves downslope, causing increased damage by dislodging and carrying away more soil. Sediments are deposited in depressions, at the bases of sparsely vegetated slopes, in stream channels, or in other bodies of water.

The Human Role in Accelerating Erosion

Human activities (e.g., Army training, construction, recreation) compress or expose soil, altering its porosity and infiltration rates. This increases runoff and erosive forces. Any activity that reduces plant cover and alters the physical state of the topsoil often enhances the efficiency of erosion processes and accelerates erosion.

Destruction of vegetation increases amounts of overland flow and greatly reduces soil surface resistance to eroding forces as they are applied directly to the bare soil surface. Construction activities such as road building or other landform modification may concentrate runoff or create impervious surfaces that increase runoff peak discharge rates across adjacent areas.

Where characteristics of natural conditions such as soils or topography do not appear to be especially conducive to erosion processes when left undisturbed, it is the impact of human activities that may reduce their erosion resistance, initiate erosion processes, and enhance their efficiency. Knowledge of current and past human activities and land use is needed in order to determine what erosion process enhancing factors have impacted natural conditions existing at the site.

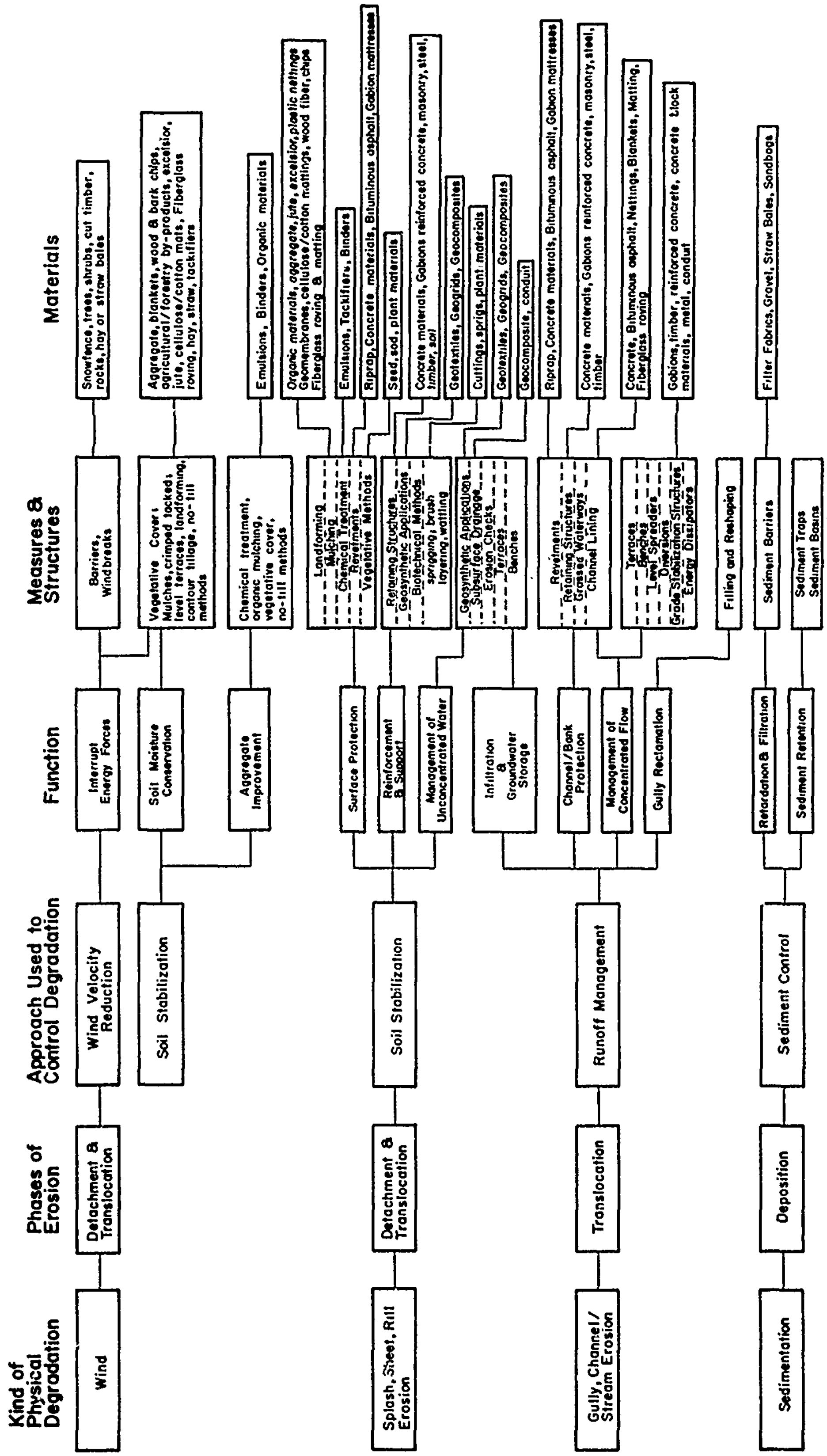

Figure 5. Classification of methods, materials, structures, and systems for soil stabilization, management of runoff, and sediment control. Adapted from *Procedures and Standards for Urban Soil Erosion and Sedimentation Control in Illinois* [Northeastern Illinois Soil Erosion and Sedimentation Control Steering committee, 1981]).

Information Sources for Step 3

Site inspection, Appendix C, and Figure 5 are used to complete item 1 of Table B3. The sections of this report pertaining to the completion of steps 1, 2, and 3, and evaluation sheets for steps 1 and 2, are sources of information for item 2 in Table B3. Sources of information about human activities include range control office, agricultural outlease records and field inspection. Range usage records and training schedules can be used to identify training activities and types of vehicles used in the training area. Outlease records indicate past agricultural management and conservation practices. Field inspection provides evidence of human contributions to accelerated erosion. The site sketch should be completed while on site. Photographs of the site (cross-referenced by roll and frame number on evaluation sheet) are also useful for office review at a later date.

Data Collection Procedures for Step 3

First review Table B3 to organize the data collection plan. Time can be saved by collecting information about human activities for item 3 when gathering other office-available data for Table B2. Review Appendix C and Figure 5 for assistance with linking field features to erosion processes. Review *Principles for Step 3* in this report to determine how natural conditions contribute to erosion. Review the previous sections discussing erosion processes and the human role in accelerating them.

Visit the site under study to see what erosion features are present and to determine what erosion processes have occurred there. In making these determinations, consider the natural factors itemized on Tables B2 and B3 as well as any human impacts at the site. The evaluator is seeking answers to two basic questions: (1) "What is going on here?" and (2) "How are natural conditions and human activities contributing to what is occurring here?" Note the success or failure of any erosion control or conservation practices previously used at the site. Take a photograph of the site, or at least make a rough sketch. Note the dimensions of areas needing treatment. Use dimensional information about the site from item 7 of Table B1 and item 8 of Table B2.

5 NEEDS ASSESSMENT FOR WIND- AND WATER-RELATED EROSION

Principles for Step 4: Assessing Erosion Control Needs

Needs assessment concepts and procedures are presented here as guidance for the site evaluator seeking solutions to the erosion problems identified. After completing site evaluation for problem identification, the evaluator determines (1) what erosion control measures and structures are needed at the site to control the erosion processes and problems occurring there, and (2) which of those controls are appropriate for natural conditions and training compatibility requirements. These determinations are derived through the use of information gathered during the problem identification procedures.

After alternative erosion control measures are identified as being functionally appropriate and suitable for natural conditions and training compatibility requirements, the evaluator quantifies soil loss and tolerance or runoff and sediment yields. Quantification of soil loss or runoff and sediment yield allows the land manager to show numerically to what extent erosion control is needed at the site. This information can be used along with other considerations in prioritizing restoration of eroded sites.

Functional Appropriateness of Control

Determination of what erosion control measures and structures are needed at the site to control the erosion processes and resulting problems is facilitated through the use of Figure 5. The evaluator uses this chart to link field features, erosion processes, functions, measures, and materials. This part of the needs assessment is best done at the site so the evaluator can readily visualize how alternative controls would fit spatially into the topography at the site to cause the desired changes. Onsite analysis enables more accurate estimation of dimensional requirements for the controls and minimizes the need to return to the site to verify field-related information. Control measures for wind- and water-related erosion are categorized on the basis of how they interrupt erosion processes and control degradation. The way in which erosion controls do this is called the "approach" in broad terms. Functions designate more specific methods of interrupting and controlling erosion.

Alternative erosion controls that might be suitable for implementation at the site alter erosive forces by reducing their energy to diminish their effects or by altering erosion-related factors to increase their resistance to withstand effects of forces without sustaining damage. Many of the measures and structures itemized in Figure 5 perform more than one function. These controls are especially useful where multiple erosion processes are occurring. The evaluator reviews the list of these alternative controls to determine the appropriateness of measures for implementation at the site.

Appropriateness of Control for Natural Conditions

To determine if it is feasible to construct particular erosion controls under existing natural conditions, the evaluator should refer to technical information sources outlining conditions and restrictions for their use. The local SCS field office is a particularly good information source because its personnel are familiar with local soil conditions and types of erosion controls that can or cannot be used under particular local conditions.

Refer to past maintenance records to identify lessons learned about control measures used previously at the site. Consider the measure's degree of success in view of the present condition, present rate of soil loss and sediment yield from the site, and time since its implementation. Indicate any modifications that might have improved the efficiency and durability of the control measure used.

When the ARMSED model is used, the effects of alternative structural measures and their siting can be compared for the given natural conditions of the site. Simulations can be run for modeling each measure to compare runoff and sediment yield amounts for subwatershed areas within the site as well as for the site as a whole. The ARMSED model can also predict effects of human impacts if continued activities further reduce the percentage groundcover or cause other impacts on natural conditions that accelerate erosion.

Publications such as the SCS *Engineering Field Manual*, the *USDA National Handbook of Conservation Practices*, and the USACERL technical report *Erosion Control Methods for Army Training Land Rehabilitation: Survey of Current Technology*[14] provide information about conditions for use of erosion control structures. Engineering characteristics of the materials and slope steepness are examples of some limitations.

Soil surveys contain a table on water management that lists limitations of soils by series. This table itemizes features affecting controls such as waterways, embankments, terraces, and diversions. The installation terrain analysis also itemizes limitations of soils for engineering purposes.

Erosion control measures usually provide multiple control benefits by disrupting more than one phase of erosion processes. When the land manager or evaluator is considering the appropriateness of alternative controls, attention should be given to the full range of prevailing natural conditions and how they will be affected or will affect implementation of the control.

Environmental Impact Considerations

Potential impacts of erosion controls must be considered for sites requiring construction activities, landforming, or other disturbance. Consideration must be given to potential damage during construction as well as permanent effects of the implementation on sensitive areas or threatened and endangered species. Wetlands or those sites having archeological, historical, or other cultural significance are protected by public laws and statutes. Actions must be taken to ensure that such sites are not adversely impacted by erosion project implementation. The land manager should know about such conditions. Sites and records of previously conducted cultural surveys should also be inspected by the evaluator for any evidence of those conditions. Locations along streams are often candidate archeological sites and should be assessed by personnel technically competent in that field. Where such conditions exist, or where proposed projects will alter the site considerably, Environmental Assessments (EAs) and perhaps Environmental Impact Statements (EIS) will be required. Choice of erosion controls to be implemented at environmentally sensitive sites will be influenced by their projected effects on those conditions. The predictive capabilities of the ARMSED model are particularly valuable in such instances.

Appropriateness of Control for Training Compatibility

Erosion controls need to be evaluated for their compatibility with training mission requirements to preclude the possibility that a structure may be a safety hazard or spatially inhibit training activities. The Range Safety Officer or other individual responsible for safety on a range or training area should be consulted to help identify any special restrictions or limitations that might apply to prospective erosion control measures. While it may be known in general what kinds of structures are not desirable, the implementation of specific structures and their design characteristics and materials may result in exceptions to very general guidelines or customs. Army policies and directives pertaining to the type of construction associated with implementation of a control should also be consulted.

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[14] *Engineering Field Manual for Conservation Practices* (USDA Soil Conservation Service, July 1984); *National Handbook of Conservation Practices*, National Technical Service Publication No. PB85-177137 (USDA, June 1984); E. G. Vachta and R. E. Riggins, *Erosion Control Methods for Army Training and Rehabilitation: Survey of Current Technology*, Technical Report N-88/05/ADA197566 (USACERL, 1988).

Durability is an aspect of compatibility that needs to be examined when considering alternative erosion controls. In many cases on Army training lands, the use of conventional agricultural conservation structures and systems is inappropriate or inadequate due to the kinds of activities that occur during training. When considering alternative erosion controls, the evaluator should keep in mind that combinations of materials in critical areas and structural modifications can, in many instances, increase the durability of a structure normally used under agronomic conditions to enable its use for prevailing training conditions. Types of erosion controls should not be ruled out without first considering the possibility of their modification unless official directives prohibit their use or they pose serious safety or serious incompatibility problems.

To ensure training compatibility, the appropriate training, range, and safety management personnel, and Army directives pertaining to construction of the erosion control under consideration should be consulted before selection.

Approach for Assessing Wind-Related Erosion Control Needs

Review Table B3 for Step 3 to determine if wind erosion is considered a major problem at the site. If so, select wind control measures alone or in conjunction with required water-related erosion control measures. Wind erosion control is achieved by (1) reducing surface wind velocities and (2) changing soil factors.

Wind Erosion Control by Reducing Surface Wind Velocities

The amount of protection provided by erosion control methods that reduce surface wind velocities through mechanical barriers such as wind breaks is influenced by the height and distance between barriers and their breaking effects on the wind. Some controls serve a dual role. Surface wind velocity reduction methods such as planting vegetation, stabilizing surface protection, and practicing proper agricultural tillage also stabilize by increasing the soil's resistance to movement.

Wind Erosion Control by Changing Soil Factors

The most important factors for wind erosion control are conservation of soil moisture and improvement of soil aggregation.[15] Controls of this type reduce the soil's vulnerability to wind action. Soil moisture is conserved through methods that increase infiltration and/or reduce evaporation. Common methods include level terracing, contouring, and surface protection through chemical treatment of the soil surface with emulsions that coat and bind together soil, sand, and rock particles to reduce moisture evaporation and suppress particle suspension. Chemical tackifiers stabilize the soil by bonding mulches, seed, and fertilizer on the soil surface until vegetation is established. Gravel blankets can be used in areas where rainfall is limited and vegetation is sparse. Consult the previously cited TM 5-630 for guidance on using gravel blankets. Under extreme conditions, ground surfaces can be paved to control blowing dust and sand particles.

Approach for Assessing Water-Related Erosion Control Needs

Controls for water-related erosion are categorized according to whether they provide soil stabilization, runoff management, or sediment control. These categories correspond to erosion phases. Soil stabilization measures furnish protection for the soil surface by preventing splash, sheet, and rill erosion. Measures such as mulching, establishing vegetation, chemical treatment, and revetments protect the soil surface from

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[15]G. O. Schwab, et al., 1981.

erosive impacts of rain and runoff. Management of unconcentrated water also stabilizes the soil. Often vegetation requires extra protection and stability from landforming, emplacement of materials, or structural support.

Runoff management is necessary to control concentrated flows of water that may lead to gully, stream, and channel erosion. Some kinds of soil stabilization measures that offer protective surface covers and have other properties that slow or reduce runoff are also suitable. Heavy-duty geosynthetic mattings and conventional materials used for revetments are examples of materials that serve more than one function. Where slopes are steep or long, runoff management measures are used to divert flow, keep velocities low, or dissipate energy. Diversion of flow can be used to reduce runoff volumes and velocities or to divert the existing flow to an area that can safely handle it without sustaining erosion damage.

Sediment controls are used for onsite sediment management. Soil particles that have become dislodged and carried away by runoff are entrapped before they are carried to areas where damage to natural habitat or cultural conditions occurs.

Quantification of Soil Loss, Tolerance, and Runoff or Sediment Yields

The evaluator next quantifies soil loss and tolerance or runoff and sediment yields. Quantitative methods are used (1) to estimate soil loss, runoff, and sediment yield amounts, (2) as input for prioritizing site restoration, (3) to develop specifications for erosion controls that require knowledge of peak rates of runoff, and (4) as input for erosion project justification. The choice of method depends on the purpose, available data, and data processing capabilities.

A land manager using the USLE wind erosion equation (1) estimates soil loss (in tons/acre/year) for the site under existing conditions, (2) compares that loss with the soil loss tolerance for that soil series, and (3) estimates the expected soil loss for the site after the erosion control is implemented at the site. If the physical process models are used, sediment yield for watershed segments is compared on a before and after implementation basis.

Soil losses are quantified for an eroded site to generate numerical data showing that erosion control is needed at the site. This numerical expression of soil loss or sediment yield can be used in project origination to justify the need for a control and its associated costs. It can also be used as one of the factors for prioritizing sites. Quantitative data are recorded on Table B4 with other needs assessment information.

Water Erosion

As stated previously, technical information about the use of the USLE is available from the local SCS field offices, textbooks on soil and water conservation, and various government and university publications.

The USLE water erosion equation estimates long-term soil loss due to splash, sheet, and rill erosion from a moderate slope having medium soil textures. It does not predict soil loss from specific storm events, nor does it estimate soil loss from concentrated flow of channels, gullies, or streambanks. The USLE may eventually be replaced by the WEPP physical process model but, at the time of this writing, it is the standard, field-tested erosion formula for soil and water conservation practices.

Soil loss tolerance T values are available for each soil series and can be obtained from the county soil survey in the table pertaining to physical and chemical properties of the soils. The T factor pertains to erosion by water and wind.

The equation used to calculate soil loss in tons/acre/year is:

$$R \times K \times LS \times C \times P = A \qquad \text{[Eq 1]}$$

where:

R = rainfall factor
K = soil erodibility factor
LS = length and steepness of slope factor
C = cropping and management factor
P = conservation support practices factor
A = computed average annual soil erosion loss (tons/acre/year).

Values for R, K, LS, and C were determined during detailed site evaluation and were entered on evaluation sheets B2 and B3. P factors for conservation support practices generally pertain to the implementation of terraces and contour agricultural practices (see Tables F4 and F5). In general, however, results of proposed erosion controls can be shown by changes in C values where the soil surface will be protected by additional cover. Changes in slope length or steepness will also change where grade stabilization or retaining structures are implemented. The SCS field office can provide guidance on selecting appropriate variables for site-specific circumstances.

The formula for calculating soil loss from gullies involves multiplying the average width of a gully by its depth and length. This results in a volumetric expression that is converted into tons of soil lost on an average annual basis.

The gully erosion calculation is as follows:

$$E = D \times \frac{(W+W_1)}{2} \times L \times \frac{(V)}{2000} \times \frac{1}{Y} \qquad \text{[Eq 2]}$$

where:

E = Annual erosion (tons)
D = Depth (ft)
W = Top width of gully (ft)
W_1 = Bottom width of gully (ft)
L = Gully length (ft)
V = Unit weight of soil (lbs/ft^3)
2000 = Pounds per ton
Y = Number of years gully existed

The value for V pertains to soil density. It varies according to texture and amounts of organic matter in the soil. The more organic matter there is in the soil, the lower this value is. Silty and loamy soils typically have values between 80 and 95. Gravelly and coarse-grained soils typically have higher values. Values for soils can be obtained from the local SCS field office.

Computer technology enables erosion prediction by means of erosion modeling to estimate concentrated flow, sediment delivery, and deposition within an area. The ARMSED and WEPP single-event physical process models perform functions such as estimating detachment or deposition of sediment during a storm on specific portions of a field, sediment yield at field outlets, and amounts of specified particle sizes. Consult user requirement guides and software operating procedures for more information about program capabilities.

ARMSED is a computerized simulation model currently being field-tested by the Army at several installations to model runoff and sediment yield for siting conservation structures and systems. Its predictive capabilities are useful for determining optimal number, capacity, and location of structures. Based on runoff and sediment yield data, ARMSED can be used to compare sites for prioritization.

In addition to computing runoff and sediment yield, the WEPP model computes sheet-rill erosion and average annual soil loss from eroding areas. Implementation of the WEPP model as the standard method for soil and water conservation practice is expected to occur after field-testing over a few years.

Wind Erosion

The wind erosion equation can be used to calculate potential soil loss by wind or to determine if a particular field is protected adequately from wind erosion. Calculation of the wind erosion equation is complex and assistance will probably be needed. USDA Agricultural Handbook 346[16] presents examples of field application and a slide rule calculator is available commercially for this purpose. Wind erosion losses can be estimated using the following equation:

$$E = f\,(I',\ C',\ K',\ L',\ V) \qquad \text{[Eq 3]}$$

where:

E = weight of annual erosion per unit area
I' = a soil erodibility index
C' = a climatic factor
K' = a soil ridge roughness factor
L' = equivalent field length along the prevailing wind erosion direction
V = equivalent quantity of vegetative cover.

Relationships among the equation variables are complex and cannot be expressed in simple mathematical form.[17] Further research on the primary variables influencing wind erosion is needed to increase the equation's accuracy and usefulness. Information needed to solve the equation is: (1) content (percent) of 0.84-mm size particle fraction, (2) wind velocity and the difference between precipitation and evaporation, (3) the heights and spacing of soil surface ridges, (4) field width, and (5) kind, orientation, and amount of vegetative cover and residue. Maps, graphs, nomographs and tables have been developed for use with this information and are included in USDA Agricultural Handbook 346. Check with the local SCS field office for availability of this or other publications for determining wind erosion losses.

Due to the complexity of this equation, quantification of wind erosion by the evaluator is not called for here. If wind erosion is prevalent, consult the local SCS office for assistance in the proper use of this equation to estimate soil loss and to determine requirements for wind barriers or soil surface protection. Enter remarks and data concerning wind erosion on Table B4.

[16] USDA Agricultural Handbook 346, *Wind Erosion Forces in the United States and Their Use in Predicting Soil Loss* (USDA, 1968).
[17] G. O. Schwab, et al.

6 COST ESTIMATES FOR ALTERNATIVE EROSION CONTROLS

Principles for Step 5: Estimating Costs for Erosion Control Selection and Resource Requirement Projections

Erosion controls that have been identified as functional for controlling the erosion processes present, appropriate for natural conditions, and compatible with training requirements, are compared in terms of cost. As described here, cost comparison is a simple means for assessing similarities and differences in relative costs of erosion control technologies. Cost elements examined relate to: (1) initial installation and construction and (2) maintenance and repair.

In Step 5, preliminary "desk" estimates are formulated and compared by the individual responsible for originating erosion control construction projects (see Table B5). The estimates are used as a basis for (1) relative cost comparisons of alternative erosion controls and (2) projections of financial requirements for erosion projects that will be placed in the installation AWP. The information presented in this chapter serves as background material that can be used by the land manager to complete the needs assessment and erosion control selection process.

Cost comparisons discussed here are used to indicate the relative magnitude of costs among erosion controls. This simple method of comparison is used because the cost data required for it is readily generated and assembled at this functional level within the DEH; also, it is the same basic information from which detailed working estimates are derived by the Engineer Resource Management Division's (ERMD) Estimating and Facility Inspection Branch. Preliminary estimates can be calculated manually or by using an automated software package suitable for this type of cost estimating. Data needed for either of these methods can be obtained through systematic collection and organization as indicated on Table B5 for Step 5.

While the purpose of performing this cost comparison is to identify the least costly, most appropriate erosion control, it does not mandate selection of the least expensive technology. Although economic considerations weigh heavily in the selection process and provide quantitative information that can be used to justify decisions, it should not always be the sole basis for technology selection. In cases for which a given control is judged more appropriate for site conditions or provides many more benefits than a less costly, yet appropriate alternative, the additional benefits should be examined closely and valued within the framework of existing budgetary constraints.

Difficulties With Real Cost Comparison and Cost/Benefit Analyses

No attempt is made here to use real cost comparison methods as a part of the technology selection process. Real cost comparison is done by estimating total costs of initial construction plus operation and maintenance, and annualizing them over the expected lifespan of the structure. A procedure called "discounting" is used for annualization. It involves the determination of capital cost by computing the straight-line amortization of capital over the useful life of the technology and adding the interest on the average balance outstanding. To annualize costs of a structure or technology by this method, the life expectancy and some economic factors must be known.

If a project is submitted through the DD Form 1391 process for MCA funding, however, it generally must have an economic analysis that includes the use of discounting/life cycle costs and other factors. The Estimating and Facilities Inspection Branch may use a 1391 Processor that uses AR 415-17, *Cost Estimating for Military Programs*,[18] and other authorized cost and pricing sources to perform this

[18] See AR 415-17, *Cost Estimating for Military Programs* (HQDA, 15 February 1980).

analysis. AR 11-28, *Economic Analysis and Program Evaluation for Resource Management*,[19] contains guidance for this analysis. The analysis generated for DD Form 1391 must present evidence that all feasible alternatives have been evaluated and rejected.

While some data exists on the life expectancy of conservation structures used for standard agricultural erosion control, there is, in general, a lack of adequate data on the life expectancy of erosion control structures that receive impacts of Army training. Research is currently underway to collect and evaluate data pertinent to monitoring erosion control structure life expectancy and maintainability.

Cost per ton of soil saved and cost per acre treated are the kinds of cost/benefit ratios that serve as measurements commonly used for standard agricultural conservation structures and systems. The outcomes of these estimates are affected by project size since some costs are fixed, regardless of project size. In these cases, costs per ton of soil saved or costs per acre treated decrease as the area treated increases. As in the case of real cost comparison, knowledge of the technology's life expectancy is needed in order to calculate total costs and total benefits accurately.

Thorough cost/benefit analyses require knowledge of total costs and total benefits and their quantified values. Detailed studies and data are needed to identify total benefits and to place accurate monetary values on them. Of particular importance to the Army are benefits derived from erosion control technologies having special design features that enhance the land's utility for training activities. Research in this area is currently underway.

Initial Installation and Construction Costs

Costs associated with initial installation and construction include design engineering and technical supervision fees, labor, material, and equipment costs. These costs are influenced by factors such as availability, material quality, location, site conditions, and project size.

For comparing alternative erosion control technologies prior to technology selection, project requirements for labor, equipment, and material must be known for making reasonably accurate cost comparisons. Kinds of tasks and project phases should be identified to derive a preliminary desk estimate. The DEH Engineering Resource Management Division (ERMD) Estimating Branch has primary responsibility for assembling detailed labor and material estimates and phasing projects using the guidance in DA Pamphlet 420-6, Appendix B, Engineered Performance Standards (EPS), after a job request is submitted for approval. However, these tasks are facilitated and performed more accurately if the project originator identifies all job components at the preliminary scoping, planning, and design stages.

Site Variability Impacts on Installation and Construction Costs

Costs are affected by site-specific factors that influence application rates, material specifications, placement requirements, and quantities required per acre of treatment. As an example, installation of a subsurface drainage system may require deeper excavation at a particular site than had been anticipated. Soil conditions such as quicksand or rocks may call for additional labor and special equipment, or groundwater conditions may require tiling of a larger diameter than originally planned. Another example is variability in application rates for chemical soil stabilizer due to soil characteristics, topography, exposure to wind, and runoff conditions. Amounts, kinds, and costs of seed and soil amendments are determined from types of applications and rates recommended by the local SCS field office from soil sampling and specifications for the locality as discussed in Step 1 (see Chapter 3).

Costs for large projects may be reduced by high-volume purchasing of materials and operation of equipment above fixed minimum costs. In some cases, fewer cost units of a higher priced technology can

[19] See AR 11-28, *Economic Analysis and Program Evaluation for Resource Management* (HQDA, 2 December 1975).

be used on a job, making the overall cost of implementing the technology less expensive than a control measure that requires installation of more units that are less expensive. Because some erosion controls can be implemented more easily and economically than others under certain circumstances, site-specific conditions should be taken into account when making comparisons. For this reason, while historical records from previous similar projects are valuable for cost estimates, the data should be used with caution.

Key Factors Affecting Construction Costs of Structures and Systems

Table 3 lists key factors affecting initial construction costs of erosion control structures and systems. Factors listed commonly contribute largely to construction costs associated with the structure or system indicated. Although other costs (e.g., engineering and technical supervision fees) are also involved, consideration of these key factors will provide a basis for the desk estimate. It is possible, however, that in certain circumstances, due to natural, market, or other conditions, some factors not listed for a particular structure or system may have major impact on cost.

Material Costs

Tables 4 and 5 list materials used in erosion control applications and structures. The materials include those used (1) for stabilization and runoff management applications and (2) as components for stabilization, runoff management, and sediment control structures and systems. After grouping materials into the categories indicating similar types of usage, bare costs for materials were determined by contacting manufacturers, distributors, and contractors and by consulting *Means Site Work Cost Data.*[20] Cost ranges were established for materials that showed price variability due to quantities purchased, marketing differences, and product design for strength or other measure of durability. Cost ranges for materials were compared only with other materials in each category and ranked L (low), M (medium), and H (high) according to relative cost. No labor or special equipment costs (e.g., hydromulcher, compressor-driven roving gun) are included in material costs. As indicated in Table 4, water costs were not included in hydro applications. Costs for materials can be kept low if local or onpost resources are used (e.g., forestry, agricultural, and mineral materials). Timber, riprap, gravel, sand, and pine straw are examples of products that might be available onpost.

Labor Costs

Labor for completing erosion control projects may be available from one or more of the following sources: the in-house workforce assigned to the DEH branch responsible for training land maintenance; private firms that are awarded contracts through competitive bid; and troop labor. Identification of tasks involved in the phases of an erosion control project provides information needed to determine requirements for labor skills, specialized work crews, equipment, and trained equipment operators. This preliminary desk estimate for cost comparison does not require the use of Engineered Performance Standards (EPS) outlined in Appendix B of DA Pamphlet 420-6.[21] The Estimating Branch uses EPS to generate detailed estimates that itemize labor costs according to five basic task elements (material handling, travel, job preparation, actual production time, and allowances). General consideration, however, should be given these elements together with working conditions imposed by site-specific factors that may affect productivity. These considerations, along with information derived from similar jobs completed in the past, will be used to generate the desk estimate for comparing alternative erosion control technologies.

When deciding if work should be done by contract or by in-house personnel, the adaptability of work to contract operations must be considered. If a project requires expertise or a size of labor force unavailable in-house, then it becomes clear that contract work is necessary. However, in many cases, it

[20] *Means Site Work Cost Data, 1988,* 7th annual ed. (R. S. Means Co., 1988).
[21] DA Pam 420-6, (HQDA, 1978).

Table 3

Key Factors Contributing to Construction Costs of Erosion Control Structures and Systems*

	MATERIALS	INSTALLATION LABOR	EARTHWORK	SQUARE YARDAGE /	SQUARE FOOTAGE	LINEAR FOOTAGE	SUBGRADE PREPARATION	GEOTECHNICAL CONDITIONS	CUBIC YARDAGE	CONDUIT TYPE & DIAMETER	OUTLET TYPE
SOIL STABILIZATION		●	●								
BIOTECHNICAL METHODS EROSION CHECKS	●	●	●								
PAVEMENTS	●	●		●			●				
RETAINING STRUCTURES	●	●			●			●			
REVETMENTS	●	●		●			●	●			
SUBSURFACE DRAINAGE SYSTEMS	●	●	●			●		●		●	●
RUNOFF MANAGEMENT BENCHES			●			●		●			
DIVERSIONS			●						●		●
GRADE STABILIZATION STRUCTURES											
STRAIGHT DROP SPILLWAYS *	●	●	●						●		
BOX INLET DROP SPILLWAYS*	●	●	●						●		
HOOD INLET SPILLWAYS *	●	●	●						●		
DROP INLET SPILLWAYS *	●	●	●						●		
PIPE SLOPE DRAINS	●	●								●	
CHECK DAMS	●	●									
CHUTES, WIDE CONCRETE BLOCK	●	●	●						●		
FLUMES, CHUTES: PAVED, NARROW, SHALLOW	●	●	●						●		
FILLING AND SHAPING			●						●		
GRASSED WATERWAYS			●						●		
LEVEL SPREADERS		●	●						●		
STILLING WELLS, BASINS	●	●	●				●		●		
TERRACES			●			●		●	●		●
WATERBARS			●			●					
SEDIMENT CONTROL DRAIN INLET STRUCTURES	●	●	●								
SEDIMENT BASINS, TRAPS			●					●	●		
SILT FENCES, BARRIERS, FILTERS	●	●									

*CONCRETE, METAL
(Lower Installation Costs For Light Weight Metal Units)

*Note: see text for other factors that may also affect cost in some cases.

Table 4

Relative Cost Comparison of Alternative Materials for Soil Stabilization and Runoff Management Applications

Material	Cost Range*
Straw, hay, cornstalks, corncobs, tobacco stalks	L**
Wood residues, chips, shredded bark, pine needles, leaves	L**
Straw, hay; punched; loose w/ top net; tackifier/hydromulch	L - M** L - M***
Fiberglass roving	M
Straw blankets, sewn netting, staples	H
Geosynthetic semirigid matting, stakes	H
Geotextiles, nylon, blankets with sewn netting, staples	H
Cellulose fabric/paper, sewn blankets, staples	H
Coconut fiber blankets with sewn netting, staples	H
Jute netting, mats, staples	H
Excelsior blankets, staples	H
Chemical stabilizers, binders	L***
Aggregates, gravel	L**

*L-low, M-medium, H-high.
**Costs influenced by local and onpost agricultural or mineral resources.
***Hydro application; special equipment and water costs not included.

Table 5

Relative Cost Comparison of Alternative Materials for Soil Stabilization, Runoff Management, and Sediment Control Structures and Systems

Material*	Cost Range**
Gabions	M - H **
Riprap	L - M **
Grouted riprap	M**
Geosynthetic confinement grids; fill	L - M **
Fabric mats, grout/concrete injected	M - H
Concrete blocks interlocking standard, building	L - M **
Plant materials	L
Timber	L**
Portland cement concrete	H
Reinforced concrete	H
Broken concrete; recycled	L**
Bituminous asphalt	H
Straw bales	L - M**
Sandbags	L - M**
Silt fence fabric	L - M

*L-low, M-medium, H-high.
**Costs influenced by local and onpost agricultural or mineral resources.

will be necessary to evaluate the relative effectiveness of each method of work and to compare the total estimated cost of work for each method. In some cases, minor construction must be contracted to avoid interfering with the maintenance mission. AR 5-20[22] should be consulted when considering in-house versus contract work.

[22]AR 5-20, *Commercial Activities Program* (HQDA, 21 October 1986).

Troop-Constructed Projects

Appreciable cost savings can be realized by using engineer troop labor and equipment for erosion control projects. Efforts are now underway to identify engineer unit Army Training and Evaluation Programs (ARTEP) tasks that are similar to procedures used for erosion control projects. Of significant benefit to the Army would be situations for which ARTEP tasks can be performed as part of military training as well as for completing erosion control projects or phases thereof. The expertise available in active and reserve engineering units can, in many cases, complete an erosion control project at a lower-than-funded cost.

Guidance pertaining to the use of military personnel for RPMA work is provided by AR 420-10, AR 600-200,[23] and AR 570-4.[24] Engineer troop units permanently assigned to an installation or assigned temporarily for training may perform maintenance, repair, and minor construction projects in accordance with AR 415-32,[25] AR 420-10, and AR 420-22.[26] Projects selected for completion by engineer troop units should contribute to their technical proficiency and to training for their wartime mission. Therefore, the troop unit commander and the DEH should select projects carefully and coordinate with the installation Troop Projects Office. Through careful planning, coordination, and cooperation between these offices, project phases can be scheduled far enough in advance to allow for timely completion by other troop units or by specially skilled DEH or contract personnel who can then perform subsequent finishing tasks pertinent only to erosion control. It is essential that careful planning and ample time for execution be allowed to realize full potential benefits.

Equipment Costs

Equipment needed for erosion control projects may be available as Maintenance and Services (M&S) units owned by the Army and be acquired from: (1) agency equipment pools where the concentration of installations or activities make these arrangements economical, (2) other agencies through Interservice Logistics Support Agreements as authorized by DOD Directive 4000.19-R,[27] and (3) the private business sector through rental or leasing agreements when they are more economical than the other alternatives (AR 420-83).[28] Estimates for equipment costs should include operating costs. Chapter 4 of DA Pamphlet 420-6, and AR 415-35 contain guidance for formulating operating-hour estimates and depreciation rates per hour for Army-owned equipment. Although detailed estimates of equipment costs are not needed for the preliminary desk estimate, the cited guidance will be of assistance in this task.

The availability and choice of labor and equipment sources may affect initial installation and construction costs considerably. An erosion control technology that uses Government-owned equipment that would otherwise remain idle may prove to be significantly less costly than an alternative, seemingly less expensive method that must be performed with leased equipment or by contract.

Maintenance and Repair Cost Estimates

Maintenance costs considered here are those specified in the Army guidance cited previously. They include expenditures involved in keeping an erosion control structure or system preserved and maintained in such a condition that it can be used effectively for its designated function.

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[23]AR 600-200, *Enlisted Personnel Management System* (HQDA, 5 July 1984).

[24]AR 570-4, *Manpower Management* (HQDA, 16 February 1987).

[25]AR 415-32, *Performance of Military Construction Projects in the Continental United States by Troop Units* (HQDA, 23 June 1967).

[26]AR 420-22, *Preventive Maintenance and Self-Help Programs* (HQDA, 6 July 1976).

[27]Department of Defense (DOD), Directive 4000.19-R, *Defense Regulation for Interservice Support (DRIS)* (March 1984).

[28]AR 420-83, *Maintenance and Services (M&S) Equipment and Facilities Engineering Shops* (HQDA, 12 January 1976).

Repair costs also are those described in the Army guidance cited previously. These are expenditures involved in restoring an erosion control structure or system to such a condition that it can be used effectively for its designated purpose. Repair may include overhaul, reprocessing, or replacement of deteriorated components or materials as well as correction of deficiencies to meet current Army standards and codes when such work, for economy, should be done concurrently with restoration of failed or failing components. Like initial construction cost estimates, M&R estimates will include costs for materials, labor, and equipment. The same methods are used to determine these elements for M&R. These costs should be considered on an annual basis.

M&R needed to preserve or restore erosion control structures and systems to conditions such that they can be used effectively as intended varies greatly under a wide range of natural and training conditions. Estimation of material, labor, and equipment needs is facilitated by first identifying M&R requirements normally associated with each erosion control technology. Appendix A summarizes the requirements generally associated with erosion control structures and systems used under agricultural conditions. Historical records pertaining to M&R costs on other similar structures at the installation may contain valuable information and serve as guidelines for these estimates if training activities and site conditions such as soils and slopes are similar. After M&R requirements are identified, labor, equipment, and material expenses for completing the tasks can be calculated. Desk estimates for each technology being considered are then compared. It may be determined from these comparisons that some erosion controls should be excluded from selection because of excessively high M&R costs under certain training conditions.

Procedures

Select for final consideration and list on Table B5 only those erosion controls having *all* of the following characteristics: appropriate for application at the site with regard to functionality, natural and environmetal conditions, and training compatibility. Based on site dimensions (see Table B1), estimate amounts of materials and labor time needed for site work. Perform and record cost comparisons for each alternative control. Record conclusions and erosion control selection. Indicate whether a project or parts of it might be suitable as a troop-constructed project.

When all erosion project sites have been assessed and estimates prepared for each, compute total costs for each class of treatment approach and a total estimate for all erosion control projects to be placed in the installation AWP. Provide information as required to the requesting DEH office for compilation of resource requirement projections and, if needed, for more detailed cost estimation.

Master lists of inventoried sites according to priority and class of treatment approach should be maintained on file electronically and/or in hard copy. As soil analyses become available for sites, information should be entered into electronic files and lab slips attached to hardcopy evaluation sheets (Tables B1 through B5) for each site. A list of projects having elements suitable for troop construction should be turned over to the DEH TPO Troop Projects Officer (TPO) for possible selection by troop units. The TPO and the Land Management Office will then coordinate scheduling and ordering of materials for those projects selected.

7 CONCLUSIONS AND RECOMMENDATIONS

USACERL has developed the Erosion Control Management Plan (ECMP) as guidance for correcting and mitigating erosion on Army training lands. The plan is the erosion control component of ITAM.

The Erosion Control Management Plan consists of systematic procedures for identifying erosion problems, assessing needs for remedial action, and selecting appropriate solutions for erosion control. Guidance also is provided for originating erosion control projects, classifying them by work type, and placing them into the installation Annual Work Plan.

The procedures have been described step-by-step. In addition, instructions have been given for comparing costs of the alternative control technologies. Although a detailed economic analysis is not required (unless projects are submitted for MCA funding), several factors must be considered in choosing an erosion control strategy. The measure(s) selected are not necessarily those representing the lowest cost, but those providing the widest range of benefits for dollars invested.

The plan was critiqued and pilot-tested in FY89 to ensure that its theoretical aspects are valid in the field and that its procedures constitute practical tools that can be implemented easily by the user. The plan has been validated and refined based on user response. Its use is now being expanded to additional Army installations for demonstration. After the demonstrations are successfully completed, it is recommended that the Army adopt the plan as the erosion control component of ITAM, to be implemented Army-wide.

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APPENDIX A:

MAINTENANCE AND REPAIR PROCEDURES FOR EROSION CONTROL STRUCTURES AND SYSTEMS

Soil Stabilization Structures

Revetments

Inspect all types for scour and undercutting at the base.

Riprap: inspect riprap blanket for slumping, holes, or scour at the ends; check for displacement of individual riprap pieces due to velocity and turbulence.

Pavements: inspect for cracks and buckling; look for signs of undermining at the edges and slippage downslope.

Gabions: inspect wire baskets and connectors for breakage; check structure for sagging, slipping or other signs of deformation; inspect foundation for signs of undermining or other instability.

Retaining Structures

Inspect all types for structural integrity, signs of stress, sliding, overall stability, foundation and embankment conditions, in addition to the following for each type.

Gravity walls: inspect joints of masonry and rock for signs of stress; check foundation and embankment conditions.

Crib walls: inspect condition of interlocking members; check for settlement and general stability in resisting cribfill and backfill.

Reinforced soil walls: inspect facing elements, connectors and anchors; inspect protective facings and exposed geotextiles used for fill encapsulation.

Gabion and welded wire walls: inspect condition of wire baskets, mats, welds, and connectors.

Pile walls: inspect condition of piles and lagging for signs of stress or damage.

Tie-walls: inspect sheeting and metal tie-rods and connectors for signs of stress damage, corrosion, or wear.

Cantilever and counterfort walls: inspect for cracks and signs of stress.

Subsurface Drainage Systems

Inlet risers, conduit and outlets must be maintained; clear debris sediment and debris from inlet riser and from the orifice plates; fill holes and tunneling developed around inlet; inlets should be kept clean of sediment buildup and sod maintained within a 5-ft minimum radius around inlet; check for sinkholes over lines that may indicate broken tile or wide cracks. Control trees and vegetation that may cause clogging of conduit from root growth. Outlets should be kept clear of obstructions such as brush debris and sediment; open drainage ditches should be kept clear of vegetation, debris, and sediment to allow free drainage; trees and shrubby vegetation should be controlled within 100 ft of tile drains. Remove roots from clogged conduit. Protect inlet risers and outlets from vehicle damage; conduit outlet must have flap gate or bin to exclude animal entry.[29] Maintain a chart showing location of lines and installed tile; repair sections of lines that have failed structurally or from corrosion to prevent damage to other parts of the system. Indications of failures are poor drainage after rain events in some sections of tiled area. Refer to TM 5-630, and TM 5-820-4, Chapter 4. Provide a marker to protect riser, vehicles, and operators during training and maintenance operations.

Runoff Management Structures

Terraces

Inspect very carefully during the first year after construction for settlement. Check terraced areas and outlet channels periodically, especially after heavy rains; maintain ridge height, outlets, and terrace capacity for storage; inspect side slopes for rilling; repair breaks in ridges; maintain good, erosion-preventive grass cover on permanently vegetated slopes; fertilize as needed; check outlet for signs of sediment or erosion in channels when necessary. Refer to TM 5-630.

Benches

Inspect several times a year, especially after heavy rains. Inspect ridges, backslopes and channels; maintain grass on permanently vegetated slopes; check and repair breaks, slumping, and signs of erosion or damage. Clear channels of sedimentation and slumped materials.

Waterways

Inspect several times a year, especially after heavy rains. Maintain capacity, vegetative cover, channel, and outlet. The first few years after seeding, vegetation should be mowed several times during the growing season to stimulate growth and control weeds.[30] Waterways dominated by tall fescue vegetation should be mowed regularly to maintain a thick, vigorous turf. Do not allow vegetation to become clumpy as this can result in water and channel meandering. Sod-forming grasses such as smooth brome grass, red canary grass, and redtop should be mowed to promote dense sod and to control weeds and shrubby vegetation. Dense cuttings should be removed.[31] Conduct regular soil tests; add fertilizer and lime as indicated Repair rills, washes, and damaged areas that have lost effective cover to reestablish sheet flow. Sod or reseed small breaks in sod; fasten down loosened sod. Slope back and sod small overfalls to avoid extensive repairs later. Control sod-damaging rodents; restrict vehicular usage--especially in wet weather--to prevent damage. Manage contributing watershed to avoid sedimentation in waterway. Remove accumulated silt, gravel, and debris from waterway to provide unrestricted drainage; remove sediment accumulations below outlets; maintain adequate height at waterway edges to maintain capacity.

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[29] *Means Site Work Cost Data, 1988.*

[30] G. O. Schwab, R. K. Frevert, K. K. Barnes, and T. W. Edminster, *Elementary Soil and Water Engineering,* 2nd ed. (John Wiley and Sons, 1971).

[31] Cooperative Extension Service Circular 1225, *Design for a Grassed Waterway* (University of Illinois College of Agriculture, December 1983).

Level Spreaders

Maintain adequately dense vegetation on stabilized area receiving discharge. Inspect and maintain condition of outlet lip for levelness and uniformity. Inspect area, especially after heavy rains, for signs of erosion and repair as needed.

Diversions, Ridge and Channel

Inspect periodically, especially after heavy rains; maintain channel capacity and ridge height; remove debris and accumulated sediments and gravel from channel; control flow-inhibiting vegetation channel; prevent growth of woody plants; keep channel open by shaping a smooth bottom as required; maintain good vegetation condition on side slopes and ridges; control rodents; fill rodent holes and repair small breaks in ridge; manage sedimentation in contributory watershed.

Waterbars

Inspect after major rains; water bar channel to allow for free drainage; inspect discharge area and repair as needed to ensure stability; remove sediment accumulation in channel and discharge area.

Grade Stabilization Structures

Inspect all types for structural integrity and signs of erosion; manage contributory watershed to avoid sedimentation.

Check dams: inspect dam after heavy rains for signs of scour and undermining at the ends; remove debris that could cause obstruction or diversion of flow toward ends of structure; inspect timber, rock, and gabion components and foundation for structural integrity.

Straight drop spillways and box inlet drop spillways: inspect for structural and foundational stability. After major rains, check for erosion around entrances and outlets; control burrowing animals on earth embankments and structure foundation. Remove debris and sediment accumulations from weir opening and stilling basin. Eliminate woody species of vegetation adjacent to structure. Provide marker to protect structure, vehicles, and operators during training and maintenance operations.

Hood inlet spillways: inspect embankments for damage by burrowing animals; eliminate woody vegetation. After major rains, check for tunneling and piping at inlet and erosion at outlet. Inspect exposed conduit and joints for cracks, holes, or signs of corrosion; check for clogged conduit and debris at inlet; in cold climates, check hood for icing.

Drop inlet spillway: inspect embankments for damage by burrowing animals; eliminate woody vegetation. After major rains, check for erosion around inlet and stilling pool; inspect exposed conduit for cracks, holes, or signs of corrosion; check for clogged conduit; remove obstructing debris from inlet trash rack and riser; inspect for tunneling around riser.

Chutes, concrete block, concrete, sod: inspect each spring for structural integrity, particularly for displaced concrete blocks, joint irregularities, or shifted concrete slabs due to frost heave or large volumes of runoff. Inspect after heavy rains for accumulation of debris at bases and in channel below structure. Inspect sod chutes for damage by burrowing animals or erosion; resod all breaks, maintain thick, vigorous turf; control weeds and shrubby vegetation.

Stilling Wells, Basins, Aprons

Inspect periodically for structural integrity such as cracks or damaged baffles, blocks, or sills. Inspect after heavy rains for signs of erosion adjacent to structure; remove debris and sediment from well, basin, or apron and ensure drain or outlet functions adequately. Maintain adequate supply, size, and distribution of riprap on riprapped aprons. Manage contributory watershed to avoid sedimentation.

Sediment Control

Sediment Retention Structures, Basins, Traps

Manage contributory watershed to avoid sediment. Maintain embankments, design capacity, and inlet. Maintain vegetative cover on embankments to prevent sheet and rill erosion or embankment gullying; control trees and woody vegetation. Design capacity shall be maintained by cleaning the basin or raising embankment height; traps and basins are generally cleaned when they have reached 50 percent of their sediment storage capacity.[32] Small traps can be cleaned by dragline and truck transport. Inspect inlets for clogging; inspect for erosion at discharge end of spillway.

Sediment Barriers and Inlet Filters, Straw, Sandbag

Inspect frequently, including after rains and human activities in area; ensure bales are tightly abutting adjacent bales and remain embedded in soil; secure stakes or rebars. Ensure sandbags are in good condition, and are stacked in place in an interlocking manner with riprap or compacted soil at base to prevent piping beneath bags. Replace broken or deteriorated bales and bags; remove debris and accumulated sediment from barrier.

Silt Fence

Inspect after rains; check fabric, fasteners, and posts; remove accumulated debris; check stability of posts; inspect fence for sagging or torn fabric; ensure fabric is fastened securely to upslope side of posts.

[32] *Erosion and Sediment Control: Surface Mining in the Eastern U.S. -- Planning*, EPA-625/3-76-006 (USEPA, 1976).

APPENDIX B:
WORKSHEETS FOR PROBLEM IDENTIFICATION, NEEDS ASSESSMENT, AND TECHNOLOGY SELECTION STEPS

TABLE B1

Step 1 — Preliminary Site Assessment

Step 1. Conduct Preliminary Site Assessment for Compiling an Erosion Project Site Inventory

1. Training Area _____ Site Coordinates_____
   Other identifying benchmark information:

2.@ Kinds of Erosion (Figure 5, Appendix C)
   Gully_______Rill________Sheet________Wind________

3.@ Does this site visibly contribute sediment to surface water or contribute runoff and sediment to downslope sites that pose water quality problems? ___Yes___No

   Preliminary Priority rating:
   (Highest) 1 2 3 4 5 (Lowest)

4.@ Treatment Approach (Table 1)

   ___ A. Routine planting and seeding

   ___ B. Agricultural or biotechnical conservation methods; no formal design needed

   ___ C. Formal agricultural or biotechnical or other engineering design for complex problems

5.* Major Soil Map Type_____ Soil Sample Taken___Yes___No

6.@ Slope percent ____ Slope length ____ (For critical treatment area only)_________

7.@ Approximate size of entire site to receive seeding treatment ________________________________
   (Dimensions will be converted later into acres or other units used in soil amendment and seeding recommendations)

8. Calculate resource estimates for Class A sites (based on site size)
   Cost estimates for time for labor & equipment____ Fuel costs____

   Seed or plant recommendations____unit/acre____ x Cost____/unit x ____acres treated = $____
   Fertilizer application rate recommended:____lb/acre x Cost____/lb x ____acres treated = $____

   Liming recommendations____ton/acre x Cost____/ton x ____acres treated = $____

   Total costs $_________

@ Requires site visit
* Refer to county soil survey

TABLE B2

Step 2 — Identification of Erosion-Related Natural Factors for Detailed Site Assessment

Step 2. Identify Erosion-Related Natural Factors

Training Area_____ Site coordinates_____

Other benchmark information:

1. Rainfall erosivity index R value________
   Snowmelt Rs________(Appendix D)

2.*@ Predominant soil texture(s) (USDA)____ Obtained from:

   ____by feel in field ____soil survey or GRASS
   ____lab analysis ____USDA texture(s) (See Appendix E for textures and classification by hand)

3.* Soil erodibility K Factor value___
   (For sheet and rill erodibility)
   (Use automated systems where available)

   Wind erodibility
   _____Moderate
   _____High
   _____Severe

4.* Hydrologic Soil Group (Use terrain analysis and Appendix E where no soil survey exists for items 4, 5, 6)

   A. High infiltration rate
   B. Moderate infiltration rate
   C. Slow infiltration rate
   D. Very slow infiltration rate

5.* Engineering suitability and water management limitations:

6.* Unified Soil Class___ Plasticity Index___ Liquid Limit %___

7.@ Vegetation/Ground Cover (Use automated systems where available for partial information)

   Type of vegetative canopy_____ height_____ percent cover_____
   Type of ground cover contacting soil surface_____ percent_____
   Stone, gravelly or other impervious cover_____percent
   C value_____ (Appendix D)

8.@ Topography (Use automated systems where available for partial info)

   Slope length___ft; Average slope steepness ___% for critical area of concern (for USLE, ARMSED, WEPP)
   LS value___ for USLE calculation (Appendix D)
   Optional: Average channel slope____percent (ARMSED)
   Slope Aspect_____

Comments about position of site within watershed (e.g., contributes or receives runoff and sediment)

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* Refer to county soil survey

@ Requires site visit

TABLE B3

Step 3 — Site Examination for Detailed Site Assessment

Step 3. Examine Site Erosion Conditions and Contributing Factors

Training Area____ Site coordinates____
Other benchmark information:

1.@ Erosion Conditions: What erosion processes are occurring at site? (See Table B1, Appendix C and Fig. 5)

2.@ Natural Factors: How are natural factors such as climate, soils, vegetation, topography, and offsite conditions contributing to the erosion processes and degraded conditions present at the site? (See text and Table B2)

3. Human Activities: What type of training activities and other human activities take place here?

@ How have these activities contributed to the prevailing erosion problems?

Have conservation practices been implemented here, and if so, were they adequate?

What type of use is planned for this site in the future?

4.@ Sketch of site indicating dimensions of areas needing treatment, lengths of slopes, sizes of gullies, runoff patterns and other notable features and critical areas.
Photo information: Roll# ______
Frame # ______

@ Requires site visit

TABLE B4

Step 4 — Needs Assessment

Step 4. Assess Needs for Erosion Control

1. List alternative erosion controls that are functionally appropriate for the site and can be effectively used under prevailing natural conditions:

2. Note special training compatibility requirements and limitations for erosion controls:

3. Note special environmental conditions or considerations that could be impacted unfavorably by erosion controls:

4. Quantitative justification of erosion control needs: Tolerance value for soil series at critical area of concern____________________. Calculation of soil loss or sediment yield for critical area (Calculate by using programmed calculator or computer):

5. Comments pertaining to final site prioritization:

6. Final priorization rating of site (circle one):
Highest 1 2 3 4 5 Lowest.

TABLE B5

Step 5 — Estimation of Costs

Step 5. Estimate Costs for Erosion Control Selection and Resource Requirement Projections.

1. Alternative controls after considering all items in Table B4:

2. Calculations for cost comparison using dimensions and per-unit costs. Use data from items 5 through 7 of Table B1. (Calculate manually or use cost-estimating computer software):

   Material Costs:

   Labor Time & Costs:

   Equipment & Fuel Costs:

   Total estimated construction cost________________

   Long-term maintenance requirements and costs for alternative controls:

3. Conclusions about technology selection and rejection of alternative controls:

4. Does this project (or parts of it) appear suitable construction by troops? ______
   If so, describe the tasks.

APPENDIX C:

EROSION PHASES AND FIELD FEATURES

Wind and water are two major geological agents of erosion. Distinction between wind and the various kinds of water erosion can be made through examination of erosion features found at the site and facilitated by knowledge of area climate and soil conditions as determined in Step 1. Figure C1 summarizes the types of erosion. Figure C2 shows the erosion process and possible preventive measures.

Wind Erosion: Wind erosion affects arid, semiarid, and some humid regions including coastal and lake environments where loose sand and some organic soils are highly susceptible to wind. Phases of wind erosion processes can be identified as (1) initial movement, (2) transportation, and (3) deposition. Particle movement is initiated as a result of wind turbulence and velocity.[33] Loose particles are lifted into the air or rolled along the ground by a process known as "deflation." Wind erosion also causes the wearing away of soil, rocks, and land surfaces by the abrasive action of the wind-driven particles. The rate of erosion depends on the intensity and persistence of the wind, protective soil cover, and size and availability of soil particles.

Evidence of wind erosion shows (Figures C3 and C4) as features such as shallow, scooped-out depressions called blowouts; dunes and dune-like landforms whose positions have migrated; dusty conditions; loss of surface soil and vegetation with remnant gravelly and pebbly surfaces, pedestalled objects or plants, rusty-iron colored, hardened soil surfaces called "duricrusts," or horizontally exposed subsurface hardpan soils; and shallow, windscoured depressions below the windward sides of rocks and other large objects, coupled with dry particle accumulations on their leeward sides and in areas locally sheltered from prevailing winds.

Water Erosion: Splash, sheet, rill, gully, channel, and streambank erosion are types of water erosion. Rills, gullies, channelbank and streambank failure and sedimentation are features associated with water erosion. Phases of water erosion can be described as (1) particle detachment, (2) translocation, and (3) deposition.

Splash erosion occurs where raindrops strike bare soil. The action of striking raindrops breaks up soil clusters and disperses soil particles, making them susceptible to transport. If the detached particles remain in place, they often form a hard crust when dry.

Sheet erosion removes continuous layers of soil (Figures C5 through C8).[34] Detached soil particles become suspended by shallow sheets of water that move over the land surface. Note the more or less uniform removal of the topsoil layer in the figures. The bare remnant soil remains especially susceptible to subsequent splash erosion, removal, and crusting. Blanket-like accumulations of sediment are generally but not always found just downslope from a sheetwashed area because slope characteristics and overland flow volumes could be great enough to transport sediments to channels draining the watershed.

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[33] G. O. Schwab et al., 1981.

[34] Agricultural Information Bulletin 260, *Soil Erosion, the Work of Uncontrolled Water* (USDA SCS, Revised August 1981).

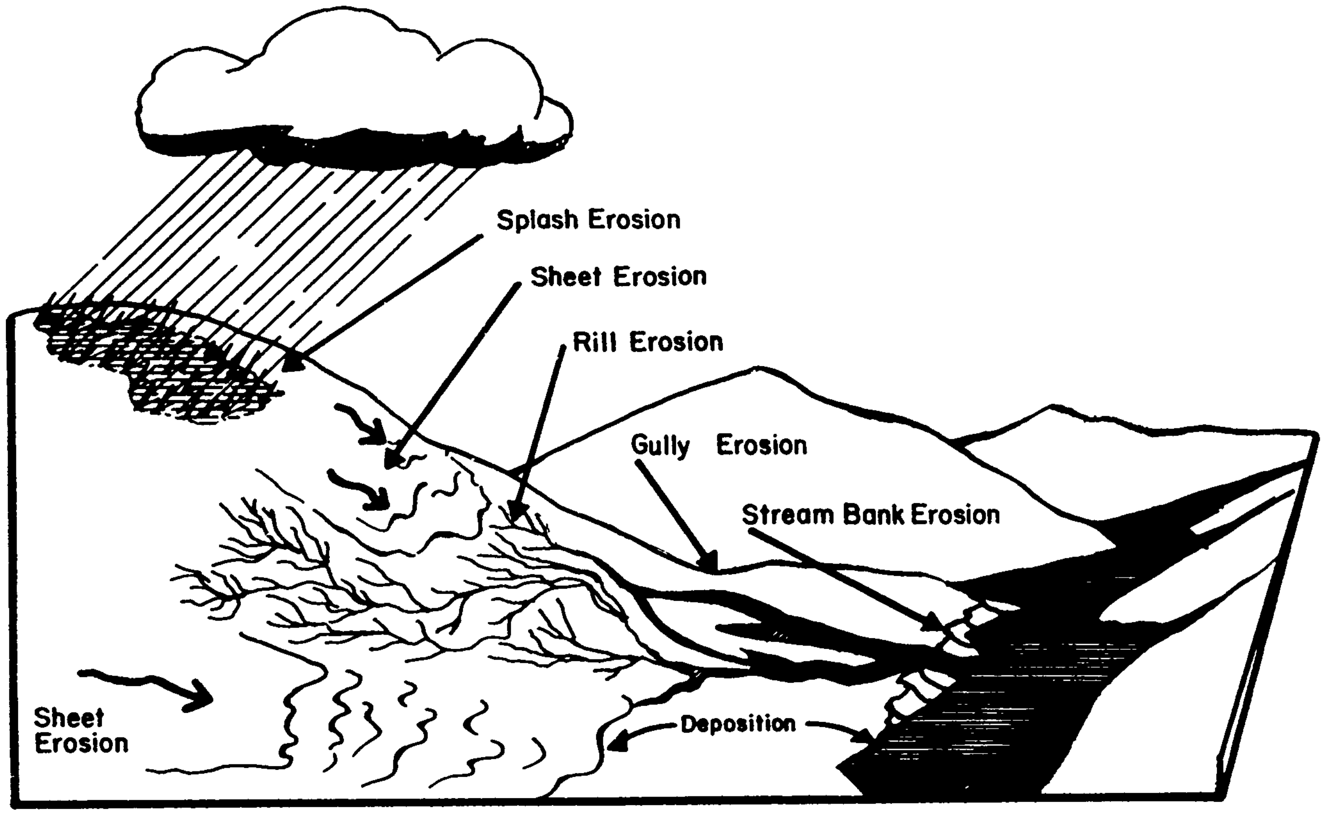

Figure C1. Types of erosion. Note that types are not limited to slope positions shown; in continuum or in combination.

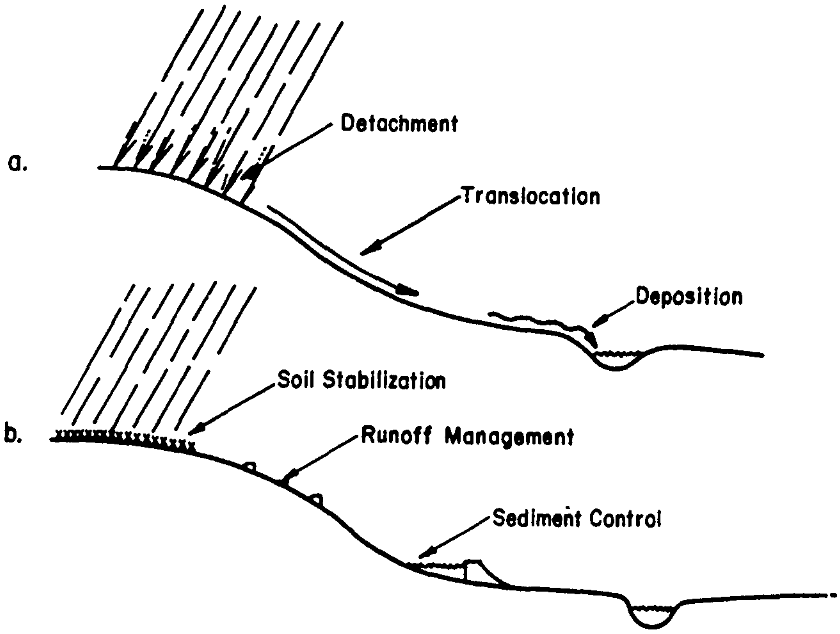

Figure C2. (a) Erosion process and (b) possible points of intervention.

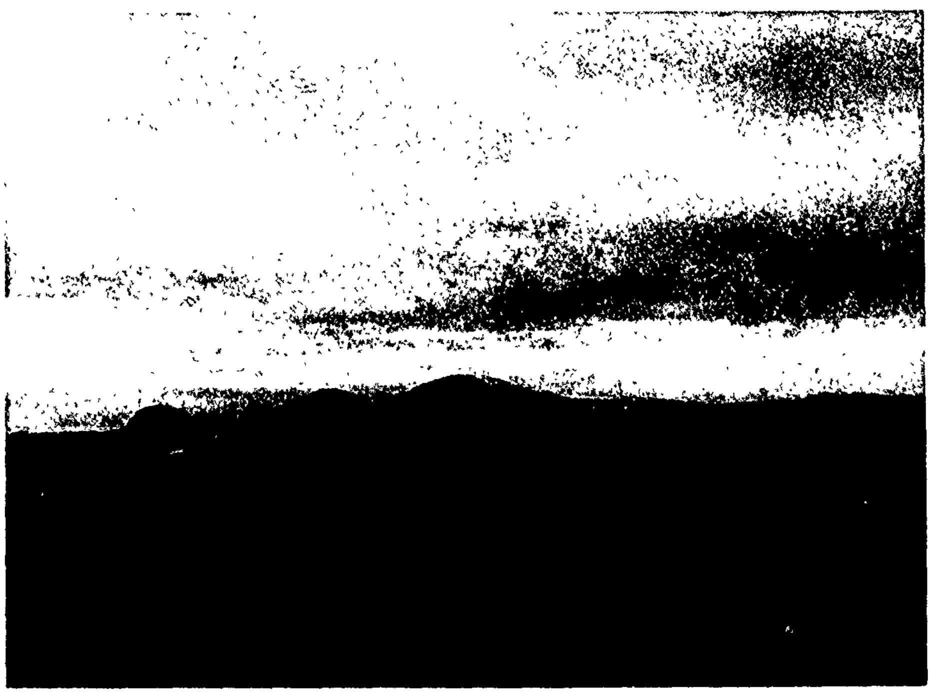

Figure C3. Evidence of wind erosion.

Figure C3. Cont'd.

Figure C3. Cont'd.

Figure C4. Accelerated wind erosion.

Figure C4. Cont'd.

Figure C5. Evidence of sheet erosion. Note removal of fine surface particles and remnant pebbles. Gully erosion with some rills also is apparent.

Figure C6. Results of sheet erosion.

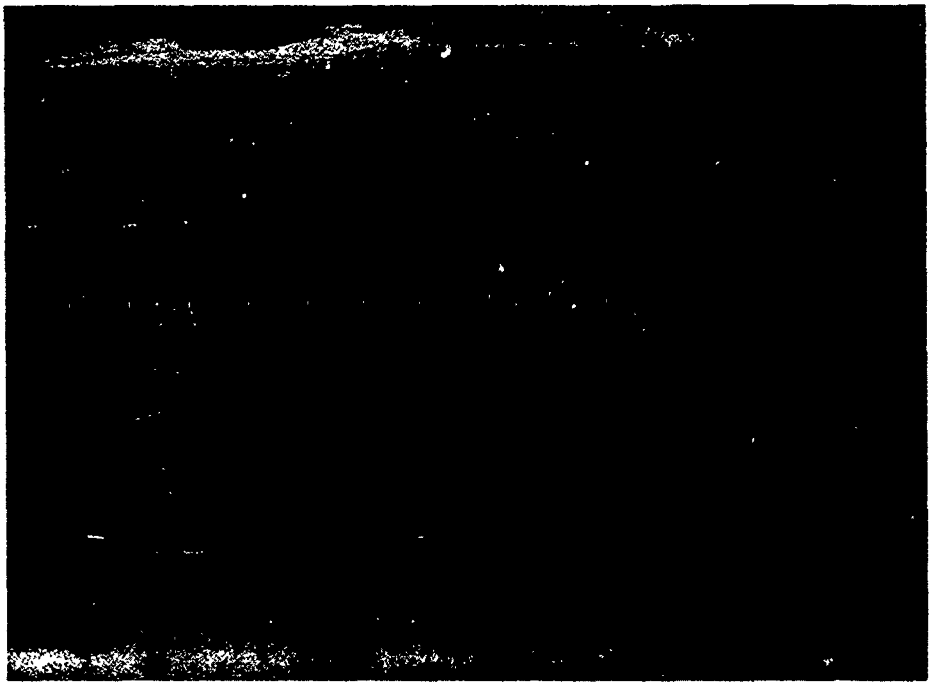

Figure C7. Results of sheet and rill erosion.

Figure C8. Blanket-like accumulation of sediment from sheet erosion.

Rill erosion appears as grooves a few inches deep and cut into the soil surface by the concentration of water into little streams called "rivulets." Figure C9 shows rill erosion. Rills eventually join together to form larger channels. When these channels enlarge to the point that they cannot be smoothed out by ordinary cultivation they have become gullies (Figures C10 and C11).[35]

Gullies are steep-sided erosion channels having V- or U-shaped profiles. Gullies can be differentiated as being continuous or discontinuous. A continuous gully begins in the headwater area of the watershed and retains its depth until a lower gradient segment above the gully mouth is reached.[36] Discontinuous gullies begin their courses on the valley floor or hillside with an abrupt headcut, diminishing its depth toward the gully mouth where an alluvial fan is formed.[37] Under advanced erosion conditions, gullies of both types may join into networks.

Streambank and *channel* erosion occur when individual soil particles are carried away from the bank surface (Figures C12 and C13). This type of erosion increases shear stresses in the bank that can lead to bank failure in which a soil layer slides down the bank or a large soil mass slips along a curved path to produce a condition called sloughing off.[38] Erosion can also occur in the stream channel bed if the stream is downcutting into substrate materials. Compared with other potential sediment sources, stream channel bed erosion is usually minor.

Sedimentation is the deposition of wind- or water-transported particles into thickly bedded accumulations. It is the final phase of the erosion process. Sedimentation by water occurs at the bottom of a slope, on a floodplain, and in a streambed or floor of a body of water into which a stream empties. Wind deposits occur where wind velocities and, hence, wind energy to transport particles are reduced. This condition is found behind natural objects or constructed barriers that block wind flow (Figures C14 through C16).

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[35] Agricultural Information Bulletin 260.

[36] B. H. Heede, "Gully Control: Determining Treatment Priorities for Gullies in a Network," *Environmental Management*, Vol 6, No. 5 (1982), pp 441-451.

[37] B. H. Heede.

[38] *Streambank Protection Guidelines* (U.S. Army Engineer Waterways Experiment Station, October 1983).

Figure C9. Rill erosion.

Figure C10. Gully erosion.

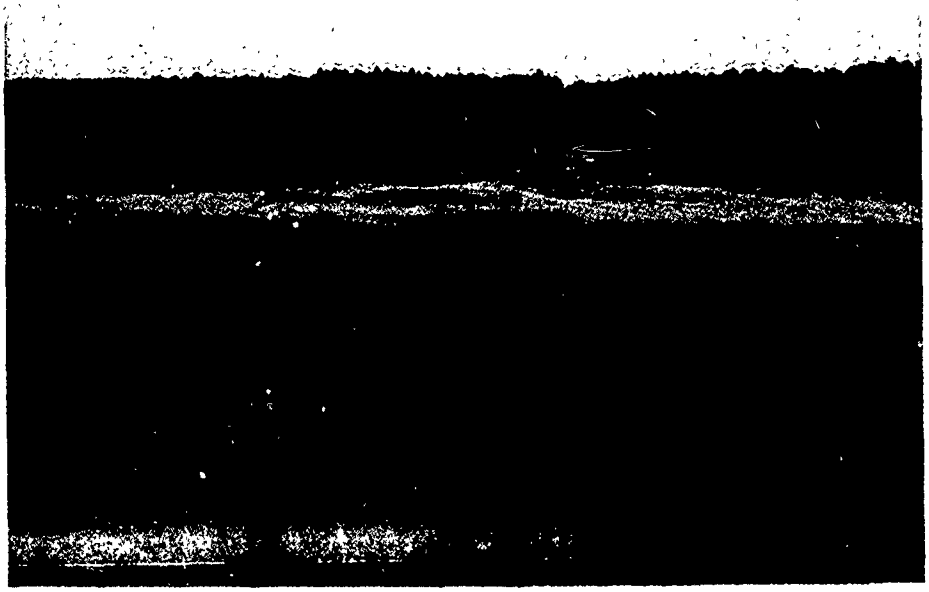


Figure C11. Rill and gully erosion.

Figure C11. Cont'd.

Figure C12. Channel erosion. Note exposed bank materials on outside curve with material accumulation on inside curve (foreground).

Figure C13. Evidence of past channel erosion. Note the slumped bank materials. Some stabilization has occurred at low water level.

Figure C14. Sedimentation.

Figure C15. Sedimentation and erosion threat to structure at outlet.

Figure C16. Sediment-choked stream.

APPENDIX D:

HOW TO COLLECT AND PREPARE SOIL SAMPLES*

In agriculture, the objective in soil sampling is to provide soil material for laboratory analysis that will serve as a basis for determining lime and fertilizer needs for production of a crop or sequence of crops. On Army training lands, lime and fertilizer needs typically refer to establishment and maintenance grasses on rangeland, or vegetation on critical areas that might receive foot or vehicle traffic. To meet this objective, the sample should be collected in a manner to reflect rather uniform soil and soil management. Soil differences that reflect yield potential differences, and those areas that have been managed differently, should be sampled separately. The person collecting the samples should be aware of soil and previous management differences, and plan to sample accordingly.

Time to Collect Soil Samples

Any time is a good time to collect soil samples if the soil is in condition for tilling. Correct moisture is essential for properly mixing the sample. If the soil is wet the sample should be dried, thoroughly mixed, and the box filled for submitting to the laboratory.

The time of year that the sample is collected will influence results obtained, especially pH. Samples collected in late winter or early spring will test 0.1 to 0.4 values higher than if taken from the same soil area in late summer or fall. Because of this, it is important to collect samples from an area or a field at approximately the same time each year.

Equipment Needed

1. A clean pail that will hold about 10 liters
2. Soil sample boxes
3. Soil record sheets
4. Sampling tool (any one of the following)
   a. Tube
   b. Spade or Shovel
   c. Trowel
   d. Mattock
   e. Auger
5. Container for packed samples

Procedures

1. Sample to plow depth in cultivated fields and 2 in. to 4 in. in pasture, semipermanent hay, and no-till crop fields.

2. Place subsample in clean pail.

3. Collect 10 or more subsamples per soil area and 5 or more per acre for larger fields (up to 50 or more subsamples) randomly across the field (see Figure D1). If there is a visible difference in soil or crop growth, take a separate sample.

*Adapted from G.R. Epperson, G.W. Hawkins, and G.D. McCart, *How to Collect and Prepare Soil Samples*, Publication MA-174 (Virginia Cooperative Extension Service, 1974).

4. Do not collect samples from eroded spots, drainageways, back furrows, depressions, or other nonconforming spots. Parts of fields that have been treated and managed differently should be sampled separately.

5. Mix sample thoroughly and fill the sample box from the pail of mixed soil.

6. Identify the sample on the sample box and the soil record sheet. Fill out the soil record sheet completely. Remember to indicate any lime applications, unusual treatments or problems within the past 2 or 3 years. The more information you give on the soil record sheet, the better your recommendation will be.

7. Fold the soil record sheet, close the soil sample box, and insert the folded soil record sheet under the cover of the sample box.

8. *Sampling Problem Areas*: Where plant growth is improper and soil reaction or fertility is suspected as the cause, several samples should be collected from the feeding zone of the plants affected. Corresponding samples should be collected from an area in which plant growth is normal for comparisons of results with those obtained from the problem area. The samples from problem and nonproblem areas should be accompanied by a letter describing plant appearance in abnormal and normal growth areas. In all cases where plant tissue is sent to a laboratory for analysis, soil samples should be collected from problem and nonproblem areas. Send them to the soil testing laboratory with a letter indicating that tissue samples have been sent for test and giving the name and location of the laboratory to which tissue samples were sent.

9. Give your soil samples to your Extension Agent or other professional agricultural worker for mailing.

Note:

The results of the test can be no better than the samples you sent to the laboratory. Collect, prepare, and identify your samples carefully.

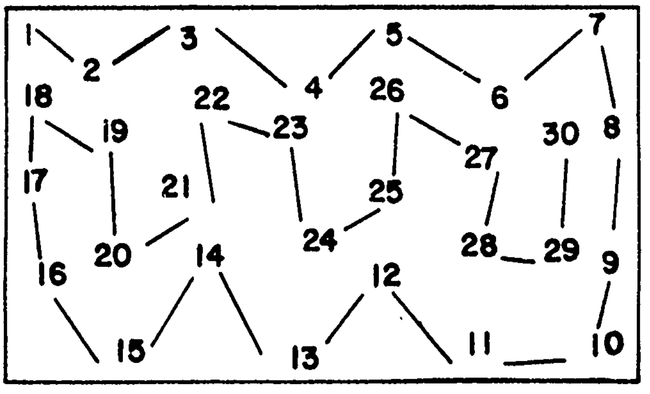


Figure D1. Suggested detail for taking soil samples.

APPENDIX E:

SOIL PROPERTIES AND CLASSIFICATION METHODS

HYDROLOGIC SOIL GROUPS

More than 8000 soils have been classified into four hydrologic soil groups. The hydrologic soil groups, according to their infiltration and transmission rates, are:

A. (Lowest runoff potential.) Soils having high infiltration rates even when thoroughly wetted. These consist chiefly of deep, well to excessively drained sands or gravels. These soils have a high rate of water transmission in that water readily passes through them.

B. Soils having moderate infiltration rates when thoroughly wetted. These consist chiefly of moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

C. Soils having slow infiltration rates when thoroughly wetted. These consist chiefly of soils with a layer that impedes downward movement of water or soils with moderately fine to fine texture. These soils have a slow rate of water transmission.

D. (Highest runoff potential.) Soils having very slow infiltration rates when thoroughly wetted. These consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very slow rate of water transmission.

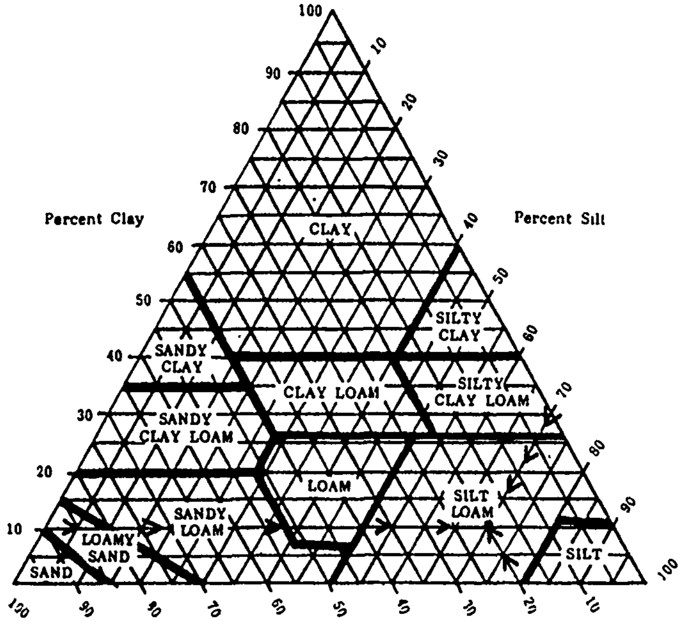


Figure E1. USDA soil textural classification.

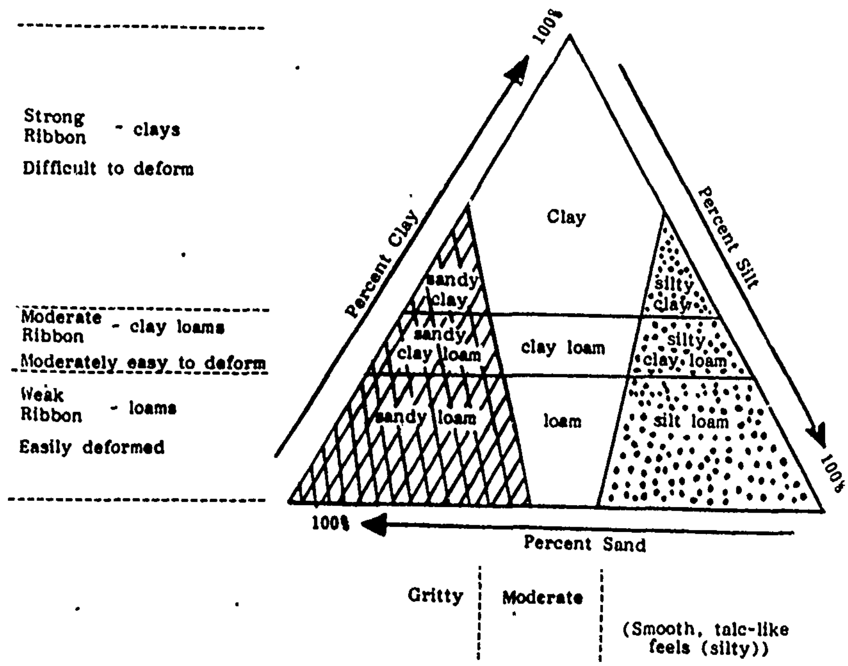
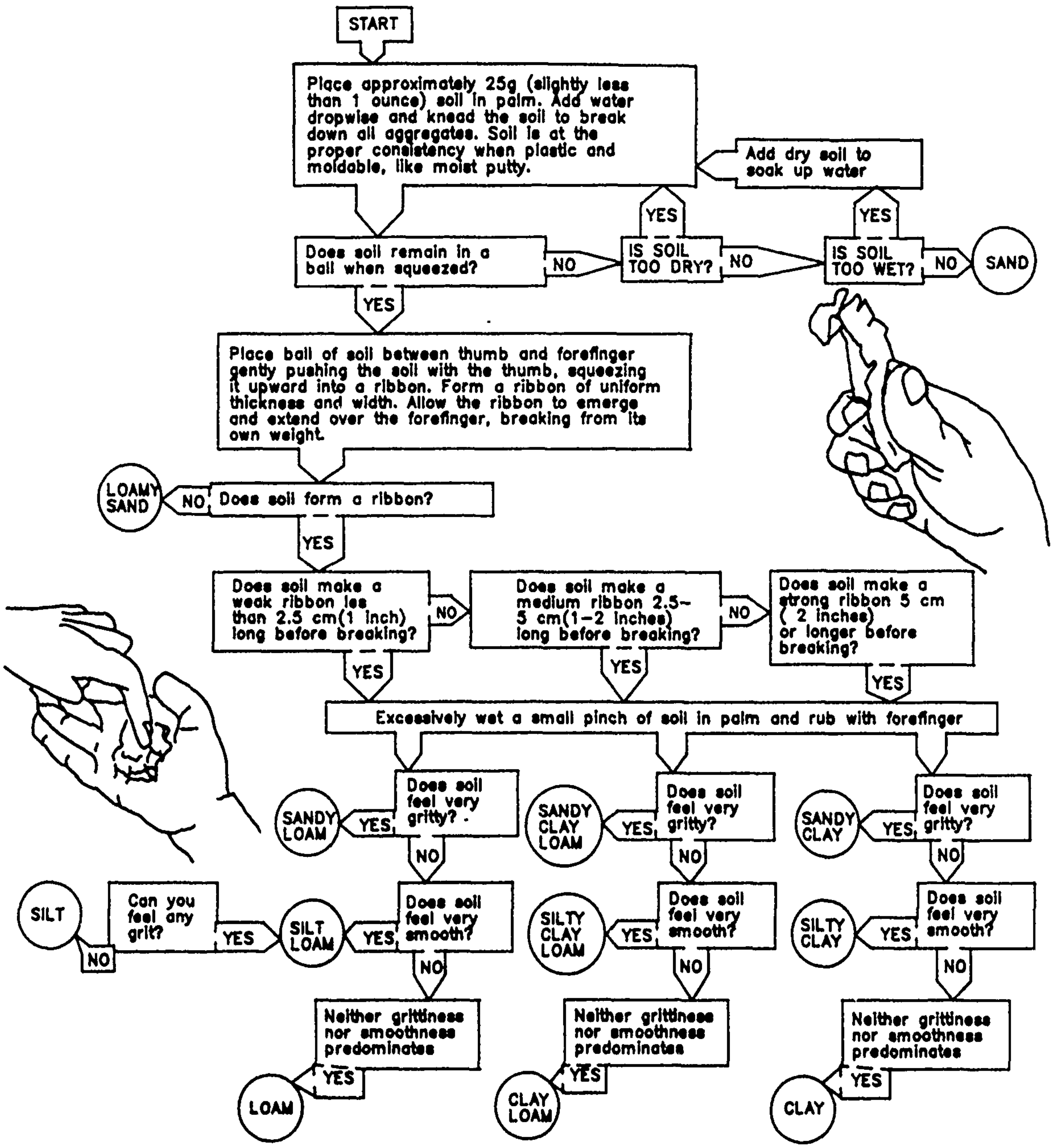


Figure E1. (Cont'd)



2.54 CM = 1 INCH

1.0 gram = 0.035 ounce

Diagram for determining soil texture by feel

reference: Introductory Soil Science: A Laboratory Manual,"1984 4th Edition R.H.Beck, W.L.Banwart, J.J.Hassett

Printed Journal of Agron. Ed. 8:54–56.

Figure E2. Procedure for determining soil texture by feel.

TYPICAL NAMES	IMPORTANT PROPERTIES: SHEAR STRENGTH	COMPRESS-IBILITY	WORKABILITY AS CONSTRUCTION MATERIAL	PERMEABILITY: WHEN COMPACTED	K CM. PER SEC.	K FT. PER DAY	UNIFIED SOIL CLASSES
Well graded gravels, gravel-sand mixtures, little or no fines.	Excellent	Negligible	Excellent	Pervious	$K > 10^{-2}$	$K > 30$	GW
Poorly graded gravels, gravel-sand mixtures, little or no fines.	Good	Negligible	Good	Very Pervious	$K > 10^{-2}$	$K > 30$	GP
Silty gravels, gravel-sand-silt mixtures.	Good to Fair	Negligible	Good	Semi-Pervious to Impervious	$K = 10^{-3}$ to 10^{-6}	$K = 3$ to 3×10^{-3}	GM
Clayey gravels, gravel-sand-clay mixtures.	Good	Very Low	Good	Impervious	$K = 10^{-6}$ to 10^{-8}	$K = 3 \times 10^{-3}$ to 3×10^{-5}	GC
Well graded sands, gravelly sands, little or no fines.	Excellent	Negligible	Excellent	Pervious	$K > 10^{-3}$	$K > 3$	SW
Poorly graded sands, gravelly sands, little or no fines.	Good	Very Low	Fair	Pervious	$K > 10^{-3}$	$K > 3$	SP
Silty sands, sand-silt mixtures	Good to Fair	Low	Fair	Semi-Pervious to Impervious	$K = 10^{-3}$ to 10^{-6}	$K = 3$ to 3×10^{-3}	SM
Clayey sands, sand-clay mixtures.	Good to Fair	Low	Good	Impervious	$K = 10^{-6}$ to 10^{-8}	$K = 3 \times 10^{-3}$ to 3×10^{-5}	SC
Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts with slight plasticity.	Fair	Medium to High	Fair	Semi-Pervious to Impervious	$K = 10^{-3}$ to 10^{-6}	$K = 3$ to 3×10^{-3}	ML
Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.	Fair	Medium	Good to Fair	Impervious	$K = 10^{-6}$ to 10^{-8}	$K = 3 \times 10^{-3}$ to 3×10^{-5}	CL
Organic silts and organic silty clays of low plasticity.	Poor	Medium	Fair	Semi-Pervious to Impervious	$K = 10^{-4}$ to 10^{-6}	$K = 3 \times 10^{-1}$ to 3×10^{-3}	OL
Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.	Fair to Poor	High	Poor	Semi-Pervious to Impervious	$K = 10^{-4}$ to 10^{-6}	$K = 3 \times 10^{-1}$ to 3×10^{-3}	MH
Inorganic clays of high plasticity, fat clays.	Poor	High to Very High	Poor	Impervious	$K = 10^{-6}$ to 10^{-8}	$K = 3 \times 10^{-3}$ to 3×10^{-5}	CH
Organic clays of medium to high plasticity, organic silts.	Poor	High	Poor	Impervious	$K = 10^{-6}$ to 10^{-8}	$K = 3 \times 10^{-3}$ to 3×10^{-5}	OH
Peat and other highly organic soils.	NOT SUITABLE FOR CONSTRUCTION						Pt

Figure E3. Unified Classification of Soils. (Source: *National Engineering Handbook*, Section 4, "Hydrology" [USDA/SCS, March 1985].)

EMBANKMENTS								
COMPACTION CHARACTERISTICS	STANDARD PROCTER UNIT DENSITY LBS. PER CU. FT.	TYPE OF ROLLER DESIRABLE	RELATIVE CHARACTERISTICS		RESISTANCE TO PIPING	ABILITY TO TAKE PLASTIC DEFORMATION UNDER LOAD WITHOUT SHEARING	GENERAL DESCRIPTION & USE	UNIFIED SOIL CLASSES
			PERME-ABILITY	COMPRESS-IBILITY				
Good	125-135	crawler tractor or steel wheeled & vibratory	High	Very Slight	Good	None	Very stable, pervious shells of dikes and dams.	GW
Good	115-125	crawler tractor or steel wheeled & vibratory	High	Very Slight	Good	None	Reasonably stable, pervious shells of dikes and dams.	GP
Good with close control	120-135	rubber-tired or sheepsfoot	Medium	Slight	Poor	Poor	Reasonably stable, not well suited to shells but may be used for impervious cores or blankets.	GM
Good	115-130	sheepsfoot or rubber-tired	Low	Slight	Good	Fair	Fairly stable, may be used for impervious core.	GC
Good	110-130	crawler tractor & vibratory or steel wheeled	High	Very Slight	Fair	None	Very stable, pervious sections, slope protection required.	SW
Good	100-120	crawler tractor & vibratory or steel wheeled	High	Very Slight	Fair to Poor	None	Reasonably stable, may be used in dike with flat slopes.	SP
Good with close control	110-125	rubber-tired or sheepsfoot	Medium	Slight	Poor to Very Poor	Poor	Fairly stable, not well suited to shells, but may be used for impervious cores or dikes.	SM
Good	105-125	sheepsfoot or rubber-tired	Low	Slight	Good	Fair	Fairly stable, use for impervious core for flood control structures.	SC
Good to Poor Close control essential	95-120	sheepsfoot	Medium	Medium	Poor to Very Poor	*Very Poor	Poor stability, may be used for embankments with proper control. *Varies with water content.	ML
Fair to Good	95-120	sheepsfoot	Low	Medium	Good to Fair	Good to Poor	Stable, impervious cores and blankets.	CL
Fair to Poor	80-100	sheepsfoot	Medium to Low	Medium to High	Good to Poor	Fair	Not suitable for embankments.	OL
Poor to Very Poor	70-95	sheepsfoot	Medium to Low	Very High	Good to Poor	Good	Poor stability, core of hydraulic fill dam, not desirable in rolled fill construction.	MH
Fair to Poor	75-105	sheepsfoot	Low	High	Excellent	Excellent	Fair stability with flat slopes, thin cores, blanket & dike sections.	CH
Poor to Very Poor	65-100	sheepsfoot	Medium to Low	Very High	Good to Poor	Good	Not suitable for embankments.	OH
DO NOT USE FOR EMBANKMENT CONSTRUCTION								Pt

Figure E3. (Cont'd)

TENTATIVE
FOR TRIAL USE ONLY

CHANNELS: LONG DURATION TO CONSTANT FLOWS. RELATIVE DESIRABILITY		FOUNDATION: FOUNDATION SOILS, BEING UNDISTURBED, ARE INFLUENCED TO A GREAT DEGREE BY THEIR GEOLOGIC ORIGIN. JUDGEMENT AND TESTING MUST BE USED IN ADDITION TO THESE GENERALIZATIONS.	RELATIVE DESIRABILITY		REQUIREMENTS FOR SEEPAGE CONTROL		UNIFIED SOIL CLASSES
EROSION RESISTANCE	COMPACTED EARTH LINING	BEARING VALUE	SEEPAGE IMPORTANT	SEEPAGE NOT IMPORTANT	PERMANENT RESERVOIR	FLOODWATER RETARDING	
1	-	Good	-	1	Positive cutoff or blanket	Control only within volume acceptable plus pressure relief if required.	GW
2	-	Good	-	3	Positive cutoff or blanket	Control only within volume acceptable plus pressure relief if required.	GP
4	4	Good	2	4	Core trench to none	None	GM
3	1	Good	1	6	None	None	GC
6	-	Good	-	2	Positive cutoff or upstream blanket & toe drains or wells.	Control only within volume acceptable plus pressure relief if required.	SW
7 if gravelly	-	Good to Poor depending upon density	-	5	Positive cutoff or upstream blanket & toe drains or wells.	Control only within volume acceptable plus pressure relief if required	SP
8 if gravelly	5 erosion critical	Good to Poor depending upon density	4	7	Upstream blanket & toe drains or wells	Sufficient control to prevent dangerous seepage piping.	SM
5	2	Good to Poor	3	8	None	None	SC
-	6 erosion critical	Very Poor, susceptible to liquefication	6, if saturated or pre-wetted	9	Positive cutoff or upstream blanket & toe drains or wells.	Sufficient control to prevent dangerous seepage piping.	ML
9	3	Good to Poor	5	10	None	None	CL
-	7 erosion critical	Fair to Poor, may have excessive settlement	7	11	None	None	OL
-	-	Poor	8	12	None	None	MH
10	8 volume change critical	Fair to Poor	9	13	None	None	CH
-	-	Very Poor	10	14	None	None	OH
-	-	REMOVE FROM FOUNDATION					Pt

No. 1 is best numerical rating.

Figure E3. (Cont'd)

				Laboratory Criteria			Unified Soil Classes
Coarse-grained soils: Less than half of material passes the No. 200 sieve size.	Gravels: Less than half of the coarse fraction passes the No. 4 sieve size.	Clean gravels: Less than 5% passing the No. 200 sieve size.	Borderline cases require the use of dual symbols.	Well graded: Meets gradation requirements	Gradation requirements are: $C_u = \frac{D_{60}}{D_{10}} > 4$ and, $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 & 3		GW
				Poorly graded: Does not meet gradation requirements			GP
		Gravels with fines: More than 12% passing the No. 200 sieve size.		Plasticity limits of material passing No. 40 sieve size plots below "A" line or P.I. less than 4.		Plasticity limits above "A" line with P.I. between 4 and 7 are border-line cases and require use of dual symbols	GM
				Plasticity limits of material passing No. 40 sieve size plots above "A" line with P.I. more than 7.			GC
	Sands: More than half of the coarse fraction passes the No. 4 sieve size.	Clean sands: Less than 5% passing the No. 200 sieve size.	Borderline cases require the use of dual symbols.	Well graded: Meets gradation requirements	Gradation requirements are: $C_u = \frac{D_{60}}{D_{10}} > 6$ and, $C_c = \frac{(D_{30})^2}{D_{10} \times D_{60}}$ between 1 & 3		SW
				Poorly graded: Does not meet gradation requirements			SP
		Sands with fines: More than 12% passing the No. 200 sieve size.		Plasticity limits of material passing No. 40 sieve size plots below "A" line or P.I. less than 4.		Plasticity limits above "A" line with P.I. between 4 and 7 are border-line cases and require use of dual symbols	SM
				Plasticity limits of material passing No. 40 sieve size plots above "A" line with P.I. more than 7.			SC
Fine-grained soils: More than half of material passes the No. 200 sieve size.	Silts and clays: Liquid limit less than 50	Below "A" line or P.I. less than 4		Above "A" line with P.I. between 4 and 7 are border-line cases requiring use of dual symbols			ML
		Above "A" line with P.I. more than 7					CL
		Below "A" line or P.I. less than 4 and $\frac{\text{L.L. (oven dry soil)}}{\text{L.L. (air dry soil)}} < 0.7$		PLASTICITY CHART			OL
	Silts and clays: Liquid limit greater than 50	Below "A" line					MH
		Above "A" line					CH
		Below "A" line and $\frac{\text{L.L. (oven dry soil)}}{\text{L.L. (air dry soil)}} < 0.7$					OH
Highly organic soils				$\frac{\text{L.L. (oven dry soil)}}{\text{L.L. (air dry soil)}} < 0.7$			Pt

PLASTICITY CHART

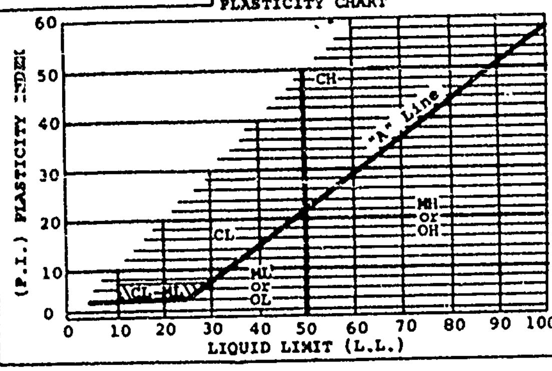


Figure E3. (Cont'd)

APPENDIX F:

EXHIBITS FOR CLIMATE AND OTHER NATURAL FACTOR EVALUATION

Rs calculation (if snowmelt is significant):__________

____

R + 1.5 (average precipitation between 1 Dec and 31 Mar) = Rs

Example: Location having an R value of 20 plus average ppt. between 1 Dec and 31 March is 12 in.

Calculate: 20 + 1.5 (12) = Rs value of 38

Figure F1. Example Rs Calculation.

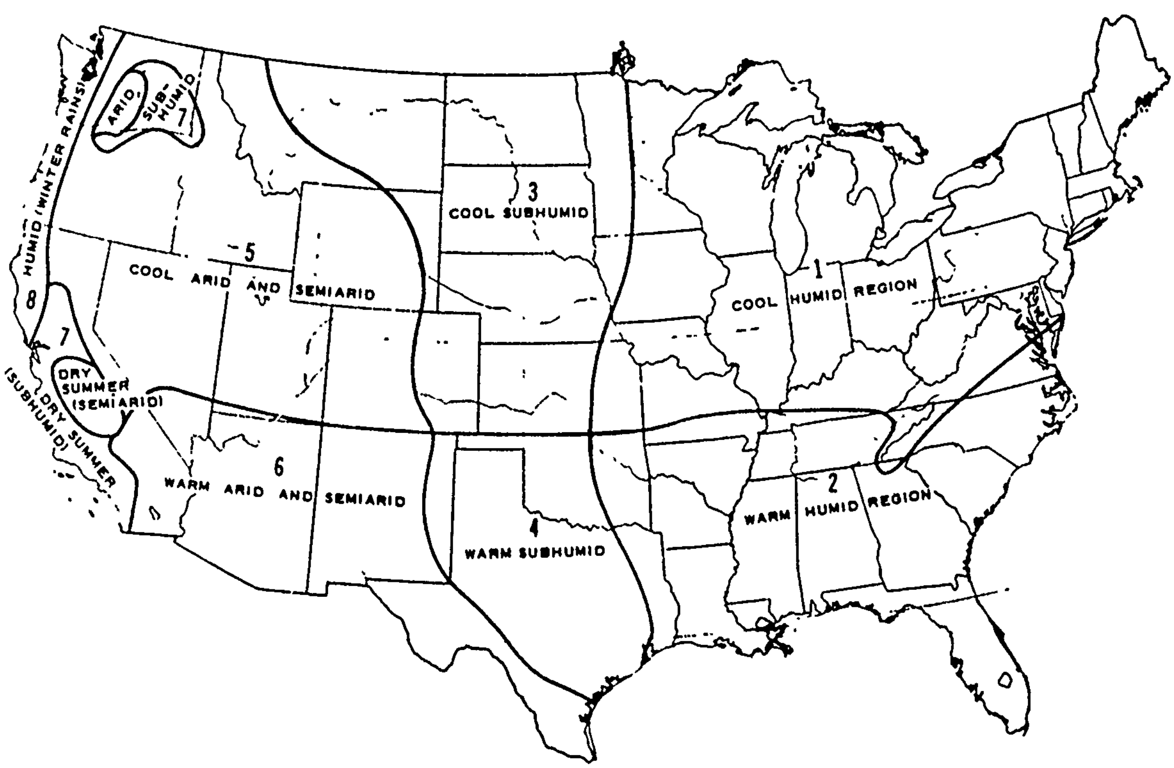


Figure F2. Climatic regions. (Source: TM 5-630/AFM 126-2/NAVFAC MO-100.1).

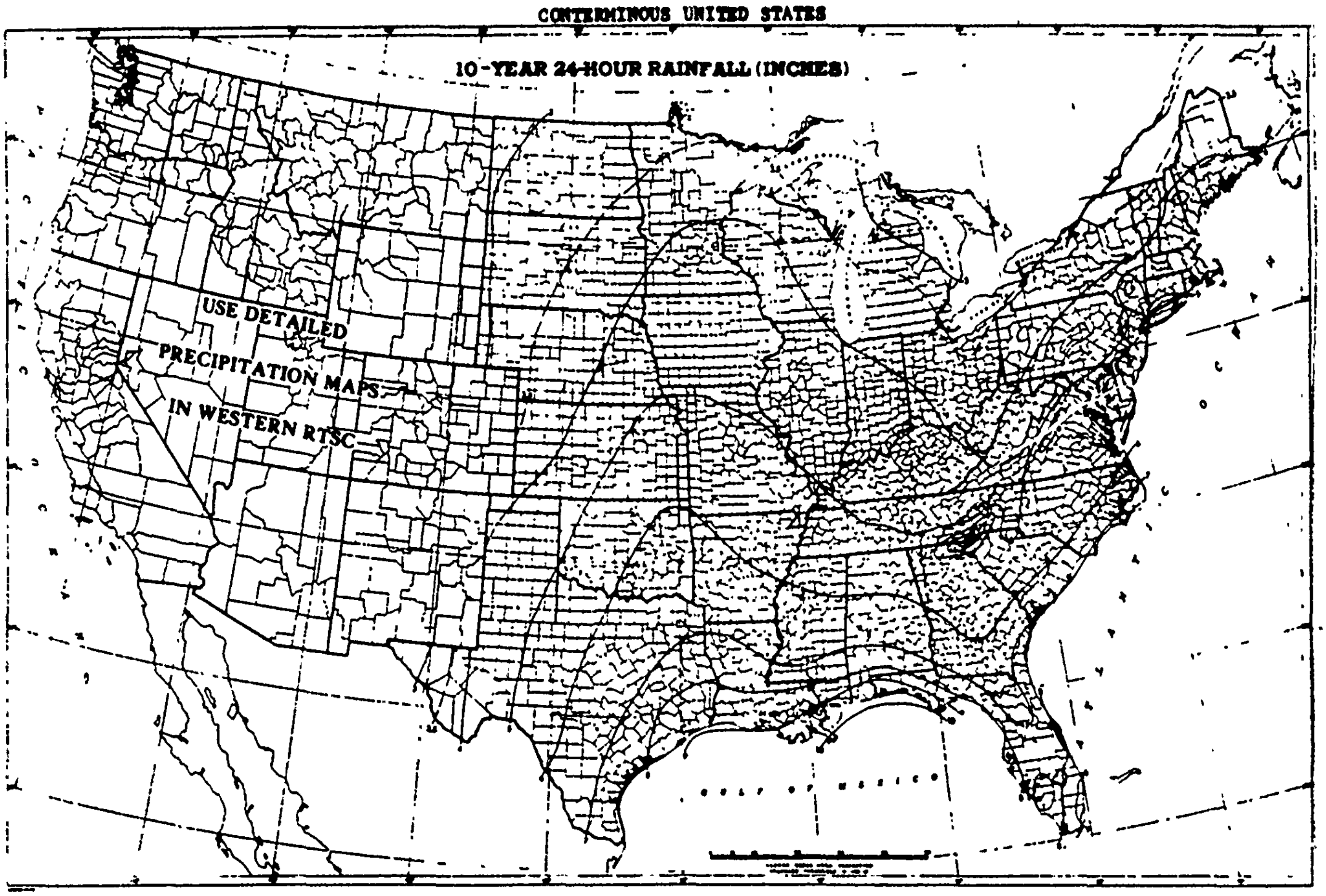


Figure F3. Ten-year, 24-hour design storm. (Source: U.S. Weather Bureau.)

ALASKA

10-YEAR 24-HOUR RAINFALL (INCHES)

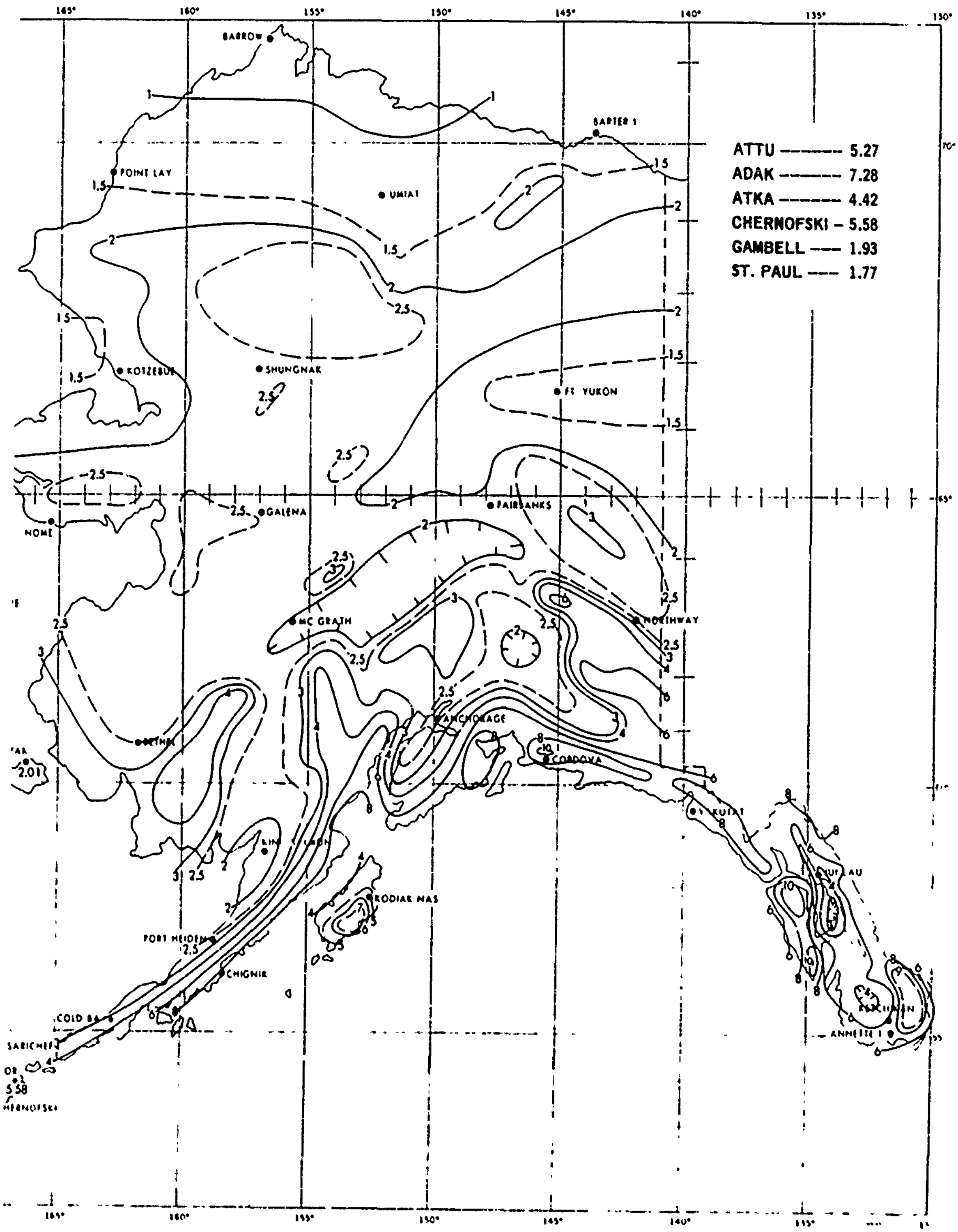


Figure F3. (Cont'd)

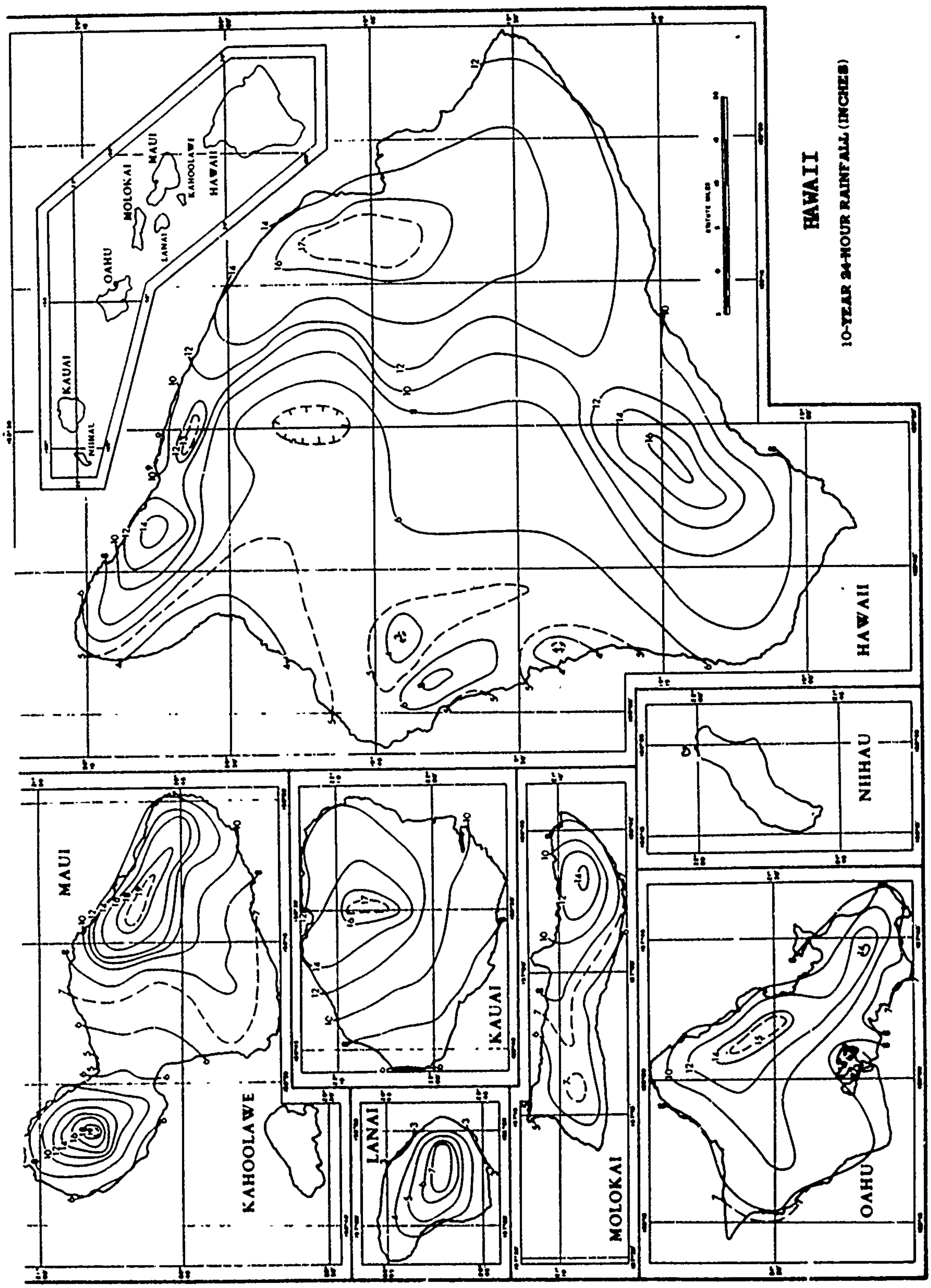


Figure F3. (Cont'd)

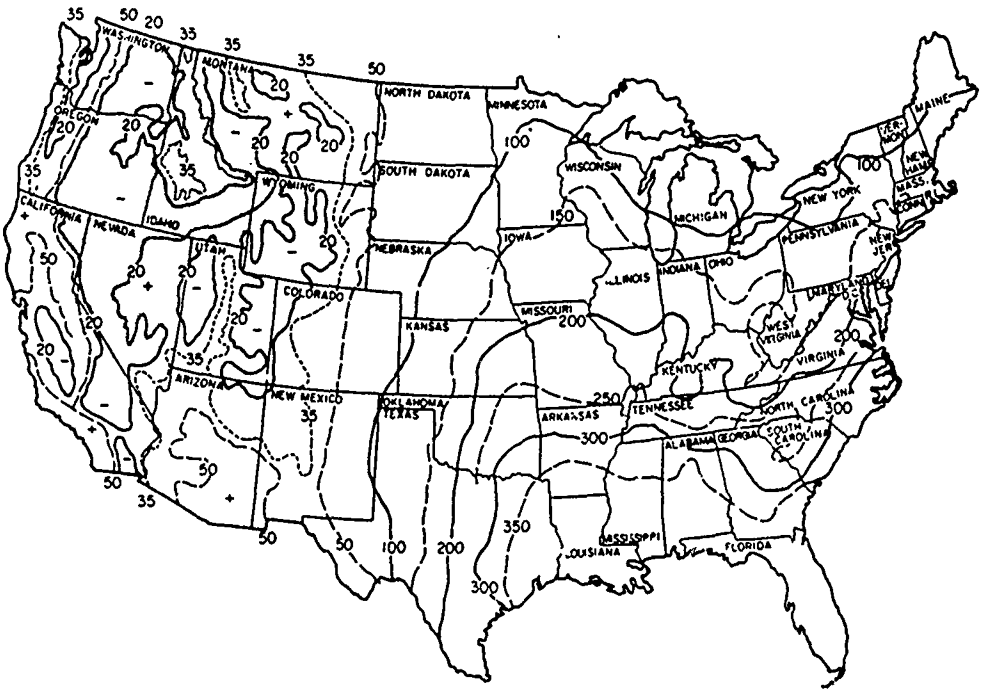


Figure F4. "R" values. (Source: G. O. Schwab et al., 1986. Used with permission.)

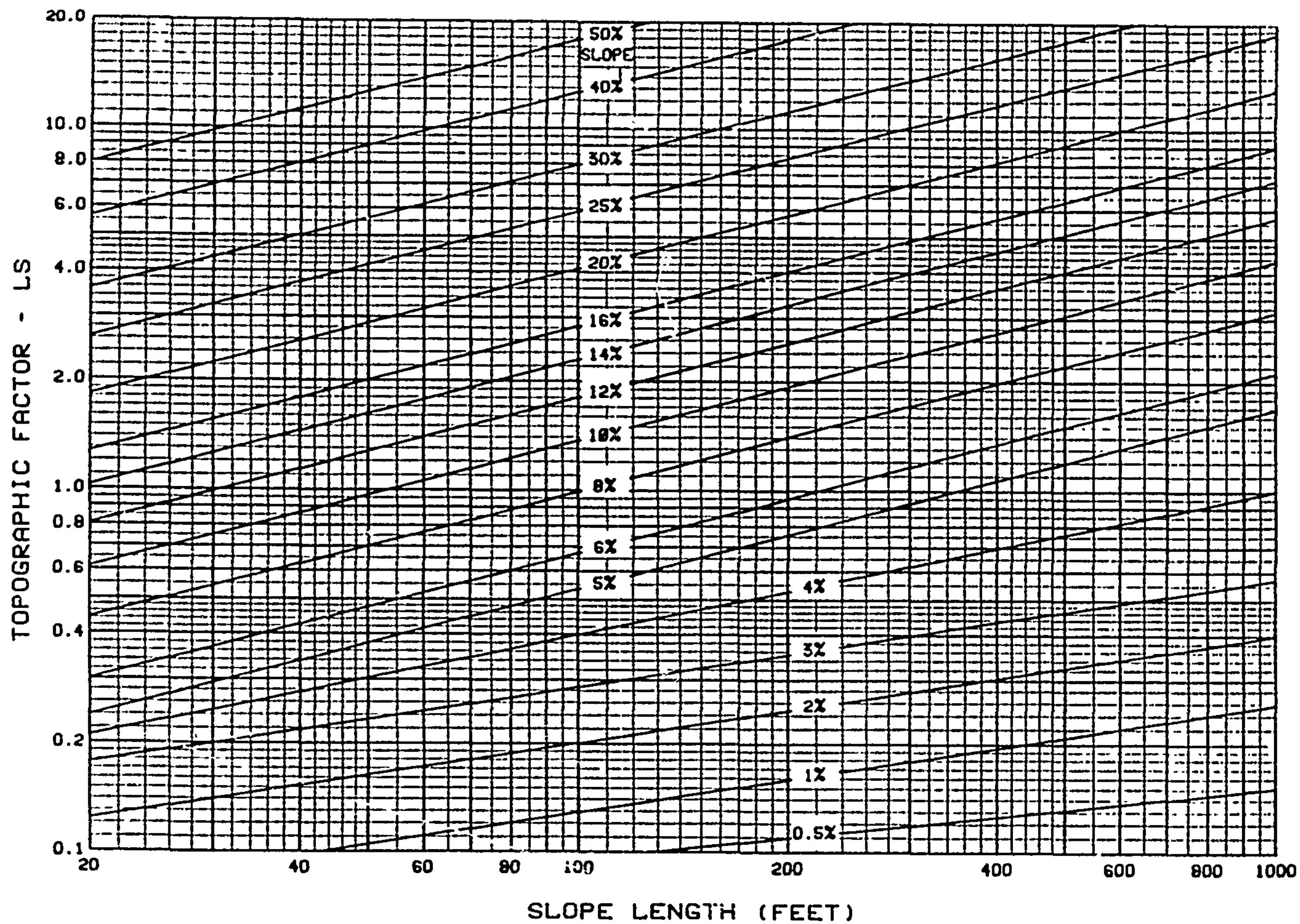
Table F1

Values of the Topographic Factor, LS, for Specific Combinations of Slope Length and Steepness*

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.)

*Source: USDA Handbook 537.



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 for 3.5 to 4.5 percent slopes, and 0.5 for slopes of 5 percent or steeper.

Figure F5. Slope effect chart for finding intermediate values of the Topographic Factor LS. (Source: USDA Handbook 537.)

Table F2

C Values for Permanent Pasture, Range, and Idle Land*

Vegetative canopy			Ground cover that contacts the soil surface						
Type	Height[a]	Percent cover[b]	Type[c]	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	20 in.	25	G	.36	.17	.09	.038	.013	.003
			W	.36	.20	.13	.083	.041	.011
	20	50	G	.26	.13	.07	.035	.012	.003
			W	.26	.16	.11	.076	.039	.011
	20	75	G	.17	.10	.06	.032	.011	.003
			W	.17	.12	.09	.068	.038	.011
Appreciable brush or bushes	6.5 ft.	25	G	.40	.18	.09	.040	.013	.003
			W	.40	.22	.14	.087	.042	.011
	6.5	50	G	.34	.16	.08	.038	.012	.003
			W	.34	.19	.13	.082	.041	.011
	6.5	75	G	.28	.14	.08	.036	.012	.003
			W	.28	.17	.12	.078	.040	.011
Trees but no appreciable low brush	13 ft.	25	G	.42	.19	.10	.041	.013	.003
			W	.42	.23	.14	.089	.042	.011
	13	50	G	.39	.18	.09	.040	.013	.003
			W	.39	.21	.14	.087	.042	.011
	13	75	G	.36	.17	.09	.039	.012	.003
			W	0.36	0.20	0.13	0.084	0.041	0.011

*Source: Cooperative Extension Service Circular 1220.

Table F3

C Value for Undisturbed Forest Land**

Area covered by canopy of trees and undergrowth (percent)	Area covered by duff at least 2 inches deep (percent)	C value
20 to 40	40 to 70	0.006
45 to 70	75 to 85	0.003
75 to 100	90 to 100	0.0005

**Source: Cooperative Extension Service Circular 1220.

Table F4

Conservation Practices (P) Values for Contour Farming and Contour Strip Cropping

Slope percent	Contour farming: P value	Contour farming: Maximum slope length (feet)[a]	Contour strip cropping: P value R-G-M-M[b,c]	Contour strip cropping: P value R-R-G-M[b,c,d]	Contour strip cropping: Strip width (feet)[e]
1 to 2	0.60	400	0.30	0.45	130
3 to 5	.50	300	.25	.38	100
6 to 8	.50	200	.25	.38	100
9 to 12	.60	120	.30	.45	80
13 to 16	.70	80	.35	.52	80
17 to 20	.80	60	.40	.60	60
21 to 25	0.90	50	0.45	0.68	50

[a]Slope length limits are based upon limited data and field observations.

[b]R = row crop; G = small grain; M = meadow.

[c]Strip cropping is most effective when there are alternate strips and equal width of row crops and sod crops, for example, corn-corn-wheat with meadow seeding, meadow, meadow.

[d]A strip cropping rotation of corn-corn-wheat-meadow is less effective.

[e]To accommodate widths of farm equipment, generally adjust strip width downward.

Table F5

Values Used in Determining P Values for Terraces Built on Contour and Used in Combination with Contour Farming and Contour Strip Cropping

Terrace interval (feet)	Closed outlets[a]	Open outlets with percent slope of[b] 0.1-0.3	0.4-0.7	≥0.8
Less than 110	0.5	0.6	0.7	1.0
110 to 140	0.6	0.7	0.8	1.0
140 to 180	0.7	0.8	0.9	1.0
180 to 225	0.8	0.8	0.9	1.0
225 to 300	0.9	0.9	1.0	1.0
300 and up	1.0	1.0	1.0	1.0

[a]Values for closed outlet terraces also apply to terraces with underground outlets and to level terraces with open outlets. However, closed outlet terraces are not normally built in Illinois because of the large amount of rainfall in Illinois.

[b]The channel slope is measured on the 300 feet of terrace closest to the outlet or on the third of the total terrace length closest to the outlet, whichever distance is less.

ABBREVIATIONS

ADP: automatic data processing
AR: Army Regulation
ARMSED: Army Sediment
ARR: annual recurring requirements
ARTEP: Army Training and Evaluation Programs
AWP: Annual Work Plan
BY: Budget Year
CA: commercial activities
COB: Command Operating Budget
CONUS: continental United States
CRRC: Construction Requirements Review Committee
C/S: Congressional/Senate
DA: Department of the Army
DEH: Directorate of Engineering and Housing
DOD: Department of Defense
DY: Design Year
EA: Environmental Assessment
ECMP: Erosion Control Management Plan
EIS: Environmental Impact Statements
EN: Environmental Division
EPS: engineered performance standards
ERMD: Engineering Resource Management Division
FY: fiscal year
FYDP: Five-Year Defense Program
FYP: Five-Year Program
GIS: geographic information system
GRASS: Geographic Resources Analysis Support System
GY: Guidance Year
HQDA: Headquarters, Department of the Army
ITAM: Integrated Training Area Management
LCTA: Land Condition Trend Analysis
LRCP: Long-Range Construction Program
MACOM: Major Command
MCA: Military Construction, Army
METL: mission-essential tasks
MMCA: Minor Military Construction, Army
MPL: Mobilization Project List
M&R: maintenance and repair
NAVFAC: Naval Facilities Engineering Command
OCE: Office of the Chief of Engineers
OMB: Office of Management and Budget
OSD: Office of the Secretary of Defense
PBC: Program Budget Committee
PBG: Program and Budget Guidance
PDB: Project Development Brochure
POM: Program Objective Memorandum
PY: Program Year
RPF: real property facility
RPMA: Real Property Maintenance Activities

SA:	Secretary of the Army
SCS:	Soil Conservation Service
SIRS:	Soil Information Retrieval System
TM:	Technical Manual
TPO:	Troop Projects Office; Troop Projects Officer
USACERL:	U.S. Army Construction Engineering Research Laboratory
USAEHSC:	U.S. Army Engineering and Housing Support Center
USCS:	Universal Soil Classification System
USDA:	U.S. Department of Agriculture
USDI:	U.S. Department of the Interior
USLE:	Universal Soil Loss Equation
WEPP:	Water Erosion Prediction Project

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